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Afghanistan National Agricultural Sciences and
Technology University
Vice-Chancellory for Academic Research

National Conference on Food Security and Safety in Afghanistan

Conference Proceedings

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The First National Conference on Food Security and Food Safety is Being Held at ANASTU University

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

الحمد لله وكفى والصلاة والسلام على عباده الذين اصطفى ، اما بعد !

The rapid progress of today's world is the result of scientific research, and none of the conveniences enjoyed by humanity today would have been achieved without research. Through research, the world seeks appropriate solutions to human needs, challenges, problems, and strives to conduct studies on issues whose benefits can reach all people and fulfill the needs and aspirations of human society. Therefore, cultural, human, social, and other common issues must be discussed and researched so that reasonable and effective solutions can be identified. Today's world highly values research that addresses and resolves the scientific, cultural, social, and other related problems of society.

The Afghanistan National Agricultural Sciences and Technology University decided to organize a national conference with the aim of ensuring food security and food safety in the country, in order to identify solutions to existing challenges in the field of food security and safety in light of national and international laws and principles.

It is a matter of great pleasure that the university leadership, with strong determination and firm commitment, succeeded in organizing the "National Conference on Food Security and Food Safety" in the year 1404 Hijri Solar, and fortunately, the conference is now on the verge of being held.

For this conference, professors, lecturers, and researchers from public and private universities and other higher education institutions across the country prepared their research papers in accordance with the conference themes and submitted them to the Afghanistan National Agricultural Sciences and Technology University for presentation and publication. Praise be to Allah, the collection of received papers has now been reviewed and is being accepted for publication. This is considered a major achievement not only for ANASTU University but also for the Ministry of Higher Education.

The leadership of the Ministry of Higher Education highly appreciates this effort. At the same time, it encourages other universities across the country to incorporate similar scientific activities into their work plans and to seek practical solutions to the nation's challenges.

In conclusion, the leadership of the Ministry of Higher Education sincerely congratulates the authors and compilers of these papers on the publication and dissemination of this collection.

With respect,

Sheikh-ul-Hadith Zia-ur-Rahman Al-Aryoubi

Deputy Minister for Academic Affairs

The Need and Importance of Conferences in Afghanistan

الحمد لله وكفى والصلاة والسلام على عباده الذين اصطفى، اما بعد!

Scientific conferences play an essential role in the progress and development of academic knowledge. Conferences further highlight the importance of research within the academic community and are considered valuable opportunities for sharing new information, data, and research results. In addition, conferences provide a platform through which a large amount of information and research results can be gathered at one time and in one place and shared with other researchers and specialists. One of the most valuable activities of academic institutions is organizing national and international conferences. This can be effectively achieved through coordination among universities, specialized institutions, and research centers. Scientific and research conferences bring together various academic and governmental institutions and, by benefiting from each other's experiences, address the needs and demands of society as well as those of different scientific and professional organizations.

The Vice Chancellor for Academic Research of the Afghanistan National Agricultural Sciences and Technology University (ANASTU) has decided to publish a collection of papers submitted by university professors and researchers for the National Conference on Food Security and Food Safety, organized by ANASTU University. These papers have been reviewed and approved for publication by the conference academic committee. All papers will be presented during the conference in the year 1404 of the Solar Hijri calendar.

One of the objectives behind publishing these papers is to help relevant sectors to benefit from these studies in formulating laws and policies and to share them with the general public, readers, and researchers. As a responsible authority within the Ministry of Higher Education and also as a participant in this conference, I consider this initiative an important step and a positive achievement.

The Directorate of Research, Compilation and Translation of the Ministry of Higher Education strives each year to encourage universities across the country to organize national and international conferences and to publish the papers presented at these conferences both in printed volumes and through their official websites. This is regarded as a major achievement, particularly for the respective universities involved and for the Directorate as a whole.

Since ANASTU University has taken the initiative to organize a national conference titled "Food Security and Food Safety," it has received research articles from professors and researchers of various universities throughout the country, which have been approved and accepted by the academic committee and will soon be published. All accepted papers will be presented during the conference at the year 1404 Hijri Solar, and the findings and outcomes of the conference will be shared with sectoral institutions for the purpose of policy formulation and implementation.

I extend my congratulations to the leadership, professors, and staff of the university, especially to those professors and researchers whose papers are included in this collection. At the same time, I encourage all professionals and researchers across Afghanistan to pay greater attention to their academic work and continue with their academic and research activities with enthusiasm and dedication.

With respect,
Dr. Hamidullah Muzammil
Director of Research, Compilation and Translation

Message from the Chancellor of the Afghanistan National Agricultural Sciences and Technology University (ANASTU)

الحمد لله رب العلمين والصلوة والسلام على رسوله واله واصحابه اجمعين
اما بعد: فقد قال الله تبارك و تعالى فى محكم كتابه و هو اصدق القائلين، اعوذ بالله من الشيطان الرجيم، بسم الله الرحمن الرحيم
يَا أَيُّهَا الرُّسُلُ كُلُوا مِنَ الطَّيِّبَاتِ وَاعْمَلُوا صَالِحًا إِنِّي بِمَا تَعْمَلُونَ عَلِيمٌ (سورة المؤمنون آيت نمبر، ۵۱)
عن عمر رضى الله عنه، عن النبي صلى الله عليه وسلم قال : الجالب مرزوق والمحتكر ملعون "رواه ابن ماجه ، والدارمي

Among the countless blessings that Allah has bestowed upon humanity, three great blessings are highlighted here. The first is the creation and existence of human beings; the second is the provision of food and other necessities for the continuation and survival of life; and the third is adorning mankind with the ornament of knowledge and learning. Food refers to edible and drinkable substances that strengthen the human body and help maintain a healthy life. Despite its importance, food in Afghanistan faces two major threats: food insecurity and lack of food safety. In other words, various challenges have made our food system insecure. For example, industrialized countries release harmful gases into the atmosphere, resulting in climate change, droughts, and other environmental problems. Likewise, the continuous invasions and attacks by occupying forces on our beloved Afghanistan severely damaged and weakened our agricultural sector. Due to insecurity, the country faced a shortage of essential water resources because it was impossible to construct check dams, canals, and other water management systems for the proper utilization of rainwater.

Similarly, some malicious groups engaged in food hoarding, while others smuggled food products out of the country under foreign influence. These and many other threats prevented the achievement of food security. In the same manner, the lack of food safety is considered the second major threat to our country. This means that the food available to us is often unsafe, contaminated, and of poor quality, making it unsafe for consumption. On one hand, the use of chemical weapons by occupying forces polluted our air, environment, and water resources, directly contaminating the food system and making it unsafe. On the other hand, fertilizers used to strengthen agricultural production are often of poor quality or improperly used, resulting in food contamination and the destruction of food safety standards. Furthermore, the absence of suitable storage facilities and warehouses causes food spoilage and various forms of damage, leading to the loss of nutritional value. Therefore, the Afghanistan National Agricultural Sciences and Technology University (ANASTU), as a center of academic and scientific expertise, recognizing its mission and responsibility in the fields of agriculture and livestock, in service to the dear people of Afghanistan, deemed it necessary to organize a national conference titled "Food Security and Food Safety." The purpose of this conference is to utilize the scientific research and expertise of specialists in this field to address the aforementioned challenges facing Afghanistan.

Fortunately, with the approval of the Ministry of Higher Education and the authorization of Sheikh-ul-Quran wal-Hadith Amir al-Mu'minin (may Allah protect him), the funding and permission for this conference were granted. Now, in order to further enhance the value of professional and scientific research, these studies are being presented in the form of a book with the support of ANASTU.

With respect,

Al-Hajj Mawlawi Syed Mohammad Dawood Agha Al-Hashimi

Chancellor of ANASTU

The Current State of Food Security and Food Safety in Afghanistan and the Need for Their Provision

الحمد لله وكفى والصلاة والسلام على عباده الذين اصطفى، اما بعد!

Human beings need sufficient food to sustain their lives and manage their daily activities properly. Food is considered one of the greatest blessings of Almighty Allah, enabling people to provide themselves with adequate and safe nutrition. However, not all people around the world have equal access to food. This means that people living in developed countries generally have access to sufficient food supplies, whereas those living in underdeveloped countries often lack access to adequate food and face numerous daily challenges. Afghanistan is also considered one of the countries where many citizens do not have access to sufficient food, and food safety is under serious threat.

Factors threatening food security and food safety in Afghanistan and around the world include climate change, population growth, poor economic conditions, low levels of plant and animal production, lack of food storage facilities, and the excessive use of low-quality chemical pesticides and medicines for controlling disasters and diseases, among others. These factors clearly indicate that humans themselves are largely responsible for the deterioration of food security and food safety, and continue to contribute to these problems through their actions.

In order to improve food security and food safety in Afghanistan, effective policies must be introduced, and the Islamic Emirate of Afghanistan, along with domestic and international institutions, should make greater efforts toward their implementation. The measures considered essential for ensuring food security and food safety include proper management of soil and water resources to combat climate change, establishment of modern and mechanized agriculture, production of improved seeds, improvement of animal breeds, storage and processing of agricultural and livestock products, raising awareness among farmers and livestock owners, implementation of food safety laws, and control of disasters and diseases.

If these measures are implemented systematically, it is hoped that poverty and hunger levels in the country will decrease, employment opportunities will be created for people, domestic production will increase, dependence on imported goods will decline, and the country will move toward self-sufficiency.

The Afghanistan National Agricultural Sciences and Technology University (ANASTU) is a specialized university in the field of agriculture and livestock at the national level, which, among its many responsibilities, is also committed to ensuring food security and food safety in the country. To achieve this objective, ANASTU decided to organize a national conference on food security and food safety to collect scientific and research papers from researchers, professionals, and professors across the country and present them to high-ranking officials of the Islamic Emirate of Afghanistan, sectoral institutions, and other responsible authorities through this national conference.

All the research conducted for this conference has been compiled by the Deputy Directorate for Scientific Research and the Directorate of Scientific Research of ANASTU University into a book containing abstracts and recommendations, which will soon be published. This collection of abstracts and recommendations will be distributed to policymakers, government officials, and other relevant organizations in the country for promotional purposes so that, in light of these studies, all matters related to food security and food safety in Afghanistan can be better managed and ensured.

With great respect,

Dr. Sharifullah Sharifi

Vice-Chancellor for Academic Research

ANASTU University

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Food Contamination Prevention Needs in Afghanistan

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Abstract

Rapid population growth in Afghanistan has led to a need for enough, qualitative and safe food, which has nourishing and nutritive components such as carbohydrates, fats, proteins, essential minerals, and vitamins, which sustains life, generates energy, and provides growth, maintenance health of body. But some time food will be vehicles for disease transmission and cause of death if contaminated with harmful microorganisms, microbial toxins of environmental contaminants. In Afghanistan at 2024 total case of diarrhea were 5922 with 6 deaths. And cases of aflatoxin were 7800 with 1600 death at Herat Province which case was food contamination but food contaminations are classified at three categories: biological, chemical and physical. Thus, knowledge about food contamination and food contamination prevention need Afghanistan is necessary. Aim of this review was to know food contamination and maintain production free from contamination during growth, process, and storage up to consumption table. Thus, in this manuscript we had discussed on concept of food contamination, Food contaminants (FCs), stages of (FC), type of (FC) which are including, biological, chemical and physical, precautions and prevention methods of (FC) and food contamination prevention need in Afghanistan. As a result, cold concluded that knowledge of biological, chemical and physical contamination methods helps to provide enough and qualitative food for all people at all time and also, can keep soil and water clear from contaminants.

Key word: contamination, food safety, food waste, sustainable practices, nutritional quality.

Introduction

Rapid growing population requires more products (Islam et al., 2022). On the other hand, annually third of production goes to waste (Thakali & MacRae, 2021). And likewise, that is estimated that at 2017, 11.8% of 15 million households will not have ability to provide qualitative, enough and safe food (Thakali & MacRae, 2021).

Qualitative Food, any substance consisting of nourishing and nutritive components such as carbohydrates, fats, proteins essential minerals and vitamins which sustains life, generates energy and provides growth, maintenance and health of the body (Alum et al., 2016a; Sharma et al., 2020). Food safety refers to handling, preparing and storing of food in that way to reduce risk of people becoming sick from foodborne illnesses (Alum et al., 2016a; Sadiku et al., 2020).

Food beside of its importance, can also serve as vehicles for disease transmission and cause of death if contaminated with harmful microorganisms, microbial toxins of environmental contaminants (chemical allergians and microphysical particles) (Alum et al., 2016a; Sadiku et al., 2020)

Contamination can be defined as, each substance intentionally/unintentionally added to the food or found inside the food, as a result of the production process, farming practices, treatment, packaging, transport or storage to contaminate food (Di Stefano & Avellone, 2014; Sadiku et al., 2020). Contaminants generally divided in to biological, chemical and physical in nature (Abdolshahi & Shokrollahi Yancheshmeh, 2020; Hussain, 2016).

Challenge is control of risks associated with mixtures of contaminants, which are changing continuously and many of these can cause severe damage to human health, reduced physical and mental development (Kantiani et al., 2010) (Afghanistan agricultural inputs project 2011, <https://faolex.fao.org/docs/pdf/afg189868.pdf>). Consumption of (CF) can causes illness in (MoP) and many death (Faizy et al., 2022; Hussain, 2016).

In 1997 from 25.2 million deaths in all over the world, 17.3 million were attributable to infectious and parasitic diseases but 2.5 million deaths cause ware from diarrhea (Gorman et al., 2002). Also, Worldwide, at 2010, 1.5 M diarrheal cases was accrued at children, and annually 700000 child deaths cause ware diarrhea (Faizy et al., 2022; Waak, 2019). Similarly, foodborne diseases have been estimated to cause 81 million illnesses and up to 9000 deaths each year (Liang & Scammon, 2016). MoPH with national disease surveillance & response of Afghanistan motioned that at 2023 total case of food poisoning, acute bloody diarrhea, acute watery diarrhea and water contamination ware 693, 124, 292 with 2 death, and 51 respectfully (National disease sevivlance & respons 2023/<https://moph.gov.af/en/node/3302>). Diarrhea diseases caused by viruses, bacteria and parasites but moderate to severe diarrhea caused are rotavirus, cryptosporidium, shigella and enterotoxigeni E. coli.

Cooking at improper temperatures, cross contamination are main causes of foodborne disease (Kamal & Nasiri, 2021). And main source of transmission for diarrhea genic agents were contaminated water and foods. Its estimated that if good hygienic care, safe water supply, hand washing by soap and sanitation could prevent diarrheal episodes by 95% (Kamal & Nasiri, 2021; Waak, 2019).

Afghanistan as an environmental disaster, poverty and internal or external conflicts at 2015 was the 171st food secure country in the world. also, about 11.1 million people are food insecure (WFP Afghanistan, situation report 2024/<https://reliefweb.int/report/afghanistan/wfp-afghanistan-country-brief-august-2024>) and more than 60% of children under five years are at chronic, 8 percent are at acute and four of 10 child are malnutrition condition (MC) (Akbay & Ahmadzai, 2020). It will cause stunted growth, low weight, wasting, anemia, vitamin deficiency, iodine deficiency and low birth weight sign among the people and death of 45% child. Causes of MC are poor hygiene practice and sanitation (Afghanistan agricultural inputs project 2011, <https://faolex.fao.org/docs/pdf/afg189868.pdf>). As Afghanistan located at developing country and it has much problem about food safety because of war (Islam et al., 2022). And correspondingly, Afghanistan government does not have law that described food control activities and also MAIL is responsible for row product and MoPH is responsible for control of processed food (Kamal & Nasiri, 2021) and stile chemical and microbiological test ability is limited (Khalid, 2015). but that can't support all of the required regulatory functions for Afghanistan (Khalid, 2015).

Thus, knowledge about food contaminations and food contamination prevention need Afghanistan is necessary, to prepare, supply and storage safe, adequate, nourishing and healthy food for wellbeing of humans (Alum et al., 2016a). For achieving of this aim, concept of food contamination, food contaminants, stages of food contamination,

type of food contamination including: biological (bacteria, virus, parasitic and mycotoxin), chemical and physical, precaution, prevention methods of food contamination and need for food contamination prevention in Afghanistan are necessary to describe.

Concept of food contamination

Spoilage of food due to bacterial growth or toxic substances present in it or any substance in food that reduces the safety and quality or depraved biologically, physically and chemically called Food contamination. Contaminants will be intentional, accidental or even natural, generally it can't see by eyes (Sadiku et al., 2020). Food contaminants could inter unintentionally to food pending agricultural production, environment, storage, transportation, selling and processing (Abdolshahi & Shokrollahi Yancheshmeh, 2020).

Food contaminants

There are several substances it can contaminate food, but majors are microbial toxins, toxic elements, radioactive isotopes, nitrosocompounds, pesticides residues (insecticides, herbicides, fungicides, nematicides, molluscicides, piscicide, avicide, rodenticide, bactericide, insect repellent, animal repellent, antimicrobials, mitigation, repelling and controlling of pests), growth regulator, defoliant, desiccants, veterinary drug residues, mycotoxins, chemical food contamination, physical food contamination. Etc. (Abdolshahi & Shokrollahi Yancheshmeh, 2020; Gyeltshen, 2021; Nerín et al., 2016).

Stages of food contamination

Contaminants not intentionally added but found inside of food at process, farming practices, treatment, packing, transport, storage of food and also from environmental sources or from reception to final consumers (Abdolshahi & Shokrollahi Yancheshmeh, 2020; Kantiani et al., 2010). Thus, food contamination will occur from farm to fork by poor management practice which provide condition for fungal and mycotoxin (Hussain, 2016), critical stages of food contamination are not clear, at every stage simple or rapidly food contamination will occur (Kantiani et al., 2010). It can be classified pre-harvest contamination (environmental, microorganism, pathogen, heavy metal, pesticides, excess use of fertilizer and poor hygiene followed worker), Harvest contamination (equipment's, knives, blades, sickles, boxes, clippers and containers for storage, and post-harvest contamination (washing, sorting, slicing, farming, shredding, packing, chilling, distribution, transportation from shops, restaurants and markets, and frozen of food) (Abdolshahi & Shokrollahi Yancheshmeh, 2020; Alum et al., 2016a; Kantiani et al., 2010; Sadiku et al., 2020)

Type of food contamination

Food at food chain pass several steps, at every step occurrence of food contamination is possible (Alum et al., 2016a). Row food passed steps: Transport to factory for processing, storage, preheating, disinfection, and cleaning and sterilization steps. Heating: boiling, cooking, baking, frying or combining with other ingredients at high temperature in an oven. Food packing: transport packed food, storage and distribution of packed food. Thus food contamination will take place from reception of raw material to final food consumers (Sadiku et al., 2020). Generally food contamination can be classified at biological, chemical and physical (foreign materials) (Abdolshahi & Shokrollahi Yancheshmeh, 2020; Gorman et al., 2002; Hussain, 2016; Sharma et al., 2020)).

Biological contamination

Environment and food contamination with derivative of microorganisms (Mo) like toxins called biological contamination (BC) or contamination by bacteria, viruses, fungi and parasites are called biological contamination. Those (Mo) found at food, wall, water, air, clothes, etc. and these can cause human diseases (Abdolshahi & Shokrollahi Yancheshmeh, 2020; Di Stefano & Avellone, 2014). Impact biological contamination cause of more than 200 diseases, 2 M death annually (Table 2), there are five (Mo) which have significant role at estimate 90% death which are salmonella 31%, listeria 28 %, toxoplasma 21%, norwalk-like virus 7%, campylobacter 5% and E. Coli O157:H7 3%). Etc. (Alum et al., 2016a). Generally, biological pollution will befall at four categories as below:

- pre-harvest (at field plant food, irrigation water, application pesticide, manure applied at fertilizer, migratory or feral animals, un hygienic practice of workers in the field)
- harvest (harvesting equipment's, un washed hand of field workers, pre slaughter and slaughter, at poultry flocks maybe infect by (drinking water, rodents, insects, dogs, cats, human tools, foot wear, work cloths))
- post-harvest (food processing, preparation, food contact equipment, un hygienic practice of food handler, packaging factors, distribution, marketing and storage factor, food serving factors) time (Alum et al., 2016a).

a) Bacteria

Bacteria are small single-celled microorganism, its split and multiply are quickly. All pathogens are hazards. its growth situations are air, human body, dust, pets and pests, raw food, soil, kitchen, factory instruments, food handlers and cloths. And its optimum survival conditions are food, water, oxygen, temperature and pH. (Abdolshahi & Shokrollahi Yancheshmeh, 2020; Hussain, 2016). Major (B) and its contamination risk is present at (Table 1)

Table 1: major bacteria and its contamination risk.

Major bacteria	Risk contamination
<i>Clostridium botulinum</i>	Intoxication, even death
<i>Salmonella</i> spp. (<i>typhimurium</i> , <i>enteritidis</i> , <i>enterohaemorrhagic</i> <i>Escherichia coli</i> , <i>Campylobacter jejuni</i> , <i>Yersinia enterocolitica</i> , <i>Listeria monocytogenes</i> , <i>Bacillus anthracis</i> , <i>Clostridium perfringens</i> , <i>Vibrio</i> spp. (<i>Vulnificus</i> , <i>parahaemolyticus</i> , <i>Brucella abortus</i> , <i>B. suis</i> , <i>Shigella</i> spp. (<i>dysenteriae</i>))	infection
<i>Bacillus cereus</i> , <i>staphylococcus aureus</i>	intoxication

(Abdolshahi & Shokrollahi Yancheshmeh, 2020)

b) Virus

Submicroscopic agent which infect organism only inside the living cell called virus. It can infect animal, feed, water and other microorganism like bacteria, etc there are some viruses and its risk of contamination in table 2. (Huang et al., 2020; Abdolshahi & Shokrollahi Yancheshmeh, 2020). Also, its live are at host cell and can easily transfer from person to person. Although, virus is resistant to heat, drying, freezing. Its contamination reason is poor hygienic practice (Abdolshahi & Shokrollahi Yancheshmeh, 2020) In Afghanistan, as a report of national disease surveillance & response during 2023 total case ill and death because of water contamination, Acute water diarrhea, acute bloody diarrhea, food poisoning and unknown poisoning were 51 persons, 292 persons with 2 deaths, 124 persons, 693 person and 450 person with 3 deaths respectively. MoPHoA. reported that at 2024, diarrhea cases were 5922 with 6 deaths and disease of 3 years (2020-2022) average are showed at (Figure 1, 2, 3).

Table 2: major viruses of food contamination and its contamination risks.

Major viruses	Risk contamination
Hepatitis A virus	Fever, abdominal discomfort
Norwalk virus	Nausea, vomiting, diarrhea, abdominal pain (gastroenteritis), headache, low-grade fever
Rotavirus	Vomiting, watery diarrhea, fever, abdominal pain

(Abdolshahi & Shokrollahi Yancheshmeh, 2020; Kantiani et al., 2010)

Indicators	W21	W22	W23	W24	W25	W26	W27	W28	Trend line
Suspected cases	4,117	4,906	4,755	4,737	3,884	5,310	5,813 *	5,922	
Suspected deaths	0	1	1	4	3	4	2	6	
CFR (%)	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.1	

Figure 1: acute watery diarrhea for 19 may up to 13 July 2023 in Afghanistan

<https://www.emro.who.int/images/stories/afghanistan/Outbreak-Situation-Report-Week-28-2024.pdf?ua=1>

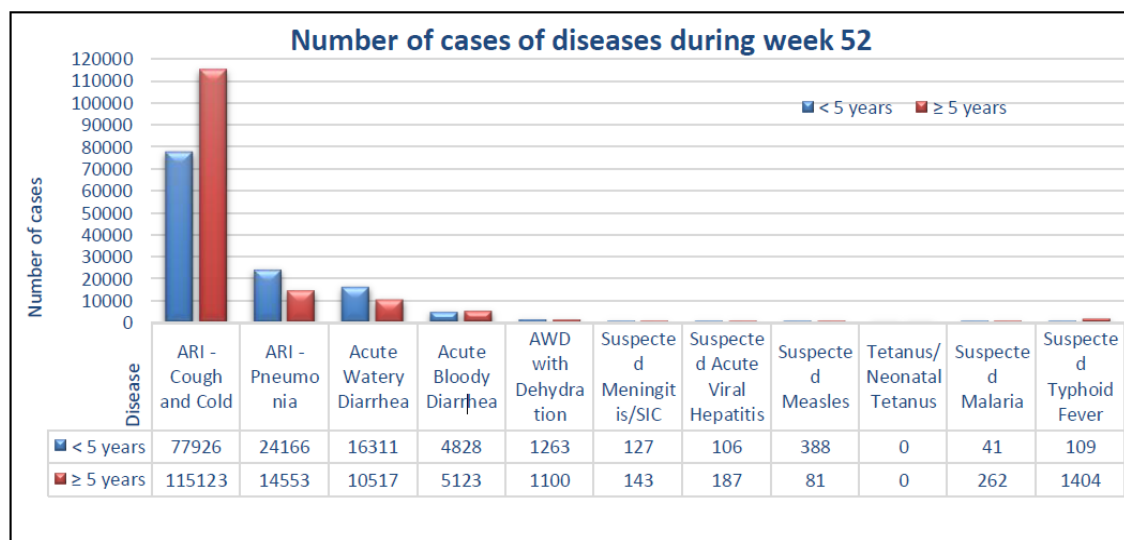


Figure 2: that total cases of different disease of 3 years (2021-2023) at most ten five and less than five child.

(<https://moph.gov.af/en/node/3302>)

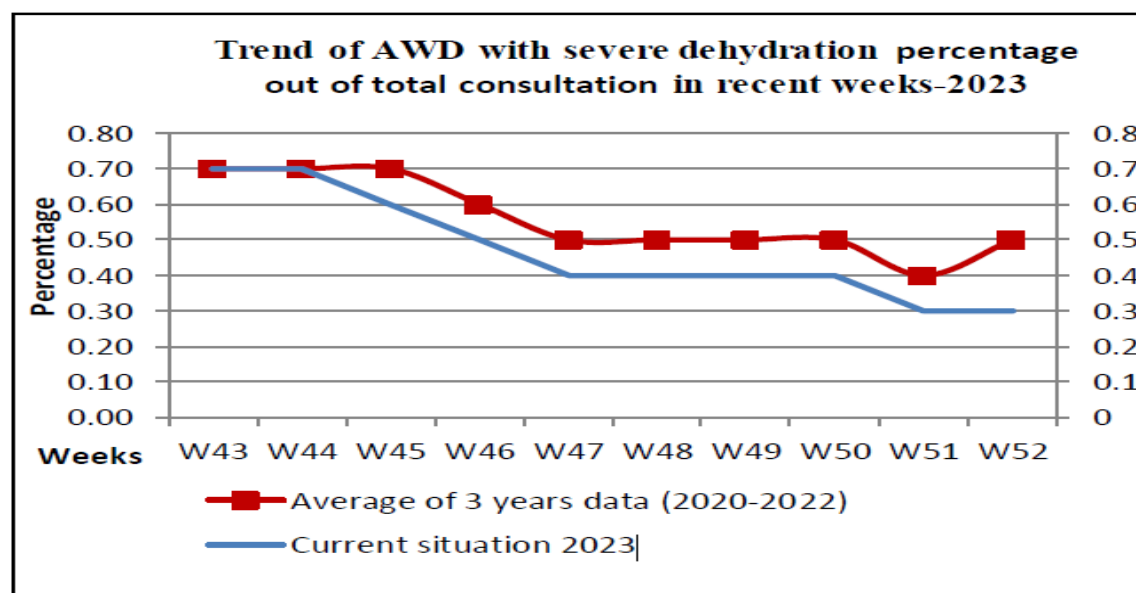


Figure3: average percentage of acute watered diarrhea at 2024 and (2020-2022)

(<https://moph.gov.af/en/node/3302>)

c) Parasites

Small microorganism that survives in or on another species which are host for it called parasites, it contaminates food and water and people can infect through it. If Poor personal hygiene, disposal of human feces, unsuitable sewage treatment and utilization of untreated sewage for crop culturing practice will infect food. Parasites are cause of different disease which indicate at table 3 and figure 4. (Abdolshahi & Shokrollahi Yancheshmeh, 2020)

Table 3: major parasites of food contamination and its risk.

Major parasites	Risk contamination
<i>Giardia lamblia</i>	Diarrhea, abdominal cramps, fatigue, nausea, flatulence (intestinal gas), weightloss
<i>Ascaris lumbricoides</i>	Dysentery (severe, bloody diaffhea)
<i>Diphyllobothrium latum</i>	Attaches to intestinal wall
<i>Cryptosporidia</i>	Respiratory, gastrointestinal illness
<i>Trichinella spiralis</i>	Intestinal wall, enter the blood (to feed on it) and lymphatic system
<i>Toxoplasma gondii</i>	Neurological disorders, particularly schizophrenia, bipolar disorder
<i>Teania solium</i>	Attaches to intestinal wall
<i>Anisakis spp</i>	Anisakiasis

(Abdolshahi & Shokrollahi Yancheshmeh, 2020; Kantiani et al., 2010)

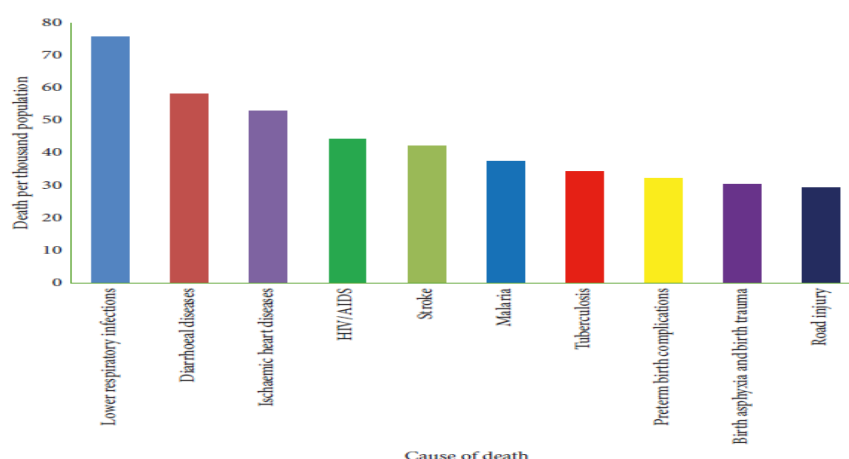


Figure 4: Different disease which were cause of death at low-income countries at 2019.

(Assefa & Geremew, 2018)

d) Mycotoxin contamination

Mycotoxins are secondary metabolites which produce by molds and contaminate products at food chain (Abdolshahi & Shokrollahi Yancheshmeh, 2020; Reddy et al., 2010). The majority of fungi can produce mycotoxins and can several adverse effects on human, animals and corps. The mycotoxins contamination could take place by ingestion, dermal and inhalation without involving the producer fungi. At all mycotoxins, aflatoxin B1 (AFB1), fumonisin B1 (FB1), and ochratoxin A (OTA) are the most toxic to mammals and causing a variety of toxic effects including hepatotoxicity, teratogenicity, and mutagenicity resulting in diseased such as toxic hepatitis, hemorrhage, edema immunosuppression, hepatic carcinoma, equine leukoencephalomalacia (LEM), Esophageal cancer, and kidney failure (Agriopoulou et al., 2020; Reddy et al., 2010). the motivating situation for mycotoxin production are mainly poor hygienic practices during transportation, unsuitable storage, unsuitable improper processing, high temperature and moisture content and heavy rains. On the other hand, mycotoxin permitted situation are different among the foods, U. S. food and drug Administration (FDA) has permitted 20 ng/g total aflatoxin in livestock feed 0.5 g/kg or 50 ng/l in milk, also European Union (EU) has permitted 0.0g to 0.5 µg/kg aflaxotoxin (Agriopoulou et al., 2020; Assefa & Geremew, 2018). Likewise, mycotoxin have impact on people health and economic.

Aflatoxin B1 maybe cause potent liver carcinogenic, child stunting, animal production reduced, reduce dietary protein, reduce milk quality, prevalent poverty and malnutrition and also, limit yield, reduce price of product, rejection of export and make animal prove to disease (Assefa & Geremew, 2018)In afghanistan, ther are some case of mycotoxyn like aflatoxin, at one investagation on raisins, almond and pistachio which are indicate at (figure 5, 6, 7) showed that there are difernet amont of aflatoxin at each sample of rasins, almond and pistachio and also sirvival and presince of aflaxotoxin related to carbohydrates, humidity, heat, air impact and isect attack, If the storage environment humidity reach up to 20 percetn then attack of phoenixes will increase and it will open way for incresing the amont of alfatoxin (Mhoamad, A. *et al* 2021).

Table 4: Different mycotoxins, its producer microorganism, food commodity and its diseases.

mycotoxin	Fungal speicies	Food commodity	Disease/syndrome
Aflatoxins	<i>A. Flavus</i> , <i>A. parasiticus</i>	Maize, wheat, rice, sorghum, ground nuts, tree nuts, figs	Liver lesions, cirrhosis, primary hepatocellular carcinoma, kwashiorkor, reyes syndrome
Fumonisin	<i>F. verticillioides</i> , <i>f. proliferatum</i>	Maize, maizeproducts, sorghum	Esophageal carcinoma
Ochratoxin A	<i>A. Ochraceus</i> , <i>P. verrucosum</i> , <i>A. carbonarius</i>	Cereals, dried vinefruit, wine, coffee	Endemic nephropathy, urothelial tumours
Deoxynivalenol	<i>F. graminearum</i> , <i>F. culmorum</i>	Cereals, cereal products	Nausea, vomiting, abdominal pain, diarrhea, dissiness, headache
Zearalenone	<i>F. graminearum</i> , <i>F. culmorum</i>	Cereals, cerealproducts.	Premature puberty in girls, cervical cancer
Patulin	<i>p. expansum</i>	Apples, apple juice	Damage of gastrointestinal, respiratory systems, DNA, many enzymes

(Abdolshahi & Shokrollahi Yancheshmeh, 2020; Reddy et al., 2010)

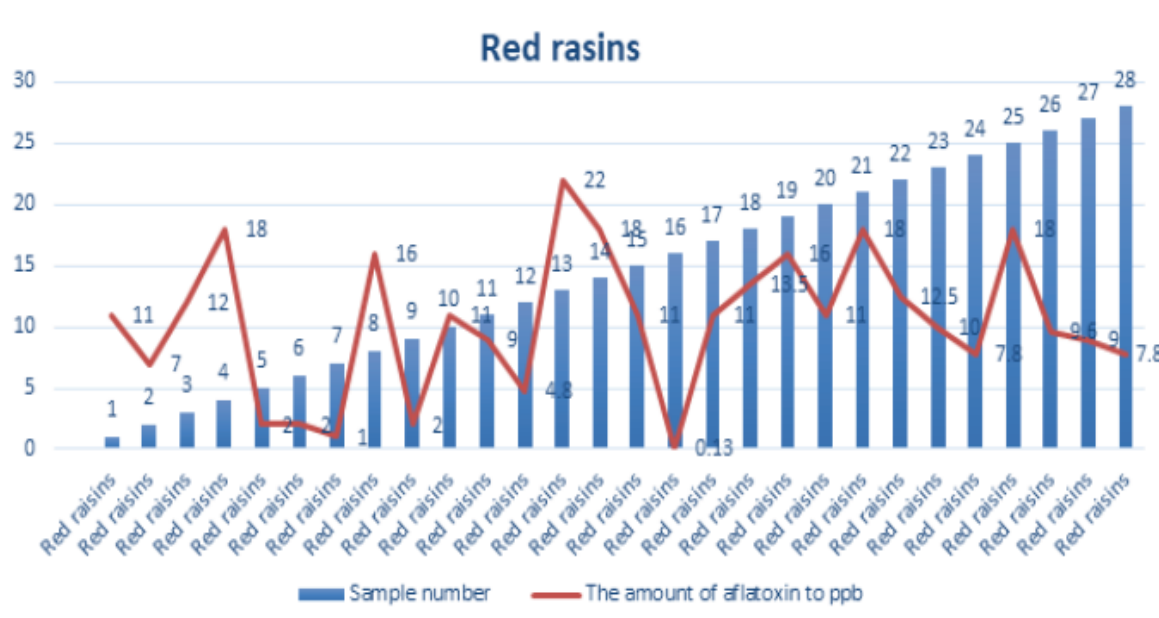


Figure 5: Dried fruit (Red sasins) contamination by aflatoxin in Afghanistan (Mhoamad, A. *et al* 2021).Figure

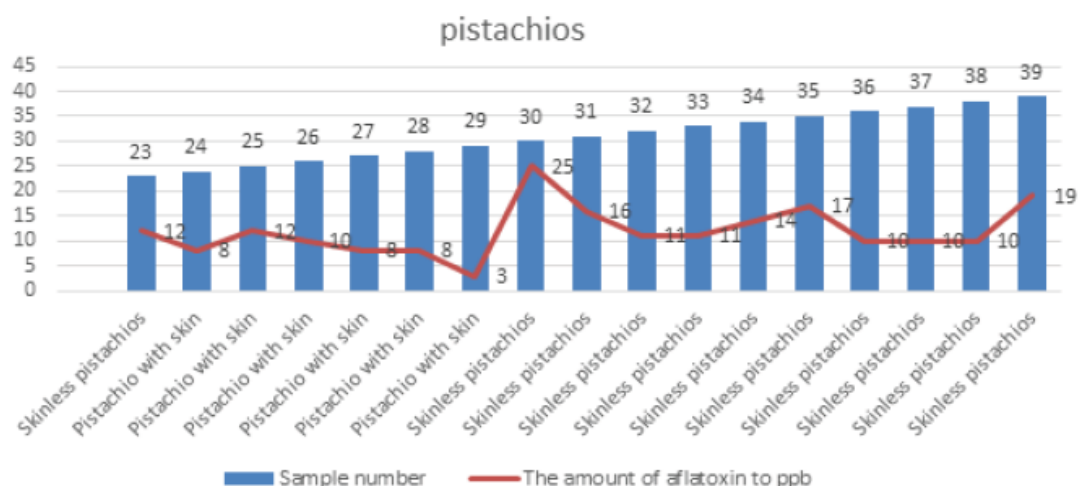


Figure 6: Dried fruit (Pistachios) contamination by aflatoxin in Afghanistan (Mhoamad, A. *et al* 2021).

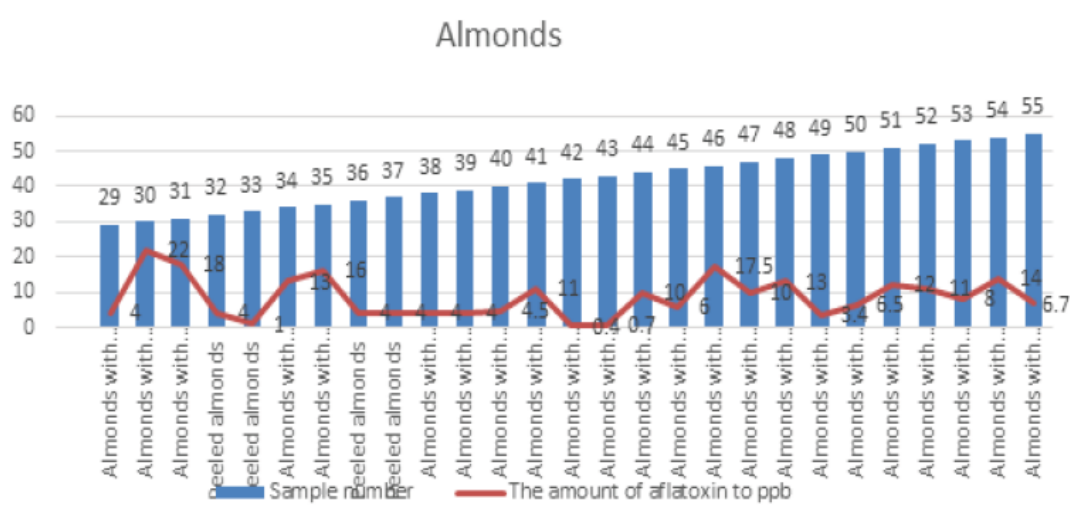


Figure 7: Dried fruit (Almonds) contamination by aflatoxin in Afghanistan (Mhoamad, A. *et al* 2021).

B. chemical contamination

Food chemical contamination is one other human concern which involves some substance like: agrochemicals, veterinary medicines residues, pesticides residues, environmental contamination, heavy metals {heavy metals source are manures, sewage sludge, fertilizers, and pesticides (at underground vegetable the accumulation of heavy metals are more, and much toxic metal enters our food chain and contaminate food for consumptions)} (Figure 8) (Abdolshahi & Shokrollahi Yancheshmeh, 2020; Din et al., 2013) persistent pollutants, and some natural toxins: it happens in food during chemical reaction as processing like: acrylamide, furan and heterocyclic amines, fermentation of ethyl carbamate, 3-monochloropropanediol and disinfection e.g., trihalomethanes and also food contact material such as : formaldehyde, melamine, phthalates, primary aromatic amines and also some chemical are naturally present in the environment, which includes ubiquitous pollutants such as dioxins and heavy metals may be increased by anthropogenic activity. ministry of public health (MoPH) of Afghanistan by project of pest and pesticide management reported that pesticide have some adverse effect on human health are intoxication, alteration, embryonic development, poisoning, death, drop in cholinesterase level and also have bad effect of soil pollution, surface water pollution and well water pollution (NGOLLO, 2011) despite of pollution cast of pesticides are very height (figure 9) (Abdolshahi & Shokrollahi Yancheshmeh, 2020; Kantiani et al., 2010; Thakali & MacRae, 2021)

Some chemical contaminants are below.

- ✓ Unwashed fruits and vegetables
- ✓ Food containers made from non-safe polymers
- ✓ Pest control products
- ✓ Chemicals used in equipment maintenance

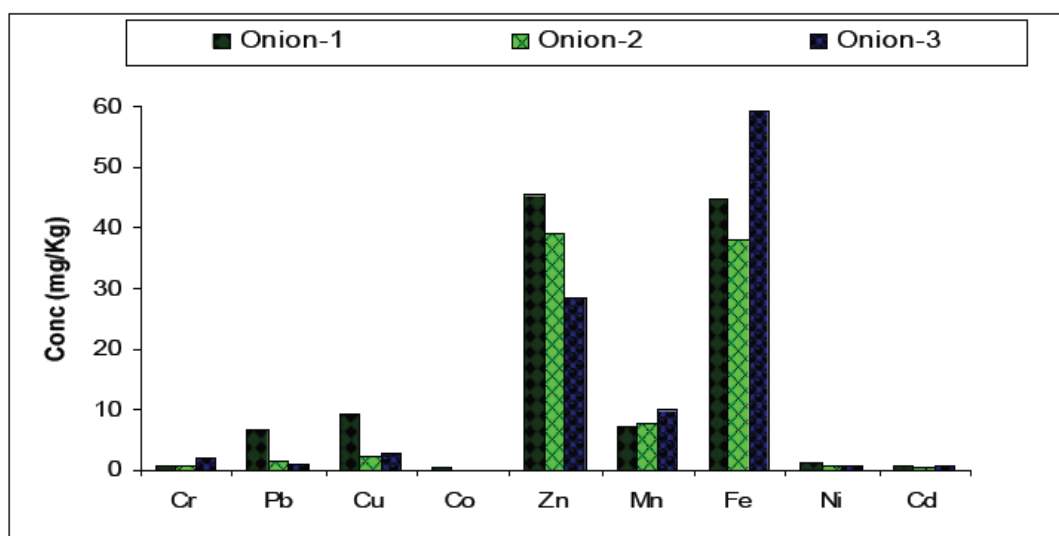


Figure 8: heavy metal concentration at onion, onion-1(Afghanistan Kabul), onion-2 (Pakistan mohmand agency) and onion-3 (Pakistan queta) (Din et al., 2013)

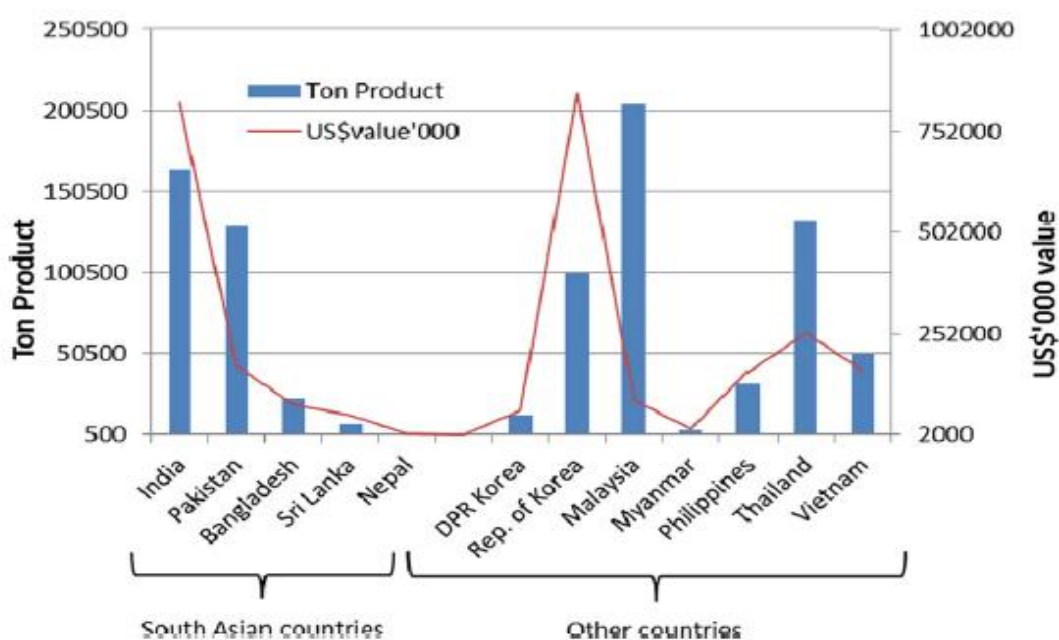


Figure 9: Use of pesticides by tone and cost of it by \$\$ at 2009 (Syed et al., 2014)

C. Physical contamination

When food contaminate by solid foreign substance during production and processing, is called physical contamination. Physical contamination source will be external (metal fragments) or internal (bone particles and pits) and these particles will inter to food accidentally due to poor agricultural practice, manufacturing, storage, transportation and retail during pre and post-harvesting stages,

there are source of food physical contamination and contaminants at table 5 (Abdolshahi & Shokrollahi Yancheshmeh, 2020; Sharma et al., 2020).

In Afghanistan Hepatic veno-occlusive disease (VOD), which are called Gulran disease, and its first report was from Gulran district of Herat province at 1976 with 7800 cases and 1600 deaths and the cause of this disease was consumption of food which was contaminated with seed of weed. Its local name was Charamac. More species of this weed are *heliotropium popoyii* H. Riedl subsp. *Gillianum* H. Riedl and *pyrrolizidine alkaloids*. Hepatic veno-occlusive disease diagnosed on liver biopsy (Kakar et al., 2010).

Table 5: source of physical contamination and its type of contaminant at different stages.

sources	Contaminants
Field	Rocks/stones/sand, asphalt, metals/bullets, concrete particles, bones, wood fragments and thorns
Processing	Glass, ceramic/chards, metal fragments, staples, blades, clips, needles, keys. Screws, magnet fragments, washers, bolts, screening, plastic, grease/lubricants, rubber, insulation/seal materials, nail polish, jewelry, coins, pieces of gloves, finger cots, bandages, cigarette butts, gum, bones, pits, fruit stones, nut and animal shells, medication/tablets/capsules, wood pants, and pencils, rodents and insects
Storage and distribution	Metal, plastic, wood fragments, insect and rodents

(Abdolshahi & Shokrollahi Yancheshmeh, 2020)

Food contamination Prevention methods

All workers that work at food preparation from farm up to kitchen are responsible to protect the public from health risks such as food-borne illness and food allergies. The following are some techniques to help form food-borne illness and allergies (Sadiku et al., 2020). Bacterial contamination prevention methods are included: For limiting access of feral animal to the field or orchard, fencing construction, at Advance level using of manure fertilizer, Clearing of farm equipment regularly, Hygiene in critical process such as removal of intestine, removal and hocking of chest organs, lymph node incisions at meat inspection, separate slaughtering of infected and non-infected animals, Sustaining portable hand washing station and toilets, Schedule of washing and sanitizing of equipment, Using of plastic and fiber glass. (Agriopoulou et al., 2020; Alum et al., 2016b). Also, mycotoxin contamination prevention methods are: good agronomic practice, including (select resistant variety, crop rotation practice, good storage condition, rapid drying and field management, use of anti-fungal preservative, Application of organic acid, antibiotics, herbs, spices, essential oil, pesticide, fumigants, antioxidant and chlorine, Remove damaged seed for grain (Assefa & Geremew, 2018). Viral contamination prevention methods are: Washing of hands, Environmental inactivation, waste treatment, disinfection, immunization, detection, and cooking (Cliver, 2009). Physical contamination methods are: Remove contaminated food item by recalling them from market circulation, conduct a thorough investigation to identify the root cause, maintain open communication with customer affected by the incident and provide transparency and reassurance regarding the steps taken to address the issue (Alum et al., 2016b; Sadiku et al., 2020). And there are some other methods for food contamination prevention: Prevent for biological contamination (cooking temperature, proper storage, effective cleaning and sanitizing techniques, remove pesticides by washing, maintain personal hygiene), radiation of foods can kill germs in food products, using of volatile organic compounds (VOCs), polymerase chain reaction (PCR) and enzyme linked immunosorbent assay (ELISA) for detecting of bacteria, limit use of chemical, follow food best practice to control bacteria growth (cleaning and sanitizing),

good agricultural practice during crop development, microbial test of farm and water, slaughter hygiene, potable hand-wash station, sanitization of equipment's,

Sanitization of working premises, good hygiene practice should be done, chemical should be away from food, health of personal working must be diagnosed, Smoking, chewing, spitting, coughing and sneezing should prohibit (Alum et al., 2016b; Sadiku et al., 2020).

Food contamination prevention need in Afghanistan

In Afghanistan, because of war and conflict all infrastructures are destroyed, people are poor, knowledge of people about agriculture input, production management, process, storage are less, child under five (41%) are at high stunting, 9.5% are at wasting, 1/3 adolescent girl suffer from Anemia, only ½ baby at first six months are breastfed, 12% child at 6-24 month have qualitative food also situation of food secure are presented at figure 10, 11. (D'Souza & Jolliffe, 2013; Krishnan et al., 2019; Waak, 2019). Food at market is not assure, microbiological and chemical test is limited, regulatory system is weak in private sector, MAIL research lab scope of work is in adequate, national medicine and food board structure are not permanent to support all required regulatory function also Afghan National Standard Authority (ANSA) can control only quality of food. Therefore, food safety and contamination prevention measure and methods are necessary (Khalid, 2015).

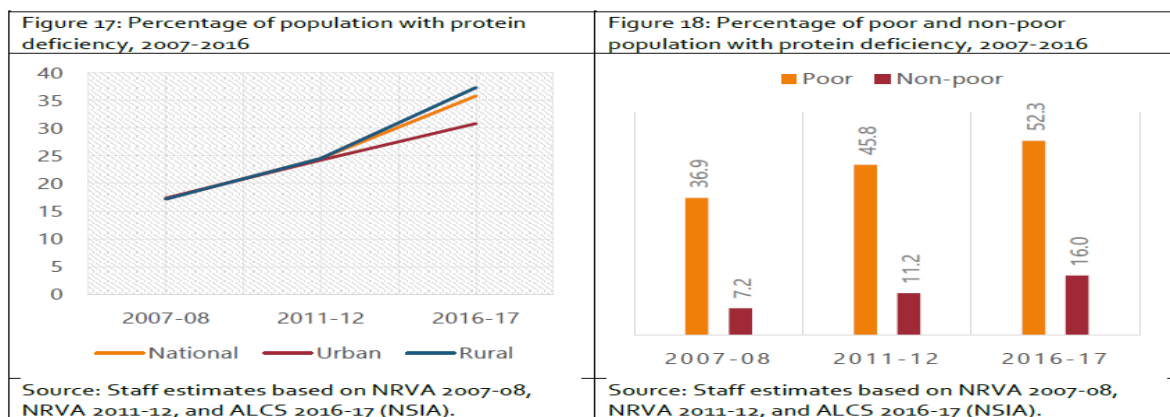


Figure 10: percentage of population with protein deficiency in national, urban and rural level, and population % of poor and non-poor population with protein deficiency from 2007 to 2016. (Krishnan et al., 2019)/ NRVA and ALCS(NSIA)

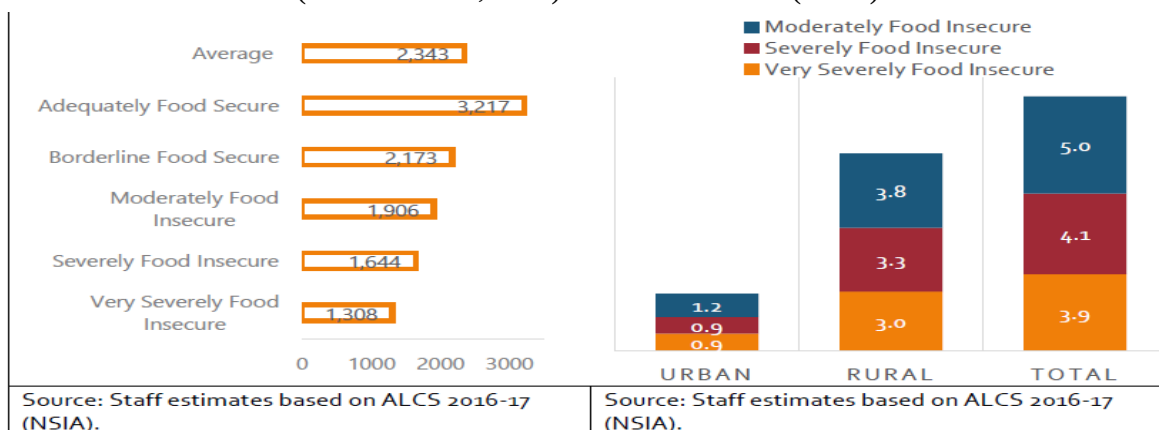


Figure 11: food security (calories per person per day) and food insecure population (caloric deficiency), in million during 2016-2017. (Krishnan et al., 2019)

All people have need for water and food to improve their life and get energy. Energetic food refer to this substance which have nourishing and nutritive components such as carbohydrates, fats, proteins essential minerals and vitamins which sustains life, generates energy and provides growth, maintenance and health of the body, on the other hand, all food are not nourishing and nutritive and can't support body need and we have need for safe food, and safety food refers to handling, preparing and storing of food in that way to reduce risk of people becoming sick from foodborne disease.

Reason for risk of people health are food contamination, and food contamination represents a significant public health and food safety challenge in Afghanistan, food contamination cause of million people death and thousand people ill, beside that food contamination will help at malnourished of people all over the world, similarly, in Afghanistan during 2023 total case of food poisoning, acute bloody diarrhea, acute watery diarrhea and water contamination were 693, 124, 292 with 2 deaths, and 51 respectfully; during 2024 in Afghanistan total case of diarrhea were 5922 with 6 deaths. And also, all cases of aflatoxin in Afghanistan were 7800 with 1600 death at Herat province, likewise, in Afghanistan at 2016 food security situation were 3.9 million people were at very severely, 4.1 million at severely and 5.0 million at moderate food insecure situation. For these problems which are very sensitive to the health of people are different type of contamination like: biological which are included bacterial, viral, and pathogenic and mycotoxin, chemical and physical. Main problem of prevention from contamination is that the main step and stage for contamination is not clear and contamination is series problem thus, needed to apply different prevention methods like Irrigation and water microbiological testing, limiting access of animal to the field, advance using fertilizer, select resistant variety, crop rotation practice, good storage condition, rapid drying and field management, use of anti-fungal preservative, Application of organic acid, antibiotics, herbs, spices, essential oil, Washing of hands, Environmental inactivation, waste treatment, disinfection, immunization, detection, and cooking, remove contaminated food item by recalling them from market circulation. Etc., for decrease of food contamination and wellbeing of human. Finally, we can say that knowledge of biological, chemical and physical contamination methods helps to provide enough and qualitative food for all people at all time and also, can keep soil and water clear from contaminants

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The Effect of Climate Change on Food Security in Afghanistan

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Abstract

The knowledge gap of the effect of climate change on food security undermined adaptation policies in Afghanistan in the last two decades. To address this gap, we utilized three rounds of Afghanistan living Conditions Surveys between 2011 and 2020 and applied a pooled cross-sectional OLS approach. Climate change is measured by higher-than-average temperature. Our findings reveal a multifaceted effect of climate change on food security. Climate change proxied with higher-than-average temperature negatively impacted calories and protein intake, whereas the intake of vitamins (e.g., A and C) was positively influenced. Thus, climate change undermines efforts to overcome food insecurity in Afghanistan, particularly in terms of lower calorie and protein accessibility at the household level, while contributing to the higher availability of vitamins A and C. Moreover, high-altitude and rural areas are much more food insecure than low-altitude and urban settings, which indicates that food security inequality exists in Afghanistan. The two-sided effect of climate change could potentially enlarge disparities further. Therefore, it is crucial to consider these inequalities while framing climate change adaptation initiatives for improved food security in Afghanistan. Food policy initiatives should consider the multifaceted effect of climate change on nutrient types and develop nutrient-based adaptation policies. Community resilience to climate change should be regarded as an adaptation policy, and agricultural policy should be formed to tackle food insecurity properly based on every region's unique landscape and challenges. Therefore, agricultural policies should be developed to meet certain nutritional gaps, to increase the availability of calorie and protein-dense crops.

Keywords: Climate change, temperature, nutrient intake, food security

Introduction

Food insecurity is among the biggest challenges faced by Afghanistan's people. Especially after a decade of improvement (2001-2010), the economic downturn resulted in deteriorating food security conditions in the second decade of the 21st century. Furthermore, between 2011 and 2020, the higher temperature and precipitation anomalies affected the livelihoods of millions through frequent drought and flooding (Kochhar & Knippenberg, 2023), increasing the vulnerability to food insecurity due to high levels of rain-fed agriculture dependency (OCHA, 2023). In addition, despite acknowledging the effects of climate change on livelihood (Akhundzadah et al., 2020), water availability (Nie, et al., 2021), seasonal shifts with longer growing days, and effects on food availability in the limited sub-national geographical landscape in Afghanistan (Jawid, 2019; Omerkhil et al., 2020), the exact countrywide link with food security is not established. Therefore, for a country with nearly 15 million (out of 40 million population) facing food insecurity (WFP, 2023) and approximately 45% of children under five are stunted (a measure of malnourishment) (UNICEF, 2023), this issue is priority number one. In addition, climate adaptation is missing in food insecurity policies, undermining the efforts and pushing households into undesired conditions while facing climatic anomalies.

Thus, quantifying the effect of climate change on food security is an essential step forward for curbing climate change adaptation policy initiatives to improve food security in Afghanistan and achieve sustainable development goals (UN, 2015).

Climate change is proxied by rising temperatures affecting the very core of livelihood and food security around the world, by decreased crop yields and productivity (Burke et al., 2015), increased susceptibility to pests and diseases (Deutsch, et al., 2018), and lower nutritional quality of crops (Zhu, et al., 2018). Moreover, evaporation from higher temperatures affects the regularity of rainfall and threatens rain-fed agriculture (IPCC, 2022) and livestock production. These chain events lead to lower levels of food availability in the markets, driving up prices and limiting food access, especially in developing nations (Hasegawa et al., 2018). Moreover, reduced agricultural income and decreased employment opportunities decrease households' ability to afford food, predominantly in vulnerable societies (Letta et al., 2018; Chaijaroen, 2019; Heyes & Saberian, 2022). As a result, households respond by reducing food consumption (Kroeger, 2023), substituting cheap, less nutritious foods, and compromising food security conditions (Niles, et al., 2021). Consequently, compromised food security leads to food-borne diseases (Zhu, et al., 2023), it also varies among geographical locations (Kandel, et al., 2023). The poorest and most marginalized populations are excessively affected, aggravating existing inequalities.

The recent surge in detailed food consumption data at the household level provides the opportunity to analyze food security from this precise angle. However, most literature focuses on a single nutrient intake or two, usually from the same group. For example, when analyzing food security from a nutritional standpoint, studies often focus on calories and protein as the primary indicators (Carpena, 2019; Chaijaroen, 2019; Zhu & Fang, 2023) or micronutrients as a base for their analysis (Stevens et al., 2022). Nevertheless, when comprehensively analyzed, this approach overlooks macro or micronutrients, which may have different relationships with climate change. Therefore, datasets with rare anthropometric measures (Cooper et al., 2019) should be used, or both macro and micronutrients should be included simultaneously in the analysis. Moreover, using anthropometric data excludes men from the analysis, which decreases the generalizability of the findings. Therefore, using the second approach to disentangle how climate change differentially affects the intake of macronutrients (calories, protein) and essential micronutrients (vitamins) at the household level seems feasible, and this approach has been adapted in this paper.

In Afghanistan, the effect of climate disasters, such as floods, on food security has been previously analyzed, showing apparent adverse effects (Oskorouchi et al., 2018; Yolchi et al., 2024). However, climate change in isolated studies offers mixed findings on the specific impact on Afghan food security, with increased food availability in some regions and decreased levels in others (Jawid, 2019; Omerkhil et al., 2020). The increased availability, documented in the central highland of Afghanistan, may have occurred due to extension and promotion policies, while the adoption seems smooth. In contrast, the overall effect of climate change on cereal production is negative (Sarwary et al., 2023), pointing to the country's failure of the government's climate adaptation policies. While the link between food production and climate change is documented, research on the specific link between temperature changes and household nutrient intake in Afghanistan remains underexplored. Previous literature lacks a comprehensive analysis of household consumption patterns across the country's diverse topography.

This knowledge gap has led to short-term climate change interventions that temporarily relieved food security (Jawid & Khadjavi, 2019), neglecting the chronic climate change adaptation challenges faced by communities and households in Afghanistan.

This paper aims to address this critical knowledge gap by analyzing the effect of climate change on household nutrient intake in Afghanistan for a better food security policy design for better adaptation to climate change. We move beyond production-focused studies and investigate food consumption patterns as a unique lens to understand the subtle effects of climate change on food security. Specifically, this paper delves into this topic using three rounds of Afghanistan Living Conditions Survey datasets (2011 - 2020) and temperature data obtained from NASA MERRA2 (GMAO, 2015). In Afghanistan, ground weather data collection points are minimal and do not cover most of the country's districts. Considering the above advantages, using grided satellite data is the only best option in this context. The mentioned time frame covers economic meltdown due to foreign troops' withdrawal in 2014, extreme weather events such as flooding of 2011-12, drought of 2017-2018, and steady increase in temperature. The research question is: While the rising temperature negatively affected food production in Afghanistan, how is it reflected in household food consumption patterns? The response to this question offers empirical evidence to guide climate change adaptation policy decisions for improved food security in Afghanistan by examining this question.

Materials and Methods

Data

The three datasets used in this paper were sourced from the National Statistics and Information Authority of Afghanistan (NSIA) such as 1) Living Conditions surveys (National Risk and Vulnerability Assessment 2011/12, 2) Afghanistan Living Conditions Survey 2016/17, and 3) Income and Expenditure & Labor Force Survey 2020. The final documents of each survey round describe a detailed two-stage sampling design, sampling unit selection, and survey administration.

The selected three datasets, alongside other socio-demographic and community-level characteristics, contain a very detailed food consumption module, where households are asked to report the amount of each food item, they consumed the week before the interview. This module is administered to female household members who do more household chores like cooking. The values are reported in kg, g and liters. Food items covered by data collection schemes vary between 98-113. In addition, food items could be self-produced, purchased, or in-kind food transfers. More information could be attained in each round's report (CSO, 2014; 2018; NSIA, 2021).

Topographical data for 398 districts, accessed through the Afghanistan district dashboard of the World Bank website. Classification is low (less than 2600 m), medium (2600-3800 m), and high altitude (over 3800 m) based on the district center location above sea level (World Bank, 2019).

Climate data

To quantify climate change, temperature and precipitation are used as different from their long-term mean. The data mentioned is available from 1980 onwards on NASA MERRA2 satellite imaging remotely sensed grided data at the district level for Afghanistan (GMAO, 2015).

Satellite imaging remotely sensed grided data validated and used in the literature in the case of Afghanistan (Ghulami, 2017; Oskorouchi et al., 2018). Using satellite imaging remotely sensed grided data is preferable due to the unavailability of time series ground climate data for Afghanistan. The limited time coverage does not allow the construction of long-term mean calculations and the estimation of climate change variables for all districts in Afghanistan. For instance, meteorological station data are missing between 1978 and 2009 (Akhundzadah et al., 2020).

As shown in

Figure 1, the temperature rise gained momentum around the 1990s, showing nearly a 1.5 °C increase till 2022 compared to past trends. The volatility and increasing temperature are evident in the 2010-2020 time frame, which coincides with our data coverage and research period.

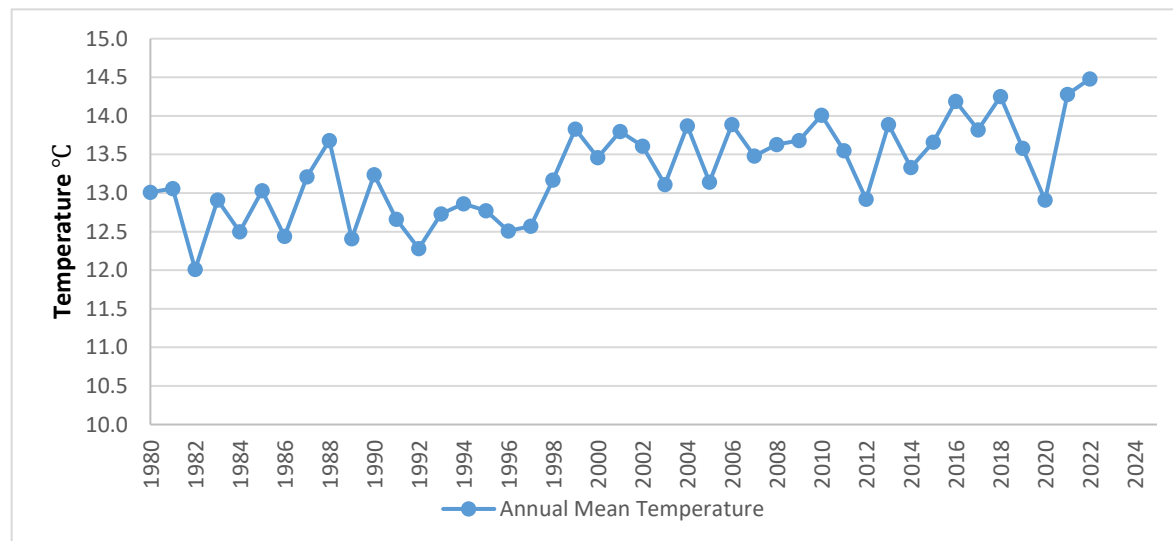


Figure 1: Annual mean temperature level in Afghanistan over time, 1980-2024 (World Bank, 2024)

Method

Variables' description

Dependent variables used in this paper are calorie, protein, vitamin A, and C per capita intakes, corrected for household composition such as size, age, and gender. These variables are commonly used in the literature to measure food security at the household level (D'Souza & Jolliffe, 2013; Oskorouchi & Sousa-Poza, 2021; Parigi, 2023). These dependent variables are constructed using the food consumption module of the NRVA-2011/12, ALCS-2016/17, and IE&LFS-2020 datasets.

Sabry and Rizek's (1982) nutrient table for the Middle East is utilized to calculate the nutrient content of every food item. Sabry and Rizek (1982) do not report nutrient values for some food items; in this case, the nutrient values from USDA have been used (USDA, 2023).

All three datasets record each food item consumed seven days before the interview. Multiplying the amount of each food item reported by the household, with respective nutrient content, and summing up all items will give the total nutrient intake at the household level using the procedure explained in Smith & Subandoro (2007). For more precise estimates, any values smaller than 500 kcal/capita/day corrected for outliers and over 12000 kcal/capita/day are removed from all three datasets following prior literature (Smith & Subandoro, 2007).

Based on this procedure, a 30-60-year-old moderately active male is taken as the reference to construct the adult equivalized (AE) calorie and nutrition consumption at the household level. Due to covering a seven-day recall period, the total adult equivalized calorie and nutrient intake is then divided by seven and by the adult equivalent household size of each nutrient to reach adult equivalized per capita intake. Because that data range is unrealistic and exaggerated by underreporting and overreporting. The same procedure is applied for protein, vitamin A, and vitamin C, except we have removed the households with zero values from these three variables.

Nutrient intake requirements based on seasons are not accounted for, and meals eaten outside the house and given to guests are not included in the analysis following prior literature (Oskorouchi & Sousa-Poza, 2021). Meals outside the home and guests account for a small proportion of foods, 1%—2%, with slight variation in each survey round.

Other control variables are household head characteristics (such as literacy, age, sex, marital status, employment status), household income (in Afghani), land and livestock ownership (dummy variables 1 if yes and zero otherwise), place of residence (dummy variable 1 if rural and 0 otherwise), self-reported food price increase (dummy 1 if experienced and 0 otherwise), district security level (factor variable with five levels from very secure to very insecure), community-level characteristics, and province dummies. The topography data was accessed from the Afghanistan district dashboard on the World Bank website. The entire country is divided into three categories based on altitude above sea level for 398 districts. Districts with altitudes less than 2600 m are categorized as low altitude, those between 2600-3800 m are classified as medium altitude, and districts with altitudes over 3800 m are categorized as high altitude (World Bank, 2019).

Climate change variables

District-level geographical locations for 398 points (one for every district) were obtained from the National Statistics and Information Authority of Afghanistan, which was used to download temperature data from the NASA MERRA2 website. Daily temperature and precipitation data were downloaded for each district between 1980-2020, and the long-term mean was calculated at the district level for each round of datasets. Then, each day's current and lagged temperature and precipitation versions are computed separately as differences from their long-term mean for each dataset. The temperature and precipitation data merged and matched every household's interview date for current, 365, and 730 days before the interview for lagged versions. For the analysis, households in districts with one degree higher than average temperatures were coded as 1 and 0 otherwise from the primary interest variable in each survey round.

Econometric model

This paper applies a pooled cross-sectional with ordinary least squares method. The literature effectively applies this approach to food security (Lazzaronia & Wagner, 2016; Tariqujjaman, et al., 2023) and health (Arah et al., 2005). Besides pooling independent cross-sections, the primary notion is to increase the sample size and estimate with more precision, have test statistics with more power, and monitor the changes in the relationship between interest variables over time (Wooldridge, 2016).

This paper has two main assumptions for applying the OLS model: First, the temperature variable is considered exogenous because of the prevalence of subsistence-level farming in Afghanistan. Furthermore, Afghanistan's effect on climate change is minimal due to its lower level of economic development.

Therefore, based on prior literature, reverse causality is also not a big issue (Fanzo & Miachon, 2023). Second, by assuming no dependency across households (cluster standard errors at PSU), which states uncorrelation of error terms with the independent variables, pooled OLS model estimations would provide unbiased estimates of the coefficients, elbaite under satisfying main assumptions of linear regression. In this case, our model satisfies all OLS main assumptions such as homoscedasticity, normality of residuals, and others (reported in supplementary online Appendix 1).

Reliant on the nature of the dependent variable, which is continuous and satisfies the main assumptions of linear regression and taking advantage of spatial and historical variation in temperature and precipitation at the district level, the following pooled OLS model are being estimated:

$$Y_{idt} = \beta_0 d.Temp_{idt} + \sigma_t + \beta_1 amPrecip_{idt} + \gamma_d + \delta H_{idt} + \varepsilon_{idt} \dots \dots \dots I$$

In model I, Y stands for nutrient intake per AE per day of household i at district d, and t stands for time, including the day, month, and year of the interview for each household. β_0 and β_1 are parameters of interest, and variables $d.Temp$ is the dummy variable that takes 1 if the household lives in a district with one degree above average temperatures,

and $amPrecip$ is precipitation as differences from the corresponding long-term mean from 1980 to each survey date. Therefore, the long-term mean for NRVA2011/2012 is calculated from daily precipitation and temperature data between 1980 and 2012; for ALCS 2016/17, it is between 1980 and 2017; and for IE&LF2020 is between 1980 and 2020. The primary interest variable is temperature, while precipitation is being added to the model due to its effect on food security based on prior literature (Skoufias et al., 2012; Sassi & Cardaci, 2013) to avoid omitted variable bias issues γ_d is a province-level time-invariant fixed effect, σ_t time-fixed effects to control for time-variant structural changes; δH_{idt} household characteristics; and ε_{idt} stands for the error term. Moreover, ## represents the interaction term between interest and time dummy.

However, the model falls short of accounting for the effects of past climatic shocks on current consumption. To address this, two distinct lagged versions of temperature above the historical mean for one and two years before the interview for each household are being added to the previous model as follows:

$$Y_{idt} = \beta_0 amTemp_{idt}##\sigma_t + \sigma_t + \beta_1 amPrecip_{idt} + \beta_2 amTemp_{idt-1} + \beta_3 amTemp_{idt-2} + \gamma_d + \delta H_{idt} + \varepsilon_{idt} \dots \dots \dots II$$

Model II is the same as model one, with two lag variables for temperature, namely $amTemp_{idt-1}$ and $amTemp_{idt-2}$ with parameters of interest being β_2 and β_3 . The terms t-1 and t-2 correspond to the temperatures of 365 and 730 days before the interview for household i in district d, respectively. Proper adjustments were made by applying the svy command in STATA 17 to account for the complex survey design and report robust standard errors at the PSU level. This adjustment will solve the multicollinearity and bias in standard errors by clustering and weighting (Moody & Marvell, 2020). Moreover, to check the findings' robustness, we added two lag versions of precipitation 365 and 730 days before the interview for each household.

Results and discussion

Descriptive statistics

Table 1 indicates the percentage of households in our three datasets living in areas with temperatures 1°C above the historical mean. The highest proportion was recorded in NRVA 2011/12, and the lowest at ALCS-2016/17. However, on average, nearly half of the sample used in this analysis experienced higher-than-average temperatures.

Table 1: Percentage of Households living in areas with 1 °C above historical mean

Survey dataset	Sample size	percentage above means	SD
NRVA-2011/12	20,604	0.593	0.491
ALCS-2016/17	19,638	0.483	0.500
IE&LFS- 2020	17,752	0.509	0.500

Source: Authors calculation (SD- standard deviation)

The summary statistics in Table 2 cover dependent variables across 2011 – 2020 time slots. The following trends and results for Afghanistan's food security over a decade could be extracted. First, the food security condition worsened from 2011 to 2016 following the economic downturn due to the withdrawal of foreign troops from Afghanistan (World Bank, 2022). However, the 2020 indicators, despite the COVID-19 outbreak, which affected food security negatively around the world (Okolie & Ogundeki, 2022; Lara-Ar´evalo et al., 2023; Castrejón, et al., 2024), show improvement compared to values in 2016/17.

It is worth mentioning that the period used in IE&FL2020 does not cover all of 2020 (the survey starts

on 4th October 2019 and ends on 21st September 2020); in this case, it may fail to detect the adverse effects of COVID-19. Second, between 2011 and 2020, households in Afghanistan substituted staples for meat, fish, and dairy. Considering the rise in food prices and economic downturn with decreased income per capita (NSIA, 2022), the substitution seems logical. This indicates quality quantity trade-off in food consumption during price rise or decreased income to maintain the intended energy requirement with cheaper substitutes, confirming prior literature on this case (D'Souza & Jolliffe, 2012; 2013; 2014). Third, the share of fruits, vegetables, and tubers has increased beyond the level of 2011, which is a sign of change toward a healthy diet in Afghanistan.

Table 2: Summary statistics of food consumption indicators based on food groups in the last decade

Variables	Food groups\Survey years	NRVA-2011-12	ALCS-2016-17	IE&LF-2020
Calories (kcal) ^a	Total calorie	3402.996 (1535.99)	3146.116 (1514.34)	3434.045 (1763.07)
	Cereals (staples)	2335.835 (1202.91)	2266.029 (1273.86)	2323.095 (1467.01)
	Pulses	54.040 (84.05)	41.433 (54.03)	60.346 (68.80)
	Meat, fish, dairy	227.471 (266.94)	131.172 (171.21)	171.562 (274.66)
	Vegetables, fruits, and	191.434 (195.67)	143.430 (121.41)	190.868 (172.42)
	Oils, sweets and condiments	594.217 (451.37)	564.052 (438.27)	689.451 (444.41)
Protein (gm) ^b	Total protein	64.961 (34.67)	59.873 (44.20)	67.554 (37.05)
	Cereals (staples)	43.522 (24.05)	42.655 (26.54)	47.085 (30.17)
	Pulses	3.026 (4.87)	2.324 (3.02)	3.624 (3.81)
	Meat, fish, dairy	11.265 (11.46)	7.257 (8.40)	9.125 (10.67)
	Vegetables, fruits, and	4.257 (4.97)	3.208641 (2.63)	4.821 (4.33)
	Oils, sweets and condiments	2.892 (10.48)	4.429 (29.38)	2.899 (4.28)
Vitamin A (gm) ^a	Total Vitamin A	492.168 (1077.99)	319.212 (638.58)	584.257 (1031.68)
	Cereals (staples)	5.627 (25.63)	2.367 (17.99)	0.088 (0.99)
	Pulses	2.408 (4.59)	1.770 (2.51)	2.456 (2.97)
	Meat, fish, dairy	211.535 (870.22)	99.740 (455.74)	134.166 (555.61)
	Vegetables, fruits, and	259.298 (582.38)	212.2 (433.32)	430.146 (857.67)
	Oils, sweets and condiments	13.301 (14.85)	3.136 (3.61)	14.082 (10.93)
Vitamin C (cmg) ^a	Total Vitamin C	54.593 (55.78)	44.536 (40.50)	56.621 (47.72)
	Cereals (staples)	N/A	N/A	N/A
	Pulses	0.401 (0.74)	0.295 (0.42)	0.408 (0.49)
	Meat, fish, dairy	1.010 (2.48)	0.470 (1.41)	0.685 (1.81)
	Vegetables, fruits, and	50.131 (52.95)	40.939 (36.41)	53.745 (46.80)
	Oils, sweets and condiments	3.0524 (9.64)	2.832 (15.30)	1.783 (2.68)
Sample size		20,604	19,638	17,752
Districts		398		

Notes: The calculations were derived from NRVA2011/12, ALCS2016/17, and ALCS2020 datasets of Afghanistan.

^a nutrient intake as per adult equivalent,

^b per capita nutrient intake- because no adult equivalent cut-off

Standard deviations are in parentheses

- Cereals (staples) – consists of bread, high- and low-quality flour, and rice
- Pulses – beans, peas, lentils and others
- Meat, fish, dairy – mutton, beef, animal organs, fresh fish, yogurt, curd, milk, dried curd
- Vegetables, fruits, and tubers – all kinds of vegetables, either fresh, dried, or wild; fruits and nuts, either fresh or dried; and potato and sweet potato
- Oils, sweets, and condiments- all kinds of cooking oils, cake, candies, sweets, spices, and seasonings.

Moreover, staples cover over 50% of the caloric needs of households in Afghanistan, which may increase the prevalence of micronutrient deficiency, as documented in some developing nations (Cakmak et al., 2010). Despite being the dominant food group, the staple share of calories slightly decreased by nearly 1% over a decade in Afghanistan. However, the share of oils, sweets, and condiments increased by 2.5%. For other food groups, the shares either stayed constant or decreased.

Regression results

Results presented in Table 3 (columns 1 and 2) show the negative impact of 1°C higher-than-average temperature on per capita calorie intake in Afghanistan over the second decade of the 21st century. The parameters are statistically significant at a 1% level. In over a decade, the higher temperature is responsible for a 200 kcal/AE/day decrease at the household level in Afghanistan. Prior literature on the effect of higher temperatures on food security (from a food production perspective) in Afghanistan points to the positive effect on highland cold areas (Jawid, 2019) and the negative effect on lowland warm places (Omerkhil et al., 2020). This paper's nationally representative and decade-long analysis confirms the adverse association of higher temperatures and calorie intake and, thus, food availability overall in Afghanistan. These findings align with similar studies in the literature regarding the negative effect of higher temperatures on calorie intake (Zhu & Fang, 2023).

In addition, price spikes in the last decade negatively affected household calorie intake, which is significant at a 1% level, confirming prior literature in the case of Afghanistan (D'Souza & Jolliffe, 2013). It reveals that despite being aware of the negative effects of price hikes, proper infrastructures to cope with price volatilities and assist households haven't been developed. Other determinants of lower caloric intake are residents of rural areas or higher altitudes compared to urban and lower altitudes.

Table 3: The effect of climate change on calorie and protein per capita intake

VARIABLES	Kcal/AE/day (1)	Kcal/ AE/day (2)	Protein/capita (3)	Protein/capita (4)
Temperature (1°C higher than average)	-96.065* (52.736)	-192.726*** (71.760)	0.164 (1.093)	-2.716* (1.551)
Current mean precipitation		-4.558 (3.452)		-0.078 (0.071)
Much an increase in food prices	-409.884*** (51.273)	-412.314*** (51.217)	-10.254*** (1.130)	-10.328*** (1.129)
Residence type (rural=1)	-692.870*** (54.847)	-691.771*** (54.988)	-19.018*** (1.205)	-18.974*** (1.206)
District level altitude (ref: low altitude)				
Medium altitude	-75.011* (41.624)	-76.292* (41.611)	-1.732** (0.863)	-1.750** (0.861)
High altitude	-151.748*** (52.145)	-151.020*** (51.996)	-3.440*** (1.052)	-3.420*** (1.049)
Constant	5,433.337*** (141.269)	5,479.427*** (142.057)	98.910*** (2.905)	100.321*** (2.932)
Observations	57,122	57,122	57,122	57,122
R-squared	0.197	0.197	0.215	0.215
Lags of temperature	No	Yes	No	Yes
Household characteristics	Yes	Yes	Yes	Yes
Community and district dummies	Yes	Yes	Yes	Yes

Notes: The estimations were derived from NRVA2011/12, ALCS2016/17, and ALCS2020 datasets of Afghanistan. All models control for a wide range of variables, such as household head characteristics, household size, per capita income, district-level security condition, ownership of irrigated and rainfed land, province of residence, and time dummy for the year of the survey with respective interaction terms with interested independent variables.

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Moreover, Table 3's results (columns 3 and 4) indicate the negative effect of 1°C higher-than-average temperature on protein intake, which follows the path of calorie intake. These findings confirm the adverse effects of higher temperatures on protein intake in the literature of developing countries (Chaijaroen, 2019) with lower confidence levels. On the other hand, the effect of price shocks is much more evident and statistically significant at a 1% level. Protein-dense foods may be much more dependent on price hikes, and households may substitute them if they cannot afford them, which has also been reported in previous literature (D'Souza & Jolliffe, 2014). This was also visible in Table 2 of the descriptive statistics.

Rural areas consume much less protein than urban settings, which is statistically significant at a 1% level. In addition, households living in high-altitude areas consume less protein than their low-altitude counterparts. These findings indicate that food insecurity (measured by lower protein intake) is bounded by geography and residence area and aligns with prior studies (Thapaa & Hussain, 2020).

They indicate the inequality level of food insecurity based on residence area and topographical locations or the so-called hidden hunger (Dame & Nüsser, 2011).

It is essential to consider the differences in calorie and protein intake when developing policies to address food insecurity. Households in rural high-altitude areas tend to have lower nutrient intake and are more likely to experience food insecurity than those in rural low-altitude areas. As a result, high-altitude residents faced chronic food insecurity due to their geographic location and lower food availability.

Curving unique adaptation and resilience policies for these communities is essential to overcome some of the adverse effects of climate change to improve food security.

Additionally, the failure to substitute soybeans for traditionally cultivated species (Cohen & Arkin, 2014) highlights the importance of integrating socio-cultural and change acceptance of the farmers/households on food security and adaptation policies in Afghanistan.

Interestingly, the effect of temperature on micronutrient intake (vitamins A and C) is positive and statistically significant, based on the results summarized in Table 4. The parameters indicate a positive effect of higher temperature on nutrient intake and are statistically significant. Investment in orchard and vegetable farming, which was carried out mainly in Afghanistan in the first and second decade of the 21st century, both by the government and NGOs (Masini & Giordani, 2016; World Bank, 2017), may have affected the availability of vegetables and fruits in a positive way in the country. Therefore, it may help the farmers to adapt to the changing climate better, which results in an abundance of such food items in the market.

Vitamin A is found in perishable food such as fresh fruits and vegetables. Given Afghanistan's low accessibility to road infrastructure, the higher temperature resulted in an increased intake of vitamin A, which may point to the local increase in the physical availability of such food items. This takeaway is also supported by food price shock and topography variables. These variables show no sign of a negative effect on vitamin A intake; in contrast, the consequences are negative and significant in the macronutrient case.

Table 4: The effect of climate change on vitamin A and C per capita intake

VARIABLES	Vitamin A/ AE/day (1)	Vitamin A/ AE/day (2)	Vitamin C/ AE/day (3)	Vitamin C/ AE/day (4)
Temperature (1°C higher than average)	-141.012*** (31.547)	108.553*** (35.525)	8.586*** (1.596)	3.633* (2.106)
Current mean precipitation		-0.841 (1.684)		0.069 (0.109)
Much an increase in food prices	-36.854 (33.242)	-30.645 (32.643)	-3.343** (1.331)	-3.471*** (1.335)
Residence type (rural=1)	-37.663 (27.433)	-40.030 (26.538)	-11.741*** (1.454)	-11.654*** (1.452)

District level altitude (ref: low altitude)				
Medium altitude	-31.168 (26.825)	-27.007 (26.580)	-7.121*** (1.411)	-7.131*** (1.408)
High altitude	-43.427 (34.520)	-45.364 (33.975)	-9.906*** (1.676)	-9.873*** (1.677)
Constant	734.933*** (80.274)	617.476*** (78.621)	76.236*** (3.350)	78.700*** (3.323)
Observations	57,122	57,122	57,122	57,122
R-squared	0.075	0.080	0.195	0.196
Lags of temperature	No	Yes	No	Yes
Household characteristics	Yes	Yes	Yes	Yes
Community and district dummies	Yes	Yes	Yes	Yes

Notes: The estimations were derived from NRVA2011/12, ALCS2016/17, and ALCS2020 datasets of Afghanistan. All models control for a wide range of variables, such as household head characteristics, household size, per capita income, rural/urban, district-level security condition, ownership of irrigated and rainfed land, district of residence, and time dummy for the year of the survey with respective interaction terms with interested independent variables.

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

However, price increase and topography are negative determinants of vitamin C intake and residence type compared to vitamin A. The negative effect of topography on vitamin C intake is significant, as we have had an epidemic of scurvy in the country in the past (Cheung, et al., 2003). Moreover, most vitamin C-rich food items are imported, which puts the vulnerable population at a higher risk of lower intake in the time of price rise. In addition, the negative residence type and altitude parameters in Table 4 (columns 3 and 4) indicate chronic problems with vitamin C intake—adaptation to higher temperatures has already begun by the farmers and community. For instance, there is an increase in lemons in northern and northeastern Afghanistan, which were previously not cultivated due to environmental conditions (MAIL, 2021), which may solve some of the deficits in vitamin C intake in those areas. Therefore, community-driven adaptation policies are much easier, faster, and cost-effective than top-down approaches such as the soybean extension programs.

Conclusion

We have analyzed the effect of 1°C higher temperature-than-historical mean on nutrient intake at the household level in Afghanistan over the 2011-2020 period, utilizing three rounds of Living conditions surveys (2011/12, 2016/17, and 2020).

The pooled cross-sectional OLS analysis results indicate the multifaceted effect of climate change on food security measured by nutrient intake (calories, protein, vitamins A and C) at the household level in Afghanistan. The prevalence of food insecurity is higher in households living at high altitudes and rural areas of Afghanistan compared to low altitudes and urban areas. This finding points to chronic food insecurity conditions for households in such communities. Therefore, it is a sign of further enlargement of the inequality in food security among residents of different settings in Afghanistan. Extra efforts are needed to help Afghan people adjust their diet in the extreme weather by promoting and adopting a diverse range of calorie and protein-dense food sources in food security policy initiatives to tackle climate change's adverse effects.

Moreover, the negative effect of self-reported price shocks over time shows that households in Afghanistan are highly vulnerable to food price shocks. That may be due to the country's dependency on food imports and low income levels.

For policy implications, climate change adaptation is crucial for Afghan food security, especially for maintaining a balanced diet. However, giving the initiative to the farmers/households would increase the chance of success. Therefore, we recommend community-driven adaptation policies for agricultural practices because they are much easier, faster, and

more cost-effective to implement (citrus fruit promotion success) than top-down approaches such as failed soybean extension programs (Cohen & Arkin, 2014). Such policy initiatives will solve the social acceptability and maximize the chance of success. Additionally, it is crucial to consider the multifaceted impact of climate change on policy initiatives and develop nutrient-based adaptation strategies to improve food security in Afghanistan. Therefore, agricultural policies should be developed to meet certain nutritional gaps, for instance, to increase the availability of calorie and protein-dense crops. Because climate change proxied with higher temperatures showcased a negative relationship with the availability and accessibility of calories and protein, at least in the second decade of the 21st century in Afghanistan.

Additionally, our findings show that considerable inequality regarding food security exists in regional and rural-urban settings. Therefore, community resilience to climate change should be considered in adaptation policies and address the widening regional and urban-rural inequalities in food security policies. These findings have implications for achieving Sustainable Development Goals of ending hunger, reducing inequality, and taking action on climate change.

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Consequences of root-knot nematodes (*Meloidogyne* spp.) on the growth of cucumber plants

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Abstract

Root-knot nematodes (*Meloidogyne* spp.) are sedentary root endoparasites that severely impact crop production, particularly in Asian Vegetable farms. In temperate regions, root-knot nematodes can cause up to 80% yield losses in vegetable crops, while in Kandahar province, Afghanistan, yield losses of up to 35% have been recorded in polyhouse-grown cucumber. The dramatic damage, lack of visible symptoms, and limited awareness among farmers hinder timely detection and management of root-knot disease. To assess the effects of root-knot nematodes on cucumber plants, a pot experiment was conducted in the Mirwais Mina area, using four inoculum levels (200, 360, 400, and 600 second stage juveniles (J_{2s})/200 cc soil) collected from naturally infested polyhouses, along with an untreated control. The randomized block design (RBD) included four replications. Results indicated significant root impairment, stunted growth, and decreased yield, with the highest reduction in plant parameters observed at the 600 J_{2s} /200 cc soil level. Symptoms of infestation included chlorosis, temporary wilting, drying and root galls, which interfere with water and nutrient translocation, ultimately impacting photosynthesis and plant vigour. Effective surveillance and timely management of root-knot nematodes are essential for preventing yield losses, thereby supporting food security and safety in regions where cucumbers are produced commercially.

Keywords: root-knot nematode, inoculum, symptoms, *Meloidogyne*, disease

Introduction

Root-knot nematodes (RKNs), *Meloidogyne* spp., belonging to Meloidogynidae family of Tylenchida order of plant parasitic nematodes (Tarla, 2017). Till to date, 106 species of the genus *Meloidogyne* are documented. (Elling, 2013; Karssen et al., 2013) Among them, *M. incognita*, *M. javanica*, *M. arenaria*, and *M. hapla* are distributed globally. They are leading vital root endoparasites taking place mostly in protected structures (greenhouse, polyhouse, net house) and open field respectively in the world (Elling, 2013; Tarla, 2017). They are able to attack various species of crops including vegetables, fruits, ornamentals, medicinal, fibre, cereals and weeds (Rusinque et al., 2023). According to their obligate parasite state, cause severe impairment to vegetable crops, leading to foremost yield destruction and economic losses globally.

Their development and egg fecundity are very high in protected cultivation system compared to open field conditions (Elsharkawy et al., 2022). Their second stage juveniles (J_2) are hatched from eggs and attracted by means of chemicals released from the roots of the host plants, thus seek to contaminate roots (Oka, 2020). In overall root system of plant, J_{2s} favour to penetrate the meristematic zone of the root system (López-Gómez & Verdejo-Lucas, 2017).

Dramatic visible symptoms (galls) production is due to hypertrophy and hyperplasia after their feeding (Favery et al., 2015). Consistent with the endoparasitic nature of damage, except from J₂ and vermiform males, all other stages can be found in infested root tissues. Optimum temperature requirement for their development is 15 to 30 °C and need 25-30 days for completion of a single generation (Karssen et al., 2013). In a favourable ecological condition, nematode population build-up increases rapidly and reaches as high as 20-25 eggs and juveniles per g soil while, the economic threshold level is 1 J₂/ 1cc soil (Goto et al., 2013).

Except form root-galls, a characteristic symptom of their infestation, sometimes above ground symptoms like chlorosis, wilting, necrosis, poor fruiting, and stunted growth are misdiagnosed. The above ground symptoms revealed as a result of destruction of xylem and phloem caused by vascular feeders (nematodes) and poor transportation of water and minerals (Bellafiore & Briggs, 2010; Patil et al., 2017; Toth et al., 2019; Sing & Chahar, 2021; Buttar et al., 2022).

Among vegetable crops, cucumber is mostly produced across the year in protected structures on account of its high consumption in the world including Afghanistan. Overall production of cucumber is about 171 t/ha in protected structures compared to 30 t/ha in open field in Afghanistan (Nimgarri et al., 2023). As a result of RKNs infestation in vegetable crops, yield manifestation is upto 80% annually in the world (Bui et al., 2022). In Afghanistan, cucumber yield loss due to RKNs infestation is reported to be about ~35% in protected cultivation system (Nimgarri et al., 2023). Overall yield losses of cucumber due to RKNs are reported to be in the extent of more than 80% (Ami et al., 2018).

RKNs pose a serious threat to global agriculture, impacting food security and safety, particularly in regions like Afghanistan where agriculture is crucial for local food production and livelihoods (Tarla, 2017). Their wide host range and adaptability can significantly reduce the yield and quality of staple crops, including vegetables like cucumber, affecting food availability and causing economic losses for farmers. The risk of widespread crop failure underscores the need for sustainable management strategies to safeguard food supplies. Understanding RKN impact on crops such as cucumber, a vital vegetable in Afghanistan, and improving disease diagnosis can help farmers implement timely and eco-friendly control measures. This research contributes to food security by providing knowledge and tools to mitigate RKN-induced losses and enhance agricultural resilience. Given cucumber's susceptibility to RKNs and the frequent misdiagnosis of symptoms leading to ineffective control methods, this trial was conducted to evaluate RKN effects on cucumber growth and to clearly identify above-ground symptoms. The goal is to support eco-friendly management and increase farmer awareness for better crop protection.

Materials and Methods

A pot experiment was conducted in a polyhouse located in Mirwais Mina area (31° 61" N, 65° 65" E) for assessing the effects of RKNs on cucumber plants in February, 2024. The polyhouse was covered with 200 µm thick low-density polyethylene and aluminate sheets. Entirely five treatments; (T₁) =200 J_{2s}/ 200 cc soil, (T₂) =360 J_{2s}/200 cc soil, (T₃) =400 J_{2s}/200 cc soil, (T₄) =600 J_{2s}/200 cc soil and (T₀) = untreated control treatments were applied in randomized block design (RBD) having four replications. In each replication, there were five pots with plants and totally 20 pots kept in distance between two adjacent replications was 50 cm and between two adjacent treatments withing each replication 20 cm.

Inoculum was prepared based on soil and root samples collected randomly form the rhizosphere of standing cucumber plants using Oak-Land tube (2.5 cm diameter) from 6-15 sites (called cores) of each polyhouse. All the cores were thoroughly mixed to prepare a composite sample.

Finally, samples were placed in polythene bags, labelled, and carried with all precautions required for the live nematodes to the laboratory of plant pathology, Afghanistan National Agricultural Sciences and Technology University (ANASTU) and preserved below 10 °C prior to processing. Thereafter, the samples were processed for the extraction of root-knot nematode from roots and soil following standard procedures (Cobb, 1918). For extraction of nematodes from the soil, 200 cc of the soil of each sample was processed by using Cobb's decanting and Sieving method (Cobb, 1918) followed by modified Baermann's technique (Bensooijen, 2006; Christie & Perry, 1951). After determination of initial soil nematode population, the infested soil was used for the experiment. One kilo gram infested soil of each polyhouse was used a separate treatment.

Fifteen days old cucumber seedlings were transplanted to experimental pots having root-knot nematode infested soil. All the standard cucumber growing procedures were applied and pots were watered when needed. After transplanting, number of leaves, flowers, plant height, chlorophyll content of leaves, and above ground symptoms of cucumber plants were recorded. The experiment was terminated after fifty days of transplanting by uprooting cucumber plants. Roots of cucumber plants were carefully washed with tap water to remove soil; roots were cut off with the help of scissors and galls were counted separately for each root system. Disease incidence and severity were calculated based 0-5 scale (Mohsen et al., 2015).

The collected data were statistically analysed through one-way analysis of variance (ANOVA), and treatment differences were evaluated using Duncan's Multiple Range Test (DMRT) for precise comparison, employing SPSS software (version 24.0.0).

Results and discussion

Three weeks after inoculation, no significant variations among treatments were observed in number of leaves and flowers (Table 1). Despite, number of leaves was significantly suppressed by T₄ (9.83, 6.58 and 9.58) followed by T₃ (4.50, 7.83 and 9.33) and T₁ (4.33, 7.92, and 10.83) compared to untreated control treatment (13.7). Significant reduction in contrast to untreated control treatment in number of flowers were observed in T₂ (1.42, 2.67 and 3.50) followed by T₃ (1.25, 3.25 and 6.13) and T₄ (1.67, 4.75 and 6.25). Nine weeks after inoculation, significant suppression of flowers and leaves were caused by T₂ (3.50 and 5.58) followed by T₄ (6.25 and 9.58) where it was highest (19.33 and 18.75 respectively) in untreated control treatment. Reduction in normal growth of the plant has direct relation to the secretion of second stage juveniles (J₂). Secretion is the parasitism proteins secreted by nematode itself and lead a direct role in plant parasitism (Rawal, 2020). J₂ secretion stimulates the root cells of the host leading to the formation of giant cells which is a source of mineral and nutrients for feeding nematodes till reproduction (Ralmi et al., 2016). This formation of galls on the root system prohibits the translocation of water and minerals to above portion of the plant. Afterward, wilting and chlorosis are initiated in the above portion of the plant (Ralmi et al., 2016). The situations get worst whether the host plant is an early stage of development; galls carry the capability of even killing the host plant in such stage (Rawal, 2020).

Table 1. Effects of different inoculum levels of RKNs on No. of leaves and flowers of cucumber plant

Treat.	No. of leaves/plant			No. of flowers/plant		
	3 WK	6 WK	9 WK	3 WK	6 WK	9 WK
T ₁	4.33 ^a	7.92 ^{ab}	10.83 ^b	0.92 ^a	5.08 ^b	7.63 ^b
T ₂	4.17 ^a	5.42 ^b	5.58 ^b	1.42 ^a	2.67 ^b	3.50 ^b
T ₃	4.50 ^a	7.83 ^{ab}	9.33 ^b	1.25 ^a	3.25 ^b	6.13 ^b
T ₄	4.83 ^a	6.58 ^b	9.58 ^a	1.67 ^a	4.75 ^b	6.25 ^b
T ₀	5.83 ^a	13.17 ^a	19.33 ^a	3.25 ^a	13.75 ^a	18.75 ^a
LSD	1.37	5.49	11.69	1.63	4.93	7.67
SEM	0.25	0.99	2.10	0.29	0.89	1.38

* Values of each column are the mean of three weeks data.

* Means followed by the same latter in a column are not significantly different by DMRT at $P < 0.05$ level of significance.

* WK= Week

Main above ground symptoms of cucumber plants were chlorosis, abnormal wilting, necrosis and stunted growth while, the below ground symptoms are galls on the root system. The similar symptoms of RKNs infection in cucumber were recorded by various researchers across the world (Chahar et al., 2021; Nimgarri et al., 2023; Kayani et al., 2017; Kayani et al., 2012; Kayani et al., 2013; Siddique et al., 2020; Ami & Shingaly, 2020; Buttar et al., 2023; Kshetrimayum & Yaikhom, 2024; Sayedain et al., 2002; Ahmed et al., 2021; Patil et al., 2017; Jones et al., 2013; Baidya et al., 2023). RKNs are able to cause significant reduction in all the plant parameters such as plant height, fresh weight and dry weight (Sayedain et al., 2020).

No significant reduction in plant height was observed in first six weeks after inoculation (Table 2). Afterward, highest reduction (28.24 cm) in plant height was recorded by T₂ (28.24 cm) followed by T₃ (25.27 cm) and T₄ (24.38 cm) while, 47.88 cm plant height was recorded by untreated control treatment (47.88 cm). Chlorophyll contents were significantly suppressed by all treatments. least chlorophyll content was recorded by T₂ (50.88, 33.22 and 30.98 SPAD) followed by T₄ (50.84, 35.14 and 34.50 SPAD) and T₁ (53.13, 50.39 and 38.61 SPAD) in all the period after inoculation (Table 2). Highest chlorophyll contents were 53.13, 50.39 and 38.61 SPAD respectively in first, second and third three weeks. While it was 69.90, 84.71 and 79.14 SPAD respectively, in untreated control treatment.

Table 2. Effects of different inoculum levels of RKNs on cucumber plant height and chlorophyll contents

Treat.	Plant Height (cm)			Chlorophyll content (SPAD)		
	3 WK	6 WK	9 WK	3 WK	6 WK	9 WK
T ₁	5.08 ^a	14.50 ^b	25.94 ^b	53.13 ^b	50.39 ^b	38.61 ^{bc}
T ₂	4.83 ^a	11.75 ^b	19.64 ^c	50.88 ^b	33.22 ^d	30.98 ^d
T ₃	5.33 ^a	15.00 ^b	22.31 ^{bc}	53.89 ^b	41.39 ^c	39.89 ^b
T ₄	5.58 ^a	15.83 ^b	23.50 ^{bc}	50.84 ^b	35.14 ^d	34.50 ^{cd}
T ₀	8.92 ^a	23.00 ^a	47.88 ^a	69.90 ^a	84.71 ^a	79.14 ^a
LSD	1.74	5.37	17.11	13.78	43.55	22.12
SEM	0.31	0.97	3.08	2.48	7.84	3.98

* Values of each column are the mean of three weeks data.

* Means followed by the same latter in a column are not significantly different by DMRT at $P < 0.05$ level of significance.

* WK= Week

Reduction in growth parameters could be due to impairment of root system that cause prevention of mineral and water translocation to the upper portion of the plant which are the result of impaired conductive tissues (Chahar et al., 2021).

Due to the induction of nurse cell system by females of RKNs for incessant feeding in infected roots, there is greater translocation of photosynthates towards these infection sites, while the above ground parts of the plant experience acute deficiency of nutrients (Wyss, 2002). As the infected plants face insufficient supply of nutrients, photosynthates, energy, water etc., development and growth of leaf tissues and their essential constituents, particularly chlorophyll pigments, are greatly hampered (Siddique et al., 2020). According to the disruption of xylem vessels, translocation of water and minerals to the above parts of the plants is greatly reduced. In polyhouse house, all situations for the growth of the plants are favourable, and the temperature is much higher than the open field. Therefore, reduction in photosynthates, water, and minerals in the leaves, and exposure to high temperature cause degradation of chlorophyll contents (Liu et al., 2023). Chlorophyll degradation in plants under stress conditions, like nematode infection or salt and heat stresses can significantly impact photosynthesis (Buttar et al., 2023). In oats (*Avena sativa* L.), exposure to salt stress has been shown to reduce stomatal conductance and photosynthetic rates, likely due to changes in osmotic potential and the inhibition of chlorophyll synthesis (Chahar et al., 2021). Heat stress conditions negatively regulated plant growth and accelerate degradations of chlorophyll contents in cucumber (Liu et al., 2023).

These physiological adjustments can accelerate chlorophyll degradation as the plant responds to unfavourable conditions. Decline in chlorophyll content not only reduces photosynthetic efficiency but also limits the plant's overall growth and stress resilience, reflecting the broader impact of adverse environmental factors on plant health (Buttar et al., 2023).

No significant variation among treatments were observed in root-knot disease incidence and severity (Table 3). Highest disease severity (33.50%) was recorded by T1 followed by T4 and T3 (Table 3). Least disease severity was observed in T2 (28.00%).

Due to RKNs which induce giant cells in nematode feeding sites within the root vascular system, galls are formed on the root system (Banora & Almaghrabi, 2019). This disturbance in the root structure reduces the uptake of water and nutrients and their transport from the roots to the shoots (Abad et al. 2003; Roduic et al. 2014). In addition, these nematodes regulate greater translocation in the output of photosynthesis toward infected root tissue while depriving the foliage parts (Di Vito et al., 2004). Plant response to nematode parasitism thus causes morphological and physiological changes that affect the photosynthetic processes (Hussey and Williamson 1998; Strajnar et al. 2012).

Secretions of oesophageal glands of root-knot nematode into the host cells cause damage to the nutrient and water uptake which substantially reduced by the resulting damage to the root system, and therefore the above ground portion of the plant become weak and vigour-less (Caillaud et al., 2008).

Table 3. Disease incidence and severity of different inoculum levels of RKNs on cucumber plants

Treat.	Incidence (%)	Severity (%)
T ₁	100 ^a	33.50 ^a
T ₂	100 ^a	28.00 ^a
T ₃	100 ^a	32.00 ^a
T ₄	100 ^a	32.00 ^a
T ₀	0.00 ^b	0.00 ^b
LSD	0	14.53
SEM	0	2.62

* Values followed by the same letter in a column are not significantly different by DMRT at $P < 0.05$ level of significance.

Damaged roots may make the plants more susceptible to infection by fungi, bacteria and/or viruses and also susceptibility can be increased to other stress factors like nutritional deficiencies, water, heat and other (Zia et al., 2014).

Conclusion

This study demonstrates that root-knot nematode (RKN) infection significantly impacts the growth and physiological processes of cucumber plants. Observations made over the experimental period indicate that increasing levels of RKN inoculum result in reduced leaf and flower counts, plant height, and chlorophyll content, which collectively hinder overall plant health and productivity. Chlorosis, abnormal wilting, and root galls were key symptoms associated with nematode-induced stress, caused by the impairment of root function, reduced translocation of water and nutrients, and the diversion of essential photosynthates to nematode infection sites.

The study highlights that RKN-induced damage not only reduces plant vigour but also disrupts photosynthetic efficiency by degrading chlorophyll content and inhibiting nutrient uptake, which is critical for growth. Additionally, RKN infection increases plant susceptibility to other stressors such as nutrient deficiencies, drought, and secondary infections. These findings underscore the importance of managing RKN infestations in cucumber cultivation, particularly under controlled environments like polyhouses where high temperatures further accelerate chlorophyll degradation. Implementing timely control measures can mitigate RKN's detrimental effects, thereby preserving cucumber crop yield and quality, essential for food security and sustainable agriculture.

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Effects of straw mulch on weed control and moisture conservation in cumin field

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Abstract

Weeds are the silent enemy and a major cause of yield reduction. In semi-arid climate, the irrigation water limitations and climate change present further challenges in maintaining adequate soil moisture for crop growth and productivity. Straw mulch plays a crucial role in suppressing weeds and conserving soil moisture, ultimately tend to high crop production and food security. To evaluate the effects of weed control and moisture conservation, a one year (2024) field experiment was conducted by growing cumin crop using five levels of straw mulch (0, 2, 4, 6, and 8 t ha⁻¹). The results showed that higher mulch levels significantly reduced weed population and weed dry weight. Specifically, the 8 t ha⁻¹ enhanced the greatest weed control efficiency by 84-90 % and weed control index by 84-94%. Moreover, soil moisture content five days after irrigation increased with higher mulch levels, with the 8 t ha⁻¹ straw mulch treatment maintaining the highest moisture retention across all crop growth stages. Overall, the application of 6 and 8 t ha⁻¹ of straw mulch proved most effective, demonstrating its potential as a sustainable practice for enhancing weed management and water conservation in crop production. These findings suggest that mulching can improve both resource use efficiency and crop productivity by reducing weed competition and conserving soil moisture.

Keywords: Straw mulch, weeds, water conservation and moisture contents

Introduction

Weeds are the silent enemy, responsible for majority of crop yield reduction. Weed management and water conservation are two critical concerns in sustainable agricultural practices, particularly in areas with limited water resources. Traditional methods of weed control, such as chemical herbicides, pose environmental risks and can lead to herbicide resistance, while water scarcity necessitates the efficient use of available water to ensure crop productivity (Chauhan et al., 2012). Mulching, especially with organic materials like straw, has gained prominence as a sustainable practice to address these concerns. Straw mulching is the practice of covering the soil surface with a layer of straw, which can be the harvested crop residue or other source, applying of straw mulch has been shown to improve crop yields and contribute to food security, especially in water scarce or arid regions, it helps retain soil moisture by reducing soil evaporation, which is crucial during dry periods, this moisture retention boosts crop yields and make agricultural systems more resilient to drought (Cheng et al., 2024; Du et al., 2022). Straw mulching is not just beneficial for weed control, it also increases moisture content, regulating soil temperature and improves nutrient concentration in the soil (Fazil et al., 2022; Fazil & Barai, 2023).

Straw mulch provides a physical barrier that suppresses weed emergence and reduces water evaporation from the soil surface, contributing to improved soil moisture retention (Teasdale & Mohler, 2000). Additionally, straw mulching can increase soil organic matter, leading to healthier soil ecosystems, which are vital for long term agricultural sustainability and food security (Waheed et al., 2023).

The application of straw much significantly enhance greater weed suppression and water conservation. Higher mulch levels provide better weed control by limiting sunlight penetration, thus inhibiting weed seed germination and thereby reducing soil water loss through evaporation (Shen et al., 2018). However, excessive mulching may also have drawbacks, such as creating overly moist conditions that could affect crop growth and soil health (Li et al., 2019). Conversely, lower levels of mulch might not be as effective in suppressing weeds or conserving soil moisture (Mulumba & Lal, 2008). Moreover, straw mulch significantly enhances soil moisture retention by reducing evaporation and improving water infiltration rates. Researches by (Liu et al., 2022; Verma & Pradhan, 2024) demonstrated that straw mulch not only reduces evaporation but also mitigates the effects of water stress on crops, particularly during dry spells. Straw mulch increases the water use efficiency of crops by slowing down the rate of moisture loss from the soil surface, which is especially important in arid and semi-arid regions.

Recent studies have confirmed that straw mulch remains an effective organic strategy for suppressing weeds by reducing light availability and creating unfavourable conditions for weed seed germination. Gao et al (2021) showed that different mulch levels can significantly impact weed seedling emergence, with thicker mulch applications achieving nearly complete weed suppression.

Straw mulching has been found to have positive effects on soil organic matter and microbial activity. Higher mulch levels enhance soil fertility by increasing the organic carbon content and encouraging microbial activities. This improves soil structure and nutrient availability, which in turn supports healthier crop growth and yields. However, the same study also warned that excessive mulching can sometimes lead to over-retention of moisture, which might negatively affect root health due to poor aeration in the soil (Zhang et al., 2021). It is necessary to mention that given the rising challenges of climate change; straw mulching has gained attention as a climate adaptation tool for farmers. Recent findings by Wang et al. (2020) suggest that straw mulch not only contributes to water conservation but also helps moderate soil temperature, which can protect crops from extreme heat or cold. This dual benefit of water conservation and temperature regulation makes straw mulch an attractive option for climate-resilient farming practices, especially in regions prone to fluctuating weather patterns.

It should be mentioned that the ongoing issue of food security and food safety in Afghanistan remains a critical concern due to several factors, including low yields, limited access to nutritious food, weak infrastructures, insufficient capacity, weak source management, drought, climate change and inadequate investments, all of which negatively impact public and local agricultural industries and insufficient food productivity (Poole et al., 2018; Babu et al., 2021). To ensure the food security and safety in the country, we need to use technics which can grow yields.

In accordance to the above facts and statements this study was conducted to investigate the effects of different straw mulch levels on weed control and moisture conservation in cumin filed in Dand district of Kandahar province. By examining the balance between weed suppression, water retention, and crop health under varying mulch applications, this research was laid out to provide the insights into optimizing straw mulch use for sustainable farming practices and to find out the importance and best level of straw mulch application in cumin fields.

Materials and Methods

A one-year field experiment was conducted during Jan 8 – May 20, 2024 at Dand district in Kandahar province of Afghanistan with five straw mulch treatments (0, 2, 4, 6 and 8 t ha⁻¹) using randomized complete block design and replicated twice.

Soil samples were collected from the experimental field with 15 cm depth and tested in laboratory using standard procedures. The results indicated that the soil was sandy loam, containing 126 kg ha⁻¹ of available nitrogen, 9.8 kg ha⁻¹ of available phosphorus, 158 kg ha⁻¹ of exchangeable potassium. The soil pH, EC and water holding capacity were 8.4, 0.42 mS/cm and 43.7%, respectively. The temperature were varied from -6 to 34 °C, average relative humidity was 39.4 % and the total rainfall was 238.8 mm during the crop season. Weed population and dry weight were recorded, using quadrat at flowering (45 days after sowing (DAS)), Fruiting (90 DAS) and at the maturity stage (133 DAS). Additionally, soil samples were collected at the same stages, five days after irrigation from each plot with the depth of 15 cm and then tested for moisture content in the laboratory.

The statistical analysis of data was done as per standard method of OPSTAT online program (<https://14.139.232.166/opstat/>). The significance of treatments effects were assessed with the help of critical difference (CD) values at $P \leq 0.05$ were used to determine the significant difference between treatments means.

Results and discussions

Weed management

The impact of straw mulch levels on weed population and weed dry weight was evaluated at the flowering (45 days after sowing, DAS), fruiting (90 DAS), and at the harvest (physiological maturity). The weed population and weed dry weight showed a significant reduction as the level of straw mulch increased (Table 1). At 45 DAS, the weed population and dry weight in the control treatment was 36.3 No. m⁻² and 0.33 g m⁻², respectively, which progressively decreased with higher straw mulch levels. The lowest weed population and dry weight at 45 DAS was observed at 8 t ha⁻¹, with only 6.1 No. m⁻² and 0.05 g m⁻², respectively. Similarly, at 90 DAS and at harvest, control plot had the highest weed population and dry weight, while the 8 t ha⁻¹ mulch treatment showed a significantly reduced weed population and weed dry weight, which was at par with 6 t ha⁻¹ mulch treatment.

The results demonstrate that straw mulch has a significant impact on reducing weed population and dry weight across different crop growth stages. The highest level of mulch (8 t ha⁻¹) consistently resulted in the lowest weed population and dry weight. This suggests that increased mulch levels provide a more effective physical barrier, limiting light penetration and reducing the germination and growth of weeds (Teasdale & Mohler, 2000). This aligns with findings from previous studies, which have shown that mulching can suppress weed growth by creating unfavourable conditions for weed seed germination (Kader et al., 2017; Nair et al., 2020).

At 45 DAS, the reduction in weed population and dry weight was already significant, suggesting that straw mulch is effective in controlling early weed growth. This early suppression is crucial for crops as weeds that emerge during the early stages of growth can compete for resources such as water, nutrients, light and space, potentially reducing crop yields, similar results were also reported by (Chauhan et al., 2012; Teasdale & Mohler, 2000).

The continued suppression at 90 DAS and at harvest indicates the long-lasting effects of mulching, which may reduce the need for multiple weeding operations during the growing season.

Straw mulch effectively controls weeds, which are a major cause of yield reductions. By suppressing weeds, it contributes to increased crop yields and promotes healthier produce through organic weed management.

Ultimately, this practice enhances and supports both food security and food safety, this statement is supported by (Du et al., 2022).

Table 1. Weed population and weed dry weight across straw mulch treatments at different crop growth stages

Treatments	Weeds population (No. m ⁻²)			Weeds dry weight (g m ⁻²)		
	45 DAS	90 DAS	Harvest (133 DAS)	45 DAS	90 DAS	Harvest (133 DAS)
Straw mulch levels (t ha⁻¹)						
S ₀	36.3	92.2	121.9	0.33	5.53	26.9
S ₂	20.9	59.8	92.8	0.17	1.97	12.1
S ₄	14.7	25.3	37.0	0.12	0.80	4.8
S ₆	9.3	13.6	17.0	0.08	0.47	2.2
S ₈	6.1	9.0	12.5	0.05	0.30	1.6
SEm±	0.8	1.5	2.5	0.007	0.08	0.5
CD = (P≤0.05)	2.6	5.0	8.3	0.02	0.27	1.8
CV	7.7	6.5	7.7	7.8	7.7	10.0

SEm: Standard error mean, CD: Critical difference, CV: Coefficient of variation, (S₀, S₂, S₄, S₆ and S₈) are 0, 2, 4, 6 and 8 t ha⁻¹ straw mulch levels, respectively.

The weed control efficiency (WCE) and weed control index (WCI) were measured across different straw mulch treatments at various crop growth stages (Table 2). Weed control efficiency was increased with higher levels of straw mulch across all growth stages. At 45 DAS, the control treatment had no weed control efficiency (0%), while the highest WCE was observed in the 8 t ha⁻¹ treatment, with 83.0%. At 90 DAS, WCE continued to improve with increased mulch levels, with the 6 t ha⁻¹ and 8 t ha⁻¹ treatments showing efficiencies of 85.3% and 90.2%, respectively. At the harvest, WCE remained higher in these treatments. The weed control index, followed a similar trend to WCE. At 45 DAS, WCI ranged from 46.9% in the 2 t ha⁻¹ mulch treatment to 84.3% in the 8 t ha⁻¹ treatment. At 90 DAS, WCI increased significantly, reaching 94.6% in the 8 t ha⁻¹ treatment, indicating substantial weed suppression. At harvest, the highest WCI was also observed at the 8 t ha⁻¹ mulch level (93.9%), while the 6 t ha⁻¹ treatment exhibited a comparable WCI of 91.8%.

These findings indicate that both WCE and WCI improved progressively as the mulch level increased. Higher mulch levels consistently provided more effective weed control across all stages of crop growth. The data on weed control efficiency (WCE) and weed control index (WCI) suggest that increasing levels of straw mulch led to enhanced weed suppression throughout the crop growth period. The 8 t ha⁻¹ mulch level consistently demonstrated the highest WCE and WCI across all stages, confirming that higher mulch levels provide better weed management. Studies have shown that straw mulch can achieve considerable WCE and WCI rates, it provide a highly effective and eco-friendly alternative with added soil health benefits, increasing yields and cooperate food security significantly (Ahmad et al., 2007; Chauhan et al., 2012; Bora & Babu, 2014; Kader et al., 2017).

Table 2. Weed control efficiency and weed control index across straw mulch treatments at different crop growth stages

Treatments	Weed control efficiency (%)			Weed control index (%)		
	45 DAS	90 DAS	harvest	45 DAS	90 DAS	harvest
Straw mulch levels (t ha⁻¹)						
S ₀	0	0	0	0	0	0
S ₂	42.4	35.2	23.8	46.9	64.3	54.9
S ₄	59.3	72.5	69.6	62.5	84.9	82.0
S ₆	74.4	85.3	86.1	76.3	91.9	91.8
S ₈	83.0	90.2	89.7	84.3	94.6	93.9
SEm±	1.8	1.0	0.9	1.7	0.6	0.6
CD = (P≤0.05)	6.1	3.4	3.1	5.6	1.8	1.8
CV	6.2	3.1	3.0	5.4	1.4	1.5

SEm: Standard error mean, CD: Critical difference, CV: Coefficient of variation, (S₀, S₂, S₄, S₆ and S₈) are 0, 2, 4, 6 and 8 (t ha⁻¹) straw mulch levels, respectively.

Moisture conservation

The control treatment (0 t ha⁻¹ straw mulch) showed the lowest moisture content. Increasing the straw mulch level from 2 t ha⁻¹ to the highest of 8 t ha⁻¹, improved soil moisture content and finally the 8 t ha⁻¹ resulted in the greatest moisture retention at all crop growth stages. The moisture content progressively increased with higher mulch levels, and the differences between treatments were statistically significant at all stages.

The increase in moisture content with increasing of straw mulch levels indicates that mulch effectively reduces surface evaporation by creating a physical barrier between the soil and the atmosphere and suggest that mulching provides long-term benefits by reducing soil moisture loss through evaporation and promoting better water-use efficiency. This aligns with previous studies that found mulching to be effective in conserving soil moisture, especially in the early stages of crop growth, similar reports were given by number of researchers (Teame et al., 2017; Kader et al., 2017; Jat et al., 2018; Zhang, 2022; Bogunovic et al., 2023). When crops have adequate moisture, they tend to produce higher yields and are less susceptible to diseases and pests, which in turn promotes stable food supplies and enhances food quality (Fan et al., 2019).

The application of high levels of straw mulch conserves moisture in the root zone, ensuring that crops receive the required water at the right time, which maximizes yield. Additionally, straw mulch increases soil organic matter, further enhancing crop productivity. This boost in yield contributes significantly to food security by improving agricultural output sustainably, the role of straw mulch in crop productivity is highlighted by (Du et al., 2022; Huang et al., 2012).

Table 3. Moisture contents five days after irrigation across straw mulch treatments at different crop growth stages

Treatments	Moisture content after five days of irrigation (%)		
	At 45 DAS	At 90 DAS	Before harvesting (112 DAS)
Straw mulch levels (t ha⁻¹)			
S ₀	10.7	11.6	8.9
S ₂	11.4	12.1	9.5
S ₄	12.0	12.6	9.7
S ₆	12.9	13.8	10.6
S ₈	13.7	14.3	10.9
SEm±	0.03	0.04	0.03
CD = (P≤0.05)	0.11	0.13	0.11
CV	0.46	0.53	0.56

SEm: Standard error mean, CD: Critical difference, CV: Coefficient of variation, (S₀, S₂, S₄, S₆ and S₈) are 0, 2, 4, 6 and 8 (t ha⁻¹) straw mulch levels, respectively.

Conclusion

Straw mulching is an important strategy for weed control and soil water conservation. The results clearly demonstrate that increasing levels of straw mulch significantly improve weed suppression, enhance weed control efficiency and increase soil moisture retention across all stages of crop growth. Higher mulch levels, particularly 6 to 8 t ha⁻¹, consistently reduced weed population and dry weight, while maintaining high weed control efficiency and weed control index. Additionally, mulching at these levels significantly increased soil moisture content, reducing water loss and improving water availability to crops. Overall, these findings suggest that the application of straw mulch at 6 to 8 t ha⁻¹ can be an effective strategy for integrated weed management and moisture conservation, leading to better crop growth, high yields and resource use efficiency.

Suggestions

In the result of this study, we suggest the following points:

- To increase irrigation water efficiency, conserves soil and improve its fertility, apply straw mulch more than 6 ha⁻¹ in the field.
- For efficient water, weed and fertility management and finally achieving high yields, repetition of this research is suggested to researchers of the country, to find out the best level of straw mulch.

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Impacts of Climatic and Economic Factors Affecting Food Security in Afghanistan

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Abstract

This study examines the key climatic and economic factors influencing food security in Afghanistan, emphasizing the impacts of temperature, precipitation, and foreign aid. Utilizing the Auto-Regressive Distributed Lag (ARDL) model, the research examines both the short-term and long-term effects of these variables on agricultural production, which serves as a key indicator of food security. The findings reveal that rising temperatures have a significant negative impact on agricultural productivity, while increased precipitation and foreign aid positively influence agricultural production. The results further underscore that climatic factors play a more substantial role than foreign aid in determining food security outcomes. Based on these findings, the study highlights the urgent need for targeted climate adaptation strategies, improved water management practices, and the effective allocation of foreign aid to support sustainable agricultural development. By addressing these challenges, the research contributes to a deeper understanding of how environmental and external economic factors interact to shape food security in vulnerable countries like Afghanistan.

Keywords: Afghanistan, agricultural production index, climate change, food security.

Introduction

Food security is a critical issue in Afghanistan, a country heavily reliant on agriculture for livelihood and economic growth. With over 80% of the population engaged in farming, this sector is highly vulnerable to the impacts of climate change, including rising temperatures, variable precipitation, and extreme weather events (World Bank, 2021). Afghanistan's agricultural system is predominantly rain-fed, making it sensitive to environmental changes. The combination of a fragile natural environment and prolonged political instability has exacerbated food insecurity, leaving millions vulnerable to hunger (FAO, 2020; UNDP, 2021).

Climate change is one of the primary drivers of food insecurity globally, with its impacts particularly evident in developing countries like Afghanistan (IPCC, 2022). Rising temperatures reduce crop yields and access to water, while irregular precipitation disrupts planting and harvesting periods, leading to changes in food production (World Bank, 2022). Over the past century, Afghanistan has experienced significant warming, with the country's average temperature rising by 1.8°C between 1901 and 2020. This warming, along with irregular precipitation, has reduced agricultural production and intensified food shortages in various regions (World Bank, 2021).

In addition to environmental factors, foreign aid plays a crucial role in Afghanistan's food security. Foreign aid programs provide vital support for agricultural development, infrastructure improvement, and emergency food assistance (WFP, 2021). Over the past two decades, Afghanistan has been one of the largest recipients of foreign aid, with budgets allocated to increase food production, improve irrigation systems, and promote climate resilience.

However, the effectiveness of aid in addressing long-term food security challenges remains debated, as short-term assistance has often failed to resolve structural issues in the agricultural sector (OCHA, 2019).

The relationship between climate change, foreign aid, and food security is complex, with multiple factors influencing outcomes. While foreign aid can mitigate some of the immediate effects of food insecurity, long-term solutions require addressing root causes, including climate change and agricultural inefficiencies. In Afghanistan, where the agricultural sector faces significant challenges such as weak infrastructure, limited access to modern farming techniques, and market access constraints, the effectiveness of foreign aid is further complicated by these structural limitations (WFP, 2021).

Previous studies have identified several key factors affecting food security in Afghanistan, including temperature and precipitation (Knippenberg, 2023; UN, 2021). Rising temperatures negatively impact crop yields, especially in drought-prone areas, while adequate precipitation is crucial for sustaining rain-fed agriculture (Asfaw & Maggio, 2016). Foreign aid has played a significant role in providing immediate assistance during food crises, but its long-term impact on agricultural production remains an area for ongoing research (FAO, 2020). Despite growing research on climate change and food security, there is limited empirical research that quantitatively assesses the joint impact of temperature, precipitation, and foreign aid on agricultural production in Afghanistan. This study addresses this gap by using the Autoregressive Distributed Lag (ARDL) model to analyse the short- and long-term relationships between climatic factors (temperature and precipitation), foreign aid, and food security, measured by agricultural production. By examining the dynamic interactions among these variables, the aim of this research is to identify the most significant factors affecting food security in Afghanistan and provide evidence-based recommendations for policymakers to strengthen climate resilience and improve food security.

Materials and Methods

To examine the climatic and economic factors affecting food security in Afghanistan, the agricultural production index has been used as a proxy for food availability. The dependent variable in this study is the logarithm of the agricultural production index, which is considered an indicator of food security. Three independent variables have been selected for the model (Table 1).

Table 1: Independent Variables Used in Model

Variable	Description	Measurement
Temperature	Represents the average annual temperature in Afghanistan.	Logarithm of the average annual temperature.
Precipitation	Represents the total annual rainfall in Afghanistan.	Logarithm of annual precipitation.
Foreign Aid	Indicates the amount of foreign aid received by Afghanistan, as an economic factor potentially influencing food security.	Logarithm of foreign aid received.

The data used in this study spans from 1961 to 2022, covering 61 time series observations, and has been estimated using EViews 10 software. The data was collected from the reputable World Bank website, ensuring the accuracy and consistency of the information.

Model Specification and Estimation

This study utilizes the Autoregressive Distributed Lag (ARDL) model, which is particularly suited for capturing the dynamic relationships between independent and dependent variables (Mukherjee, 1998). The ARDL framework allows for a comprehensive examination of the dynamic interactions among climatic factors, foreign aid, and food security.

To ensure the robustness and validity of the ARDL model, two diagnostic tests were employed: the unit root test and the Granger causality test. The Granger causality test verified the unidirectional relationship of each independent variable with the dependent variable and confirmed the exogeneity of the independent variables. Additionally, all classical assumptions underlying the econometric model were rigorously tested. The validation of these assumptions affirms the reliability and efficiency of the estimated model.

The stationarity of the variables was examined, with the results summarized in Table 2. The analysis revealed that the precipitation variable is stationary at level, whereas the remaining variables achieve stationarity after first differencing. This combination of variable stationarity supports the application of the ARDL model as an appropriate methodological choice for this research.

Table 2: Unit Root Test

Variable	ADF test statistic	
	Level*	First difference**
LCPI	-2.59	-10.29
LTem	-2.60	-9.72
LPer	-6.84	-
LAid	-1.004	-4.35

Source: Results

*Significant 10%

**Significant 1%

Results

Estimation of ARDL Model and ECM Results

Initially, the ARDL model estimates the short-term relationships between the variables. The model estimation, shown in Table (3), clearly illustrates the short-term effects of climate and foreign aid on the agricultural production index (food security). The results indicate that agricultural production itself, with two lags, has a direct effect on increasing food security. Although temperature shows an inverse relationship with food security, precipitation significantly affects food security. Similarly, foreign aid has a meaningful direct effect.

Table 3: Short-Term Relationships in the ARDL Model

Variable	Coefficient	T Statistics
LCPI(-1)	0.518635	5.019003
LCPI(-2)	0.362523	3.558868
LTem	-0.42842	-4.04003
LPer	0.219746	4.935705
LAid	0.027557	4.324082

The estimates suggest that the elasticity of agricultural production with respect to foreign aid is 0.2%, while precipitation increases agricultural production by 21%. Rising temperature shows a significant inverse relationship with the dependent variable, such that a 1% increase in temperature leads to a 42% decrease in agricultural production. However, agricultural production itself remains the most influential variable, with a 51% effect up to two periods before. Equation (1) below represents the ARDL model for short-term estimation based on the coefficients in Table (3), Where $LCPI_t$ is the logarithm of agricultural production (serving as the food security index), representing the dependent variable, $LTem$ denotes the logarithm of temperature. $LPer$ represents the logarithm of precipitation, $LAid$ is the logarithm of foreign aid, u_t is the error term, the indices i, j, k , and t correspond to the lags for the respective variables,

which are included as specified by the optimal lag structure and $(\beta_i, \gamma_j, \tau_k, \delta_t)$ are the dynamic parameters estimated for the short-term relationships between the variables.

$$LCPI_T = \alpha_0 + \beta_i \sum_{i=1}^2 LCPI_{t-i} + \gamma_j LTem_t + \tau_k LPer_t + \delta_t LAid_t + u_t \quad (1)$$

Following the Schwarz criterion, the optimal lag structure for the ARDL model is identified as (2, 0, 0, 0), suggesting that the best model specification includes two lags for the dependent variable and no lags for the independent variables. This selection ensures that the model adequately captures the short-term interdependencies between the variables while maintaining parsimony.

Cointegration Test (Testing the Existence of Long-Term Relationships)

As shown in the F-statistic in Table (4), with a confidence level of 99% and 95%, it exceeds the critical bounds, and thus, the null hypothesis of no long-term relationship is rejected. Therefore, there is a long-term relationship among the variables in the model.

Table 4: Cointegration Test

F-statistic	Critical Value%5		Critical Value1%	
8.524728	I(0)	I(1)	I(0)	I(1)
	2.79	3.6	3.65	4.66

As observed, if the F-statistic were below the two critical points, the model would not show a long-term relationship.

ECM (Error Correction Model) and Long-Term Estimation Results

The ECM represents the residuals or disturbances from the long-term regression, appearing with one lag. The obtained error correction coefficient has been adjusted exponentially, with the model being corrected at a speed of 36% and gradually converging to equilibrium. This means that policies and management addressing the factors affecting food security could bring the model to a balanced and stable state in the short term.

The findings from the long-term relationships in Table (5) show a stable relationship between food security and the independent variables. The long-term relationships indicate that the coefficients of all independent variables are statistically significant, with precipitation and foreign aid significant at the 5% level, and temperature at the 10% level. The elasticity of food security with respect to climate is greater than foreign aid, with precipitation being eight times more influential. Although the equilibrium relationship of temperature remains inversely related, with a coefficient of -3.60, an increase of 1% in temperature leads to a 3.6% decline in food security. Additionally, the variables precipitation and foreign aid significantly contribute to improving food security in Afghanistan, with coefficients of 1.84 and 0.23, respectively.

Table 5: Long-Term Estimation Results of the ARDL Model and ECM

Variable	Coefficient	T Statistics
LTem	-3.60495	-1.64534
LPer	1.849074	1.965629
LAid	0.231881	3.090284
ECM(-1)	-0.36252	-3.55887

Discussion

The results of the study indicate a significant negative relationship between temperature and agricultural production, both in the short and long term.

Rising temperatures reduce food security, which is consistent with previous studies showing that increased temperatures lead to reduced agricultural yields, water scarcity, and increased evaporation, all of which affect agricultural productivity (IPCC, 2022). In Afghanistan, where agriculture is largely rainfed and highly dependent on stable climatic conditions, rising temperatures are particularly detrimental. This negative relationship underscores the urgent need for climate adaptation strategies that can mitigate the effects of temperature rise on food production. These strategies may include promoting drought-resistant crops, improving irrigation infrastructure, and adopting sustainable farming practices that reduce vulnerability to heat stress (Knippenberg, 2023). Furthermore, policies that focus on providing farmers with climate information and early warning systems can help communities better adapt to climate changes (UNDP, 2020).

Additionally, the study found a significant positive relationship between precipitation and agricultural production, highlighting the importance of adequate precipitation for food security.

This result is consistent with existing research, which emphasizes the critical role of water availability in supporting agriculture in arid and semi-arid regions (Alharbi et al., 2024). Given Afghanistan's dependence on rainfed agriculture, any increase in precipitation positively impacts agricultural production, thereby improving food security. However, the challenges posed by irregular precipitation patterns in Afghanistan must be considered. While increased precipitation can improve agricultural outcomes, periods of heavy precipitation followed by droughts can damage crops and reduce soil quality (Kundel et al., 2020). To address this challenge, water resource management must be prioritized in national policies. Investments in efficient irrigation systems, rainwater harvesting, and water-saving techniques can help stabilize agricultural production despite fluctuating precipitation patterns (FAO, 2020). On the other hand, the positive impact of foreign aid on agricultural production confirms the role of international support in improving food security. The results show that aid dedicated to agricultural development, infrastructure improvements, and emergency assistance significantly impacts food access. However, the magnitude of this impact is smaller compared to the effects of climate factors, suggesting that while aid is beneficial, it cannot fully compensate for the negative effects of climate change on food production. This finding aligns with previous studies that question the long-term sustainability of food security strategies dependent on aid in vulnerable countries like Afghanistan (OCHA, 2019). Although foreign aid provides immediate relief during crises, long-term food security depends on building local resilience to climate shocks and reducing dependence on external assistance. Strengthening domestic agricultural capacity through technology transfer, education, and institutional support can make Afghanistan less reliant on foreign aid and better prepared to face food security challenges (WFP, 2021; CARE International, 2021).

Conclusion

This study highlights the significant role of climate factors and foreign aid in determining food security in Afghanistan. While foreign aid plays a positive role, temperature and precipitation are the most important factors, with high temperatures having a particularly negative effect. The results emphasize the urgent need for climate adaptation strategies and water resource management to ensure food security in the face of ongoing climate change. Policymakers must prioritize climate adaptation strategies, improve water management, and ensure that foreign aid is effectively used to foster long-term resilience. Addressing these challenges will be crucial to ensuring food security in Afghanistan amidst ongoing climate changes.

Practical Recommendations

1. The negative relationship between temperature and food security highlights the importance of climate adaptation strategies such as improving irrigation systems, growing drought-

resistant crops, and investing in climate-resilient infrastructure.

2. The positive impact of precipitation on agricultural production underscores the importance of water resources. Given Afghanistan's reliance on rain-fed agriculture, changes in precipitation due to climatic fluctuations will directly affect food security. Investments in water management systems, such as improved irrigation and rainwater harvesting, can reduce this risk.

3. While foreign aid positively impacts food security by supporting agricultural development and infrastructure, the relatively small effect compared to climate variables indicates that aid alone cannot mitigate the negative impacts of climate change. A balanced approach that combines international support with local resilience-building programs is essential for long-term food security. Strengthening institutional frameworks for aid management will improve effectiveness and transparency, ensuring that aid reaches the most vulnerable populations.

Research Recommendations

1. While agricultural production is used as a proxy for food security in this study, it does not encompass all dimensions of food security, such as access, utilization, and sustainability. Future research could explore these additional aspects by using a more comprehensive set of indicators.

2. The reliance on secondary data may limit the depth of analysis, particularly in areas where data collection is limited or inconsistent. Future research could integrate primary data, such as household surveys, to better understand local factors affecting food security.

3. The role of socio-political factors in shaping food security was not considered in this study. Factors such as governance, conflict, and access to markets also play critical roles in determining food security outcomes and should be explored in future research.

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The impact of food safety and security on the economy of Kandahar

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Abstract

Food safety and security are essential for the economic stability and well-being of any society. In the context of Kandahar, Afghanistan, these issues have a significant impact on economic growth, public health, and overall development. This study examines the correlation between food safety, food security, and economic outcomes in Kandahar, using quantitative research methods with a sample size of 62. Data was collected through structured questionnaires and analysed using SPSS. Descriptive and inferential statistical analysing methods such as mean, standard deviation, correlation and ANOVA tests have been used, revealing strong positive correlations between food safety, food security, and economic impact. Specifically, food safety showed a stronger association with economic improvement than food security. Improvements in food safety, as indicated by the high Pearson correlation with economic impact ($r = 0.748$), are essential for fostering economic growth and development in the region. The research highlights the need for stricter regulations, public awareness campaigns, sustainable farming practices, and better supply chain management to enhance both food safety and security. Involving both government and private sectors is crucial to achieving long-term economic resilience and improving public health. These findings emphasize the urgent need for policy interventions to address food safety and security challenges in Kandahar, which can further stimulate economic growth and social well-being.

Keywords: Food Safety, Food Security, Economy, Public Health, Policy

Introduction

Food is a fundamental human right as well as the most vital basic human need. Therefore, a country like Afghanistan strives to ensure that its citizens have access to food by promoting a number of activities aimed at achieving sustainable food security and nutrition. Within the framework of national resilience, national food security policies must also be implemented in a comprehensive and integrated manner to enhance economic independence and competitiveness. Afghanistan has enough resources to ensure food safety and security. (Dyah Andrianti et al., 2024)

The Unsafe food contains hazardous agents, or contaminants, that can make people sick, either immediately or by increasing their risk of chronic disease. Such contaminants can enter food at many different points in the food production process, and can occur naturally or as the result of poor or inadequate production practices. (J.unnevehr, 2020). Food safety is an important aspect of public health that affects all individuals, regardless of their age, race, gender, or social status. The issue of food safety has gendered and social dimensions that cannot be ignored. However, food safety is not a gender-neutral issue. For example, because of social norms women in households may not have access to foods that contain the right amount of nutrients, such as meat, which can negatively affect a woman's health and the health of the baby during pregnancy.

Women play a significant role in ensuring the safety of food in households, as they are often the primary caregivers and food handlers. Although they do not always possess adequate food safety knowledge and skills, the safety of food consumed by their families is dependent on basic food safety knowledge and practice. (Natalia Milovanova et al., 2024)

Food safety is important to prevent foodborne illnesses, which affect approximately 1 in 10 people around the world. Although food safety management systems and legislation are placed for ensuring food safety, their effectiveness can be impacted by social and cultural factors, especially in developing countries. (Natalia Milovanova et al., 2024)

Food security is widely seen as access by all people at all times to enough food for an active life, while food insecurity is the inability of a household or individuals to meet the required consumption levels in the face of fluctuating production, price and income. At the national level, food security exists when all people at all times have the physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for active and healthy life, while the household level, food security implies physical and economic access to food that is adequate in terms of quantity, safety and cultural accessibility, to meet each person's need. (Ahmadzai, 2014)

The major pillars of food security that practitioners believed are critical to achieving its sustainability include food Availability, Access, Utilization and Stability. (Bach et al, 2014)

Household food insecurity has become a significant problem in recent years in Afghanistan particularly in the eastern region which is caused by numerous factors. Hence, the purpose of this paper was to examine and analyse the factors that affect food security at the household level in the eastern region of Afghanistan. Government and international organizations have jointly conducted the household survey in the Eastern Region of Afghanistan containing 9774 households over 99310 individuals in 49 districts. The result showed that the critical factors of food insecurity were caused by insecurity, poverty; unsustainable livelihoods, lack of job opportunities; low wage and income, landlessness in rural areas, and a huge influx of refugee and internally displaced people (IDP) migration. The study found that 46.9% of households were food insecure while 49.6% faced hunger in the last one month and 48% of households had poor and borderline food consumption score. (Asif Khan Ahmadzai and Cuma Akbay, 2019)

The main aim of this article is to find out the impact of food safety and security on the economy.

Research Hypothesis

The study has following hypothesis for testing in order to draw viable and reliable/valid conclusions respectively for contribution to the frontiers of the study.

First Hypothesis

H0: There is no significant relationship between food safety and Economy of Kandahar.

H1: There is significant relationship between food safety and Economy of Kandahar.

Second Hypothesis

H0: There is no significant relationship between food security and Economy of Kandahar.

H1: There is significant relationship between food security and Economy of Kandahar.

Literature Review

Food safety refers to the proper handling, preparation, and storage of food to prevent foodborne illnesses. A lack of food safety standards can lead to widespread health problems, affecting not just public health but also economic stability.

According to (Henson, S., & Caswell, J, 1999), foodborne diseases are costly for national economies due to productivity losses, healthcare expenses, and legal liabilities for food industries. In Kandahar, a region with limited healthcare infrastructure, poor food safety practices may burden the economy by overwhelming the healthcare system and reducing workforce productivity.

The economic impact of foodborne diseases is particularly significant in agriculture-dependent economies like Afghanistan. Kandahar's agriculture, which largely relies on traditional practices, often lacks stringent food safety regulations. This leads to the contamination of food products, which can result in trade bans, reduced market access, and a damaged reputation for exports, further aggravating the local economy. Studies by (Unnevehr, L. J., & Hirschhorn, N, 2000). highlight how nations that invest in food safety see long-term economic benefits through increased consumer confidence, stronger trade relationships, and better public health outcomes.

Food Security and Economic Stability

Food security refers to the availability, accessibility, and affordability of sufficient, safe, and nutritious food to maintain a healthy life. In Kandahar, food security has long been a concern due to the combined impact of conflict, environmental challenges, and limited infrastructure. (Sen, 1981). "Entitlement Theory" of food security explains how food insecurity often stems from an inability to access food, even when it is available. This is relevant to Kandahar, where political instability and conflict have hindered local markets and reduced the population's purchasing power, thus aggravating food insecurity.

A lack of food security can destabilize economies by causing inflation, pushing people into poverty, and driving dependency on international aid. In Afghanistan, food insecurity is not only a humanitarian issue but an economic one. A report by the (World Food Program, 2017). estimated that food insecurity costs Afghanistan billions of dollars annually due to lost economic productivity. Kandahar, as a southern agricultural hub, has the potential to contribute significantly to food production, yet inefficiencies in the supply chain, coupled with the lack of access to modern farming technologies, diminish its potential economic contribution.

Impact of Food Insecurity on the Workforce and Agricultural Sector

Food insecurity can undermine the labor market in regions like Kandahar. According to research by (Smith and Haddad, 2015), food insecurity leads to malnutrition, which affects physical and cognitive development, resulting in a less productive workforce. In regions like Kandahar, where agriculture forms the backbone of the economy, malnutrition can have devastating effects on the agricultural workforce's productivity.

Moreover, as the agricultural sector remains highly labor-intensive, any reduction in labor productivity due to either foodborne illness or malnutrition has a direct impact on food output. This vicious cycle of poor food safety, low productivity, and food insecurity perpetuates economic stagnation. Studies have shown that countries with widespread food insecurity tend to experience slower economic growth compared to food-secure nations (FAO, 2014).

Conflict and its Impact on Food Security and Economy

The ongoing conflict in Afghanistan has made the situation in Kandahar more complex. Studies have demonstrated a clear link between conflict and food insecurity (Justino, 2009). In Kandahar, conflict has disrupted farming activities, destroyed infrastructure, and limited access to markets, all of which are crucial to food security. According to (Gates et al., 2014), regions affected by conflict experience long-term economic decline due to disruptions in both agriculture and trade. Moreover, conflict exacerbates poverty and restricts access to essential resources, making it harder for populations to secure adequate food.

As Kandahar struggles to emerge from decades of conflict, food security remains a major hurdle to economic recovery. The lack of stable food production, combined with high inflation and import dependency, creates a fragile economic environment.

Policy and Regulatory Frameworks for Improvement

To address these challenges, stronger food safety regulations and food security policies must be implemented in regions like Kandahar. The World Health Organization (WHO) recommends stricter food safety regulations as a pathway to improving public health and supporting economic growth. However, the unique political, social, and economic context of Kandahar necessitates localized policies that address both the immediate and long-term issues surrounding food safety and food security.

International organizations such as the Food and Agriculture Organization (FAO) and USAID have already initiated food security programs in Afghanistan, focusing on improving agricultural practices, building infrastructure, and promoting food safety awareness. However, local governance and capacity-building efforts are crucial to ensuring that these programs lead to sustainable economic improvements in Kandahar. By enhancing food security and food safety standards, the region could experience significant economic benefits through improved agricultural productivity, enhanced trade opportunities, and reduced healthcare costs.

In conclusion, this literature review highlights the critical importance of food safety and food security in Kandahar, Afghanistan. Food safety includes proper handling, preparation, and storage of food to prevent illnesses, while food security assures the availability, accessibility, and affordability of nutritious food. Poor food safety practices can lead to health problems, overwhelming healthcare systems, and economic instability. In agriculture-dependent economies like Afghanistan, foodborne diseases can result in trade bans, limited market access, and damaged reputations. Investing in food safety offers long term economic benefits, including increased consumer confidence and stronger trade relationships. Food security is also a concern in Kandahar due to conflict, environmental challenges, and limited infrastructure.

Materials and Methods

This study employs a quantitative research design to investigate the impact of food safety and security on the economy (Kandahar). Data has been collected through structured questionnaires, and Descriptive and inferential statistical analysis methods have been conducted using SPSS to derive meaningful conclusions.

A snowball sampling technique has been used for data collection. This non-probability sampling method is particularly effective in reaching populations that are difficult to access or identify. Initially, a small group of participants have been selected based on certain criteria relevant to the research.

These participants will then refer others who meet the criteria, allowing the sample to grow over time. Although this method may introduce potential biases due to the non-random selection process, it is suitable for exploratory studies where a well-defined sampling frame is absent. The sample size depends on the ability to reach participants through referrals, but a target sample size of approximately 60 participants have aimed for to ensure sufficient data for meaningful statistical analysis.

Data Analysis

The data collected has been analysed using SPSS (Statistical Package for the Social Sciences). The analysis includes:

Descriptive statistical method has been used to summarize and describe the characteristics of the sample, measures such as mean and standard deviation. Depending on the research questions, inferential statistical tests will be applied like correlation analysis and ANOVA tests. For the reliability internal consistency of the questionnaire has been tested using Cronbach's alpha in SPSS to ensure the reliability of the scales. Results

Reliability Statistics Overview:**Reliability Statistics**

Cronbach's Alpha	N of Items
.876	14

Cronbach's Alpha: The value of **.876** indicates a high level of internal consistency among the items in the scale. Cronbach's Alpha ranges from 0 to 1, with values above 0.7 generally considered acceptable, and values above 0.8 indicating good reliability. (Nunnally, J. C., & Bernstein, I. H, 1978). A value of .876 suggests that the items are measuring the same underlying construct effectively.

Correlations

		Food Safety	Food Security	Economic Impact
Food Safety	Pearson Correlation	1	.600**	.748**
	Sig. (2-tailed)		.000	.000
	N	62	62	62
Food Security	Pearson Correlation	.600**	1	.520**
	Sig. (2-tailed)	.000		.000
	N	62	62	62
Economic Impact	Pearson Correlation	.748**	.520**	1
	Sig. (2-tailed)	.000	.000	
	N	62	62	62

** . Correlation is significant at the 0.01 level (2-tailed).

A very strong positive correlation exists between Food Safety and Economic Impact ($r = 0.748$, $p < 0.01$). This suggests that higher levels of perceived food safety are associated with greater perceived economic benefits.

There is a moderate positive correlation between Food Security and Economic Impact ($r = 0.520$, $p < 0.01$). This indicates that increased perceptions of food security are also linked to a recognition of positive economic impacts, though this relationship is not as strong as the relationship between Food Safety and Economic Impact.

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
What your Gender?	62	1	2	1.06	.248	3.634	.304	11.577	.599
What is your age group?	62	1	5	2.65	1.161	.609	.304	-.894	.599
How familiar are you with food safety regulations in your country?	62	1	3	1.77	.493	-.457	.304	.019	.599
How often do you consider food safety (e.g., contamination, hygiene) when purchasing food?	62	1	4	1.65	.704	1.212	.304	2.278	.599
Do you believe that food safety issues (e.g., foodborne diseases) have a significant impact on the economy?	62	1	3	1.58	.666	.724	.304	-.520	.599
In your opinion, how effective are government regulations in ensuring food safety in your country?	62	1	4	2.10	1.097	.419	.304	-1.240	.599
How concerned are you about food security (i.e., access to sufficient, nutritious food)?	62	1	4	1.74	.957	1.243	.304	.637	.599
Have you or anyone in your community ever experienced food insecurity (e.g., difficulty accessing food)?	62	1	4	1.61	1.014	1.437	.304	.666	.599
In your opinion, what is the greatest challenge to food security in your region?	62	1	4	2.35	.907	.313	.304	-.602	.599
Do you believe that food safety and security directly impact the economy in your region?	62	1	3	1.65	.655	.521	.304	-.651	.599

In your opinion, which of the following areas are most affected by issues of food safety and security? (Write more than one all that apply)	62	1	6	2.61	1.692	.764	.304	-.711	.599
What measures do you believe can be implemented to improve food safety standards in your country?	62	1	4	2.16	.891	.535	.304	-.279	.599
What strategies would you recommend to enhance food security in your region?	62	1	5	2.26	1.144	1.234	.304	1.016	.599
In your opinion, how can the private sector contribute to food safety and security in your country?	62	1	5	2.10	1.387	1.115	.304	-.013	.599
Valid N (list wise)	62								

The descriptive statistics reveal insights into respondents' demographics and perceptions regarding food safety and security. Notably, there is a predominance of one gender and generally low familiarity and concern regarding food safety and security. Additionally, perceptions of the impact of these issues on the economy are also low. These findings could inform further research and initiatives aimed at enhancing food safety awareness and security measures.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.754 ^a	.568	.553	.71593

a. Predictors: (Constant), Food Security, Food Safety

The value of **R = 0.754** indicates a strong positive correlation between the predictors and the dependent variable. This suggests that as Food Security and Food Safety improve, the dependent variable is likely to increase as well.

R Square = 0.568 means that approximately **56.8%** of the variability in the dependent variable can be explained by the predictors (Food Security and Food Safety). This indicates a moderate to strong fit of the model, suggesting that the predictors provide a meaningful explanation of the variation in the outcome.

The **Adjusted R Square = 0.553** accounts for the number of predictors in the model and adjusts the R Square value accordingly. This value being close to R Square indicates that the model remains a good fit, even after considering the number of predictors. It suggests that the inclusion of the predictors improves the model's explanatory power.

The **Std. Error of the Estimate = 0.71593** indicates the average distance that the observed values fall from the regression line. A smaller standard error suggests a better fit of the model to the data, indicating that the predictions are relatively close to the actual values.

ANOVA^a

ANOVA						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	39.727	2	19.863	38.754	.000 ^b
	Residual	30.241	59	.513		
	Total	69.968	61			

a. Dependent Variable: Economic Impact

b. Predictors: (Constant), Food Security, Food Safety

The ANOVA results indicate that the regression model, including Food Security and Food Safety as predictors, significantly explains the variation in Economic Impact. With an F-value of **38.754** and a significance level of **.000**, these findings suggest strong evidence that improving food security and food safety can have a substantial impact on economic outcomes.

Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-.503	.313		-1.610	.113
	Food Safety	1.333	.209	.682	6.375	.000
	Food Security	.135	.131	.110	1.029	.308

a. Dependent Variable: Economic Impact

- The coefficient (B) for Food Safety is 1.333 with a p-value of 0.000. Since the p-value is less than 0.05, we reject the null hypothesis (H0) and accept the alternative hypothesis (H1). It means Food Safety has a statistically significant positive impact on the economy of Kandahar Province.
- The coefficient (B) for Food Security is 0.135 with a p-value of 0.308. Since the p-value is greater than 0.05, we fail to reject the null hypothesis (H0). It means Food Security does not have a statistically significant impact on the economy of Kandahar Province.

Results and discussion

The results of the analysis offer insightful justification regarding the impact of food safety and food security on Kandahar's economy. The coefficient for **Food Safety (B = 1.333, p-value = 0.000)** indicates a statistically significant positive effect on Kandahar's economy. This is consistent with previous studies, such as those by **(Henson, S., & Caswell, J, 1999)**, which highlight how poor food safety practices can cause widespread economic losses through healthcare costs and reduced productivity. In Kandahar, a region already struggling with limited healthcare infrastructure, improving food safety could bolster economic stability by preventing foodborne diseases, enhancing trade opportunities, and fostering consumer confidence.

In contrast, the coefficient for **Food Security (B = 0.135, p-value = 0.308)** shows no statistically significant impact on the local economy, likely because food security issues in Kandahar are deeply intertwined with broader structural challenges, such as conflict, limited infrastructure, and market access. As highlighted by **(Sen, 1981)** Entitlement Theory, food insecurity often arises not from scarcity but from access issues, which remain prevalent in Kandahar.

Although food security is crucial, its immediate economic impact may not be easily quantifiable, unlike food safety, which directly influences workforce productivity and market stability.

This highlights key findings from the analysis of food safety, food security, and their economic impacts in Kandahar Province. A Cronbach's Alpha of 0.876 confirms strong internal consistency in survey data. Pearson correlation analysis shows a robust positive relationship between food safety and economic impact ($r = 0.748$), while food security has a moderate connection ($r = 0.520$). Food safety was perceived as more crucial than food security by respondents. Regression analysis indicates food safety significantly predicts economic benefits, while food security's impact was less direct. The ANOVA results confirmed the overall model's significance, reinforcing the need for food safety focused policies to drive economic growth in Kandahar. The study suggests future research should further explore food security's complex relationship with economic stability.

Conclusion

In conclusion, this study underscores the significant impact of food safety and food security on the economy of Kandahar. The research findings demonstrate that both food safety and food security are strongly correlated with economic outcomes. Improvements in food safety, as indicated by the high Pearson correlation with economic impact ($r = 0.748$), are essential for fostering economic growth and development in the region. Furthermore, although food security also influences economic conditions, its impact is moderately lower compared to food safety, indicating that food safety plays a more critical role in economic stability.

The regression analysis further supports these findings, as the model explains approximately 56.8% of the variability in the economic impact, suggesting that food safety and security are key drivers of economic performance in Kandahar. The ANOVA results reinforce this, showing a significant relationship between the predictors and economic outcomes, highlighting the urgent need to address these issues in policy-making and local interventions. In light of the strong relationships identified between food safety, security, and economic growth, it is recommended that policymakers in Kandahar prioritize food safety regulations, public awareness campaigns, and interventions to improve food security. Strengthening these areas will not only safeguard public health but also contribute to the region's economic resilience and prosperity.

Recommendations and Solutions

- **Stricter Regulations:** Governments should implement and enforce stricter food safety regulations to ensure that food products meet health and safety standards throughout the supply chain. This includes regular inspections, compliance audits, and penalties for non-compliance.
- **Public Awareness Campaigns:** Launch nationwide campaigns to educate the public about the importance of food safety, proper hygiene, and contamination risks. Increasing public knowledge helps in adopting safe practices when handling, preparing, and consuming food.
- **Improved Supply Chain Management:** Strengthening the food supply chain by enhancing traceability, storage, and transportation methods can reduce contamination risks and improve food quality. Technology such as block chain can be used to track and verify food safety.
- **Other:** Stakeholders should invest in research and development of innovative solutions, such as modern food preservation technologies and better packaging to extend shelf life and reduce spoilage.
- **Subsidizing Local Farming:** Governments should provide subsidies to local farmers to encourage increased agricultural production, which can contribute to food availability and affordability, especially in rural areas.

- Encouraging Sustainable Agricultural Practices: Promoting sustainable farming techniques like crop rotation, organic farming, and water conservation practices can ensure long-term food production without harming the environment. This helps enhance food security in the face of climate change.
- Providing Financial Support to Low-Income Households: Offering financial aid or food vouchers to vulnerable populations can directly improve food access and security for low-income families. Additionally, job creation and skills development programs can be introduced to improve household incomes.
- Other: Governments should establish food banks and emergency food relief programs in times of crisis to ensure that no one is left without access to sufficient, nutritious food.
- Investing in Better Food Storage Technologies: The private sector can invest in advanced storage solutions, such as temperature-controlled warehouses and smart storage technologies, to reduce food spoilage and maintain food quality from farm to consumer.
- Ensuring Transparency in Food Production: Companies should be transparent about their food production processes, providing consumers with detailed information about sourcing, ingredients, and safety protocols. This builds trust and encourages responsible consumption.
- Partnering with the Government for Regulatory Compliance: The private sector should collaborate with government agencies to adhere to food safety regulations, contributing to the development of safe production standards and improving overall food safety and security.
- Other: Private companies could also support local farmers by providing them with better access to markets, technology, and financial resources, fostering a more robust and secure food supply chain.

These combined efforts from both the public and private sectors will help ensure better food safety and security, fostering economic growth and improving public health in the region.

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Cultivating Safer Choices: Assessing Consumer Awareness and Willingness to Pay for Organic Produce in Kunduz, Afghanistan

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Abstract

Organic Agriculture is relatively new in Afghanistan, with limited awareness among farmers and consumers. Concerns regarding agricultural safety have emerged due to the prevalent use of chemical fertilizers, excessive pesticides, and hormones. Concurrently, issues such as poverty, lack of awareness, and unavailability hinder consumers from paying a premium for organic products. This study evaluates consumers' awareness and willingness to pay for organic products in Kunduz Province, Afghanistan. To achieve this, a structured questionnaire was developed and administered to 196 consumers, focusing on key demographic variables, awareness levels, and willingness to pay for organic products. The data was analyzed using SAS 9.4 software. To assess the willingness to pay, we employed the Contingent Valuation Method and performed a logistic regression. Furthermore, chi-square was used to compare awareness of organic products across various demographic categories. The findings reveal that a significant proportion of consumers are aware of organic products, with higher levels of awareness among younger, educated, and female respondents. While there is a general willingness to pay a premium for organic produce, factors such as income, age, and perceived food safety significantly influence this willingness. The study highlights the potential for organic agriculture in Afghanistan and the need for targeted marketing strategies to promote organic products.

Keywords: Awareness, Consumer, Food safety, Kunduz city, Organic products, willingness to pay

Introduction

Agriculture is a cornerstone of the economy in Kunduz province, Afghanistan, where farmers predominantly cultivate staple crops such as rice, wheat, fruits, like almonds, grapes, apples, pomegranates, peaches, watermelons, melons, vegetables such as tomatoes, potatoes onions, carrots, and several other crops like maize, barley, saffron, soybean, and cotton (NSIA, 2022). Despite the significance of these crops, conventional farming practices often rely heavily on synthetic fertilizers and pesticides, raising concerns about food safety and environmental sustainability. The annual fertilizer consumption in Afghanistan is approximately 273,750 t nutrients, which is equivalent to 35 kg of nutrients per hectare of arable land. Nearly 150 active ingredients of pesticides are available in Afghan urban and rural farm stores (Lankester & Znaor 2009). Organic agriculture, as defined by the FAO/WHO (FAO, 2014), emphasizes the recognition of potential environmental and social effects by eliminating synthetic inputs such as artificial fertilizers, pesticides, veterinary medications, genetically modified organisms, preservatives, and irradiation. This approach adopts localized management techniques that enhance and sustain soil fertility over time, while effectively preventing pests and diseases.

While organic farming is relatively new to the Afghanistan community, it is a well-established practice in 188 countries, encompassing over 96 million hectares of agricultural land managed organically by approximately 4.5 million farmers worldwide. In 2022, global sales of organic food and beverages approached nearly 135 billion euros (Willer et al., 2023). The advantages of organic food are numerous, with one of the most significant being its potential for long-term sustainability. This form of agriculture considers the medium and long-term impacts of agricultural practices on the agroecosystem, aiming to produce food while establishing an ecological balance that prevents soil fertility depletion and pest issues. Importantly, organic agriculture adopts a proactive approach, addressing problems before they arise (FAO, 2014). Central to organic practices are soil-building techniques, including crop rotations, inter-cropping, symbiotic associations, cover crops, organic fertilizers, and minimum tillage. These methods not only enhance soil fertility but also improve its water-holding capacity and promote biodiversity by minimizing pesticide use (Gomiero et al., 2011).

Despite these benefits, Afghanistan remains one of the few countries where organic farming concepts and practices have yet to gain attraction. However, increasing health concerns regarding food safety—stemming from the excessive use of pesticides—are gradually fostering a demand for organic products. The potential for organic food production in Afghanistan has not been thoroughly explored, leaving a significant gap in the literature. In recent years, the global demand for organic produce has surged, driven by increasing consumer awareness regarding health, environmental sustainability, and food safety. As noted by (Rodríguez-Bermúdez et al., 2020), although the organic sector remains relatively small, understanding consumers' perceptions and attitudes towards organic food is crucial for developing effective marketing strategies that can attract conventional consumers. Research indicates that consumer perceptions vary significantly across regions, for instance, a systematic review by (van Bussel et al., 2022) emphasizes that consumers primarily consider price, convenience, taste, and health when making food choices, but many lack a clear understanding of sustainability in the food supply chain. This gap in knowledge presents a unique opportunity for enhancing educational initiatives around organic products, particularly in agricultural regions like Kunduz. The role of certification in building consumer trust is also critical. (Truong et al., 2022) explored how perceptions of food quality certifications can influence consumer choices, noting that trust in food systems and actors significantly impacts perceptions of organic produce. This relationship is particularly relevant in the Afghan context, where trust in local agricultural practices may influence consumer willingness to pay for organic options. Moreover, (Aitken et al., 2020) emphasize the importance of product labeling in shaping consumer behavior towards organic foods. As consumers become more informed about the health and environmental benefits of organic products, their willingness to pay may increase, provided that information is communicated effectively. Even with the growing interest in organic food, challenges such as high prices and limited availability persist. (Sandran et al., 2020) identifies these barriers, suggesting that campaigns promoting the health benefits of organic consumption could enhance its appeal among consumers. Similarly, (Tsakiridou et al., 2008) highlight the importance of understanding consumer attitudes towards organic products, noting that demographic factors can influence perceptions and actual purchasing behaviors.

This study aims to assess consumer awareness and willingness to pay for organic produce in Kunduz, Afghanistan, contributing to the existing literature by providing insights into local consumer behaviors and attitudes. Specifically, this research aims to pursue the following objective:

- To examine the factors influencing consumers' willingness to pay for organic products in Kunduz Province, Afghanistan.
- To investigate consumers' knowledge regarding food safety in Kunduz Province, Afghanistan.

Methodology

Research Area

This study employs exploratory research to examine findings from both qualitative and quantitative data through a pre-tested questionnaire. Secondary data were gathered from national and international journals, printed magazines, and websites. The research was conducted in Kunduz city in 2024, which has a population of 330,665, comprising 166,853 men and 163,812 women. Kunduz province is predominantly agricultural, with 85% of its population engaged in livestock, agriculture, and horticulture. The province shares borders with Tajikistan to the north, Baghlan and Samangan to the south, Takhar and Badakhshan to the east, and Balkh to the west. This region boasts significant natural resources, including forests and grasslands (NSIA, 2023).

Target Population

The target population for this study consists of individuals with a higher level of education and knowledge about health and nutrition, specifically doctors, academia, and merchants. This demographic was chosen due to their potential influence on public perceptions of organic products and their likely awareness of the associated benefits.

Sampling Method

A non-probability sampling method, purposive sampling, was employed to select participants. This technique allows for the intentional selection of individuals with specific characteristics relevant to the study (Rai & Thapa, 2004). To accurately achieve the research aim, a questionnaire was drafted, peer-reviewed by faculty members, piloted, and subsequently distributed among residents of Kunduz city from October to November 2024.

Sample Size Calculation

The sample size was calculated using Cochran's (1977) formula (Bartlett et al., 2001). Based on estimates from experts and data obtained from Kunduz University and Kunduz Regional Hospital (Shaheed Azizullah Safar Hospital), the total target population was determined to be 684. Using Cochran's formula with parameters set at $Z=95\%$, $p=0.05$, and $E=0.06$, the calculated sample size was approximately 193. Consequently, 200 questionnaires were distributed, and after initial screening, 196 samples were used for further analysis.

Data Collection Instrument

The questionnaire consisted of three main sections:

Socio-demographic characteristics

Awareness of organic products

Influential factors considered by consumers when purchasing organic products

Method of Analysis

To identify factors affecting the willingness to pay for organic food products, the study utilized contingent valuation to assess this willingness. The contingent valuation method employs survey techniques to ask participants about the values they would assign to non-market commodities if markets existed (Richard C. Bishop & Thomas A. Heberlein, 1990). The study also adopted revealed preference methods to evaluate the hypothetical willingness to pay for organic foods. For the revealed preference approach, the averting behavior method was employed. This method acknowledges that individuals seek to protect themselves when confronted with environmental risks, such as contaminated drinking water (Dickie, 2003; Tussupova et al., 2015).

For this study, the following scenario was developed to facilitate the assessment: "Imagine that organic vegetables/fruits are available in the market.

These vegetables/fruits have been grown without the use of chemical fertilizers, pesticides, hormones, or artificial growth agents, and they offer health benefits and are environmentally friendly. The price of these organic vegetables/fruits is up to 50% higher than that of conventional vegetables/fruits."

Given this scenario, participants were then asked to indicate their willingness to purchase organic products on a scale from 1 to 5 (1 indicating very unlikely and 5 indicating very likely). The scale was subsequently categorized into 0 and 1 (0 indicating not willing to purchase and 1 indicating willing to purchase), which served as the dependent variable for logistic regression analysis. Logistic regression was revealed to be a suitable model to study influential factors in such studies (Al-Ghamdi, 2002).

Independent Variables

In addition to socio-economic characteristics (Fynn-Green et al., 2019a), the questionnaire also asked consumers about their considerations when purchasing organic food, including price, quality, health, availability, trusted seller, and certification. These factors were scaled on a five-point Likert scale (1 = not important, 5 = very important) and were used as independent variables in the logistic regression analysis (Aitken et al., 2020; Basha & Lal, 2019; Chiciudean et al., 2019; Fynn-Green et al., 2019a, 2019b; Sandran et al., 2020b; Trento et al., 2018; Tsakiridou et al., 2008). The final equation of the logistic regression model can further clear the concept of the study:

$$\begin{aligned} \text{Logit}(P(Y = 1)) \\ = \beta_0 + \beta_1 \text{Age} + \beta_2 \text{Education} + \beta_3 \text{Income} + \dots + \beta_4 \text{Price} \\ + \beta_5 \text{Quality} + \beta_6 \text{Health} + \beta_7 \text{Availability} + \beta_8 \text{Trusted Seller} \\ + \beta_9 \text{Certification} + \epsilon \end{aligned}$$

Results and Discussion

The sample comprised individuals from different age groups, marital statuses, genders, income levels, occupations, and educational backgrounds (Table 1). This diversity provides a comprehensive overview of the local consumer landscape, which is essential for understanding the factors influencing the acceptance and demand for organic products in the region.

The analysis revealed notable trends in willingness to pay based on age and income. As acquired in Table (1), younger respondents, particularly those aged 31 to 45, demonstrated the highest willingness to pay for organic produce, with 68.5% expressing a favorable disposition towards investing in organic options. Furthermore, income levels significantly impacted consumer behavior, with individuals earning between 21,000 to 40,000 Afghanis showing a willingness to pay of 73.5%. Interestingly, marital status also played a role, as married individuals exhibited a greater inclination to purchase organic products compared to their single counterparts, highlighting potential differences in family-oriented purchasing decisions.

Table 1- Demographic representation of respondents and their willingness to pay for organic produce

Demographic categories	Sub-categories	Statistics	Willing to Pay	Not willing to Pay	Total
Age	18-30 Years Old	N	45	65	110
		%	40.9%	59.1%	100%
	31-45 Years Old	N	50	23	73
		%	68.5%	31.5%	100%
	46-60 Years Old	N	9	2	11
		%	81.8%	18.2%	100%
	Above 60	N	1	1	2
		%	50.0%	50.0%	100%
	Total	N	105	91	196
		%	53.6%	46.4%	100%
Marital Status	Married	N	70	45	115
		%	60.9%	39.1%	100%
	Single	N	35	46	81
		%	43.2%	56.8%	100%
	Total	N	105	91	196
		%	53.6%	46.4%	100%
Gender	Female	N	37	22	59
		%	62.7%	37.3%	100%
	Male	N	68	69	137
		%	49.6%	50.4%	100%
	Total	N	105	91	196
		%	53.6%	46.4%	
Income	Below 10 thousand	N	20	39	59
		%	33.9%	66.1%	100%
	11 - 20 thousand	N	35	36	71
		%	49.3%	50.7%	100%
	21 - 40 thousand	N	36	13	49
		%	73.5%	26.5%	100%
	41 - 60 thousand	N	11	2	13
		%	84.6%	15.4%	100%
	60 - 80 thousand	N	1	1	2
		%	50.0%	50.0%	100%
	Above 80 thousand	N	2	0	2
		%	100.0%	0.0%	100%
	Total	N	105	91	196
		%	53.6%	46.4%	100%
Occupation	Health Sector Other than Professional Doctors	N	17	32	49
		%	34.7%	65.3%	100%
	Merchants	N	16	17	33
		%	48.5%	51.5%	100%
	Professional Doctors	N	32	5	37
		%	86.5%	13.5%	100%
	Professors	N	26	15	41
		%	63.4%	36.6%	100%
	Teachers	N	14	22	36
		%	38.9%	61.1%	100%
	Total	N	105	91	196
		%	53.6%	46.4%	100%
Education	Associate Degree	N	11	16	27
		%	40.7%	59.3%	100%
	Bachelor	N	64	55	119
		%	53.8%	46.2%	100%

Demographic categories	Sub-categories	Statistics	Willing to Pay	Not willing to Pay	Total
	High School	N	4	11	15
		%	26.7%	73.3%	100%
	Master	N	23	9	32
		%	71.9%	28.1%	100%
	PhD	N	3	0	3
		%	100.0%	0.0%	100%
	Total	N	105	91	196
		%	54%	46%	100%
Previously Heard of Organic Food	Have Heard	N	102	69	171
		%	59.6%	40.4%	100%
	Haven't Heard	N	3	22	25
		%	12.0%	88.0%	100%
	Total	N	105	91	196
		%	53.6%	46.4%	100%

Gender and education further influenced consumer attitudes towards organic produce. Female respondents showed a higher willingness to pay at 62.7%, while educational attainment positively correlated with this willingness. Those with higher degrees, such as Master's and PhD holders, exhibited strong support for organic products, indicating that education may enhance awareness and concern for health and food safety. Overall, these descriptive findings suggest that targeted marketing strategies considering these demographic factors could effectively promote organic produce in Kunduz, fostering a more health-conscious consumer base.

Composition of family members, family members with income and concern about food security

Table (2) provides an analysis of the composition of family members, family members with income, and concerns about food safety.

Table 2- Composition of family members and other continuous demographics

Variable	N	Mean	Std Dev	Minimum	Maximum
Family members	195	8.66	4.51	1	40
Family members with Income	196	2.27	1.57	1	10
Concerned about Food Safety	196	4.29	1.03	1	5

As evident from the table, the average number of family members among respondents was approximately 8.66, with a standard deviation of 4.54, indicating a wide range in family size, from a minimum of 1 to a maximum of 40 members. Among these families, an average of 2.27 family members contributed to the household income, with a maximum of 10 contributing members. The average concern regarding food security was notably high, with a mean score of 4.29 (on a scale of 1 to 5), suggesting that consumers are significantly concerned about food safety.

Results of Logistic Regression Analysis

The logistic regression analysis was conducted to explore the factors influencing individuals' willingness to pay for organic food. The dataset included a total of 196 observations, with the response variable being binary, indicating whether respondents were willing to pay (1) or not (0) for organic products. The analysis employed a binary logit model using Fisher's scoring optimization technique, ensuring that the model fit the data accurately. The results are presented in Table (3). The variable "Age" emerged as a significant predictor of willingness to pay, with a coefficient of 0.9985 ($p = 0.0043$). This finding indicates that for each additional year of age, the odds willing to pay for organic food increase significantly. The odds ratio for age was calculated to be 2.714, suggesting that older individuals are approximately 71.4% more likely to express a willingness to pay compared to younger individuals.

Gender was another critical variable in this analysis, with females exhibiting a coefficient of 0.9717 ($p < 0.0001$). This indicates that female respondents have significantly higher odds of being willing to pay for organic food compared to their male counterparts. The odds ratio for gender was found to be 6.983, meaning that females are nearly seven times more likely to be willing to pay than males. The occupation variable was divided into several categories, revealing significant differences in willingness to pay among various professions. The coefficients indicated that individuals in the health sector (other than professional doctors) had a lower likelihood of being willing to pay, with a coefficient of -1.0991 ($p = 0.0012$).

Conversely, professional doctors showed a positive coefficient of 1.0204 ($p = 0.0237$). Professors also demonstrated a higher likelihood with a coefficient of 0.7219 ($p = 0.0466$). The findings suggest that occupation influences consumer preferences for organic products.

The variable "Concerned about food safety" significantly influenced willingness to pay, with a coefficient of 1.0493 ($p < 0.0001$). This positive relationship indicates that greater concern about food safety increases the likelihood of willingness to pay for organic food. The odds ratio of 2.856 suggests that respondents who express higher levels of concern are approximately 85.6% more likely to be willing to pay. The variable "Importance of food safety to the family" also demonstrated a significant impact on willingness to pay, with a coefficient of 1.4167 ($p = 0.0188$). This indicates that individuals who place a higher importance on food security within their family context are more likely to be willing to pay for organic products.

Table 3- Estimated Coefficients and Odds Ratios from Logistic Regression Analysis

Parameter	D F	Coefficient (B)	Standard Error	Wald	P- value	Odds ratio	95% Wald Confidence Limits	
Intercept	1	-12.3038	3.2078	14.7115	0.0001	2.714	1.368	5.386
Age	1	0.9985	0.3497	8.1520	0.0043	6.983	2.588	18.841
Gender (female)	1	0.9717	0.2532	14.7271	0.0001	0.954	0.307	2.963
Occupation (Health sector other than professional doctors)	1	-1.0991	0.3389	10.5158	0.0012	4.305	1.156	16.033
Occupation (Merchant)	1	0.4082	0.3943	1.0721	0.3005	7.940	2.035	30.981
Occupation (Professional Doctors)	1	1.0204	0.4511	5.1165	0.0237	5.891	1.711	20.284
Occupation (Professor)	1	0.7219	0.3628	3.9604	0.0466	2.856	1.769	4.611
Concerned about food security	1	1.0493	0.2444	18.4322	<.0001	4.124	1.265	13.441
Importance of food security in family	1	1.4167	0.6029	5.5226	0.0188	2.714	1.368	5.386

Model Fit and Evaluation

The model's fit was assessed using various statistics, including the -2 Log Likelihood, which was reduced from 270.713 to 196.181 after including all significant predictors. The likelihood ratio tests indicated strong overall model significance ($p < 0.0001$). The c-statistic of 0.848 signifies excellent discrimination between those willing to pay and those not willing, with a percent concordant of 83.9%. These metrics confirm that the logistic regression model effectively predicts willingness to pay for organic food based on the included variables.

The Receiver Operating Characteristic

The Receiver Operating Characteristic (ROC) curve analysis was conducted to evaluate the performance of the logistic regression model predicting the variable of willingness. The ROC curve is a graphical representation that illustrates the trade-off between sensitivity (true positive rate) and specificity (1 - false positive rate) across different threshold values. In this analysis, the area under the ROC curve (AUC) was calculated to quantify the model's ability to discriminate between the two response categories: those who are willing and those who are not.

The ROC curve (Figure 1) demonstrated a strong performance, with an AUC value of 0.848. This indicates that the model has a high level of accuracy in distinguishing between the two classes of willingness.

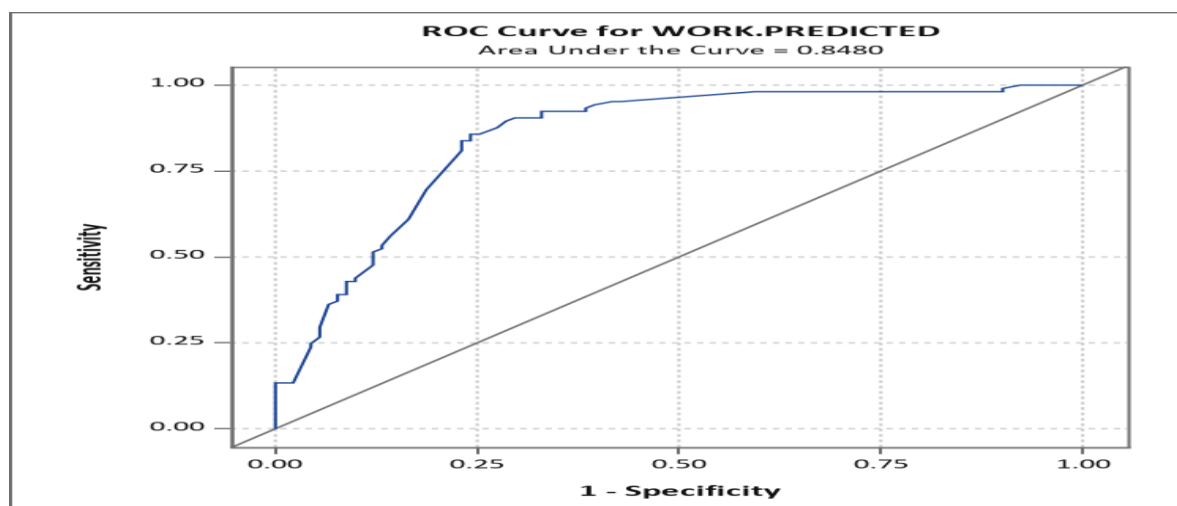


Figure 1- The Receiver Operating Characteristics of Regression Model

Classification Table and Confusion Matrix

The classification table and confusion matrix serve as crucial tools for assessing model performance in the evaluation of classification models, particularly in logistic regression analysis.

Confusion Matrix

The confusion matrix provides a comprehensive overview of the model's predictive accuracy by comparing the predicted classes against the actual classes. For the logistic regression model developed to predict willingness, the confusion matrix is structured as follows:

Table 4- confusion matrix assessing model performance

True Positive	False Positive	False Negative	True Negative	Precision	Recall	Accuracy
90	22	15	69	0.804	0.857	0.811

True Positives (TP): 90 instances were correctly identified as willing (1).

False Positives (FP): 22 instances were incorrectly predicted as willing (1) when they were unwilling (0).

False Negatives (FN): 15 instances were incorrectly predicted as unwilling (0) when they were willing (1).

True Negatives (TN): 69 instances were correctly identified as unwilling (0).

The classification table (attached in the appendix) expands upon the confusion matrix by incorporating additional performance metrics that provide deeper insights into the classification model's effectiveness. The key metrics derived from the confusion matrix are as follows:

Precision: Calculated as the ratio of true positives to the total predicted positives, precision is approximately 0.804. This indicates that about 80.4% of the instances predicted as willing were indeed willing.

Recall (Sensitivity): This metric is the ratio of true positives to the total actual positives, yielding a recall of approximately 0.857.

This means that the model successfully identified about 85.7% of the actual willing cases.

Accuracy: The overall accuracy of the model, defined as the ratio of all correct predictions to the total number of observations, is approximately 0.811. This indicates that around 81.1% of all predictions made by the model were correct.

Awareness of Organic Products Among Kunduz Citizens

The awareness of organic products among consumers is influenced by various demographic factors, including marital status, age, education level, gender, and occupation. The combined analysis of demographic factors reveals significant associations between awareness of organic products and various demographic characteristics. Notably, married individuals demonstrate the highest awareness rate at 91.30%, compared to 81.48% among singles, highlighting the influence of marital status on consumer knowledge. Additionally, younger age groups exhibit greater awareness, particularly those in the first two categories, with rates of 80.91% and 94.52%, respectively. The analysis indicates that educational attainment also plays a crucial role; individuals with a bachelor's degree have the highest awareness at 87.39%, suggesting that higher education correlates with increased knowledge of organic products.

Gender differences further underscore the findings, as female respondents show an impressive awareness rate of 98.31%, compared to 82.48% for males, indicating a potential gender bias in awareness levels. Occupation analysis reveals that those in the health sector are among the most informed, with an awareness rate of 83.67%, which may reflect their occupational exposure to health-related topics. These findings collectively suggest that targeted educational initiatives and marketing strategies could enhance organic product awareness.

Table 5- Awareness of Organic Products by Sociodemographic

Demographic Factor	Categories	Awareness Rate (%)	Chi-Square Statistic	P-value
Marital Status	Married	91.3	4.1208	0.0424
	Single	81.48		
Age Group	18-30 Years Old	80.91	9.3411	0.0251
	31-45 Years Old	94.52		
	46-60 Years Old	100		
	Above 60	100		
Education Level	Associate Degree	88.89	12.8776	0.0246
	Bachelor	87.39		
	High School	100		
	Master	93.75		
	PhD	100		
Gender	Male	82.48	9.2787	0.0023
	Female	98.31		
Occupation	Health Sector Other than Professional Doctors	83.67	16.0664	0.0029
	Merchants	69.7		
	Professional Doctors	100		
	Professors	90.24		
	Teachers	91.67		

Perception of food safety and willingness to pay for organic products

We also examined the relationship between consumers' perceptions of the safety of organic products and their willingness to pay for these items using a heatmap illustration (Figure 2). Participants were asked whether they perceive organic products to be safer than conventional food, with response options of "No," "Not Sure," and "Yes." The data demonstrates the strong connection between perceived safety and willingness to pay for organic products. Consumers who view organic products as safer exhibit the highest mean willingness to pay, reaching around 0.6. In contrast, those who do not perceive organic products as safer have a considerably lower mean willingness to pay,

averaging around 0.4. Interestingly, the "Not Sure" category, representing consumers who are uncertain about the safety of organic products, shows the lowest mean willingness to pay at around 0.3. This indicates that even when consumers are skeptical about the safety claims, they are still willing to pay more than those who outright do not perceive organic products as safer. These findings underscore the critical importance of safety perceptions in driving consumer behavior and purchasing decisions in the organic products market.



Figure 2- Interaction between Perceived Safety of Organic Products and Willingness to Pay

The exploration of consumer knowledge and willingness to pay for organic produce in Kunduz, Afghanistan, reveals critical insights that resonate with findings from global studies on organic agriculture. As highlighted by the FAO/WHO (1999) and supported by (Gomiero et al., 2011), organic agriculture's focus on environmental and social sustainability aligns with the growing demand for health-conscious food choices observed worldwide. The studies conducted in various regions, such as Galicia, Romania, and Greece, demonstrate that consumers often associate organic products with health benefits, quality, and reduced pesticide residues—perceptions that are similarly echoed in Kunduz. This study contributes to the growing body of research on consumer knowledge and behaviors towards organic products. Similar to findings from previous studies conducted in various contexts (Rodríguez-Bermúdez, 2019; Brata, 2022; van Bussel, 2022; Truong, 2022; Aitken, 2020; Sandran, 2020; Tsakiridou, 2008), our study highlights the importance of perceived health benefits, environmental concerns, and food safety in shaping consumer attitudes and purchasing decisions. However, unlike some studies that have found a significant influence of demographic factors on organic consumption (Tsakiridou, 2008), our findings suggest that while demographics may play a role, other factors, such as perceived food safety and health benefits, are more influential in driving consumer behavior. This aligns with the findings of van Bussel (2022), who noted that consumers often prioritize factors like price, convenience, taste, and health over sustainability considerations. Furthermore, the role of labeling in influencing consumer behavior is consistent with the findings of Aitken (2020), who emphasized the importance of product-specific information in shaping attitudes and intentions. In our study, while not explicitly measured, the availability of clear and informative labels on organic products likely played a role in consumer decision-making. While the findings of this study are encouraging, it is important to acknowledge the limitations. The sample size and geographic scope may limit the generalizability of the results. Future research could explore consumer perceptions and behaviors in other regions of Afghanistan and delve deeper into the factors influencing purchasing decisions. Additionally, longitudinal studies could track changes in consumer attitudes and behaviors over time, particularly in response to evolving market dynamics and policy interventions.

Conclusion

This study explored consumer awareness and willingness to pay for organic products in Kunduz, Afghanistan, where conventional agricultural practices heavily rely on synthetic fertilizers and pesticides.

The findings indicate a growing awareness among the target population—comprising doctors, academics, and merchants—regarding the benefits of organic products, particularly in terms of health and environmental sustainability. The results suggest that key factors influencing willingness to pay include price, quality, health considerations, availability, trusted sellers, and certification.

The contingent valuation and revealed preference methods provided valuable insights into consumer behavior, revealing that despite the higher cost of organic products, a significant portion of respondents expressed a willingness to pay a premium for safer and healthier food options. Logistic regression analysis identified socioeconomic factors such as age, education, and income as significant predictors of consumer attitudes toward organic purchases.

Given the relatively nascent stage of organic farming in Afghanistan, this research underscores the importance of targeted educational campaigns to enhance consumer knowledge and trust in organic certification systems. Additionally, policymakers and stakeholders should focus on improving the availability and affordability of organic products to encourage wider adoption.

Overall, the study contributes to the limited body of literature on organic food markets in Afghanistan and provides practical recommendations for the development of the organic sector in Kunduz. Future research should explore larger sample sizes and diverse demographic groups to gain a more comprehensive understanding of consumer preferences and behaviors in the region.

Recommendations

Policy Involvements

Support for Organic Agriculture: Implement supportive policies, such as subsidies, tax incentives, and technical assistance, to encourage organic farming practices in Kunduz province and other regions of Afghanistan.

Food Safety Regulations: Enforce stricter regulations on the use of chemical pesticides and fertilizers to ensure the safety of conventional food products and promote the adoption of organic farming practices.

Consumer Education and Awareness Campaigns: Launch public awareness campaigns to educate consumers about the benefits of organic food, including its health, environmental, and social impacts.

Industry Recommendations

Certification and Labeling: Promote organic certification to facilitate market access for organic products.

Product Innovation: Encourage the development of a diverse range of organic products to meet consumer preferences and dietary needs.

Marketing and Branding: Implement effective marketing and branding strategies to differentiate organic products from conventional ones and create a strong brand identity.

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Public Health Risk Associated with Mycotoxin contaminated poultry products: A Review

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Abstract

The poultry sector in Afghanistan is essential for employment, economic growth, and food security. However, human health is at risk due to mycotoxins. These toxic compounds, produced by fungi such as *Fusarium*, *Aspergillus*, and *Penicillium*, can contaminate poultry. The most common mycotoxins in poultry feed are aflatoxin, fumonisin, and ochratoxin. When poultry consume contaminated feed, these mycotoxins can accumulate in their organs, including eggs produced by layer hens. Suppose humans consume eggs or meat from contaminated poultry. In that case, they may experience negative health effects, including immune system suppression, liver and kidney damage, and an increased risk of cancer, particularly hepatocellular carcinoma. Vulnerable populations, such as children, pregnant women, and individuals with weakened immune systems, are particularly at risk for health issues related to mycotoxin contamination. This review examines the primary sources and pathways of mycotoxin contamination in poultry feed and discusses the acute and chronic impacts on human health. It also outlines mitigation strategies to reduce mycotoxin contamination, including the use of binding agents, quality control measures, and effective feed management practices. Overall, this review underscores the urgent need for strict control measures to minimize mycotoxin contamination and its associated public health risks, both in Afghanistan and globally.

Keywords: Mycotoxin, Poultry, Public health risk

1. Introduction

Afghanistan's poultry industry is a crucial agriculture subsector that offers food, employment, and other economic resources for the nation. The production of poultry products, including meat and eggs, may be at risk if fungi and their mycotoxin contaminate feedstuffs (Akinmusire et al., 2019). Mycotoxins are secondary metabolites of fungi, mainly belonging to the genera *Aspergillus*, *Alternaria*, *Fusarium*, *Cladosporium*, *Claviceps*, and *Penicillium*. Over 400 mycotoxins have recently been found in feed and food. Major mycotoxins that have a significant impact on human health worldwide include Aflatoxin B1 (AFB1), Aflatoxin B2 (AFB2), Aflatoxin G1 (AFG1), Aflatoxin G2 (AFG2), fumonisins (FBs), trichothecenes such as deoxynivalenol (DON) and T-2 toxin (T-2), and ochratoxin A (OTA) (Kemboi et al., 2020).

Toxins are produced by fungal infections in crops before and after harvesting in natural environments worldwide (Haque et al., 2020). Temperature, humidity, and insect activity are environmental factors that can increase crop susceptibility to mycotoxin contamination. They promote growth and mycotoxin production through toxigenic fungi. According to estimates from the Food and Agriculture Organization (FAO), mycotoxins are present in approximately 25% of the world's food supply (Magnoli, Poloni, & Cavaglieri, 2019). Moreover, the components of poultry feed are consistent across different regions and include animal protein sources such as fish, meat, and bone meal. Key plant protein sources include soybean meal, cottonseed, sunflower seed cake, and peanut products, with maize as the primary energy source (Ssepuuya et al., 2017). Furthermore, mycotoxins can contaminate feed ingredients, contaminating final chicken feed supplies (Ochieng et al., 2021). Mycotoxins are metabolized in the digestive system, liver, and kidneys. They can harm human health if present in animal products such as meat and eggs (Awuchi et al., 2022). Fungal contamination poses a risk of toxicosis and can affect the nutritional value and sensory properties of animal feeds. The biological effects of mycotoxins depend on the amount consumed, the level of toxins present, the duration of exposure, and the sensitivity of the animal (Hossain, Haque, Kumar, Sontakke, & Tyagi, 2011). Mycotoxicosis is a condition characterized by decreased animal productivity, including lower body weight gain, reduced litter sizes, malformed offspring, reduced egg production, immunological suppression, and decreased body weight. It can occur when animals consume feed contaminated with high levels of mycotoxin, leading to significant financial losses. (Akinmusire et al., 2019). Both humans and animals can be exposed to mycotoxins, which can have acute or long-term consequences, such as immunosuppression, endocrine disruption, mutagenicity, carcinogenicity, or teratogenicity. Acute poisoning can occur when moderate levels of toxins are consumed, leading to severe impairment of liver or kidney function and even death. Chronic exposure to moderate to low levels of toxins can result in decreased productivity, sluggish growth, and lower-quality products (Fung and Clark, 2004). Consuming low levels of toxins increases the risk of developing infectious diseases, including secondary bacterial infections or rapid development of parasitic diseases (Haque et al., 2020). The purpose of this review is to highlight the public health risks associated with mycotoxin contamination, as well as to identify its sources, pathways, and mitigation methods.

2. Sources and pathways of contamination

Human exposure to secondary metabolites sourced from contaminated poultry products for instance eggs and meat has occurred through consumption of these products contaminated with mycotoxin (Filazi et al., 2017). The constant exposure of poultry feed, especially maize, wheat, barley, and soybeans, to fungi that produce mycotoxins during cultivation, harvesting, and storage makes it extremely vulnerable to mycotoxin contamination (Neme and Mohammed, 2017). These crops may become contaminated in the field, during processing, or before or after harvest. *Fusarium* species, which produce fumonisins, zearalenone, and trichothecenes, are common in cereals like maize and wheat. Conversely, *Aspergillus* species create aflatoxins, which are especially prevalent in peanuts and maize and flourish in warmer regions (Pitt, 2009). In a study conducted in Pakistan, it was found that the prevalence of mycotoxin in poultry ingredients (865 broiler and layer feed samples) was as follows: AFB1 was present in 84.70% of the 182 feeds sampled, followed by OTA in 51% of 41 feeds, Zon in 49.33% of 150 feeds, Don in 38% of 150 feeds, T-2 in 34.65% of 101 feeds, 3ac-Don in 19.41% of

67 feeds, and 15ac-Don in 11.94% of 67 feeds (Ul Hassan & Ahmad, 2015). Several factors can affect how likely feed ingredients are to become infected by fungi. High humidity (70 - 90%), high temperatures (up to 37°C), and physical damage to grains can all increase the risk of mycotoxin development during storage. Additionally, improper handling and transportation of feed materials can worsen fungus invasion and contamination (Magan, Medina, & Aldred, 2011). Mycotoxin contamination can occur through various pathways:



Figure 1: The illustration depicts five maize cobs infected with aflatoxins. Mold growth is visible, primarily at the tops and along the lengths of the cobs. Aflatoxin contamination is evident in the affected areas' discolored, whitish-to-grayish fungal growth. This picture demonstrates the impact of aflatoxins on maize quality and safety by showcasing the various levels of infection (<https://www.flickr.com/photos/iita-media-library/6835939312>).

The primary cause of contamination is fungus, which produces mycotoxins, particularly *Aspergillus*, *Fusarium*, and *Penicillium* species, which infect crops in the field (Payne, 1998). The growth of fungi and the production of toxins can be promoted by factors such as temperature, humidity, and plant stress resulting from pest damage or drought. For instance, *Aspergillus* species thrive in warm, dry conditions to produce aflatoxins, while *Fusarium* species are known to generate fumonisins and trichothecenes in moist environments (Bhat, Rai, & Karim, 2010). Furthermore, mycotoxin contamination is also greatly influenced by post-harvest procedures. Improper drying and storage methods can result in the proliferation of fungi (Choudhary and Kumari, 2010). Aflatoxin and ochratoxin levels increase when storage conditions are not ideal, such as excessive moisture and inadequate aeration, allowing *Aspergillus flavus* and *Penicillium* species to proliferate (Magan & Aldred, 2007). Moreover, since many mycotoxin compounds are resistant to heat and chemical treatments, they can persist during poultry feed processing, contaminating feed ingredients. (Milani & Maleki, 2014). Poultry that consume feed contaminated with mycotoxins absorb these toxins in their digestive tracts, where they can accumulate in organs such as the liver, kidneys, muscles, and eggs.

Notably, many major mycotoxins remain stable and resistant to breakdown even when cooked (Adegbeye et al., 2020). Consequently, these toxins pose significant health risks, as they can enter the human food chain through various routes.

1. Bioaccumulation in Poultry Products

Poultry feed ingredients can become contaminated with mycotoxins if conditions are unfavorable. When chickens eat this contaminated feed, the mycotoxins are metabolized in their digestive systems and can accumulate in their tissues. After ingestion, mycotoxins enter the bloodstream of poultry and build up in various organs. Research indicates that aflatoxins and ochratoxins tend to significantly accumulate in muscle tissue and the liver, both of which are commonly consumed by humans (Bryden, 2012; Duarte, Pena, & Lino, 2011; Gallo, Giuberti, Frisvad, Bertuzzi, & Nielsen, 2015).

While each type of mycotoxin has a different tendency to bioaccumulate, aflatoxins are particularly concerning due to their longevity in edible tissues. Additionally, some mycotoxins can contaminate eggs. Aflatoxin and ochratoxin residues have been found in the eggs of laying hens that were fed mycotoxin-contaminated feed. These eggs are often consumed, potentially exposing humans to harmful substances (Stoev, 2013).

2. Transfer by Ingestion

Conventional cooking and processing methods do not eliminate mycotoxins, as many of them remain stable at high temperatures. For instance, research has shown that aflatoxins can survive baking, roasting, and frying. As a result, even well-prepared poultry products can still pose a risk of exposure (Dohlman, 2003). Humans can be exposed to mycotoxins found in contaminated chicken products, whether through eating the meat or consuming the eggs. Over time, this exposure can accumulate, especially in regions where mycotoxin monitoring is insufficient and poultry products are a staple food (Wild & Gong, 2010).

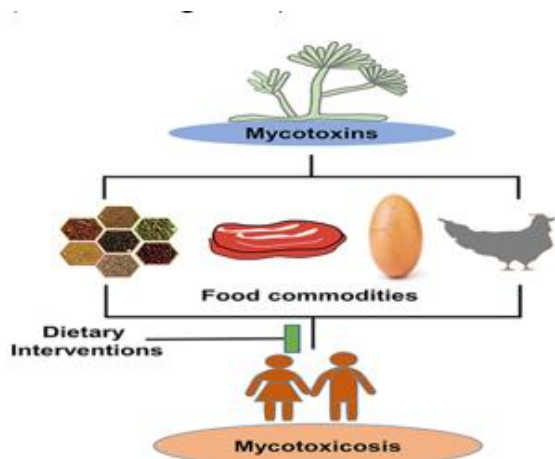


Figure 2: The image illustrates how fungi produce mycotoxins that contaminate various food items such as grains and poultry products (including eggs and meat). When humans consume these contaminated foods, it can lead to a condition known as mycotoxicosis. Adapted from (Sharma & Patial, 2021)

3. Public Health Risk

The harmful substances known as mycotoxins, produced by fungi, can be extremely dangerous to human health, depending on the extent and duration of exposure. These toxins can have both short-term (acute) and long-term (chronic) health impacts (Rea et al., 2003).

3.1. Acute Health Effects

Mycotoxicosis, also known as acute mycotoxin poisoning, is caused by a short, high-level exposure to mycotoxins, often from contaminated food or feed. Depending on the type of mycotoxin, symptoms may include diarrhea, vomiting, stomach pain, and liver damage. For instance, aflatoxins, produced by *Aspergillus* species, have been linked to outbreaks of aflatoxicosis in areas with poor food storage conditions and can lead to sudden liver failure, particularly at high doses (Williams et al., 2004). Trichothecenes, such as DON, can lead to gastrointestinal discomfort, skin irritation, and suppression of the immune system following acute exposure (Fung & Clark, 2004). Human aflatoxicosis can lead to severe symptoms such as edema, lethargy, bile duct proliferation, and hemorrhagic necrosis of the liver (Williams et al., 2004).

3.2. Chronic Health Effects

Prolonged and chronic exposure to low levels of mycotoxins can lead to serious long-term health problems.

For example, aflatoxins are potent carcinogens that are particularly associated with liver cancer.

Prolonged exposure to aflatoxins has been linked to a higher occurrence of hepatocellular carcinoma, especially in individuals infected with hepatitis B (Liu & Wu, 2010). *Penicillium* and *Aspergillus* species produce ochratoxin A, which is linked to immunosuppression and chronic kidney disease. It can harm the kidneys. Fumonisin, produced by *Fusarium* species, have been linked to neural tube defects and esophageal cancer in populations consuming high amounts of maize (Pouris et al., 2024). Aflatoxin is primarily associated with the development of liver cancer in humans. Handling contaminated grain can also increase the risk of lung cancer. Deletion mutations in the tumor-suppressing gene P53 and the activation of dominant oncogenes cause an increased risk of hepatomas (Ahmed Adam et al., 2017). The lifetime accumulation of aflatoxin is the main factor contributing to the well-established risk of cancer from exposure to its various forms. Aflatoxin is regulated to low amounts in marketed commodities. In the United States, the limit is 20 parts per billion (ppb) in cereals and 0.5 ppb in milk (Tahir and Ali, 2021). In several European nations, the limit is 4 ppb in foods. This regulation is in place because the International Cancer Research Institute classifies aflatoxin as a Class 1 carcinogen (Williams et al., 2004). Chronic hepatitis B virus (HBV) infection and high aflatoxin exposure significantly increase the liver cancer risk in many parts of Asia and sub-Saharan Africa (Chandra, 2021). For instance, reports indicate high levels of aflatoxins in Pakistani youth, with 100%, 69%, and 60.5% affected (Ashraf, Rehman, Rabbani, Shaukat, & Wang, 2023). An estimated 25,200–155,000 of the 550,000–600,000 new cases of HCC that occur globally each year may be related to aflatoxin exposure (Liu & Wu, 2010).

Fusarium species produce zearalenone, a toxin that reduces male fertility in humans and can cause cancer. When it comes to carcinogenicity, IARC has categorized zearalenone, trichothecenes, and fumonisins as Group 2B, and ochratoxin A and ochratoxin B as Group 3 (Kaynarca, Hecer, & Ulusoy, 2019). Currently, over 55 billion people worldwide are experiencing uncontrolled exposure to aflatoxins. The number of liver cancer cases worldwide that can be linked to aflatoxin exposure is still unknown (Liu et al., 2012). The Centers for Disease Control and Prevention (CDC) and the World Health Organization (WHO)-organized Aflatoxin Workgroup have identified four immediate priorities: measuring the impact of aflatoxin exposure on human health and the disease burden, compiling a list of current treatment methods, evaluating their result and disseminating the findings (Liu & Wu, 2010). The table below discusses the harmful effects of mycotoxins on human health, excluding their carcinogenic effects.

Table 1: Key types of mycotoxins and their impacts on human health (Pouris et al., 2024).

No	Mycotoxin species	Impacts on human health
1	Aflatoxin	Teratogenicity, Hepatotoxicity, hepatitis, suppression of the immunological system, changed DNA structure, hemorrhage, and kidney lesions.
2	Ochratoxin OTA	Damage to the kidneys and liver, immune system weakness, appetite loss, nausea, and vomiting.
3	Fumonisin	Encephalomalacia, neurotoxicity, liver destruction, heart failure, and human pulmonary edema.
4	Zearalenone	Reproduction problems, teratogenic disorders, and estrogen-related consequences can all result from hormonal imbalances.
5	Patulin	Mutagenicity, neurological disorders, skin lesions, lung issues, brain hemorrhages, and antibacterial activity.

3.3. Vulnerable population

All people are susceptible to mycotoxicosis, but some demographic groups are more vulnerable to the negative effects of mycotoxins due to factors such as age, health, and socioeconomic status (Rezwan et al., 2012).

Children and newborns are especially vulnerable due to their lower body weight and developing organs.

Exposure to certain elements can lead to stunted growth and weakened immune systems (Khlanguiset, Shephard, & Wu, 2011). The immunosuppressive nature of mycotoxins makes people with compromised immune systems, such as those with HIV/AIDS or cancer, more vulnerable (Wu, Groopman, & Pestka, 2014). Mycotoxins can be transmitted from pregnant or breastfeeding mothers to their fetuses or infants, potentially leading to developmental issues (Wild & Gong, 2010). Population in underdeveloped nations are disproportionately affected by mycotoxins due to poor food storage and inadequate healthcare access, particularly in regions relying on crops such as maize and peanuts (Liu & Wu, 2010).

4. Global incidence and regulatory measures

4.1. Prevalence of mycotoxin contamination

The investigation into the prevalence of mycotoxins in poultry production is crucial due to their significant impact on animal health and food safety. Mycotoxins produced by molds in feed ingredients can lead to various health issues in poultry, including immunosuppression, reduced growth rates, and reproductive problems (Filazi et al., 2017). The economic complication for poultry producers is substantial, as contaminated feed can result in poor performance and increased mortality rates. Regular monitoring and assessment of mycotoxin levels in feed are essential for implementing effective management strategies. Understanding the prevalence of these toxins helps ensure the safety and quality of poultry products for consumers.

Table 2: Displays the prevalence rates of various mycotoxins in poultry products across different regions.

Region	Types of mycotoxins	Prevalence in poultry products (%)	References
Pakistan, Sindh (southern zone)	Aflatoxins B1	58% (in meat)	Shabir et al., 2019
Rusia	Aflatoxin, Deoxynivalenol (DON)	8-15% (in poultry products)	Shcherbakov et al., 2017
Mozambique	Aflatoxin B1	39% (in liver) 11% (in gizzard)	(Sineque, Macuamule, & Dos Anjos, 2017)
Pakistan (Punjab)	Aflatoxins (AFs), ochratoxin A (OTA), and zearalenone (ZEN)	41% (in meat) 35% (in egg)	(Iqbal, Nisar, Asi, & Jinap, 2014)
Egypt	AflatoxinB1, M1	45% (in liver) 32% (in gizzard) 25% (in heart)	(El-Desouky, Mohamed, Abou-Arab, & Salim, 2014)
Iraq, sulaimani	Ochratoxin A	86.66% (in meat) 56.6% (in liver)	(Murad, 2015)
China	DON	31% (in egg)	(Wang et al., 2018)
Jourdan	zearalenone	30% (in liver) 8% (8%) kidney	Alaboudi et al., 2022
Pakistan	Fumonisin	18% (in chicken)	Zain, 2021
Pakistan	Aflatoxins B1	35% (in meat) 28% (in egg)	(Iqbal et al., 2014)
Iran	Aflatoxin B1	72% (in liver) 58% (egg)	(Amirkhizi et al., 2015)
Pakistan	Zearalenone	52% (in meat) 32% (in egg)	(Iqbal et al., 2014)
Egypt	Aflatoxin B1	18% (in egg)	(Youssef et al., 2024)
Korea	Aflatoxin Zearalenone Ochratoxin	0 % (in egg)	(Lee et al., 2016)
Nigeria	Aflatoxin B1	48% (in meat)	(Olatoye et al., 2020)
Jourdan	OTA	100% (in Tigh and leg, liver, gizzard) 66% (in breast sample)	(Al Khalaileh, 2018)
Italy	OTA	53% (in blood)	(Schiavone et al., 2008)
Serbia	OTA	(38.33% (in liver) 28.3% (in kidney) 26.6% (in gizzard)	(Miličević et al., 2011)

4.2. Regulatory framework

This study provides an overview of the global regulatory system concerning mycotoxins, focusing on the major regulatory strategies used in different countries such as the US and Europe, as well as international organizations like the Codex Alimentarius Commission.

4.2.1. International Regulatory Framework

The Codex Alimentarius Commission, which sets food safety standards recognized by the World Trade Organization (WTO), plays a key role in the global regulatory system for mycotoxins. The Codex provides guidelines to member nations for sampling protocols, analytical techniques, and the maximum allowable amounts of mycotoxins in food and feed. Aflatoxin, a regulated mycotoxin, is commonly found in nuts, cereals, dried fruits, and spices worldwide. The Codex sets maximum levels of aflatoxins in food, with aflatoxin B1 being the most researched due to its carcinogenic potential. According to the Codex guidelines, the maximum allowable aflatoxin content in peanuts for human consumption should not exceed 15 µg/kg, while for maize intended for further processing, it should not surpass 10 µg/kg and Codex also provides a framework for creating national legislation, it is not legally binding. Countries that comply with Codex criteria are considered to meet the minimum food safety requirements in international trade agreements (CAC, 2020).

Table 3: The table shows the allowable levels of mycotoxins for humans.

No	Mycotoxins	Permitted level (ppb *)	References
1	aflatoxins (AFB1, AFB2, AFG1, and AFG2)	15 ppb	(Brankov et al., 2013)
2	Ochratoxin A	1 – 50 ppb	(H. P. van Egmond, 1991)
3	Deoxynivalenol (DON)	750ppb	(Chen & Inbaraj, 2016)
4	Fumonisin	2 - 4 ppb	(Groopman, Kensler, & Wu, 2012)
5	Patulin	50 ppb	(Mbundi et al., 2014)
6	Zearalenone	20 – 1000 ppb	(Patriarca & Pinto, 2017)

*1part per billion (ppb) = 1µg

4.2.2. Challenges and Emerging Trends in Mycotoxin Regulation

Despite national and international frameworks, several obstacles to mycotoxin regulation exist. Variability in the climate influences fungal growth and mycotoxin production, posing a significant challenge. It is expected that climate change will lead to an increase in mycotoxin occurrences, necessitating more adaptable and flexible regulatory approaches (Strachan, 2023). International trade may be hindered by the challenge of harmonizing legislation across nations, posing another obstacle. For example, exporters from developing countries, where aflatoxin contamination is more prevalent due to hot and humid conditions, often encounter barriers due to the EU's strict limits on aflatoxins (González-Curbelo and Kabak, 2023). To facilitate international trade and ensure food safety, it is essential to harmonize global standards, as achieved through organizations like the Codex Alimentarius.

Emerging advances in mycotoxin regulation include the development of rapid detection methods, such as immunoassays and molecular approaches, which can permit speedier screening of food products for mycotoxins. Furthermore, there is an increasing trend in controlling the co-occurrence of mycotoxins, where multiple mycotoxins are found in a single food product. There is still much to learn about the potential differences between the toxicological effects of individual mycotoxins and those of mycotoxin combinations (Zhang et al., 2024).

5. Mitigation Strategies

5.1. Feed Management

Mycotoxins in poultry feed pose a significant threat to the health, efficiency, and productivity of chickens. Mycotoxins are secondary metabolites produced by fungi, which can contaminate feed components during growth, harvest, or storage. Fumonisin, ochratoxin, and aflatoxin are common mycotoxins that can have various negative effects on chickens, such as reduced feed intake, growth rates, immunosuppression, and increased susceptibility to illnesses (Bryden, 2012). Proper feed management measures are essential for controlling mycotoxin contamination in poultry feed. Important topics such as quality control and the use of feed additives such as binding agents are discussed in this section.

5.1.1. Quality Control in Poultry Feed Management

To minimize mycotoxin contamination in chicken feed, it is crucial to have a robust quality control system in place. This involves regularly testing the feed and its components for mycotoxin levels. Implementation of Good Manufacturing Practices (GMPs), Good Storage Practices (GSPs), and Good Agricultural Practices (GAPs) throughout the feed ingredient supply chain and production process is essential to reduce the risk of contamination (Grenier & Oswald, 2011). It is crucial to regularly test feed ingredients for mycotoxin contamination to identify mycotoxins before they become dangerously contaminated. Both rapid and confirmatory approaches can be used for this purpose. Rapid mycotoxin screening can be done using techniques like enzyme-linked immunosorbent assay (ELISA). In contrast, more thorough confirmatory techniques like liquid chromatography coupled with mass spectrometry (LC-MS) offer more accurate mycotoxin quantification (Kabak, Dobson, & Var, 2006). Early identification allows producers to take corrective measures such as rejecting contaminated feed batches or combining infected feed with uncontaminated batches to lower the total mycotoxin concentration below legal limits (Bryden, 2012).

To reduce mycotoxin contamination, it is essential to properly store feed ingredients. Mycotoxins are often produced when feed is stored in conditions that promote fungus growth, such as high moisture and warm temperatures. The growth of fungi and the development of mycotoxins can be prevented in controlled storage conditions, such as low humidity and cold temperatures (Zain, 2011). The risk of contamination is further reduced by regularly inspecting storage facilities for leaks, ensuring proper ventilation, and controlling pest populations.

It is crucial to select high-quality feed ingredients from reliable suppliers as part of quality control. Some ingredients, such as maize and wheat, are susceptible to mycotoxin contamination. Therefore, feed materials must be sourced from vendors who adhere to strict mycotoxin monitoring protocols (Rodrigues & Naehrer, 2012). Additionally, the total burden of mycotoxins in chicken feed can be reduced by using ingredients such as barley or sorghum, which are less likely to be contaminated by fungi (Guerre, 2016).

5.1.2. Use of Additives in Feed to Mitigate Mycotoxin Absorption

Using feed additives is a valuable strategy for reducing the harmful effects of mycotoxins in poultry, in addition to quality management.

Adsorbents, also known as binding agents, are often included in poultry feed to prevent mycotoxins from entering the gastrointestinal system and being absorbed. These binding agents attach themselves to mycotoxins, preventing the toxins from being absorbed into the bloodstream and spreading throughout the bird's body (Vila-Donat, Marín, Sanchis, & Ramos, 2018). One of the most popular binding agents in chicken feed is bentonite clay.

Due to its layered structure and negatively charged surfaces, this naturally occurring clay has a high adsorption capacity and can bind to positively charged mycotoxins, such as aflatoxins. Research has shown that adding bentonite clay to contaminated feed can significantly reduce the bioavailability of aflatoxins in chickens, leading to improved growth and minimizing harmful consequences (Phillips, 1999). Bentonite is not the only binding agent that has shown promise in reducing the harmful effects of mycotoxins on chicken health. Other binding agents include zeolites, activated charcoal, and yeast cell wall components. To enhance their effectiveness against a wide range of mycotoxins, these adsorbents are often combined (Vila-Donat et al., 2018).

The effectiveness of binding agents in absorbing mycotoxins without obstructing the absorption of essential nutrients depends on their capacity. Some specific adsorbents have a strong affinity for certain mycotoxins, such as aflatoxins, which makes it easier to neutralize them. However, other mycotoxins, like fumonisins and DON, are more challenging to bind and may require alternative approaches, such as using biotransformation agents. Biotransformation agents enzymatically break down mycotoxins into less harmful substances, which the bird can then expel (Grenier & Oswald, 2011).

It's important to carefully consider the inclusion levels in feed, as binding agents can effectively reduce the absorption of mycotoxins. However, excessive use of binding agents can lead to nutritional imbalances in chickens by impeding the absorption of essential vitamins and minerals (De Mil, 2016). Consequently, it is important to properly balance feed compositions to prevent mycotoxin mitigation from compromising nutritional sufficiency.

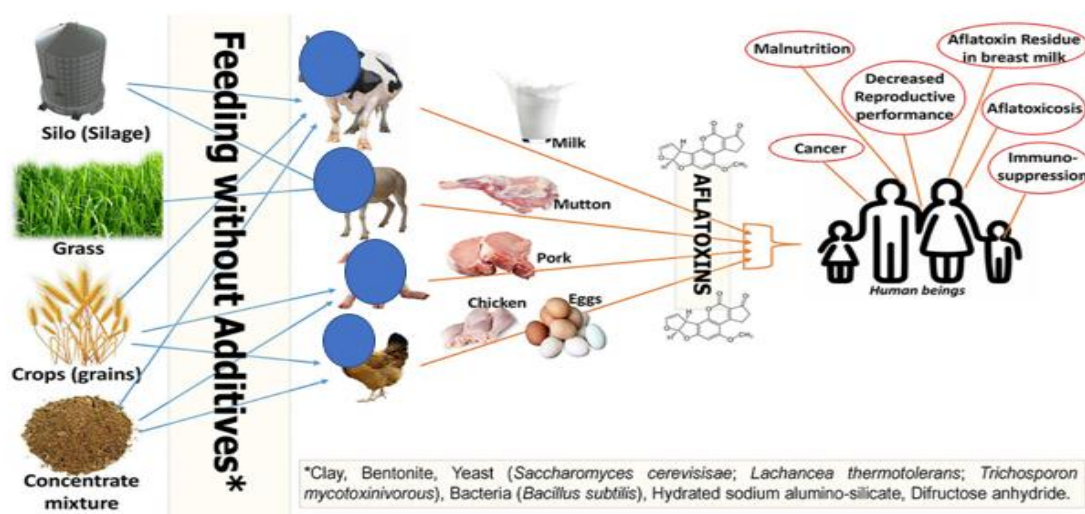


Figure 3: This illustration shows how mycotoxins can contaminate animal products when fed without additives. These contaminated items pose serious health risks to anyone who consumes them. Adapted from (Adegbeye et al., 2020).

5.2. Education and Awareness

Toxic secondary metabolites produced by various fungal species contaminate grains. These toxins, known as mycotoxins, can enter the food chain through contaminated feed. If not properly managed, mycotoxins pose a significant risk to human health. Therefore, farmers and consumers must be more aware of the dangers of mycotoxins to reduce their harmful effects on human and animal health (Bryden, 2012).

Farmers can benefit from educational programs promoting improved agricultural practices to reduce mycotoxin contamination. This includes timely harvesting, proper drying, and safe grain storage (Kumar, Mahato, Kamle, Mohanta, & Kang, 2017). Consumer awareness campaigns can educate people about the importance of purchasing high-quality poultry products. This is necessary because chicken meat and eggs can contain harmful mycotoxins such as ochratoxins and aflatoxins, which can negatively impact human health. (Hans P Van Egmond, 2002).

Moreover, contamination can be significantly minimized if farmers are knowledgeable about early detection methods and the use of mycotoxin binders in chicken feed. By incorporating these practices, public health will be protected, and chicken products will be certified as safe for human consumption (Murugesan et al., 2015).

6. Conclusion

Mycotoxins in poultry feed pose a significant risk to the health of the birds and the safety of human food. This contamination can lead to reduced poultry productivity, financial losses, and potential risks to public health when contaminated animal products enter the human food chain.

Addressing this issue requires comprehensive measures such as regular monitoring of feed, the use of effective mycotoxin binders, and proper environmental management in production and storage facilities. Establishing regulatory frameworks and standards for mycotoxin levels in food and feed is crucial to ensuring food safety worldwide. Collaboration among regulatory agencies, researchers, and poultry producers is essential to efficiently control the risks associated with mycotoxins, thereby protecting the health of both people and animals. Additionally, I recommend further studies to evaluate the prevalence of mycotoxins in poultry and humans and to explore strategies for their mitigation.

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The use of commercial yeast *Saccharomyces cerevisiae* on production performance and egg quality traits of broiler breeders

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Abstract

This study evaluated the effects of commercial yeast *Saccharomyces cerevisiae* on the production performance and egg quality traits of broiler hens. A total of 100 broiler hens and 25 roosters were randomly assigned to five treatments with five replications each, forming experimental units of four hens and one rooster per replication. The treatments included a control group (no yeast) and groups supplemented with 150, 300, 450, or 600 g/t of live yeast in their feed. The study spanned 12 weeks, divided into three four-week periods (ages 54–57, 58–61, and 62–65 weeks). Results showed no significant effects of yeast supplementation on body weight changes, egg weight gain, eggshell strength, or the percentage of malformed eggs. However, in the first experimental period, hens fed 600 g/t of yeast demonstrated significantly higher egg production compared to the control and 150 g/t groups ($P < 0.05$). This trend persisted in the third period, where hens receiving 600 g/t also exhibited significantly higher production compared to the control group. Eggshell thickness at 61 weeks improved significantly in the 300 and 600 g/t groups, but no differences were noted at 65 weeks. Additionally, hens fed 300, 450, and 600 g/t of yeast had significantly fewer broken eggs than the control and 150 g/t groups ($P < 0.05$). Overall, the study concluded that 600 g/t of *Saccharomyces cerevisiae* was the optimal supplementation level, as it enhanced production percentage, increased eggshell thickness, and reduced the percentage of broken eggs without adverse effects.

Keywords: Shell thickness, productive performance, live yeast, broiler breeder hen.

Introduction

The growing population and the subsequent rise in demand for livestock and poultry products have driven researchers to develop growth-promoting additives. While antibiotics are commonly used to control and treat pathogenic bacterial infections—such as those caused by *Escherichia coli*, *Clostridium perfringens*, and *Salmonella* in chickens—their use during the laying period has been increasingly banned in many countries. This shift is due to concerns over microbial resistance and environmental pollution (Wang et al., 2015). With the removal of antibiotics as growth promoters in poultry nutrition due to concerns over microbial resistance, researchers are actively seeking suitable alternatives (Hutjens, 1991; Kim et al., 2007; Ruiz et al., 2015). As the number of laying hens increases, older hens become more susceptible to various stressors, which can result in issues such as gut microbiota imbalance, reduced antioxidant capacity (Liu et al., 2018), heightened immune-inflammatory responses (Attia et al., 2020), decreased performance and lower egg quality (Kuwata et al., 2024). These challenges contribute to significant economic losses for the poultry industry.

One such additive is the live yeast *Saccharomyces cerevisiae*, which has been extensively studied for its effects on growth performance, safety, and animal health. Composed of fermentation metabolites, live yeast has been a staple in poultry nutrition for many years.

Additionally, yeasts are among the oldest sources of single-cell proteins (Santovito *et al.*, 2018). Yeast contains a variety of metabolites, including proteins, small peptides, oligosaccharides, vitamins, minerals, enzymes, and various unknown growth factors. These metabolites can nourish gut microbes, stimulate the proliferation of beneficial bacteria, and inhibit the growth of harmful bacteria (Liu *et al.*, 2019). Numerous studies have examined the effects of yeast supplementation in laying and broiler chickens. For example, researchers reported that adding 3 g/kg of live yeast to the diet of laying hens late in the production period improved production performance by enhancing intestinal digestive enzyme activity and regulating the expression of genes related to gut health (Zhang *et al.*, 2020). Another study reported that adding 1 kg/t of yeast to the diet of broiler chickens improved daily weight gain and reduced *Campylobacter* in the cecum (Froebel *et al.*, 2019). In general, most research on the effects of yeast has focused on broiler and layer chickens, with limited studies examining the impact of live yeast *Saccharomyces cerevisiae* in broiler breeder chickens. This study aimed to investigate the effects of using *Saccharomyces cerevisiae* yeast from the Chitacell Chitica product on the production performance and quality traits of broiler eggs.

Materials and Methods

In this study, in order to investigate the effects of using live yeast *Saccharomyces cerevisiae* on the production performance and egg quality traits of broiler hens, 100 broiler hens (with an average weight of 4025 grams) and 25 roosters were randomly distributed into 5 treatments, 5 replications, and 5 experimental units (4 hens and 1 rooster per replication). All stage of this experiment was conducted in the poultry research Hall of Ferdowsi University of Mashhad, located 15 km along the Mashhad-Quchan road in Iran. The test hens were obtained from the Fariman mother hen farm. Nutritional requirements for the hens were derived from the Ross 308 strain tables (2016), and the experimental diets were formulated using UFFDA software. The components and compositions of the base experimental diet are presented in Table 1. *Saccharomyces cerevisiae* yeast was supplied by Chitika Company under the brand name Chitika Cell, containing 3×10^{12} CFU/g of live yeast.

Table 1- Composition and chemical compounds of basal diets

Ingredient	Percent
Corn	71/0
Soybean meal (CP: 44%)	15/40
Wheat bran (CP: 16/8 %)	2/00
Calcium carbonate	7/79
Oyster shell	1/30
Mono-calcium phosphate	0/83
Salt	0/20
Choline chloride (60%)	0/80
¹ vitamin supplement	0/25
² mineral supplements	0/25
DL methionine	0/16
L-threonine	0/02
Nutrient composition	
Metabolisable energy (kcal/kg)	2715
Crude protein (%)	12/49
Digestible lysine (%)	0/52
Digestible methionine (%)	0/34
Digestible threonine (%)	0/42
Calcium (%)	3/34
Available phosphorus (%)	0/32
Sodium (%)	0/18

¹Vitamin permix Supplied the following, per kilogram of diet: vitamin A, 11025 IU; vitamin D₃, 3528 IU; vitamin E, 33 mg; vitamin K₃, 0/91 mg; Vitamin B₁, 0/18 g; Vitamin B₂, 0/825 g; Vitamin B₃, 1/00 g; Vitamin B₅, 3/00 g; Vitamin B₆, 0/30 g; Vitamin B₉, 0/125 g; Vitamin B₁₂, 0/15 g; choline chloride, 50g;

²Mineral permix Supplied the following per kilogram of diet: Fe (Fe-sulfate), 50g; Zn(Zn-sulfate), 11g; Mn (Mn-sulfate), 110 mg; Cu (Cu-sulfate), 6g; (calcium iodate), 1g; Se (Sodium selenite), 0/2 g.

The experimental treatments included 1- control group (no yeast) and treatments 2 to 5 groups receiving 150, 300, 450, and 600 g/t of live yeast (*Saccharomyces cerevisiae*) in their feed, respectively. The experiment lasted 12 weeks, divided into three four-week periods, corresponding to the ages of 54–57, 58–61, and 62–65 weeks. The rearing house conditions, including temperature, lighting duration, and other management factors, were maintained according to the standard guidelines of the strain manual. The birds were housed in mesh pens measuring one meter square. The production period was divided into three four-week intervals. At the end of the fourth, eighth, and twelfth weeks, the birds were weighed using a digital scale with an accuracy of one gram. Eggs from each experimental treatment were collected and counted separately throughout the experimental period to evaluate production performance and calculate the production percentage. Broken and malformed eggs were also counted separately and reported as a percentage of the total eggs produced during the experimental period. The average egg weight was measured daily throughout the experimental period using a digital scale with an accuracy of 0.001 grams, and the results were recorded. To evaluate the quality traits of eggs, two eggs were randomly selected from each replicate at the end of weeks 8 and 12. The average values from these two weeks were included in the study results. Eggshell strength was assessed using a Japanese resistance tester (Co., Ltd., Tokyo, Japan Robotmation), where eggs were placed vertically and cracked under applied force, measured in kilograms per square centimeter (Zhu et al., 2020). After breaking the eggs, shell thickness was measured at three locations—the tip, middle, and end—using a caliper (Ozenturk and Yildiz, 2020).

Statistical Analysis

All data were organized and sorted using Excel software. Normality was assessed using JAMP software. Statistical analysis was performed using the GLM procedure in SAS 3.9-3 software, based on a completely randomized design. Duncan's multiple range test was applied to compare the means, with a significance level set at 0.05.

Results and discussion

The effects of different levels of live yeast (*Saccharomyces cerevisiae*) on body weight changes in broiler breeders during the periods of 54–57, 58–61, and 62–65 weeks are presented in Table 2. The results of this experiment indicated that adding 2 grams per kilogram of yeast to the diet of laying breeders aged 55–63 weeks had no significant effect on body weight changes (Liu et al., 2021). Another study found that incorporating 1 g/kg of inactive yeast and 0.5 g/kg of live yeast into the diet of laying hens over a 16-week period had no significant effect on body weight changes (Yalcin et al., 2015). Similarly, a study investigated the effects of 50, 100, and 200 g/ton of yeast culture in the diets of laying hens. The researchers reported that these different levels of yeast supplementation had no significant impact on body weight changes compared to the control group (Özsoy et al., 2018).

Table 2- Influence experimental treatments on body weight (gr) in Ross 308 broiler breeder

Treatments*	Yeast gr/ton	First period 54-57 week	Second period 58-61 week	Third period 62-65 week
1	0	4258	4357	4462
2	150	4271	4364	4442
3	300	4253	4334	4451
4	450	4257	4364	4472
5	600	4253	4357	4450
SEM		11/279	11/05	10/308
P. Value		0/7846	0/9379	0/2950

*Experimental treatments include: 1- control treatment (without *Saccharomyces cerevisiae* yeast), 2- 150 gr/ton of diet *S. cerevisiae* yeast, 3- 300 gr/ton of diet *S. cerevisiae* yeast, 4- 450 gr/ton of diet *S. cerevisiae* yeast wall, 5- 600 gr/ton of diet *S. cerevisiae* yeast.

Table 3 presents the effect of different levels of live *Saccharomyces cerevisiae* on the egg production percentage in broiler hens.

The results showed that the different yeast levels had a significant effect on egg production percentage ($P < 0.05$). In the first period of the experiment (54-57 weeks), adding 600 g/ton of live yeast significantly increased the egg production percentage compared to the control group and the group receiving 150 g/ton ($P < 0.05$).

Additionally, adding 150 g/ton of yeast significantly increased the egg production percentage compared to the control group ($P < 0.05$). In the second period of the experiment (58-61 weeks), the percentage of egg production was not affected by the experimental treatments. However, in the third period of the experiment (62-65 weeks), hens fed 600 g/ton of live yeast had a significantly higher egg production percentage compared to the control group ($P < 0.05$). A study conducted in 2020 reported that adding 3 g/kg of live yeast to the diet of laying hens significantly increased egg production percentage (Zhang *et al.*, 2020). In another study, it was reported that adding 0.4%, 0.8%, 1.2%, and 1.6% yeast to the diet significantly increased egg production percentage compared to the control group (Hassanein and Soliman, 2010). In contrast to the present study, other studies have reported that the use of live yeast in the diet did not have a significant effect on egg production percentage (Gül *et al.*, 2013; Sacakli *et al.*, 2013; Yalçın *et al.*, 2014). This difference may be attributed to variations in yeast strain, animal type, experimental diets, and rearing conditions.

Table 3- Influence experimental treatments on egg production (%) in Ross 308 broiler breeder

treatments	Yeast gr/ton	First period 54-57 week	Second period 58-61 week	Third period 62-65 week
1	0	50/55 ^c	56/26	63/14 ^b
2	150	52/35 ^b	56/90	63/60 ^{ab}
3	300	52/66 ^{ab}	56/60	63/26 ^{ab}
4	450	52/99 ^{ab}	57/28	63/46 ^{ab}
5	600	53/56 ^a	57/69	63/73 ^a
SEM		0/255	0/358	0/133
P. Value		0/0001	0/0801	0/0335

^{a-b} Means within the same column with different letters differ significantly ($P < 0.05$).

*Experimental treatments include: 1- control treatment (without *Saccharomyces cerevisiae* yeast), 2- 150 gr/ton of diet *S. cerevisiae* yeast, 3- 300 gr/ton of diet *S. cerevisiae* yeast, 4- 450 gr/ton of diet *S. cerevisiae* yeast wall, 5- 600 gr/ton of diet *S. cerevisiae* yeast..

Table 4 presents the effect of treatments containing 150, 300, 450, and 600 g/ton of live yeast (*Saccharomyces cerevisiae*) on egg weight in broiler hens. The results indicated that supplementation with different levels of live yeast had no significant effect on egg weight ($P > 0.05$). Consistent with the results of this experiment, a study conducted in 2018 investigated the effect of adding *Saccharomyces cerevisiae* live yeast on performance, egg yolk fatty acid composition, and fecal microflora in laying hens. The findings of this study showed that including yeast in the diet had no significant effect on egg weight (Özsoy *et al.*, 2018). Similar to the results of this experiment, it has been reported that adding live yeast to the diet had no significant effect on egg weight (Zhang *et al.*, 2020). However, other research has shown that adding 3 g/kg of live yeast to the diet of laying hens significantly increased egg weight compared to the control group (Zhang *et al.*, 2020). This discrepancy in results may be attributed to factors such as the health of the digestive tract and the microbiota present. Additionally, some studies have suggested that these differences could be due to variations in the type of yeast used, experiment duration, animal species, experimental diets, and rearing conditions (Gadde *et al.*, 2017).

Table 4- Influence experimental treatments on egg weight (gr) in Ross 308 broiler breeder

treatments	Yeast gr/ton	First period 54-57 week	Second period 58-61 week	Third period 62-65 week
1	0	68/43	67/66	67/36
2	150	68/56	67/79	67/35
3	300	68/64	67/69	67/48
4	450	68/58	67/84	67/45
5	600	68/72	67/84	67/41
SEM		0/1072	0/0723	0/1236
P. Value		0/4333	0/2771	0/9224

*Experimental treatments include: 1- control treatment (without *Saccharomyces cerevisiae* yeast), 2- 150 gr/ton of diet *S. cerevisiae* yeast, 3- 300 gr/ton of diet *S. cerevisiae* yeast, 4- 450 gr/ton of diet *S. cerevisiae* yeast wall, 5- 600 gr/ton of diet *S. cerevisiae* yeast.

The effect of treatments containing different levels of live yeast on eggshell thickness and strength at 61 and 65 weeks of age in broiler breeders is reported. The results showed that the experimental treatments had no significant effect on eggshell strength. However, eggshell thickness at 61 weeks of age was significantly increased in the groups receiving 300 and 600 g/t of live yeast feed compared to the control group. No significant effect was observed at 65 weeks of age. In a study by (Liu *et al.* 2021),

who investigated the effect of live yeast on egg quality and reproductive performance in laying hens, it was reported that adding live yeast to the diet increased eggshell strength but had no significant effect on shell thickness. However, many studies have investigated the effects of live yeast and yeast cell wall on shell strength and thickness. Some of these studies were consistent with the results of this experiment (Gaboardi *et al.*, 2019; Özsoy *et al.*, 2018; Zhong *et al.*, 2016), while others were contradictory (Yalçın *et al.*, 2008; Zhang *et al.*, 2020).

Table 5- Influence experimental treatments on egg shell thickness and Shell resistance in Ross 308 broiler breeder

treatments	Yeast gr/ton	shell thickness (nm)		Shell resistance	
		61 week	65 week	61 week	65 week
1	0	394/2 ^b	400/0	3/396	3/580
2	150	399/4 ^{ab}	401/4	3/468	3/614
3	300	404/4 ^a	403/8	3/444	3/622
4	450	400/8 ^{ab}	404/2	3/456	3/606
5	600	405/6 ^a	402/4	3/460	3/632
SEM		1/858	1/811	0/0318	0/0246
P. Value		0/0026	0/4766	0/5349	0/6368

^{a-b} Means within the same column with different letters differ significantly (P<0/05).

*Experimental treatments include: 1- control treatment (without *Saccharomyces cerevisiae* yeast), 2- 150 gr/ton of diet *S. cerevisiae* yeast, 3- 300 gr/ton of diet *S. cerevisiae* yeast, 4- 450 gr/ton of diet *S. cerevisiae* yeast wall, 5- 600 gr/ton of diet *S. cerevisiae* yeast.

Table 6 presents the effect of different levels of *Saccharomyces cerevisiae* yeast on the percentage of broken and malformed eggs in broiler hens aged 54 to 61 weeks. The results indicated that the experimental treatments had no significant effect on the percentage of malformed eggs. However, the percentage of broken eggs was significantly influenced by the experimental treatments. Hens fed 300, 450, and 600 g/t of live yeast (*Saccharomyces cerevisiae*) had significantly lower percentages of broken eggs compared to the control group and the group receiving 150 g/t of live yeast. Many studies have reported positive effects of probiotics and various probiotic strains on the percentage of broken eggs in laying hens, with both multi-strain and single-strain probiotics shown to reduce the percentage of broken eggs (Mikulski *et al.*, 2012). In a study conducted by (Liu *et al.* 2021), the effect of using live yeast on laying hens was investigated, and it was reported that live yeast had no significant effect on the number of malformed eggs. The positive impact of live yeast on egg quantitative and qualitative traits could be attributed to the presence of bioactive compounds such as enzymes, vitamins, amino acids, polypeptides, and oligosaccharides (Jensen *et al.*, 2008).

Table 6- Influence experimental treatments on egg shell thickness and Shell resistance in Ross 308 broiler breeder

treatments	Yeast gr/ton	Deformed egg (%)	Broken egg (%)
		54-61 Week	54-61 Week
1	0	1/79	1/90 ^a
2	150	1/76	1/83 ^a
3	300	1/73	1/67 ^b
4	450	1/78	1/68 ^b
5	600	1/74	1/68 ^b
SEM		0/652	0/0285
P. Value		0/9821	0/0001

^{a-b} Means within the same column with different letters differ significantly (P<0/05).

*Experimental treatments include: 1- control treatment (without *Saccharomyces cerevisiae* yeast), 2- 150 gr/ton of diet *S. cerevisiae* yeast, 3- 300 gr/ton of diet *S. cerevisiae* yeast, 4- 450 gr/ton of diet *S. cerevisiae* yeast wall, 5- 600 gr/ton of diet *S. cerevisiae* yeast.

Conclusion

The results of this study showed that adding live yeast *Saccharomyces cerevisiae* to the diet, in addition to having no negative effects on body weight changes, egg weight gain, eggshell strength, and the percentage of malformed eggs, could simultaneously improve the percentage of egg production, increase eggshell thickness, and reduce the number of broken eggs. Overall, based on the findings of this study, it can be concluded that the use of commercial *Saccharomyces cerevisiae* yeast had beneficial effects on the parameters studied. The optimal level for use, considering the economic aspect of the diet, was found to be 600 grams per ton.

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Impact of Humic Acid on Wheat Genotypes in the Saline Soil of Kandahar

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Abstract

Wheat is an important cereal grain worldwide, including in Afghanistan. Various factors influence wheat crop productivity and quality, while poor soil micronutrient availability might be a more effective cause of low productivity and quality. Adequate humic acid (HA) application is a well-known input that increases micronutrient availability in saline soil, significantly increasing crop growth and productivity as well as boosting grain quality among different wheat genotypes. Therefore, the study was conducted at the ANASTU research farm on six genotypes of wheat (Soola, Chont, Shesham Bagh, Moqaiem, Sad Dana, and Ghor Ghor) inspected under three different levels of HA (0, 30, and 60 kg/ha) in a split-plot design with three replications in 2023. The observations of plant height, dry weight/plant, spikes/plant, spikelets/spike, grains/plant, and grain and straw yield/plant were measured at 30, 60, and 90 days after sowing (DAS). The results revealed significant differences under different HA levels among the genotypes. The Sad Dana variety showed the highest plant height (58.2 cm), dry weight (26.8 g/plant), spikelets (20.3/spike), grains (42.4/spike), and grain yield (4.04 t/ha). The findings suggest that the Sad Dana genotype performs well under saline conditions, and HA can enhance wheat growth and yield attributes.

Keywords: Wheat, Humic Acid, Genotypes, Growth and Yield attributes

Introduction

Wheat (*Triticum* spp.) is the important crop of the world. Wheat grain makes up to 40% of food for the world population (Giraldo et al., 2019). Among the cereals, it is the most important staple food in many countries that contributes 20% of calories and 55% of carbohydrates for humans (Radwan et al., 2015; Giraldo et al., 2019). However, wheat's productivity is limited in many parts of the world, where the average production in developed countries reached around 4 t/ha, while in Afghanistan it is 2.2 t/ha (FAOSTAT., 2022). There are many soil and climatic factors that affect proper crop growth and production. Soil salinity is one of the most important factors that can negatively affect crop growth and yield. Around 20% of arable land in the world suffers from soil salinity, where soil salinity is a major constraint for field crop production, and nearly 10 billion hectares of arable land are currently affected by salt, which continuously increases worldwide (Sabag et al., 2021; Asik et al., 2009).

Climate is arid and semi-arid in the southern part of Afghanistan, specifically Kandahar, receiving an annual minimum rainfall (100-200 mm), thus the salt left on the soil surface and most of the soil suffers from soil salinity. To obtain maximum return from salt-affected areas, soil improvement has to be carried out. Humic acid (HA) is one of the most important organic compounds that acts as a soil conditioner and crop growth regulator. HA affects soil physiochemical properties, which favored soil conditions for proper crop growth (Ulukan, 2008). HA is a water-soluble organic compound that naturally occurs in organic matter and plays a crucial role in soil structural improvement, accelerating biological activities in soil, and as a crop growth regulator. In addition, it increases soil micronutrient availability (Radwan et al., 2015).

Soil fertility degradation is a major problem, especially in young soil. To overcome the problem, mainly organic matter (OM) and microorganism active agents (microorganisms) are utilized. OM is the most important part that increases soil fertility, improving soil structure and aggregate formation and enhancing water-holding capacity. In recent years, HA application as a soil organic amendment has been adopted, and many research studies have reported its positive effects on crop root length, growth regulators, hormone regulators, crop growth, micronutrient adsorption, and enhancing crop tolerance of environmental stress (Mady et al., 2009; Delfine et al., 2005).

Afghanistan's food security and safety are mainly dependent on wheat production, and it is a staple food in the country, but there was no scientific evidence of comparing various cultivars under different HA levels in the climatic and soil conditions of the Kandahar province. However, HA application not only enhances crop growth and yield but also improves soil health and physiochemical properties, which could be ecofriendly to the environment. It was necessary to study its effects on the most important crop of Afghanistan, because there was no previous research work. Hence this research was carried out to compare the yield potential of 6 wheat genotypes under different levels of HA input.

Materials and Methods

A field study was conducted at the ANASTU research farm in wheat growth season (Nov-Apr, 2023). The experiment involved a combination of main and sub-factors. Six wheat genotypes (Soola, Chont, Sheshambagh, Moqaiem, Sad Dana, and Ghor Ghor) were used as the main factor, while the levels of HA (0, 30, and 60 kg/ha) served as the sub-factor. Overall treatments combinations (18) were arranged in a split-plot design in three replications. The HA sourced from Hewad Agricultural Company was tested for purity at the ANASTU lab and was found to contain 70% pure HA. All the HA levels were applied as a basal dose in soil along with the recommended doses of NP fertilizers (120+60 NP₂O₅ kg/ha). The selected observations (e.g., plant height (cm), dry weight (g/plant), number of spikelets/spike and grain/spike, and grain and straw yield (t/ha)) were measured at 30, 60, and 90 days after sowing. The data was analyzed with SPSS software (IBM Statistics 26).

Results and discussion

1. Growth Parameters

1.1. Plant Height

The data presented in Table 1 indicate significant differences in plant height among the various wheat genotypes. The Sad Dana wheat variety exhibited a significantly greater plant height compared to the other genotypes at 30, 60, and 90 days after sowing (DAS).

Specifically, the Sad Dana variety plant heights on average were 13, 29, and 58 cm at the 30, 60, and 90 DAS, respectively. While the application of HA did not result in significant changes in plant height at 30 days after sowing, it had a notable impact at 60 and 90 DAS. HA application (30 kg/ha) led to a significantly greater plant height at both 60 and 90 DAS, consistent with earlier studies (Soofizada et al., 2023a; Walayat, 2023; Giraldo et al., 2019). The higher plant height of Sad Dana may be attributed to its genetic potential for faster elongation and better nutrient uptake, particularly in the local soil conditions, HA application enhances soil structure, micro nutrients availability and cation exchange capacity, thus increasing plant growth. The finding of the study inline with (Soofizada et al., 2023a; Walayat, 2023; Giraldo et al., 2019; Alabdullah, 2019; Daur & Bakhshwain, 2013; Khan et al., 2018; Radwan et al., 2015).

Table 1 plant height (cm) of wheat genotypes affected by different levels of humic acid application

Treatments	30 DAS*	60 DAS	90 DAS
Crop Genotypes			
Soola	9.8	24.2	46.1
Chunt	9.9	26.7	53.2
Shesham Bagh	9.8	22.4	43.4
Muqayem	9.7	24.7	46.7
Sad Dana	12.8	29.3	58.2
Ghur Ghuri	10.4	29.3	56.7
SEm[†](±)	0.51	1.36	2.70
CD[‡] (p≤ 0.05)	1.63	4.33	8.62
Humic acid levels			
[†] HA0	10.3	25.0	49.0
HA30	10.6	27.9	53.5
HA60	10.3	25.4	49.6
SEm±	0.25	0.47	1.26
CD (p≤ 0.05)	NS	1.38	3.70

*DAS, [†]SEm, and [‡]CD, [†]HA, are stand for days after sowing, standard error of mean, and critical differences, respectively.

1.2. Plant Dry Weight

The data presented in Table 2 show significant differences in plant dry weight among the various wheat genotypes. At 30 DAS, the Sad Dana and Ghur Ghuri genotypes produced significantly higher plant dry weight compared to the other genotypes. At 60 and 90 DAS, the Sad Dana variety consistently recorded the highest plant dry weight, reflecting superior growth and biomass accumulation (Agha et al., 2016; Soofizada et al., 2023a). The application of HA (30 kg/ha) had greater plant dry weight at 30, 60, and 90 days after sowing compared to the control, humic acid application improve soil condition, increasing nutrient availability and increasing plant growth, the results are in close agreement with (Elsabagh et al., 2021; Iqbal et al., 2016; Ulukan, 2008; Tahir et al., 2011).

Table 2 plant dry weight (g/plant) of wheat genotypes affected by different levels of humic acid application

Treatments	30 DAS	60 DAS	90 DAS
Crop Genotypes			
Soola	0.29	12.3	25.4
Chunt	0.18	13.0	25.0
Shesham Bagh	0.22	11.9	24.8
Muqayem	0.27	13.1	25.8
Sad Dana	0.31	13.6	26.8
Ghur Ghuri	0.31	11.6	24.1
SEm±	0.02	0.38	0.89
CD (p≤ 0.05)	0.05	1.21	NS
Humic acid levels			
HA0	0.23	11.17	21.81
HA30	0.24	14.06	27.78
HA60	0.32	12.50	26.42
SEm±	0.01	0.25	0.22
CD (p≤ 0.05)	0.01	0.74	0.65

2. Yield Attributes

2.1. Spikelets Number

The data shown in Table 3 revealed significant differences in the number of spikelets/spikes among the various wheat genotypes. The Sad Dana variety produced the highest number of spikelets/spikes, with an average number of spikelets (21 spikelets/spike), which were significantly higher compared to other genotypes, and followed by Sheshambagh and Ghur Ghuri, due to its superior vegetative growth and reproductive success (Walayat., 2023; Rassam et al., 2015) The HA application (30 kg/ha) resulted significantly higher number of spikelets/spike compared to the control, attributed to efficient growth and resource allocation ((Iqbal et al., 2016; Elsabagh et al., 2021).

2.2. Grain/spike

The data in Table 3 show significant differences in the number of grains/spikes among the six wheat genotypes. The Sad Dana variety produced a notably higher number of grains/spikes, followed by Ghur Ghuri, it might be due to greater vegetative growth and better light interception which allow them to use resources efficiently ((Iqbal et al., 2016; Elsabagh et al., 2021). The HA application (30 kg/ha) had a significant impact on the number of grains/spikes, and was significantly greater compared to the control, due to enhanced nutrient availability and plant health (Iqbal et al., 2016; Elsabagh et al., 2021).

3. Yield

3.1. Grain yield

The data presented in Table 3 show significant differences in grain yield (t/ha) among the six wheat genotypes. The Sad Dana variety produced the highest grain yield (4.04 t/ha), which was significantly outperforming all other tested genotypes, followed by the Ghur Ghuri variety, reflecting its genetic traits and efficient resource use (Agha et al., 2016; Soofizada et al., 2023a). The HA application (30 k/ha) resulted significant maximum grain yield, and the observed yield was significantly greater compared to control treatment, suggesting a positive influence on grain formation through improved soil fertility (Khan et al., 2018; Iqbal et al., 2016).

3.2. Straw yield

The data presented in Table 3 show significant differences in straw yield among the wheat genotypes. The Sad Dana variety achieved a significantly higher straw yield compared to the other genotypes, its genetic traits producing greater plant canopy, plant height, and dry matter accumulation greatly affecting straw yield, the finding inline with those reported by (Agha et al., 2016; Soofizada et al., 2023a) Although the application of HA did not have a significant effect on straw yield, the highest straw yield was recorded with the application of 30 kg of HA per hectare, suggesting minor benefits in biomass accumulation due to improved soil conditions (Agha et al., 2016; Soofizada et al., 2023b; Iqbal et al., 2016; Ulukan, 2008).

Table 3 yield attributes and yield of six wheat genotypes affected by different levels of humic acid

Treatments	Spikelets/spike	Grains/spike	Grain yield (t/ha)	Straw yield (t/ha)
Crop genotypes				
Soola	18.63	31.74	2.93	6.85
Chunt	17.19	35.52	3.25	7.15
Shesham Bagh	19.70	37.52	3.19	7.44
Muqayem	19.59	37.11	3.24	6.96
Sad Dana	20.26	42.44	4.04	7.56
Ghur Ghuri	19.63	32.96	3.42	7.37
SEm±	0.22	1.46	0.13	0.22
CD (p≤ 0.05)	0.71	4.66	0.43	NS
Humic acid levels				
HA0	17.52	34.96	7.09	3.25
HA30	20.35	37.89	7.24	3.44
HA60	19.13	35.80	7.33	3.38
SEm±	0.21	0.59	0.19	0.07
CD (p≤ 0.05)	0.62	1.74	NS	NS

Conclusion

The results of this study highlight the superior performance of the Sad Dana wheat variety in terms of growth, yield attributes, and final yield compared to other genotypes. The application of humic acid (HA) had a significant positive effect on several growth and yield parameters, particularly at the 30 kg/ha HA application. Although the impact on grain and straw yield was not drastic, the overall improvements in plant height, dry weight, and reproductive traits suggest that HA has the potential to enhance wheat productivity under saline soil conditions and will support country food security and safety. Future research could explore the interaction between genotype and HA more deeply, as well as the long-term effects of HA on soil health and crop sustainability.

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Factors Affecting Food Security Among Small-Holder Farming Households in Hazrat-e-Sultan District

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Abstract

Food security is fundamental for societal development, particularly in rural areas where livelihoods are primarily dependent on agriculture. This study evaluates the food security status of smallholder farming households in Hazrat-e-Sultan District, Samangan Province, Afghanistan. Using a sample of 348 households selected through stratified random sampling, the study employs the Household Dietary Diversity Score (HDDS) and Food Consumption Score (FCS) to measure food security. Regression analysis, performed using EViews V.13, identifies key factors influencing food security, including economic, agricultural, and informational variables. The results reveal that 68.68% of households experience moderate food insecurity (HDDS), while 55.17% fall within this category based on FCS. Critical determinants of food security include household income, livestock ownership, training, and access to agricultural extension services, which positively impact dietary diversity and food consumption. Conversely, larger family size and greater distance to markets significantly hinder food security, underscoring logistical and resource-related challenges. This research highlights the multidimensional nature of food security and the importance of integrated policy interventions. Recommendations include improving market access through rural infrastructure development, enhancing agricultural training programs, and facilitating access to financial tools such as credit and subsidies. These strategies can empower smallholder farmers, improve resilience, and address barriers to food security in rural Afghanistan. This study contributes to the growing body of knowledge on food security and offers actionable insights for targeted policymaking.

Keywords: Food Security, Factors, Hazrat-e-Sultan District.

Introduction

Health relationship with economic development has been extensively confirmed through global research, particularly over the past decade, using scientific principles and empirical evidence (Sarwar, et al., 2021). The foundation of ensuring these elements lies in food security. Scientifically, food security represents a calculated approach to addressing food and nutrition issues within a defined framework for planning and managing development (Goczek, et al., 2021). The history of food security dates back more than fifty years to the Universal Declaration of Human Rights in 1948 (Liu and Zhou, 2021). Many experts and scholars attribute the growing public attention to food security in the 1980s to several key factors, including the famine in Africa during 1984–1985, challenges in securing a minimum livelihood in many countries during structural adjustment programs, and the evolution of multi-sectoral nutritional planning concepts (Fones, et al., 2020).

During this period, food security and malnutrition emerged as critical issues for investigation by international organizations.

In response, institutions such as the UN, and FAO initiated efforts to address this issue (Mulwa and Visser, 2020). A widely accepted definition of food security describes it as a condition in which all individuals, at all times, have physical and economic access to sufficient, safe, and nutritious food that meets their dietary needs and preferences for an active and healthy life (Liliane, & Charles, 2020).

Food security is, in essence, the foundation of a developed society and a cornerstone for the intellectual, mental, and physical well-being of its members. Ensuring food security within a society is a fundamental duty of governments and is considered essential for achieving national security (Akbari, et al., 2020).

Food security is a multidimensional and interdisciplinary concept with various aspects, similar to many modern concepts of sustainable development. On one hand, it serves as a general indicator for measuring sustainable development; on the other hand, its assessment relies on diverse data and indicators, including poverty, nutrition, agricultural production, food supply, income, and self-sufficiency in consumption. Consequently, food security is influenced by a range of factors (Behera, et al., 2024).

Materials and Methods

Research Area

Hazrat-e-Sultan District is one of the seven districts of Samangan Province, situated in the northern region of Afghanistan. It is classified as a third-tier district within Samangan Province, Hazrat-e-Sultan spans an area of 985 square kilometers. As of 2020, it had a population of 47,583. The district's demographic composition primarily includes rural communities that depend heavily on agriculture and livestock for their livelihoods. Geographically, Hazrat-e-Sultan District lies 20 kilometers north of Aybak city. The district shares borders with Kunduz Province to the north and east, Feroz Nakhchir District to the west, Aybak and Khuram-wa-Sarbagh Districts to the south, and Dara-e-Suf Payin District to the southeast (CSOA, 2020).

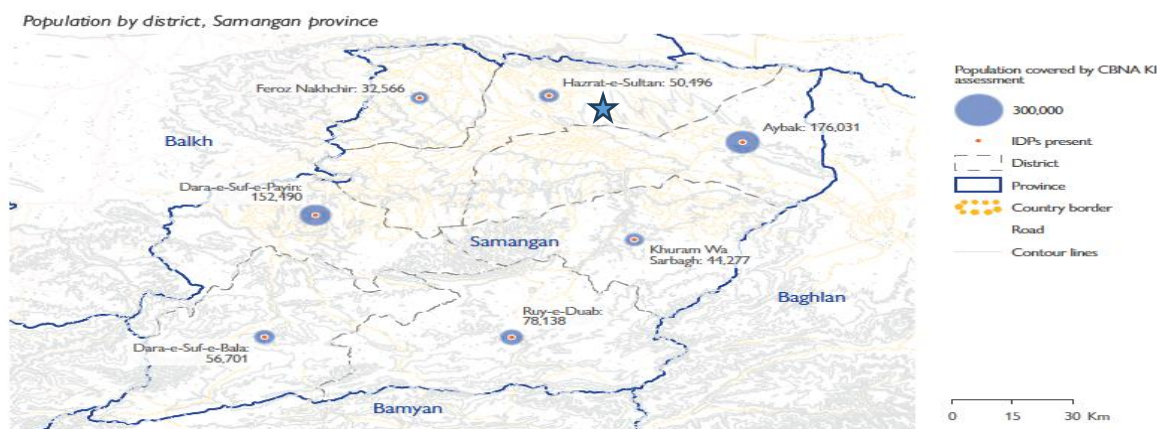


Figure 1. Geographical Location of Hazrat-E-Sultan District (IOM DTM CBNA Assessment, December, 2021)

Sampling Procedure

Data collection took place through a structured survey using questionnaires administered to a sample of 348 households. The sample was selected using stratified random sampling to ensure representation across the district.

Study Model

This study uses a linear econometric model to analyze factors influencing food security:

$$Y_i = \alpha_i + \beta X_i + \varepsilon_i \quad (1)$$

Where Y_i represents food security, α is the constant term, X_i are the independent variables, and ε_i is the error term (Mahrous, 2019; Kinda, 2016).

$$HDDS/FCS = \alpha - \beta_1 FS_i + \beta_2 HI_i + \beta_3 Age_i + \beta_4 TLU_i + \beta_5 LHS_i + \beta_6 FE_i + \beta_7 Labor_i - \beta_8 DTM_i + \beta_9 NOEC_i + \beta_{10} EDU_i + \beta_{11} ATC_i + \beta_{12} LO_i + \beta_{13} ATS_{it} + \beta_{14} TR_i + \varepsilon_{it} \quad (2)$$

As shown in relation 2 the dependent variables used are Household Dietary Diversity Score (HDDS) and Food Consumption Score (FCS), with explanatory variables including family size (FS), household income (HI), age, tropical livestock units (TLU), landholding size (LHS), farming experience (FE), productive labor (Labor), distance to market (DTM), annual contact with extension agents (NOEC), education (EDU), access to credit (ATC), land ownership (LO), access to subsidies (ATS), and training received (TR) (Kinda, 2016). The regression analysis was performed using EViews 13.

Measurement of Food Security

HDDS quantifies the diversity of food groups consumed by households over a given period. Each food group is scored as 1 if consumed and 0 if not, and the scores are summed to obtain the HDDS, which ranges from 0 to 7. Thresholds proposed by IFPRI (2006) classify households as having high (>6), medium (4.5–6), or low (<4.5) dietary diversity (IFPRI, 2006; Coates et al., 2007).

FCS is a frequency-weighted diet diversity score based on the consumption of eight food groups over the past seven days. Frequencies exceeding seven are capped at seven. Each group's frequency is multiplied by its nutritional weight, and the values are summed to compute the FCS. Households are categorized as having poor (0–28), borderline (28.5–42), or acceptable (>42) food consumption (WFP, 2008; Wiesmann et al. 2009; Aworh 2023).

Regression Analysis

To analyze the factors influencing the food security of smallholder farming households in Hazrat-e-Sultan district, the study examined the effects of personal factors such as age, EDU, FS, LHS, FE, TLU, LO, labor, DTM, ATC, FI, ATS, NOEC, and TR on food security. Table 1 describe variables used in this model and specifies their expected effect on food security.

Table 1. Description of Variables Used in the Model

Variables Symbol	Description	Expected Value
HDDS	Household Dietary Diversity Scale (No)	
FCS	Food Consumption Score (No)	
FS	Family Size (No)	-
HI	Household Income (AFG)	+
Age	Age (Year)	-/+
TLU	Tropical Livestock Unit (No)	+
LHS	Land Holding Size (Total Crop Landholding in Hectare)	+
FE	Farm Experience (Actual Farming Experience in Years)	+
Labor	Productive Labor (No)	+
DTM	Distance to Market (km)	-
NOEC	Annual Contact with Extension Agents (No)	+
EDU	Education (1=Illiterate, 2=Primary, 3=Secondary, 4=Higher Education)	+
ATC	Access to Credit (1 for Farmers Had Access to Credit, 0 Otherwise)	+
LO	Land Ownership (1 for owners, 0 Otherwise)	+
ATS	Access to Subsidy (1 for Farmers Had Access to Subsidy, 0 Otherwise)	+
TR	Training Received (1 if Farmer Received Training, 0 Otherwise)	+

Results and Discussion

Food Security Status

Table 2 and 3 shows food security status of small-holder farming households in Hazrat-e-Sultan District.

Table 2. Household Food Security Status (HDDS)

Category	Baseline	Percentage
Poor	19	5.46
Borderline	239	68.68
Acceptable	90	25.86
Total	348	100.00

Table 2 indicates that in the HDDS model the majority of households in Hazrat-e-Sultan district experience moderate food insecurity (68.68%). Additionally, 5.46% of households face severe food insecurity, while 25.86% are in an acceptable state of food security.

Table 3. Household Food Security Status (FCS)

Category	Baseline	Percentage
Poor	63	18.10
Borderline	192	55.17
Acceptable	93	26.72
Total	348	100

Table 3 shows that in the FCS mode the majority of farming households in Hazrat-e-Sultan district are experiencing Moderate food insecurity (55.17%). Additionally, 18.1% of households are in a state of severe food insecurity, while 26.72% are in an acceptable state of food security. The findings from both methods of food security estimation indicate that most residents in the study area are in a state of moderate food insecurity.

Descriptive Statistics

Table 4 provides description of the variables used in the model.

Table 4. Descriptive Statistics of Variables Used in the Model

Variable	Obs	Mean	Std. dev.	Min	Max
HDDS	348	5.6092	1.5116	3.0000	12.0000
FCS	348	36.2428	8.8832	14.0000	60.0000
HS	348	5.3420	2.3029	2.0000	9.0000
HI	348	13959.7700	6640.0750	4000.0000	37000.0000
Age	348	43.2471	14.8992	18.0000	70.0000
TLU	348	1.7500	1.2796	0.0000	8.0000
LHS	348	1.4266	1.2645	0.2000	5.0000
FE	348	24.3994	12.1891	4.0000	45.0000
Labor	348	4.3793	2.1726	1.0000	9.0000
DTM	348	1.2960	0.6409	0.5000	5.0000
NOEC	348	1.8649	1.8194	0.0000	6.0000

As shown in table 4, HDDS ranged from a minimum of 3 to a maximum of 12, with a mean of 5.06. The FCS ranged from a minimum of 14 to a maximum of 60, with a mean of 36.2428. HS varied between a minimum of 2 and a maximum of 9 members, with a mean of 5.352 members. HI ranged from a minimum of 4,000 AFN to a maximum of 37,000 AFN, with a mean of 13,959.77 AFN. The age of respondents ranged from a minimum of 18 to a maximum of 70 years, with a mean of 43.2471 years, indicating that most respondents were middle-aged. TLU ranged from a minimum of 0 to a maximum of 8, with an average of 1.75 units. LHS varied from a minimum of 0.2 hectares to a maximum of 5 hectares, with a mean of 1.4266 hectares.

FE ranged from a minimum of 4 to a maximum of 45 years, with a mean of 24.3994 years.

Labor ranged from a minimum of 1 member to a maximum of 9 members, with a mean of 4.3793 members. The DTM ranged from a minimum of 0.5 to a maximum of 5 kilometers, with a mean of 1.296 kilometers. Finally, the NOEC ranged from a minimum of 0 to a maximum of 6 contacts per year, with a mean of 1.8649 contacts.

Table 5 shows descriptive statistics of qualitative variables used in this research.

Table 5. Descriptive Statistics of Qualitative Variables Used in the Model

Indicators	Frequency	Percentage
EDU		
Illiterate	126	36.207
Primary	135	38.793
Secondary	81	23.276
Higher Education	6	1.724
Total	348	100.000
ATC		
Yes	166	47.70
No	182	52.30
Total	348	100.00
LO		
Yes	206	59.20
No	142	40.80
Total	348	100.00
ATS		
Yes	92	26.44
No	256	73.56
Total	348	100.00
TR		
Yes	134	38.51
No	214	61.49
Total	348	100.00

As shown in Table 5, the majority of respondents (38.793%) have a primary education level, followed by those who are illiterate (36.207%), those with secondary education (23.276%), and those with higher education (1.724%). Most respondents (52.30%) do not have access to credit. Additionally, the majority (59.2%) own agricultural land, while the rest cultivate leased land. Furthermore, most respondents (73.56%) lack access to subsidies, and a similar proportion (73.56%) have not participated in agricultural training programs.

To ensure the model's goodness of fit and the accuracy of its results, diagnostic tests were conducted. The results of these tests are presented in Table 6.

Table 6. Diagnostic Tests of the Model

Test	HDDS		FCS	
Normality (Jarque-Bera)	3.727	0.1551	2.3075	0.3154
Serial Correlation LM Test	0.9002	0.8944	2.06625	0.143751
Heteroskedasticity (Bruech-Pagan)	1.71034	0.172	1.0954	0.3467
Multicollinearity (VIF)	2.05		3.65	

Source: Research Findings

As shown in table 6. the test results show no multicollinearity, heteroscedasticity, or autocorrelation in the model. Also, data are normally distributed.

Table 7 shows factors affecting small-holding household's food security.

Table 7. Regression Results of Factors Affecting Food Security

Table 7: Regression Results of Factors Affecting Food Security									
HDDS					FCS				
Variable	Coefficient	Std. Error	t-Statistic	Prob.	Coefficient	Std. Error	t-Statistic	Prob.	
C	5.295	0.291	18.168	0.000*	34.364	0.620	21.304	0.000**	
FS	-0.135	0.077	-1.755	0.050*	-0.753	8.178	-6.157	0.000**	
HI	0.001	0.000	4.669	0.000*	0.001	3934.323	3.576	0.003**	
EDU	0.021	0.024	0.869	0.386	0.186	7.622	1.414	0.159	
AGE	0.001	0.001	0.566	0.572	-0.002	136.670	-0.341	0.734	
TLU	0.437	0.204	2.146	0.025*	0.020	115.161	2.281	0.050*	
LHS	0.068	0.060	1.133	0.258	0.302	7.668	2.315	0.024*	
FE	0.058	0.022	2.626	0.012*	-0.005	111.316	-0.582	0.561	
LABOR	-0.010	0.010	-1.014	0.312	0.024	18.471	0.450	0.653	
DTM	-0.546	0.058	-9.474	0.000*	-4.379	3.134	-13.723	0.000**	
ATC	0.080	0.039	2.027	0.044*	0.156	4.595	0.715	0.475	
LO	0.179	0.088	2.028	0.044*	-0.758	2.049	-1.553	0.122	
ATS	0.004	0.043	0.096	0.924	-0.087	4.222	-0.365	0.715	
NOEC	0.013	0.010	1.255	0.211	0.100	19.578	1.960	0.050*	
TR	0.028	0.014	2.014	0.038	1.471	2.198	3.233	0.001**	
R-squared				0.866	R-squared				0.959
Adjusted R-squared				0.864	Adjusted R-squared				0.948
F-statistic (Prob)				473.348 (0.000)	F-statistic (Prob)				535.848 (0.000)
Durbin-Watson stat				1.932	Durbin-Watson stat				1.886

Table 7 presents the regression results of factors influencing food security, evaluated using two measures: HDDS and FCS. For the HDDS and FCS models, the R-squared value are 0.866, and 0.948 indicating that 86.6% and 94.8% of the variation are explained by the model respectively. The F-statistics are significant ($p < 0.01$), suggesting that the model as a whole is a good fit for the data. Both models have acceptable Durbin-Watson statistics (1.932 for HDDS and 1.886 for FCS), indicating minimal autocorrelation in the residuals.

As shown in table 7, in the HDDS model HI and DTM have coefficients of 0.001, and 0.546 at the 1% significant level. FS, TLU, FE, ATC, and LO have coefficient of 0.135, 0.437, 0.058, 0.080, and 0.179 at the 5% level of significant level respectively. Also, in the FCS model FS, HI, DTM, and TR have coefficient of -0.753, 0.001, -4.379, and 1.471 respectively at the 1% significant level. TLU, LHS, NOEC have coefficient of 0.03, 0.302, and 0.1 at the 5% significant level respectively.

FS has a negative impact on food consumption, suggesting that larger households may face resource constraints that limit food availability. This is consistent with the work of Jayne et al. (2014) and Gao et al. (2022). HI has a positive and highly significant impact, demonstrating that higher income enables households to diversify their diets. This is supported by Aweke et al. (2021), Menezes-Junior et al. (2022), and Umunnakwe et al. (2023). Similarly, TLU positively affects HDDS, as livestock ownership provides both direct food sources and income diversification opportunities.

This finding aligns with Herrero et al. (2013) and Majeed et al. (2022). FE also positively and significantly impacts HDDS. Experienced farmers are better equipped to optimize resources, which improves food security outcomes. This observation matches the findings of Meijerink and Roza (2007) and Rashid et al. (2023). On the other hand, DTM shows a negative and highly significant impact, as greater distances limit access to food markets, increase transaction costs, and reduce dietary variety.

This is consistent with Omamo (1998), Aweke et al. (2021), and Aung et al. (2023). ATC, although modest in its effect, is positively significant. Financial support enables households to secure inputs and invest in dietary improvements, a conclusion supported by Carter and Barrett (2006) and Koirala et al. (2022). Surprisingly, LO positively impacts HDDS, possibly due to efficiencies in land use or reliance on subsistence farming. This finding mirrors the complexities highlighted in Deininger and Jin (2006) and Zahid et al. (2023).

As shown in table 7, the analysis of the Food Consumption Score (FCS) models highlight key drivers of food security. FS, HI, TLU, and DTM has significantly impacted food security as in the HDDS model. TR, as a critical variable, plays a transformative role in improving both food production and dietary outcomes, reinforcing the importance of agricultural information in enhancing food security outcomes, consistent with the findings of Fite et al. (2022), and Anyanwu et al. (2023). Interestingly, NOEC positively influences food consumption, suggesting that extension services play a crucial role in enhancing food security. This finding aligns with Fite et al. (2022), and Anyanwu et al. (2023). Also, Landholding size has a positive impact on food security. It shows the importance of land ownership on food security of small-holding farming households. This finding aligns with recent studies by Herrero et al. (2013), Koirala et al. (2022), and Umunnakwe et al. (2023).

Conclusion

This study emphasizes the importance of economic empowerment, livestock ownership, and access to credit in improving food security. At the same time, it highlights significant barriers, such as distance to markets and inefficiencies in subsidies, which require targeted policy interventions. The positive role of training received and extension services offers opportunities for enhancing agricultural practices, while the negative impacts of factors like family size and market access call for investments in infrastructure and tailored support for households with greater resource demands. Overall, the findings suggest that policies aimed at improving rural infrastructure, providing better access to financial tools, and enhancing agricultural training can significantly improve food security outcomes.

To address these challenges and leverage opportunities, policymakers should prioritize strategies that enhance rural infrastructure to reduce market distances, invest in agricultural technologies, and facilitate access to credit for smallholder farmers. Supporting income diversification through vocational training and non-farm economic activities can further strengthen household resilience. Moreover, a critical review of subsidy systems and land-use policies is necessary to optimize their impact on food security. These recommendations provide a pathway for addressing food insecurity by combining economic empowerment, infrastructure development, and technological innovation.

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Effect of Using Chitika Multi-Component Toxin Binder on Productive and Reproductive Performance in Holstein Dairy Cows

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Abstract

In order to investigate the effect of using the multicomponent binder toxin Chitika on productive and reproductive performance in Holstein dairy cows, an experiment was designed involving 42 dairy cows with 2 to 3 calving's, an average of 31 ± 8 days in milk, and an initial weight of 686 ± 6 kg over a period of twelve months. The cows were divided into two groups: a treatment group and a control group, each with 21 cows. One kilogram of the Chitika endotoxin binder was added to the feed of the treatment group per ton of feed. Milk production was recorded daily. Samples were sent to the laboratory twice a month throughout the entire experimental period to examine the levels of fat, protein, and lactose in milk, as well as somatic cell counts, using a spectrophotometer. The results showed that the use of the multicomponent toxin binder significantly increased the amount of milk produced and the percentage of milk fat, while also reducing somatic cell counts compared to the control group. On the other hand, the group receiving the toxin binder had the lowest incidence of lameness, retained placenta, and abortion. Overall, the use of a multicomponent toxin binder can significantly contribute to profitability in dairy farms by mitigating the adverse effects of mycotoxins in the feed. Based on the results obtained in this study, the use of one kilogram of the multicomponent Chitika endotoxin binder per ton of feed is recommended.

Keywords: Abortion, Dairy cow, Milk fat, Multicomponent toxin binder, Performance

Introduction

Several external and internal factors, including subclinical abortion, affect the reproductive status of cows. Abortion can occur at different stages of pregnancy and for various reasons which is negatively impacting the reproductive and economic performance of dairy herds (Wiltbank et al., 2016). According to some authors, abortion between 38 to 90 days of pregnancy should not exceed 10% of the total number of pregnant animals within the corresponding gestation period (Almería & López-Gatius, 2015). Abortion in cows has also been reported to be influenced by exotoxins (Sheldon, 2015; Smith et al., 2022) and mycotoxins (Carlos et al., 2017). Furthermore, pregnancy can be disrupted due to the accumulation of heavy metals such as lead, arsenic, mercury, and cadmium in the body, primarily in the liver, kidneys, muscles, and adipose tissue (Wrzecińska, Kowalczyk, Cwynar, & Czerniawska-Piątkowska, 2021).

Numerous reports indicate a decrease in reproductive performance in cows fed with mycotoxin-contaminated feed, especially with zearalenone.

Therefore, the primary cause of infertility in cows and heifers is considered to be the disturbance in the maturation and ovulation of follicles as well as the formation of ovarian cysts (Abbasiyan et al., 2018; Fushimi et al., 2015; Kadokawa, 2020).

Other authors claim that the occurrence of abortion in cows is due to the impact of *Neospora caninum*, linking it to a decrease in the body's resistance caused by the effects of zearalenone and deoxynivalenol on the liver and kidneys.

Additionally, the impairment of liver protein synthesis due to the formation of necrotic foci and the disruption of the glomerular filtration capacity of the kidneys has been demonstrated (Weston, Heuer, Parkinson, & Williamson, 2012). Other authors indicate significant economic losses from early abortions in cows, which include overgrazing and multiple ineffective inseminations (Reichel, Ayanegui-Alcérreca, Gondim, & Ellis, 2013).

Several studies have reported low-quality feed and contamination with mycotoxins as dangerous factors that may cause latent infections of *N. caninum* and ultimately lead to abortion, as mycotoxins suppress the immune system and cause reproductive disorders (Bartels, Wouda, & Schukken, 1999; Conzuelo Sierra, Medina-Esparza, Ramos Parra, García-Vázquez, & Cruz-Vázquez, 2011). Zearalenone is a mycotoxin produced by *Fusarium* species, which occurs as a natural contaminant in corn, barley, wheat, sorghum, and the silos of these grains, particularly in corn and wheat. Zearalenone a non-steroidal estrogenic Mycotoxin, and its toxic effects appear to depend on their interaction with estrogen receptors. It is associated with infertility, mammary gland enlargement, and reduced milk production, especially in heifers, as well as prolapse, abortion, delayed ovulation, fertilization defects, implantation issues, and embryonic growth problems (Cortinovis, Pizzo, Spicer, & Caloni, 2013; Zinedine, Soriano, Moltó, & Manes, 2007)."

Materials and Methods

This experiment aimed to evaluate the effects of using the commercial multi-component toxin binder Endotox Chitika on the productive and reproductive performance of dairy cows. A total of 42 Holstein dairy cows with 2 to 3 parities and an initial body weight of 686 ± 6 kg were assessed over 12 months in a private dairy farm in Mashhad. All selected cows were kept under uniform conditions regarding body condition, nutrition, and health status. The cows were divided into two groups of 21 animals each:

1. **Control Group:** Fed the basal diet.
2. **Treatment Group:** Fed the basal diet supplemented with 1 kg of Endotox Chitika toxin binder per ton of feed.

According to the manufacturer, Endotox Chitika is a multi-component toxin binder containing live *Saccharomyces cerevisiae* yeast, yeast cell walls derived from *Saccharomyces cerevisiae*, activated carbon, diatomaceous earth, and bentonite. The study investigated the product's effectiveness in mitigating the negative effects of feed borne toxins on the productivity and reproductive performance of dairy cows.

The basal diet was formulated according to the requirements of dairy cows producing 35 kilograms of milk per day, based on the NRC 2001 nutritional guidelines. Milk production was recorded daily.

Twice a month throughout the experimental period, milk samples were collected and sent to the laboratory for analysis of fat, protein, and lactose content, as well as somatic cell counts (SCC) using a spectrophotometer.

Simultaneously, health status, the incidence of lameness, and reproductive disorders were recorded monthly and entered into Excel software for analysis.

Table 1: Ingredients and Chemical Composition of the Basal Diet

Diet Ingredients	Percentage of Dry Matter
Dry alfa alfa	15
Corn silage	25
Beet pulp	3
Ground corn	13.5
Ground barley	17.5
Soybean meal	13
Cottonseed meal	6
Wheat barn	4.5
Fish meal	1
Calcium carbonate	0.7
Sodium bicarbonate	0.4
Dicalcium phosphate	0.1
Salt	0.3
Mineral-vitamin supplement	0.5
Chemical Composition of the Diet (%)	
Crude protein	18
Natural detergent fiber	31
Acid detergent fiber	18.5
Net energy for lactation (MgCal/kg DM)	1.59

Results and discussion

Table 2 reports the effects of using the endotoxin binder Chitika on the kilograms of milk produced and the dry matter consumed during different seasons of the year and for the entire experimental period separately. The kilograms of dry matter consumed were not significantly affected by the multi-component toxin binder. The amount of milk produced in the first two seasons (spring and summer) was not influenced by the consumption of the toxin binder. In autumn and winter, the group fed with the diet containing the endotoxin binder had a significantly higher milk production compared to the control group. Numerous studies have examined the effect of different components of the endotoxin binder in dairy cows. In a study conducted by Robinson and colleagues Robinson & Erasmus (2016), it was reported that the daily consumption of 10 grams of *Saccharomyces cerevisiae* yeast increased milk production. Although there are various reports from researchers on this matter, the effects of additives will be much clearer under stress conditions (Köknur, Beyzi, & Konca, 2022).

Table 2- The effect of using toxin binder on kg of milk produced and dry matter consumed in Holstein cows.

	Dry Matter Intake (kg)					Milk Production (kg)				
	Spring	Summer	Fall	winter	Total	Spring	Summer	Fall	winter	Total
Control	22.35	22.57	22.49	22.84	22.56	27.49	27.06	27.02 ^b	26.73 ^b	27.07 ^b
Toxin binder	22.91	22.29	22.73	22.49	22.60	27.77	27.56	27.77 ^a	27.33 ^a	27.61 ^a
SEM	0.2585	0.2116	0.2253	0.2804	0.1205	0.1577	0.2193	0.1559	0.1303	0.0933
P	0.142	0.3463	0.449	0.388	0.828	0.224	0.1219	0.001	0.003	0.000
Value	7		0	5	2	1		9	0	4

^{a-b} In the above table, the English numbers show a significant difference.

Table 3 shows the effect of using a toxin binder on milk fat percentage and the kilograms of milk corrected based on 4% fat in Holstein cows during different periods of the year. The results indicated that the kilograms of milk produced, adjusted for 4% milk fat, were not affected by the experimental treatment. Milk fat percentage in the first three months (spring) at the beginning of the experiment was not influenced by the use of the toxin binder.

However, in summer, autumn, winter, and over the entire experimental period, cows receiving the toxin binder had a significantly higher milk fat percentage than the control group. Many studies have investigated the effect of using toxin binders on milk composition. In most of these studies, the effect of using toxin binders on milk fat was not significant. This variation in results may be due to factors such as the length of the rearing period, the animals used, the diet, and breeding conditions.

Table 3- The effect of using toxin binder on milk fat percentage and kg of milk corrected based on 4% fat in Holstein cows.

	Milk corrected for 4% fat (kg/day)					Milk fat (%)				
	Spring	Summer	Fall	winter	Total	Spring	Summer	Fall	winter	Total
Control	24.30	24.05	23.72	23.73	23.95	3.22	3.21 ^b	3.19 ^b	3.18 ^b	3.20 ^b
Toxin binder	24.44	24.12	24.06	23.93	24.14	3.27	3.31 ^a	3.28 ^a	3.26 ^a	3.28 ^a
SEM	0.1308	0.1212	0.1347	0.0953	0.0577	0.0225	0.0129	0.0110	0.0136	0.0056
P Value	0.4554	0.6946	0.811	0.1583	0.0311	0.0963	0.0001	0.0001	0.0005	0.0001

^{a-b} In the above table, the English numbers show a significant difference.

In Table 4, the effect of using the commercial endotoxin Chitika multicomponent binder toxin on the percentage of lactose and the percentage of milk protein is reported. The results showed that the consumption of the toxin binder had no significant effect on the percentage of lactose or milk protein. Previous studies have reported that the use of yeast does not affect milk lactose (Bayat et al., 2015; Dann, et al., 2000; Ferraretto et al., 2012). In contrast, one study stated that consuming 10 grams of yeast per day increases lactose in milk, while 14 grams per day had no significant effect (Robinson & Erasmus, 2016).

Table 4 presents the effect of using binder toxin on the percentage of lactose and milk protein in Holstein cows.

	Protein (%)					Lactose (%)				
	Spring	Summer	Fall	winter	Total	Spring	Summer	Fall	winter	Total
Control	2.67	2.47	2.35	2.42	2.48	4.83	4.81	4.82	4.79	4.81
Toxin binder	2.65	2.57	2.42	2.44	2.52	4.85	4.77	4.83	4.81	4.81
SEM	0.0491	0.0280	0.0287	0.0272	0.0159	0.0200	0.0236	0.0205	0.0241	0.0112
P Value	0.7177	0.0214	0.0961	0.5609	0.0688	0.5614	0.3266	0.6825	0.5764	0.7384

The investigation of the effect of using a domestic commercial multicomponent binder toxin on the number of somatic cells in milk from dairy cows is reported in Table 5. The results showed that the use of the binder toxin had a significant effect on the number of milk somatic cells. Throughout different seasons of the year and the entire testing period, the use of the endotoxin Chitika multicomponent binder toxin significantly reduced the number of somatic cells in milk compared to the control group. This result was consistent with the findings of some studies (Jovaisiene, 2016; Kiyothong, Rowlinson, Wanapat, & Khampa, 2012). The number of somatic cells in milk is an important economic factor as it directly affects the price of milk. The use of toxin binders in feed prevents their negative effects on the immune and digestive systems by absorbing and deactivating them. A study conducted in 2022 reported that adding binder toxin in organic form to the diet significantly reduced the number of somatic cells in milk (Ghamsari, Ebrahimi, Varzaneh, Iranbakhsh, & Sepahi, 2022).

The number of somatic cells is a key component in determining milk quality and breast health (Stocco et al., 2020).

Table 5- The effect of using toxin binder on the number of milk somatic cells in Holstein cows

	Somatic cell (log cells/ μ L)				
	Spring	Summer	Fall	Winter	Total
Control	4.06 ^a	4.02 ^a	4.02 ^a	4.25 ^a	4.09 ^a
Toxin binder	3.40 ^b	3.48 ^b	3.46 ^b	3.59 ^b	3.48 ^b
SEM	0.0828	0.0509	0.0606	0.0388	0.0349
P Value	0.0001	0.0001	0.0001	0.0001	0.0001

^{a-b} In the above table, the English numbers show a significant difference.

In Table 6, the effect of using the endotoxin Chitika multicomponent binder toxin on the frequency of lameness, retained placenta, and abortion during different seasons of the year in Holstein dairy cows is reported. In the autumn season, the number of cases of lameness was 4 in the control group and 2 in the group receiving the toxin binder. Additionally, one case of retained placenta was reported in the control group during this season. In the winter season, the number of cases of lameness, retained placenta, and abortion in the control group and the group receiving the binder toxin were 6, 1, 1 and 2, 1, and 0, respectively. The highest frequency of lameness in the spring season was observed in the control group, with a frequency of 7, which decreased to 4 in the summer. One abortion was reported in the control group during both the spring and summer seasons. The presence of toxins in feed negatively affects abortion and placental abruption.

Zearalenone toxin causes an estrogenic response in cattle, resulting in abortion and changes in the reproductive organs. In a study conducted by Kallela and Ettala in 1984, cows fed hay containing 10 mg/kg of zearalenone prematurely aborted their fetuses (Kallela & Ettala, 1984). In another study, irregular estrus cycles and behavioral estrus in pregnant and sterile cows were reported in cows receiving 1.5 mg/kg of zearalenone (Gupta, 2012).

Table 6- The effect of experimental treatments on the frequency of lameness, retained placenta and abortion in dairy cows in different seasons of the year.

Season		Control group	1 Kg/Ton toxin binder
Fall	Lameness	4	2
	Retained placenta	1	0
	Abortion	0	0
Winter	Lameness	6	2
	Retained placenta	1	1
	Abortion	1	0
Spring	Lameness	7	2
	Retained placenta	0	0
	Abortion	1	0
Summer	Lameness	4	1
	Retained placenta	0	0
	Abortion	1	0

Conclusion

The adverse effects of mycotoxins on suppressing the immune system and causing liver damage have been well-documented in many studies. In this study, the use of the multicomponent binder toxin significantly increased milk production (kg) and milk fat percentage, while also reducing milk somatic cell counts compared to the control group. Additionally, the group receiving the binder toxin showed the lowest frequency of lameness, placental abruption, and miscarriage. Overall, the use of the multicomponent binder toxin can greatly contribute to the profitability of livestock farms by inhibiting the harmful effects of fungal toxins in feed. Based on the results of this study, it is recommended to use one kilogram of the multicomponent endotoxin Chitika binder toxin per ton of feed.

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Study on Microbiological Quality of Selling Butcher Shops Meat in Jalalabad City

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Abstract

Meat is a rich source of protein and important component of human diet as well as better media for microbial growth. The study aims to evaluate microbiological quality of commercial meat during winter and summer seasons in Jalalabad, Afghanistan. The study was planned with 72 meat samples of cattle and buffaloes' in summer and winter seasons. From 72 samples, 36 samples were from each cattle and buffalo meat and examined in the laboratory of Veterinary Sciences Faculty, Nangarhar University. The experiment of the winter season indicates that the Salmonella and Shigella colonies were detected in 2(11.11%) and 5(27.7%) of 18 cattle meat samples, respectively, however in summer, the Salmonella and Shigella colonies were found in 17 (94.4%) and 13(83.3%) samples respectively, the result was highly significant ($p < 0.05$). The result from 18 Buffalo meat samples at winter season revealed that the Salmonella and Shigella colonies were presented in 1(5.5%) and 3(16.6%) samples, respectively. Comparatively in summer season, the Salmonella colonies were positively detected in 4(22.2%) and Shigella in 15(83.3%) samples, given the highly significant result ($p < 0.05$). It is concluded that the contaminated rate of the cattle and buffalo meat in summer season is higher and the cattle meat was highly contaminated than buffalo meat regarding to pieces' differentiation and the presence of higher fat composition as well. Thus, the use of half cooking meat and unhygienic condition for diet will be causing of food borne illnesses.

Keywords: Meat, Microbial quality, contamination, Hygiene.

Introduction

Meat is very rich source of protein and favourite food for humans. Meat is having higher content of water. If 0.99% water content is still remaining in meat create suitable conditions for microbial Growth (Rao *et al.*, 2009). The alteration of meat texture is due its own enzyme, presence of microbial activities and its own chemically oxidized fat. Microorganisms release metabolites during growth and multiplication on meat causing visual, textural and organoleptic changes (Jackson *et al.*, 2001). Factors affecting microbial growth on the meat are intrinsic and extrinsic factors (Rombout *et al.*, 1994).

Major affecting factors of microorganisms growth in meat are storage temperature, moisture content and oxygen availability (Forest *et al.*, 1985; Frazier *et al.*, 2004). Meat is the flesh of animals suitable for consuming as food of high nutritional value and moisture content with pH value of 5.4 serves as a good medium for microbial growth and contaminating agents of meat spoilage (Lawrie, 1985). Half cooked meat is suitable for microbial growth and is main sources of food-borne illnesses (Bhandare *et al.*, & Podpečan *et al.*, 2007). Meat, the production of livestock is a nutritious food for human diets.

The commonly used animals for meat production are cattle, buffalo, sheep, goat and poultry (ABCB, 2001). Globally, the buffalo meat demand is increased, and its herd raising is also increasing nowadays (MAPA, 2014). The extreme usage of buffalo meat is due to its nutritional value compared to beef as buffalo meat is rich source of iron, valuable proteins and essential fatty acids along with lower quantities of fat and cholesterol (Giuffrida *et al.*, 2015; Lira *et al.*, 2005 & Ziauddin *et al.*, 1994). These features make this food acceptable as a healthy product and buffalo meat has slow decline in post-mortem pH as well (Neath *et al.*, 2007). The higher moisture content and water holding capacity of buffalo meat provide ideal conditions for microbial growth, which is different from beef (Lira *et al.*, 2005; Tateo *et al.*, 2007). Most important pathogens found in meat, include; *Salmonella*, *Staphylococcus aureus*, *Escherichia coli*, *Clostridium perfringens*, *Campylobacter jejuni*, *Listeria monocytogenes*, *Yersinia enterocolitica* and *Aeromonas hydrophila* (Koutsoumanis and Sofos, 2004). The carcass of animal contaminating by Microorganisms via butcher's hands, tools, clothing, water etc., and its proliferating occurs during cutting and distribution (Wilson *et al.*, 1981; Khedkar *et al.*, 2003). Meat quality is always evaluated by microbial population size capable of rapid growth at 30-37°C. So this count is most used to monitor hygiene (Brown and Parker, 1982). Bacterial spoilage of meat occurs due to metabolites production and development of robust odour and discoloration. The meat spoilage passes a series of changes due to bacterial metabolism and its abnormalities appearing by the senses. This would allow a more exact judgment of shelf-life of meat, to avoid meat loss in spoilage development but not overt, to provide a source for regulations controlling meat quality and also to assist manufacturers to use a suitable method of preservation (Waskar, 1993).

Jalalabad city and its around population of more than 3-4 million purchase meat from city market. Due to overcrowding, lack of area, inadequate sanitary conditions, and poor general hygiene, food-borne infections are escalating in this area. Raw meat available in open-air local retail shops without appropriate temperature control is purchased by approximately 80% households (Anjum *et al.*, 2004).

Therefore, microbiological quality of cattle and buffalo meat was evaluated in butcher shops meat to provide information about food borne diseases.

Materials and Methods

72 samples of raw meat were collected from butcher shops from 15/12/2022 -15/11/2023. Collection and transportation of the meat samples was carrying out following the procedures of Mogessie (1994) and Deriba and Mogessie (2002).

100-gram fresh meat samples purchased from different butcher shops of Jalalabad city and were aseptically collected with sterile sampling containers, labelled and transports in ice packed cooler to the laboratory of Nangarhar University, veterinary faculty and analysed immediately on reaching the laboratory. The microbiological quality and safety of meat were assessed on the basis of *Shigella* and *Salmonella* Spp. Detections for (SSD), we used MacConkey agar (MCA) and *Salmonella* agar (SA), respectively.

Diluted meat samples in normal saline were spread onto agar containing plates and incubated at 37 °C for 24 hr. The meat samples were cultured and the colonies of pathogenic bacteria were counted separately.

Sample was fixed with methanol and stained with Giemsa stain and examined under microscope (100 X) with immersion oil for the identification of Meat microbes.

T, test of SPSS-2022 version was used for data analysis in this work.

Results and discussion

Meat contamination is not occurring from the internal tissues of healthy animals, but comes from external sources during slaughtering, bleeding, handling and processing. After slaughtering, the major sources of microorganisms are exterior parts of the animal which includes hide, hooves, hair and the intestinal tract. Without the external parts of animal there are many kinds of microorganisms come from soil, dirt, water, feed and manure as well as its natural flora and the intestinal organisms. It has also been studied that during handling, contamination comes from slaughtering tools like carts, boxes or containers, other contaminated meat, air and colleagues. Eventually, resulting in increasing microbial load in fresh meat (Rombout *et al.*, 1994; Frazier *et al.*, 2004). The present study carried out on 72 samples of cattle and buffalo meat during summer and winter season divided in two categories and enhanced 36 samples from each cattle carcasses and buffalo, respectively. As a result of winter seasons' the cattle meat from 18 samples, there was 2(11.1%) samples positive for Salmonella colonies and 5(27.7%) samples for Shigella and the data was highly significant ($p < 0, 05$). Similarly, in summer season, the Salmonella and Shigella colonies were grown in 17(94.4%) and 15(83.3%) samples respectively and the described result was also highly significant ($p < 0, 05$). Moreover, out of 18 Buffalo meat samples at winter season, the Salmonella colonies were presented in 1 (5.5%) sample, Shigella in 3 (16.6%) samples and the result was highly significant ($p < 0, 05$). Out of 18 samples of buffalo meat in summer season, the Salmonella and Shigella colonies were detected in 4(22.2%) and 13 (72.2%) samples, respectively with highly significant value ($p < 0, 05$). In conclusion, the result showed that cattle and buffalo meat have higher contamination rate in summer season and the cattle meat has high contamination chance than buffalo meat indicating the presence of Salmonella and Shigella in vending shape free selling meat with high contamination rate. The present result shows in below diagrams.

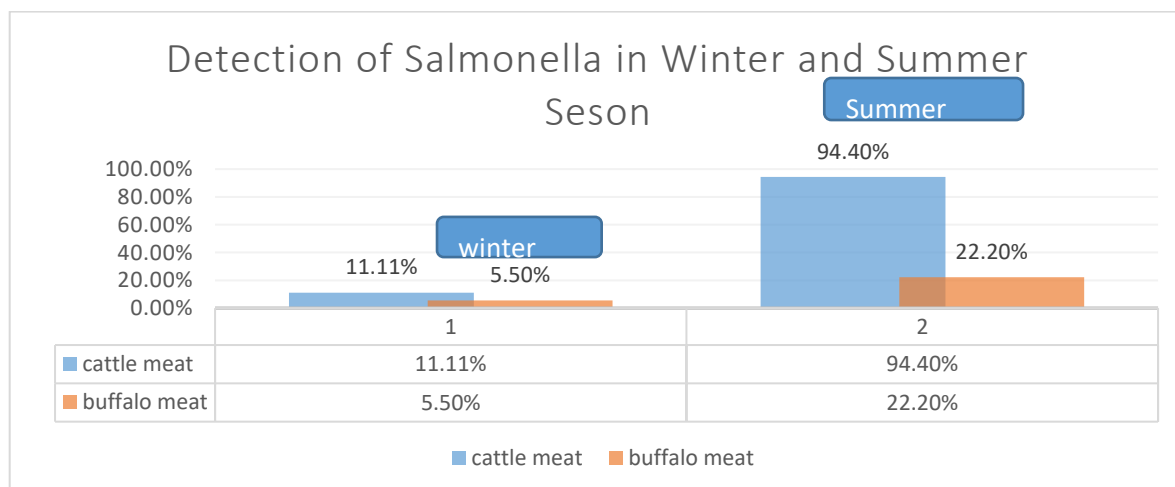


Fig 1: Shows cattle and Buffalo meat contamination rate by Salmonella in winter and summer seasons.

A study carried out on Buffalo meat in Portugal, The percentage of Salmonella and Shigella positive samples were 60% and 33%, respectively (Khedkar *et al.*, 2003). Likewise, a study carried out on cattle carcass in Switzerland, has shown 8.13% positive samples for Salmonella and 23% for Shigella (Hedberg *et al.*, 1992). However, a study carried out in Poland for Salmonella and Shigella findings in cattle carcass, had detected 7.23% positive samples for Salmonella and 5.12% for Shigella (Mikolajczyk and Radkowski, 2002).

Consequently, the present research is carried out to study 18 samples of buffalo meat for Salmonella detection in winter season, results less 49.89% for salmonella and 27.5% for Shigilla findings of than that of Khedkar *et al.* (2003) and less higher 4.77% for salmonella and nearly same % of Shigella findings of than Mikolajczyk and Radkowski (2002), as well as less

higher 2.87% of Salmonella and less 16.5% of shigella findings than the result of Hedberg *et al.* (1992).

In a study by Ahshraf and Shimamoto (2014) in the Egypt by raw meat, Isolated from 800 samples, Salmonella and Shigella was positively detected in 69 (8.625%) and 27(3.3%) samples, respectively. The present study resulted that cattle and buffalo meat in winter season are highly than a study complete by Ahshraf and Shimamoto (2014).

A recent research done by Kalambhe *et al.* (2016) on cattle and buffalo carcass in Nigahpoor, India, shown 6% positive samples for Salmonella in cattle meat and 2% positive samples for buffalo meat. The present study results are higher than the study of Kalambhe *et al.* (2016) in winter.

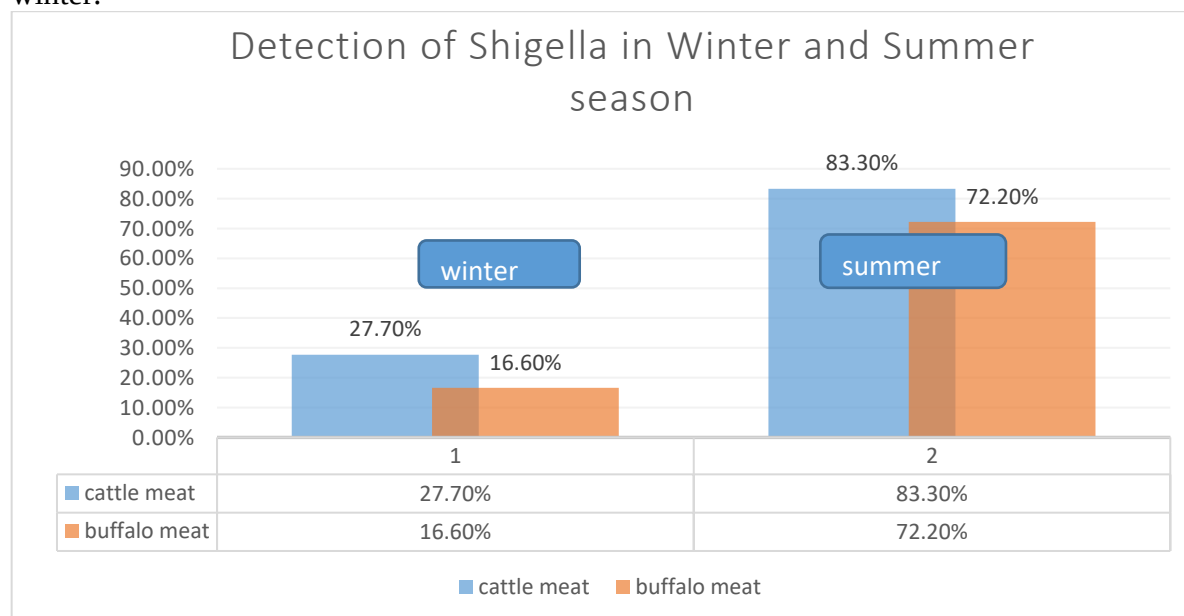


Fig 2: Shows cattle and Buffalo meat contamination rate by Shigella in winter and summer seasons.

Similairly the result of summer season from cattle and buffalo meat for Salmonella and Shigella detection were higher than the results of Khedkar *et al.* (2003), Mikolajczyk and Radkowski (2002), and Hedberg *et al.* (1992). Also the present study resulted that cattle and buffalo meat in summer season are High than a study complete by Ahshraf and Shimamoto (2014) and then the study of Kalambhe *et al.* (2016).

A similar study in Ethiopia by Nyeleti *et al.* (2000), who examined cattle minced and fresh meat for detection of Salmonella showed, 7.7% minced meat samples and 9% fresh meat samples positivity for Salmonella. So the present study result is higher than Nyeleti *et al.* (2000).

A study on buffalo meat for Salmonella diagnosis (Sen and Garode, 2016) in India shown 6.66% positive samples for Salmonella. Thus stated result is higher than the result of present study on buffalo meat in winter and summer seasons. Correspondingly, a study on cattle meat in Egypt for the detection of Shigella indicated 2% positive samples for Shigella (Ahmed *et al.*, 2014).

A study on cattle and buffalo meat for the diagnosed of Shigella (Jour *et al.*, 2016) detected 8.57% positive samples for Shigella. Hence, results of the present study are higher than Ahmed *et al.* (2014) and Jour *et al.* (2016).

Conclusion

Microbiological contamination of meat depends on the keeping, slaughtering and processing conditions of animals. Meat contaminations by Salmonella and Shigella are important factor, which causes high incidences of food borne illnesses in developing countries. This study concluded that degree of contamination of meat by Salmonella and Shigella is dependent on

hygienic condition during meat handling, cutting and preparing.

Our findings indicate that unhygienic and unscientific method of handling, lack of sanitation and knowledge about microorganisms result in high contamination and spoilage by *Salmonella* and *Shigella* in summer season and thus the cattle meat was highly contaminated than buffalo. The sanitary condition is needed to improve and the government must develop microbiological standards and put them in practice. The meat act must be implemented effectively and must be vigilant for control agency. Awareness programs for butchers and meat sellers must be launched as well.

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The Calcium Chloride (CaCl_2) and Ultraviolet (UV-C) Treatments Effects on Shelf-life of Fresh Figs (*Ficus carica* L.)

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ABSTRACT

Fruits play an important role in human food supply; however, they are highly perishable and prone to spoilage. The preservation and storage of fruits is one of the priorities of today's era, which is done by using different methods to prevent their waste. White mountain fig (*Ficus carica* L. cv. Safed Kohi) is an extremely nutritious, high-quality and at the same time perishable fruit, which in order to prevent spoilage and continue its storage in a completely random factorial manner with 4% calcium chloride and ultraviolet rays (UV-C) treated. The first factor of calcium chloride treatment (4% and 0), the 2nd factor of ultraviolet radiation (5, 10 and 15 minutes) and the 3rd factor of storage time (7, 14 and 21 days) were determined. The results of analysis of variance showed that the effect of calcium chloride, calcium chloride and ultraviolet radiation on different retention times was significant at the probability level of 1% on all traits in this study. Analysis of the means demonstrated that the storage percentage of fruits improved to 20.79%, 69.28%, and 67%, and total phenol content increased by 65.266%, highlighting the important role of these treatments. The use of 4% calcium chloride and ultraviolet radiation at different times, especially for 15 minutes, can improve these traits and preserve the marketability of this fruit for a longer time. Therefore, the use of these treatments is recommended to increase the shelf life of fresh fig fruits.

Keywords: CaCl_2 , UV-radiation, weight loss, Phenol, Browning

INTRODUCTION

The genus *Ficus*, consisting of 700 species, is found mainly in tropical regions (Berg, 2003). Common fig (*Ficus carica* L.) is a fruit belonging to the Mulberry family (Moraceae), which includes more than 1400 species distributed in 40 genera (Watson and Dallwitz, 2004). Fig is extremely nutritious fruit which contains more calories than milk (269), rich in protein, fiber, calcium and iron (Singh and Meghwal, 2015). Mousavi et al., 2016 reported that the chemical composition of food differs depending on fruit shape. Fresh harvested figs have a soft texture, sweet taste and pleasant aroma, but their storage time is long due to the ripening process, and their respiration and speed are difficult due to the effect of ethylene (Venditti *et al.*, 2005). High sensitivity to spoilage (Plaza, 2003 and Venditti *et al.*, 2005), but from the perspective of nutritional and pharmaceutical values, the new products available to the participants a better way to reduce corruption with products and increase inventory lead times needs to be considered. Fig is one of the oldest and most used fruits in the world and has been known to humans since ancient times (Vicente et al., 2004). This fruit has been cultivated for 11,000 years and is one of the first plants cultivated by humans (Kislev *et al.*, 2006). Fig varieties commonly grown locally but for commercial purposes in Kandahar, Afghanistan, are called Safed Kohi, Sabz and Seyah. The fruit of Safed Kohi fig is green and green with red skin, has a very sweet taste, has a good guevara aroma, and its beautiful color makes it more source friendly than other varieties. The tree growth is large, salt and drought tolerant, and the crops are similar to Kadota plants but with higher yields (Samadi, 2013 and Shirzad, 1982).

According

to the FAO (2019), fig cultivation in Afghanistan covers 3,625 hectares, with 5,884 tons exported in 2017.

The major areas of commercial production of figs in Afghanistan are the Arghandab, Shahwalikot and Daman villages in Kandahar province, Rodat and Chaparhar villages in Nangarhar province, Tashqirghan and Dehdadi villages of Balkh Province, and the Darabad and Anardara villages of Farah province (Shirzad, 1982).

Calcium chloride (CaCl_2) has significant effects on prolonging the storage life of many fruits and vegetables (apples, strawberries, peaches, tangerine, potatoes, tomatoes, edible fungus, etc.). This chemical delays the ripening of fruit, prevents the postharvest decay of the product, controls physiological damages and raises the calcium level in the food products (Mishra, 2002).

The UV radiation effect is directly lethal for microorganisms. However, the amount of UV bactericidal effect is strongly dependent on the natural resistance of microorganisms to the aforementioned rays. Shama and Alderson in 2005 shown that the resistance of microorganisms to inactivation against the severity of ultraviolet radiation doses are different. Another important factor of survival is the superficial in which microorganisms are linked to it. According to the report of Lado and Yousef in 2002, irradiation ultraviolet radiation is caused by a disorder in cellular development of microbial microorganism. This function occurs so that ultraviolet radiation strengthens the hydroxyl radicals through the removal of hydrogen atoms of water contained in the Deoxyribonucleic acid (DNA) of sugars and the main content of cells. The ultraviolet 254 nm in the formation and regulation of pyrimidine has prevented the DNA binding protection and ultimately deters the proliferation of microorganism cells. The cells that are destroyed by their DNA system cannot be rebuilt. When the irradiation is used at optimum levels, ultraviolet radiation causes the accumulation of photo axing, which has an important role in the resistance against many diseases of the plant system (Ben-Yehoshua et al., 1992; Mercier *et al.*, 1993 and Rodov *et al.*, 2005) and active genes to code the pathogenesis proteins (Green and Fluhr, 1995).

Therefore, this research project aimed to increase the shelf-life of fresh figs using different chemical and transient ray treatments in order to reduce the waste and increase the sustainability of figs (*Ficus carica* L. cv Safed Kohi), which in Afghanistan has special commercial importance.

MATERIALS AND METHODS

The study was designed to evaluate two factors (1) Calcium Chloride (CaCl_2) in Stage 2 (4% and Control) and (2) Ultraviolet Radiation (UV-C) in Stage 4 (5, 10 and 15 minutes and Control). A total of 280 seeds were used in this design and each experiment was performed in triplicate. The cold room was the food industry department of the same university.

Herbal Ingredients

First, when the fig fruit exhibited 60–70% of its natural color and in terms of gardening was completed, it was harvested from the fig local garden (Shahwalikot district, Kandahar province, Afghanistan) in early morning, then the initial refrigeration (Precooling) in cold water was performed for 15 minutes. The samples were placed inside the 6kg plastic baskets (37x25x9cm) in two rows and transported to store room. Then stored at temperatures of 2 to 5 °c with 90-95% relative humidity.

Calcium Chloride Solution Treatment (4%)

30 fresh and ripe fruits based on color, ripeness and free of disease, without the size of the selection, were immersed in the solution of calcium chloride 4% for 2min. Then the treated samples were placed for 30 minutes in the shade and room temperature to dry out. The container contains 10 untreated fruits as controls (Antunes et al., 2003). The samples were placed in

disposable foam containers and image with plastic cover in which the ventilation holes were embedded. The containers containing the samples were transferred to the morgue and stored at temperatures of 2 to 5 °C and moisture of 95-90%.

UV Treatment (UV-C)

A set of 90 fresh and ripe fruit based on the color, the ripeness, free of the disease and without the size were selected and placed in 9 containers.

Treatment applied by irradiation on the samples from the 50cm height, based on the method of Nigro and others (Nigro *et al.*, 1998). Ultraviolet lamp (Philips, Japan) with a diameter of 5.2cm, length of 88cm, output power of 20 watts and the maximum wavelength of 253.7nm in a separate room with the safety interval installed. Treatments were performed for 5, 10 and 15 minutes. Untreated specimens were used as controls (Bal, 2012). The samples were placed in disposable foam containers and covered with plastic cover in which the ventilation holes were embedded. The containers containing the treated and control samples were transferred to the morgue and stored at 2-5 °C and 95-90% humidity.

Calcium chloride (4%) and Ultraviolet (UV-C) treatment

The rest number of (90) fresh and ripe fruit based on the color, the treatment and free of the disease, without considering the size of the selection and in the solution of calcium chloride, 4% were immersed in one level for 2 min. Then, samples were placed for 30minutes in the shade and room temperature to dry out. Then, on treated samples the UV-C applied by irradiation from the 50cm height. Ultraviolet lamp (Philips, Japan) with a diameter of 5.2cm, length of 88cm, output power of 20 watts and the maximum wavelength of 253.7nm in a separate room with the safety interval installed. Treatments were performed for 5, 10 and 15 minutes. Untreated specimens were used as controls. The samples were placed in disposable foam containers and covered with plastic cover in which the ventilation holes were embedded. The containers containing the treated and control samples were transferred to the morgue and stored at 2-5 °C and 95-90% humidity.

Methods

Before applying the treatments (zero day), physical traits (weight loss, decaying rate and fruit dimensions) based on visual observation and taste panel were measured by scoring (excellent = 9, very good = 7, normal = 3 and very bad = 1), and biochemical changes of samples (amount of sugars Solution, soluble solids and phenol) were evaluated after laboratory tests in three replications and the obtained data were recorded as initial control. Then, to measure the aforementioned traits, in the 7, 14 and 21 storage days, completely randomly from each container, the number of 3 fruits were selected and transferred to the laboratory and the experiments were carried out. Then, the obtained data were analyzed in a completely randomized design. ($P \leq 0.05$) LSD data was evaluated by means of mean analysis of variance (Irfan *et al.*, 2013).

Weight loss

The samples were recorded before the test (zero day) with the digital scale of the model (AND GF-400) with accuracy of 001.0 weighing and number obtained. Then, the same process was applied to evaluate the weight loss of fruit treated in the days 7, 14 and 21 of storage on treated samples that were harvested from cold room. The weight loss of samples was calculated according to the following formula and the obtained data was recorded (Asghari and Tawhidian, 2017).

Decay rate

The percentage of decay of samples removed by visual observation and through scoring method of Nunes *et al.*, 2006: (1: Very Low, 2: Low, 3: Moderate, 4: High, 5: Very High, and 6: Severe) were evaluated. The obtained data was recorded.

Phenol Content

To assessment the phenolic compounds, first methanolic extract of samples was prepared, so that 5g of the samples were mixed in 10ml methanol 80% and after homogenization with methanol 80% to the volume of 50ml. After that, a homogeneous sample was placed on the vibrator for 24 hours (Shaker) to mix well. The homogeneous solution was initially passed from the filter paper.

In order to measure total phenol, 40ml of methanolic extract, 200 μ l reagent folin ciocalteu and 2.22ml of distilled water were combined and after 1-8 minutes, 60ml of sodium carbonate 1mol was added. Then, the obtained combination was dark in Laboratory water bath for 30 minutes at a temperature of 40°C.

Then, the Gallic acid adsorption curve was read in 765nm wavelength by optical spectrophotometry machine (CECIL-CR2502-USA) and finally, the total phenol content of the sample according to the standard line relationship ($y=0.0013x + 0.04$) in GAE mg/g was achieved. In this regard (y) displays the number spectrophotometer and (x) displays the phenol content (Ebrahimzade et al., 2008).

Statistical analysis

This design was conducted to test the comparison of different chemical and transients' methods on the quantity and quality of storage of Kandahar, Afghanistan's fresh figs (*Ficus carica* L. cv Safed Kohi), which was carried out at the postgrad laboratory. The deliberate factors included CaCl₂ in 2 levels (4% and control), UV-C rays at 4 levels (5, 10, 15 min, and control) and CaCl₂ of 4% at 1 level with UV-C irradiation at 3 levels (5, 10 and 15 minutes) and control. In statistical analysis, data is based on the interaction effects and duration of storage samples and repetitions. Data analysis was performed using analysis of variance (ANOVA) with *jmp* 11.0.0 software (SAS Institute Inc. USA 2013). For statistical study, a completely randomized factorial experiment of 3 samples of all three replications was selected in each treatment. The test was compared with the criteria $P \leq 0.05$ using the Least Significant Difference (LSD). Sources of change contained within the type of storage time.

RESULTS AND DISCUSSION

Weight loss

The results of this study showed that the effects of calcium chloride and ultraviolet radiation (UV-C) at 1% concentration at different storage times had a significant effect on the weight loss of fig fruits (Table 1). A comparison between the data showed that more fruit weight (84.30%) was observed when CaCl₂ 4% and UV-C irradiation were not used and the samples were stored for 21 days (Figure 1). On the 7th day (excluding control treatment) CaCl₂ 4% and 1% were observed in UV-C irradiation and storage.

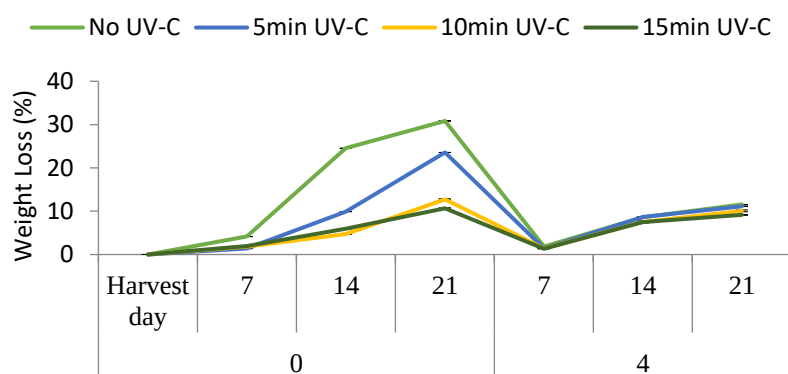
Table 1: Calcium chloride and UV-C Treatments ANOVA analysis of the final results

Change Treatments	sources	df	Mean Square			
			Weight Loss	Browning	Decay	Phenol
CaCl ₂ 4%		1	254/44**	56/27**	150/66**	0/12**
UV-C		3	163/55**	22/85**	202/08**	0/10**
Time		2	160/55**	95/12**	241/33**	1/72**
CaCl ₂ 4% x UV-C		3	114/79**	11/10**	188/02**	0/04**
UV-C x Time		6	47/76**	5/86**	57/19**	0/34**
CaCl ₂ x Time		2	98/34**	17/00**	158/11**	0/14**
CaCl ₂ x UV-C x Time		6	35/19**	3/34**	48/65**	0/015**
Error		48	0/02	0/43	0/74	0/0009

***Significant at the 1% level.

According to the results of this study conducted on lemon (Hosseini Farahi and Haghani fard, 2017), the decrease in fruit weight during fresh fruit storage showed that this decrease in fruit weight was due to water loss. It occurs through evaporation and reduction of the dry matter of the fruit by consuming it in the form of respiration (El-Badawy, 2012).

Evidence that calcium chloride causes a delay in aging and a reduction in fruit weight (Montealegre and Valdes, 1993) of apples (Lurie and Klein, 1992) and peaches (Abdel Gayed et al., 2017) is consistent with its results. Since the use of calcium chloride before and after harvesting seeds resulted in delayed aging and reduced spoilage in fruits and vegetables, the weight loss of fruits in this study may be the same. Moreover, the effect of increasing under calcium chloride on reducing seed weight can be shown that this substance has the ability to maintain the structure of cells and therefore increase the strength of seeds, as well as increase the activity of causing destruction. As weight loss decreases, cell wall and gas exchange enzymes also decrease (Levy and Poovaiah, 1979). Previous studies on plums and tomatoes have shown that weight loss can be prolonged by UV-C radiation (Bal and Çelik, 2008; Mahraj et al., 1999), which is consistent with the findings of this study. Irradiation and ultraviolet radiation applied after planting cause a delay in the whiteness of the seed and the respiration rate decreases, the percentage of dry matter allocated to the plant for respiration decreases (Vicente et al., 2004) and therefore the weight of the plant decreases. seed. In this study, it can be seen that the decrease in the number of seeds were observed for a reason. Another reason for seed weight loss during storage may be that seeds become infected with pathogens during storage and these factors can reduce storage weight (Park, 1999). In addition, the density of the seeds was reduced by increasing the storage time of the seeds, and



therefore the weight of the seeds was reduced by increasing the number of storage days (El-Badawy, 2012).

Figure 1. Comparing the effects of calcium chloride triplet and ultraviolet irradiation on fruit weight reduction rate.

The percentage of Browning and Decay

The results of variance analysis of the interactions of calcium chloride (CaCl_2), UV-C radiation and storage duration at the probability level of 1% on the percentage of brown fruit and decay of figs were significant (table 1). The highest percentage of coffee (66.9%) (Fig. 2) and fruit rot (33/29%) (Fig. 3) was not used in the treatment of calcium chloride, lack of UV radiation irradiation and in twenty-one days of storage. Also, the results showed that the amount of brown and fruit decay except for harvest time which has not yet been in stock in treatment of calcium chloride 4%, irradiation UV-C in all three radiation levels and on the seventh day of the storage. So that even irradiation the UV-C rays for 10 and 15 minutes, the amount of these traits is zero and this means that the treatments of brown and decay did not occur. The results of this study matches the results of Bal, 2012 and Irfan, 2013 researches on common fig fruit, Hosseini Farhi and Haghani Fard in 2017 researches on sweet lemon fruit.

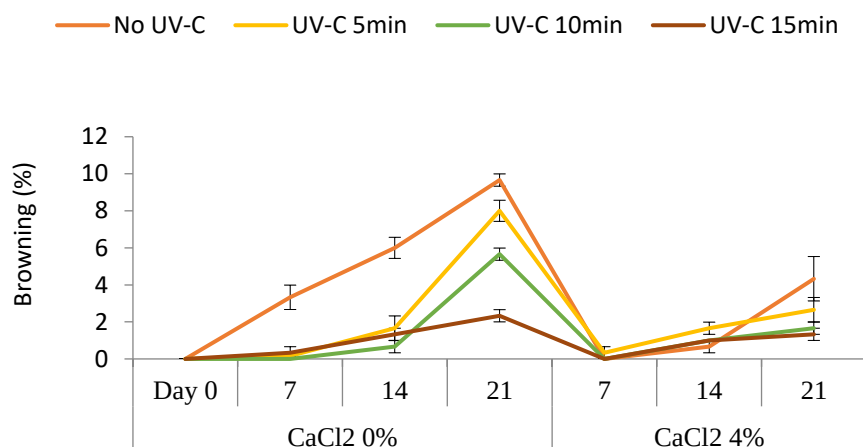


Fig. 2. Comparing the effects of calcium chloride triplet and ultraviolet irradiation on the percentage of browning and decay in figs.

Weight Loss

Weight loss of fruits and vegetables has a rapid dependence on the transpiration and respiration process. Also, the loss of fresh fruit moisture can be considered as one of the most important factors of quality reduction (Guilbert et al., 1996). Therefore, disruption of the transpiration process, breathing and reduction of water potential in the cells leads to reduced volume and physical quality of fruit and this has a direct relationship with weight loss during storage time. Also, fresh fruit has a variety of causes such as gas exchanges and breathing intensity, reduce the humidity of the storage environment and the fluctuations of the temperature of the volume and its dimensions, which the fig fruit is no exception that this is the main cause of qualitative reduction, quantitative and market.

The results of a study by Burdon et al., 2007. Gayle et al., 2012 and Bal, 2012 showed that kiwi and figs dissolved in the final stage of the reaction, causing a % increase in digested peels and shredded pectin, which are the phenolic compounds of the fruit. It may be caused by the decrease in moisture and the hydrolysis of the amount of polysaccharides, which confirms the results of this study. Treatment with calcium chloride and UV radiation appears to reduce and increase the internal surface area of these materials relative to untreated samples.

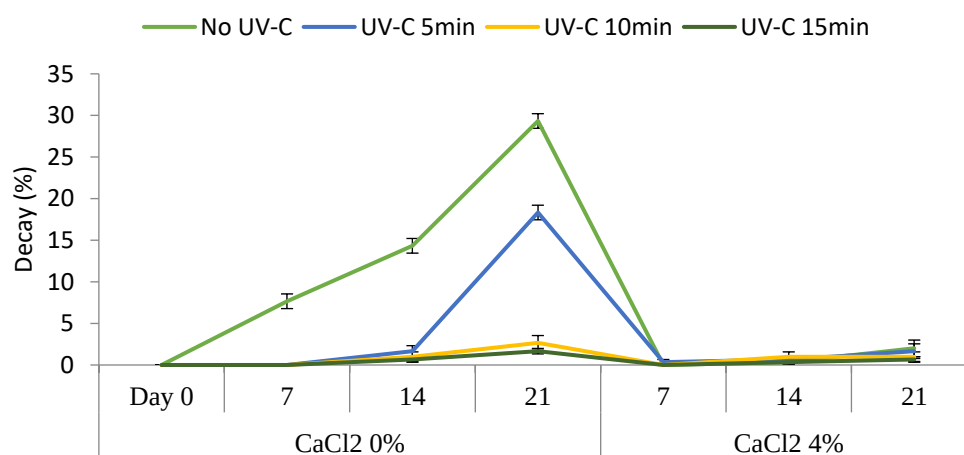


Figure 3. Comparing the effects of calcium chloride triplet and ultraviolet irradiation on the percentage of fig fruit weight loss.

Total phenol

Total phenol results showed that the effects of calcium chloride and UV radiation on percentage at different storage times were potentially significant (Table 1). The results showed that total phenolic content decreased as storage time increased. However, since the maximum amount of this quality (73.0 mg/g fresh fruit) was achieved in the treatment with 4% calcium chloride and 15 minutes of UV radiation, no significant difference was created in the treatment without radiation (Figure 9).). The results of this study are consistent with those of a study by Mighani et al., 2018. According to the results of this study, treatment of seeds with calcium chloride also increased the total phenolic content of Spice (Soleimani Aghdam et al., 2013) and Pear (Kou et al., 2013). The cause of reduction of phenolic compounds during the storage period can be that by increasing the storage period, the enzyme activity of polyphenols oxidase and peroxidase, and these compounds cause degradation of phenol content and the application of calcium chloride and UV radiation by reducing the activity of these enzymes caused increased phenol (Kou et al., 2013).

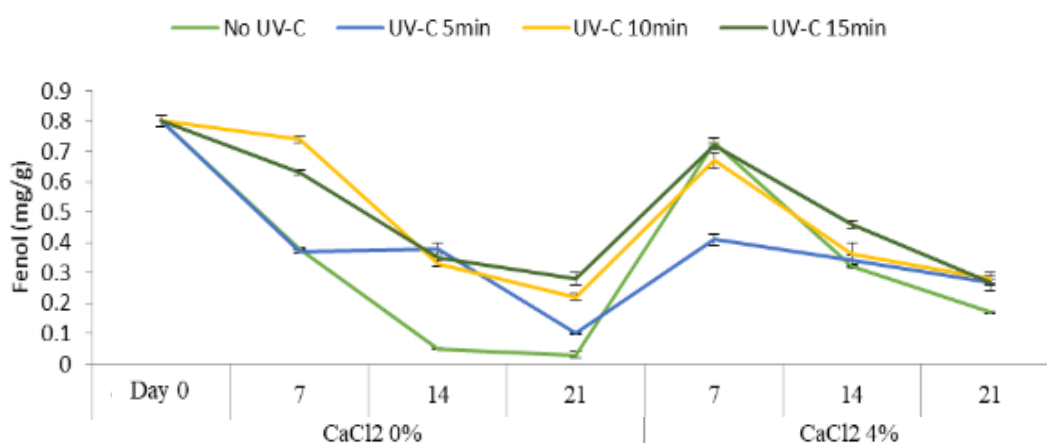


Figure 4. Comparing the effects of calcium chloride triplet and ultraviolet irradiation on the percentage of fig fruit total phenol content.

CONCLUSION AND SUGGESTIONS

One of the main causes of damage to fruits and other gardening products is the inappropriate conditions of keeping them after harvesting. Due to poor maintenance, the quality of the fruit is getting low and even up to 90 percent of the product can be lost and destroyed. Among the damages that come to the fruits can be reduced the weight, brownness of the fruit tissue and its decay, which results in reduction of apparent, quality and flavor of fruits. Besides, the increasing period of fruit storage, biochemical changes such as changes in phenolic content also caused. In this study, the fresh fruit of the treated white species was stored in three times of 7, 14 and 21 days in storage under temperature of 2 to 5 °C and during this period it was determined that with increasing the storage time of fruits weight decreased and also suffered decay, their texture went towards getting brown were reduced as a measure of apparent quality and flavor of fruits. The treatments used in this research are greatly effective in maintaining the quality of fruits in postharvest. The results showed that the treatment of calcium chloride 4% and ultraviolet irradiation for 15 minutes had the greatest impact on fruit weight and greatly reduced the weight of fruits during the 21 storage period, which prevented most of the damage. The results also showed that this level of treatments had the highest role in reducing brown and fruit tissue decay. With increasing the duration of fruit storage and phenol of fresh fig fruits were also decreased. However, the lowest of them were observed in the treatment of 21 days' storage and without application of calcium chloride and irradiation radiation UV, and the application of calcium chloride and irradiation 15-minute UV radiation had the greatest impact on the fruit traits. Therefore, for increasing life after harvesting fresh fruit of fig, CaCl₂ 4% and UV-C irradiation, especially for 15 minutes, are highly suggested and recommended.

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Impact of Weed Control Methods on Cotton Genotypes Yield and its Implications for Food Security and Safety

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Abstract

The study aimed to assess how different weed control methods impact food security and safety through improvement of cotton productivity. To test these characteristics, a one year field study was carried out to evaluate the growth, yield, and economic performance of three cotton genotypes under semi-arid conditions of Kandahar. The experiment consisted 12 treatments as three cotton (V1: Acala 15-17-99, V2: FAO-108, V3: N-726) genotypes and four weed control methods (W1: Control (no weed control), W2: Manual weeding (Hand weeding), W3: Roundup 2L/ha and W4: Roundup 4L/ha). Among different cotton genotypes, the (V3=N-726) showed superior growth parameters, yield attributes, yield production, resource-use efficiency, and economic returns as compared to other genotypes. Moreover, among different weed control methods, the Roundup 4L/ha significantly increased seed cotton yield and enhanced maximum net profit as compared to the control treatment. Overall, V3= N-726 emerged as the best variety, and the application of Roundup 4L/ha was found to be the most effective method for increasing productivity, profitability, and resource-use efficiency, contributing to food security by ensuring higher cotton yields under semi-arid conditions. This approach also supports food safety by enhancing cotton production while minimizing the risks associated with excessive use of chemical inputs.

Keywords: Cotton genotypes, Food Security, Methods of Weeds Control, Resource-Use Efficiency, Yield.

Introduction

Cotton (*Gossypium spp.*) is one of the world's most important cash crops, widely grown for its fibers, which are essential for the textile industry and contributing significantly to the economy of many semi-arid and arid regions. In semi-arid regions such as Kandahar, Afghanistan, cotton production faces several challenges, including limited water availability, poor soil quality, and weed competition. In these areas, cotton farming plays a critical role not only in providing raw materials for the textile industry but also in ensuring economic stability and food security for rural communities. However, cotton production faces numerous challenges, with weed competition being one of the most significant. Weeds, if left unmanaged, can reduce cotton yields by up to 30%, severely impacting the income of farmers and their food security (Imran et al., 2024). Effective weed management is crucial in enhancing crop productivity, sustainability, and ensuring food safety standards. Weeds are a significant threat to cotton yield, as they compete with crops for essential resources like water, light, and nutrients (Sharma et al., 2019). Effective weed management is crucial for maximizing cotton production, improving resource use efficiency, and ensuring sustainability in these regions (Zhang et al., 2020).

Weed control methods, ranging from chemical herbicides to mechanical and cultural practices, influence both the yield and the economic outcomes of cotton farming (Singh et al., 2021). And ranging from manual weeding to chemical herbicides, have long been used to mitigate weed pressure in cotton fields. Each method has its advantages and challenges, with varying impacts on yield, economic return, and environmental health. In recent years, the use of herbicides like glyphosate has been widely adopted due to its effectiveness in controlling weeds while minimizing labor costs. However, concerns regarding herbicide resistance and environmental sustainability have led researchers to explore integrated weed management (IWM) strategies, combining cultural, mechanical, and chemical approaches (Ali et al., 2025). While herbicides like Roundup (glyphosate) are commonly used, their impact on food safety, environmental sustainability, and long-term soil health remains a concern (Khan et al., 2020). Therefore, it is essential to adopt integrated weed management strategies that not only enhance yield but also contribute to food security by minimizing the risk of pesticide residues and maintaining a healthy ecosystem (Ghosh & Kumar, 2018). Furthermore, with the rising global population and the increasing demand for agricultural products, ensuring food security and safety has become a key objective in agricultural research. Food safety concerns arise from the potential residues of chemical herbicides in cotton products, which could affect human health. Therefore, it is critical to adopt weed control methods that not only maximize cotton yield but also meet the required safety standards for food products (Gupta & Mehta, 2024). The impact of various weed control methods on cotton yield and food security has been the focus of many studies. Recent research has emphasized the need for sustainable and safe weed management strategies that can improve yield while reducing the risk of contamination and promoting environmental health (Pandey et al., 2025). By evaluating and comparing different weed control methods, it is possible to identify practices that enhance productivity, profitability, and sustainability, all of which contribute to food security and food safety in cotton-producing regions. In addition to enhancing food security, the profitability of cotton farming is of great concern, especially in semi-arid conditions where farmers face high production costs. The economic aspect of weed control, alongside its effect on yield, is therefore crucial for assessing the viability of different farming practices (Ali et al., 2021).

This study aims to investigate the impact of various weed control methods on the growth, yield, and economic performance of three cotton genotypes in Kandahar, with a focus on their implications for food security and safety. By exploring modern weed control technologies and methods, this research provides insights into best practices for improving cotton production and ensuring the safety and sustainability of the crop.

Materials and Methods

The field experiment was conducted at the research farm of ANASTU University, located in Kandahar, Afghanistan, at 65°52'02" East longitude and 31°27'03" North latitude.

The farm is situated at an altitude of 1050 meters above sea level, which provides the semi-arid climatic conditions suitable for cotton cultivation. The experiment was carried out from May to November 2021. The design of the study was a Factorial Completely Randomized Block Design (F-CRBD) with three replications, ensuring the results are statistically reliable and robust.

Soil Characteristics

Soil samples were collected from the topsoil (0 - 30 cm depth) prior to planting to assess the physico-chemical properties of the soil. The results of the soil test revealed the following characteristics:

- Soil Texture: Sandy clay loam
- NH₄-N: 10 mg/kg
- NO₃-N: 29 mg/kg
- Phosphorus: 21 kg/ha
- Total Potassium: 65 kg/ha
- Organic Matter: 0.11%

These results indicated moderate levels of nitrogen, phosphorus, and potassium, but low organic matter. Based on this soil fertility status, supplementary fertilization was applied, adjusting for the required nutrients, especially nitrogen and phosphorus, to optimize cotton growth.

Treatments

The experiment included 12 treatment combinations, consisting of three cotton genotypes and four weed control methods:

1. Cotton Genotypes:
 - V1: Genotype 1 (Acala 15-17-99)
 - V2: Genotype 2 (FAO-108)
 - V3: Genotype 3 (N-726 variety)
2. Weed Control Methods:
 - W1: Control (no weed control)
 - W2: Manual weeding (Hand weeding)
 - W3: Chemical herbicide (Roundup 2L/ha)
 - W4: Chemical herbicide (Roundup 4L/ha)

Crop Management

Cotton seeds of the selected genotypes were sown at the recommended seed rate and proper row spacing. Based on the soil test results, the required amounts of fertilizers (nitrogen, phosphorus, and potassium) were applied in both basal and top-dressing applications. Irrigation was provided as needed, considering the semi-arid nature of the region. Pest and disease management was performed following recommended safe practices to ensure food safety and reduce pesticide residues.

Statistical Analysis

The data were analyzed using Analysis of Variance (ANOVA), and means were compared using Duncan's Multiple Range Test (DMRT) at a significance level of 5%. The statistical analysis was conducted using the Statistical Package for Social Sciences (SPSS), ensuring the reliability and significance of the results.

Food Security and Food Safety Considerations

Food security was addressed by evaluating the potential of improved weed control methods and cotton genotypes to enhance yield and ensure sustainable productivity under semi-arid conditions. The study also considered food safety by minimizing the use of harmful chemicals, ensuring that all treatments met safe standards for chemical use, and focusing on minimizing pesticide residues in the final cotton produce.

Results

This section presents the findings of the study, which aimed to assess the impact of different weed control methods on food security and safety through the improvement of cotton productivity. The study evaluated the growth, yield, and economic performance of three cotton genotypes under the semi-arid conditions of Kandahar.

Genotypes

The results showed that cotton genotypes V3 had a significant effect on yield attributes and yields as compared to other cultivars in terms of 1000-seed weight, seed yield, and stalk yield. V3 produced the highest 1000-seed weight (134.0 g) compared to V1 (103.9 g) and V2 (121.5 g). Similarly, V3 recorded the highest seed yield 4,863.3 kg/ha compared to V2 (3,079.2 kg/ha) and V1 (2,713.3 kg/ha). In respect to stalk yield V3 produced the highest yield (5,583.2 kg/ha), which was statistically significant than V2 (5,062.4 kg/ha) and V1 (4,329.8 kg/ha). V3 (N-726) outperformed both V1 (Acala 15-17-99) and V2 (FAO-108) in terms of lint yield, biological yield, and harvest index (HI). The lint yield for V3 (N-726) was 1,808.9 kg/ha, which was significantly higher compared to V1 (Acala 15-17-99) at 959.2 kg/ha and V2 (FAO-108) at 672.9 kg/ha. Similarly, V3 (N-726) recorded the highest biological yield of 10,446.6 kg/ha, followed by V2 (FAO-108) at 8,141.6 kg/ha and V1 (Acala 15-17-99) at 7,043.1 kg/ha. In terms of harvest index (HI), V3 (N-726) also showed the best performance with a value of 46.6, significantly higher than V1 (Acala 15-17-99) at 38.6 and V2 (FAO-108) at 37.7. Economically, V3 (N-726) yielded the highest net return (214,315 AFN/ha) and the highest benefit-to-cost ratio (BCR) of 4.870, making it the most profitable cultivar. V2 (FAO-108) followed with a BCR ratio of 3.065, while V1 (Acala 15-17-99) had the lowest economic returns (BCR = 2.702). These findings align with previous research showing that high-yielding cotton cultivars with superior fiber quality enhance profitability and contribute to farmer income security (Ali et al., 2025).

Table 1. Yield performance of cotton genotypes under different weed control methods.

Treatment	Yields parameters and Yields					HI%
	1000 Seeds weight (g)	Seeds yield kg ha ⁻¹	Stalk Yield kg ha ⁻¹	Lint yield kg ha ⁻¹	Biological yield kg ha ⁻¹	
Genotypes						
V ₁ = Acala 15-17-99	103.9	2,713.3	4,329.8	959.2	7,043.1	38.6
V ₂ = FAO-108	121.5	3,079.2	5,062.4	672.9	8,141.6	37.7
V ₃ = N-726	134.0	4,863.3	5,583.2	1,808.9	10,446.6	46.6
SEm±	0.451	23.656	18.805	18.4	21.3	0.251
SE(d)	0.638	33.455	26.595	26.0	30.1	0.355
C.D(P=0.05)	1.820	95.372	75.816	74.2	85.8	1.012
Methods of Weeds Control						
W ₁ = Control	101.1	3098.3	4212.9	743.0	7311.2	41.4
W ₂ = Hand weeding	117.7	3521.7	4902.7	1042.7	8424.4	41.2
W ₃ = Round up 2L/ha	128.0	3691.1	5333.2	1249.8	9024.4	40.4
W ₄ = Round up 4L/ha	132.4	3896.7	5518.4	1552.5	9415.1	40.9
SEm±	0.410	12.678	17.069	10.3	21.0	0.145
SE(d)	0.579	17.929	24.1	14.5	29.7	0.204
C.D(P=0.05)	1.226	37.959	51.1	30.7	62.9	0.433

Control methods

The results showed that control methods on cotton had significant effect on yield attributes and yields as compared to other treatments in terms of 1000-seed weight, seed yield, and stalk yield were found superior where **Roundup 4L/ha (W4)** were applied. **W4 produced the highest** 1000-seed weight (**132.4 g**) compared to **control (101.1 g)** W1 and hand weeding (**117.7 g**) W2. Similarly, **W4** recorded the highest seed yield **3,896.7 kg/ha** compared to W3 (**3,691.1 kg/ha**), W2 (**3,521.7 kg/ha**) and W1 (**3,098.3 kg/ha**). In respect stalk yield, **W4** recorded the highest stalk yield **5,518.4 kg/ha** compared to W3 (**5,333.2 kg/ha**), W2 (**4,902.7 kg/ha**) and W1 (**4,212.9 kg/ha**), respectively. **Roundup 4L/ha (W4)** treatment resulted in the highest lint yield of **1,552.5 kg/ha**, followed by **Roundup 2L/ha (W3)** at **1,249.8 kg/ha**, **Hand Weeding (W2)** at **1,042.7 kg/ha**, and **Control (W1)** at **743.0 kg/ha**. Similarly, the biological yield for **Roundup 4L/ha (W4)** was the highest at **9,415.1 kg/ha**, followed by

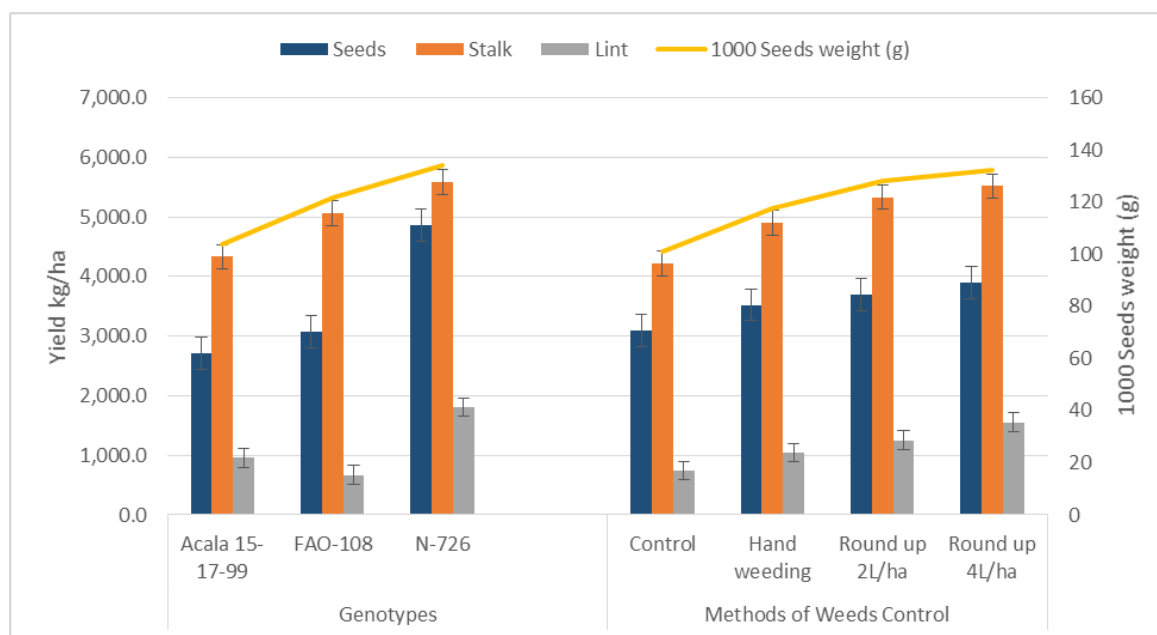
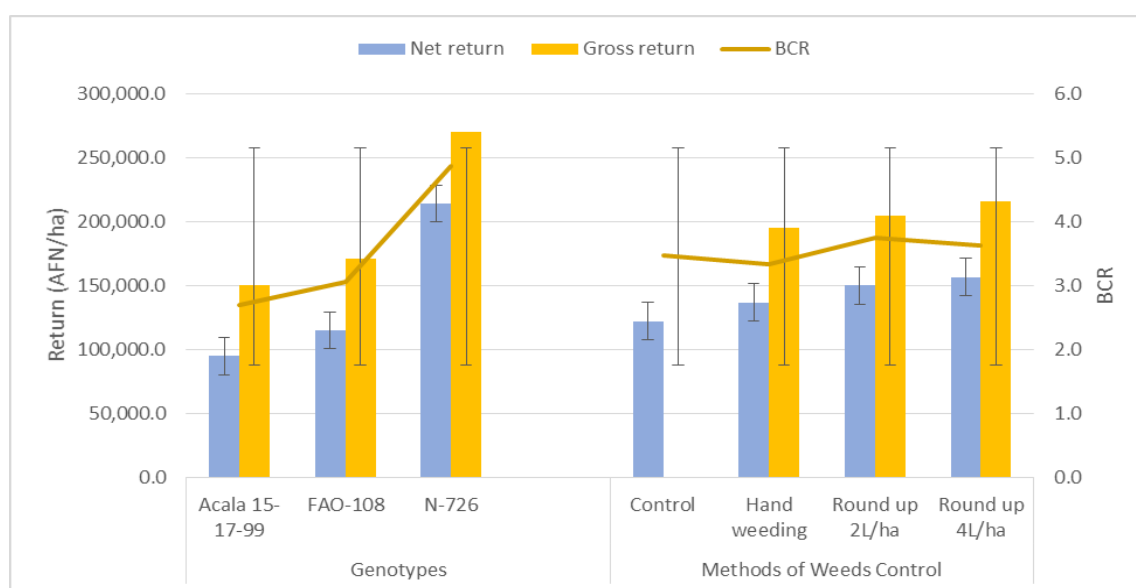


Fig. 1. Yield performance of cotton genotypes under different weed control methods.

Roundup 2L/ha (W3) at 9,024.4 kg/ha, Hand Weeding (W2) at 8,424.4 kg/ha, and Control (W1) at 7,311.2 kg/ha. The harvest index (HI) was highest for Control (W1) at 41.4, followed closely by Hand Weeding (W2) at 41.2, Roundup 4L/ha (W4) at 40.9, and Roundup 2L/ha (W3) at 40.4. Economically, W4 (Roundup 4L/ha) achieved the highest net return (156,665 AFN/ha) and a BCR ratio of 3.629, making it the most profitable weed control method. W3 (Roundup 2L/ha) followed closely with a BCR ratio of 3.752, while hand weeding (W2) was less effective (BCR = 3.335) due to increased labor costs. The control (W1) yielded the lowest net return (122,357.5 AFN/ha), highlighting the economic loss due to weed infestation. These findings align with previous studies that demonstrate chemical weed control methods significantly increase cotton yield and profitability compared to manual weeding, particularly in semi-arid conditions (Rao et al., 2024). However, long-term herbicide use should be managed carefully to prevent resistance development and environmental risks (Gupta & Mehta, 2024).

Table 2. Economic analysis of cotton genotypes under different weed control methods.

Treatment	Economics parameters AFN ha ⁻¹			BCR
	COC	Gross return	Net return	
Genotypes				
V ₁ = Acala 15-17-99	55600	150,590.0	94,990.0	2.702
V ₂ = FAO-108	55600	170,893.8	115,293.8	3.065
V ₃ = N-726	55600	269,915.0	214,315.0	4.870
SEm±	-	1312.9	1312.9	0.024
SE(d)	-	1856.7	1856.7	0.034
C.D(P=0.05)	-	5293.2	5293.2	0.097
Methods of Weeds Control				
W ₁ = Control	49600	171,957.5	122357.5	3.467
W ₂ = Hand weeding	58600	195452.5	136852.5	3.335
W ₃ = Round up 2L/ha	54600	204856.7	150256.7	3.752
W ₄ = Round up 4L/ha	59600	216265.0	156665.0	3.629
SEm±	-	703.6	703.6	0.012
SE(d)	-	995.1	995.1	0.018
C.D(P=0.05)	-	2106.7	2106.7	0.037

**Fig. 2.** Economic performance of cotton genotypes under different weed control methods.

Interaction between cultivars and weed control methods

The interaction between cotton cultivars and weed control methods revealed that the highest yields for both seed and stalk were observed when V₃ (N-726) was combined with Roundup 4L/ha (W₄). This treatment combination yielded 3896.7 kg/ha of seed cotton and 5,518.4 kg/ha of stalk. This suggests that both the choice of cultivar and the weed control method significantly influence cotton yield, with N-726 showing a particularly strong response to the use of Roundup 4L/ha. These results indicate that N-726 is the most productive cultivar under the semi-arid conditions of Kandahar and that Roundup 4L/ha is the most effective weed control method in terms of maximizing both seed and stalk yield. Further studies should focus on the long-term effects of these treatments on soil health, resource-use efficiency, and food safety. The interaction between cotton cultivars and weed control methods revealed that the highest lint yield and biological yield were obtained when V₃ (N-726) was paired with Roundup 4L/ha (W₄), resulting in 1,808.9 kg/ha of lint yield and 10,446.6 kg/ha of biological yield. This combination also led to a relatively high harvest index of 46.6, indicating efficient resource allocation from biomass to marketable cotton fiber.

Contribution to Food Security and Food Safety

Food security refers to the availability, access, and utilization of food in sufficient quantity and quality. The results from this study suggest that the adoption of optimal cotton cultivars and efficient weed control methods can contribute significantly to food security, especially in semi-arid regions like Kandahar, Afghanistan. Cotton is a cash crop that plays a crucial role in the livelihood of many farmers, contributing to economic stability and food security by generating income.

By enhancing the yield and profitability of cotton farming through better weed control (such as Roundup 4L/ha) and the use of high-yielding cultivars (such as **N-726**), farmers can improve their financial resources, which in turn may support the purchase of food and other essential goods. Improved cotton productivity can also lead to better employment opportunities in cotton processing industries and trade, further bolstering local food security. Moreover, higher crop yields can ensure a more stable supply of cotton for industries, reducing dependency on imports and mitigating potential price fluctuations.

Food safety is the assurance that food is free from contaminants (like pesticides, pathogens, and harmful chemicals) that could pose health risks to consumers. In cotton farming, **food safety** can be indirectly influenced by practices such as weed control and pest management, which affect the health of the environment and the final product. This study highlighted the importance of using safe and recommended weed control methods, such as Roundup 4L/ha, in improving cotton yield without jeopardizing food safety. While herbicides like Roundup are commonly used in modern agriculture, it is critical to apply them at the correct dosage to minimize pesticide residues in cotton and other crops. The study's focus on optimizing weed control practices ensures that chemical use is both effective and compliant with safety standards, reducing the risk of harmful pesticide residues in the cotton harvest.

Moreover, by using integrated pest management practices and adhering to safe pesticide application methods, farmers can reduce the chances of chemical contamination in the cotton, which is important for maintaining food safety, especially for consumers of cotton-based products like cottonseed oil. Reducing pesticide use to the minimum required for effective weed control also helps maintain the sustainability of ecosystems and reduces environmental pollution.

Key Points on Food Security and Food Safety:

- **Increased Cotton Yields:** The significant increase in cotton yields, especially with V3 (N-726) and Roundup 4L/ha, can result in higher profits for farmers. These profits can be reinvested into local economies and used to buy food, improving both food access and food availability.
- **Economic Stability:** Higher cotton yields can contribute to greater economic stability for farmers, providing a financial buffer to purchase food and other essentials.
- **Livelihood Improvement:** Enhanced productivity can create employment opportunities, contributing to improved food access and availability.
- **Sustainable Practices:** The study also emphasizes the importance of adopting sustainable practices that ensure food safety while maintaining high yields. By combining high-yielding cotton cultivars with optimal weed control methods, farmers can improve crop productivity without compromising the health of consumers.
- **Reduced Environmental Contamination:** The appropriate use of chemical herbicides, in line with recommended application rates, reduces the risk of environmental contamination, thereby safeguarding not only food safety but also ecosystem health.

- **Higher Productivity and Income Stability:** Farmers adopting V3 (N-726) with Roundup 4L/ha achieved significantly higher economic returns, reducing economic vulnerability and ensuring better access to food (Pandey et al., 2025).
- **Resource Efficiency and Sustainability:** Optimized weed control improved water-use and nutrient efficiency, ensuring sustainable cotton production and economic resilience (Ali et al., 2025).
- **Employment and Market Stability:** Increased cotton production strengthens the textile industry, creating jobs and supporting local and global cotton-based food products like **cottonseed oil**, which contributes to food security (Jafari et al., 2024).
- **Minimized Residue Risks:** The study followed recommended herbicide application rates, reducing the risk of chemical contamination in cottonseed oil (Liu et al., 2025).
- **Sustainable Weed Control Strategies:** While chemical weed control is effective, integrated weed management (IWM)—which combines herbicides, mechanical weeding, and crop rotation—is recommended to balance productivity and food safety (Gupta & Mehta, 2024).
- **Long-Term Environmental Impact:** Sustainable weed management prevents herbicide resistance and soil degradation, ensuring long-term food safety and environmental protection (Rao et al., 2024).

The findings of this study underline the pivotal role that effective cotton farming practices can play in both food security and food safety. The choice of high-yielding cultivars, such as N-726, and efficient weed control practices, such as the use of Roundup 4L/ha, can significantly boost cotton productivity, providing economic stability to farmers and contributing to food access and availability. Furthermore, careful management of pesticide use in weed control ensures that food safety is not compromised, maintaining the health of both consumers and the environment. Through the improvement of cotton farming systems, especially in regions like Kandahar, these practices offer a sustainable path towards enhancing food security while ensuring that agricultural products meet safety standards for consumption. This role of cotton cultivation in food security and food safety emphasizes how improved agricultural practices, such as the use of the right cultivars and weed control methods, can positively impact both economic stability and the health of consumers, leading to better outcomes for both farmers and the broader community. Let me know if you need further elaboration or additional insights! And the significant role that cotton cultivars and weed control methods play in improving both food security and food safety. By increasing cotton yield and economic returns for farmers through the use of N-726 and Roundup 4L/ha, the study contributes to economic stability and food access. At the same time, ensuring that herbicides are used properly reduces the risk of pesticide residues in cotton and its by-products, thereby safeguarding food safety. This balance of productivity and safety is essential for sustainable cotton farming systems, ultimately contributing to better food security and food safety in semi-arid regions like Kandahar.

Discussion

The results from this study indicate that both cotton cultivars and weed control methods have significant impacts on cotton yield and associated parameters such as biological yield, lint yield, and harvest index (HI), which are essential for improving food security and food safety. This discussion aims to analyze the results and relate them to existing literature on cotton cultivation, weed control practices, and their broader implications for food security and safety. In this study, V3 (N-726) exhibited the highest lint yield, biological yield, and harvest index among the three cultivars tested. This finding is consistent with other studies that have highlighted the importance of selecting high-yielding cultivars for improving agricultural productivity. According to Ariyaratne et al. (2018), selecting superior cultivars is essential for maximizing yield potential, especially in resource-limited environments.

High-yielding cultivars, like N-726, are often more resilient to environmental stress, which is crucial in semi-arid regions such as Kandahar, where water scarcity and temperature extremes can limit crop growth. The harvest index (HI for V3 (N-726) was also the highest, which indicates better efficiency in converting biomass into marketable yield. This is significant because a higher harvest index generally correlates with better resource use efficiency and improved economic returns for farmers, both of which are vital components of food security in cotton-growing regions (*Duan et al., 2017*). The results of this study thus emphasize the importance of cultivar selection in optimizing cotton production, ensuring that farmers are able to achieve higher yields and better economic outcomes.

The results also show that the application of Roundup 4L/ha significantly improved lint yield and biological yield compared to other weed control methods, such as hand weeding and the use of Roundup 2L/ha. The effectiveness of Roundup as a herbicide is well-documented in the literature, where it is shown to be highly effective in controlling a wide range of weeds, thereby reducing competition for nutrients, water, and sunlight (*Rao et al., 2020*). The higher lint yield observed with Roundup 4L/ha treatment can be attributed to the effective suppression of weeds, allowing the cotton plants to grow without competition, ultimately leading to improved resource allocation and higher yield potential.

Additionally, the study found that hand weeding also improved cotton yield compared to the control treatment, but it was less effective than the herbicide treatments. This supports the findings of Siddiqui et al. (2016), who concluded that although hand weeding is labor-intensive, it can still be a viable option for weed control in small-scale farming operations. However, herbicide treatments like Roundup are generally more efficient and cost-effective, especially for large-scale cotton farming.

Weed control is a critical factor in ensuring both food security and food safety in cotton farming. Weeds not only compete with cotton for essential resources but can also harbor pests and diseases, leading to reduced crop health and yield. Effective weed control, as demonstrated in this study, can therefore improve cotton productivity, which is an important cash crop for many farmers. Increased cotton yields contribute to better economic stability for farmers, which is an essential component of food security. Farmers who can achieve higher cotton yields and profits are more likely to be able to invest in purchasing food, improving access to nutritious food for their families and communities (*FAO, 2019*).

Furthermore, food safety concerns in cotton farming primarily revolve around pesticide and herbicide residues. This study's results show that the appropriate use of Roundup, particularly at the recommended rate of 4L/ha, can help control weeds effectively without compromising food safety. The use of herbicides must always be carefully managed to avoid pesticide residues that could contaminate cotton and cotton by-products such as cottonseed oil. According to Liu et al. (2019), proper pesticide management, including adherence to correct application rates, is essential for minimizing the risks of pesticide residues in agricultural products.

One of the main advantages of using herbicides like Roundup is their efficiency in controlling weeds while minimizing the need for additional chemical inputs or excessive labor. However, it is crucial to consider the sustainability of herbicide use. Excessive use of herbicides can lead to environmental concerns, including soil degradation and the development of herbicide-resistant weed species.

This underscores the need for integrated weed management (IWM) practices, where herbicides are used in combination with other methods, such as crop rotation and mechanical weed control, to promote sustainable farming practices (*Barrows et al., 2021*).

The study suggests that Roundup 4L/ha provides an effective weed control solution under the semi-arid conditions of Kandahar, but continued research into alternative weed control practices, such as the use of organic herbicides or mechanical weeding, would be beneficial for the long-term sustainability of cotton farming in the region. The findings of this study highlight the importance of selecting high-yielding cotton cultivars, such as N-726, and adopting effective weed control methods, such as Roundup 4L/ha, in improving cotton yields. These practices not only enhance the economic stability of farmers but also contribute to food security by increasing cotton productivity and profitability. Additionally, proper pesticide management ensures that food safety is maintained, reducing the risk of pesticide residues in cotton and its by-products. By optimizing cotton farming practices, the study contributes to the broader goals of achieving both food security and food safety in semi-arid regions like Kandahar.

Conclusion

This study highlights the significant role of cultivar selection and weed control methods in improving the productivity and sustainability of cotton farming under semi-arid conditions in Kandahar. The results demonstrate that the cotton cultivar V3 (N-726) consistently outperformed the other cultivars (V1 - Acala 15-17-99 **and** V2 - FAO-108) in terms of lint yield, biological yield, and harvest index. This cultivar, along with optimal weed management, particularly the use of Roundup 4L/ha, resulted in the highest yields and most efficient use of resources.

The application of Roundup 4L/ha proved to be the most effective weed control method, significantly improving cotton yield and biological output compared to the other methods, including hand weeding and Roundup 2L/ha. These findings underscore the importance of using appropriate and effective weed control methods to maximize cotton productivity, which is critical for both the economic stability of farmers and food security in the region.

Moreover, the adoption of efficient farming practices, such as selecting high-yielding cultivars and integrating effective weed control strategies, not only enhances the economic outcomes for farmers but also contributes to food security by increasing the availability of cotton as a cash crop. Higher cotton yields lead to better income, which can improve access to food and other essential goods for farmers and their communities. Additionally, careful and responsible herbicide use ensures food safety by minimizing the risk of pesticide residues in cotton and its by-products. In conclusion, V3 (N-726) and the use of Roundup 4L/ha offer a practical and effective approach for enhancing cotton production in Kandahar. These practices can contribute to long-term food security and economic resilience, while maintaining food safety standards. Continued research into sustainable cotton farming practices and the development of integrated weed management strategies will be essential for ensuring the sustainability of cotton farming in the region.

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An Overview on Poultry Production in Afghanistan: Current Status, Challenges and Future Prospects

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Abstract

The poultry sector makes a considerable contribution to food security, nutrition and supplies energy, protein, and essential micronutrients to humans. The poultry current production as well as product availability and consumption rate is not well studied in Afghanistan. This review aims to address the current status, highlight the constraints, and predict the prospect of poultry production in Afghanistan to contribute to future studies, policies and planned development strategies. The demand for poultry products in the world and Afghanistan is continuing to increase which is mainly attributed to an improved economy and urbanization. The trend of investment in the sector has increased from 5.0 billion Af in 1986 to 200 billion Af in 2022. A total of about 11000 commercial poultry farms are under operational practices across the country that can produce about 219000 metric ton (MT) of meat while the total market demand is estimated as 295000 MT in 2024. The availability of poultry meat and egg per capita in Afghanistan is estimated at 6.5 kg and 40, respectively that can meet 46 percent of World Health Organization (WHO) recommendations. However, the subsector development is also hindered by various factors such as traditional management practices, poor infrastructure, lack of technical expertise, disease outbreaks, antimicrobial uncontrol use, poor quality input, and end product price variations that could impact the farming production performance. By equipping the poultry sector with modern technology and expertise and sustainable farming practices, Afghanistan can enhance the resilience of production capacity. The average annual growth of this sector is estimated at 13.8 percent, and the future production capacity is projected to reach 400332 MT by 2030.

Key words: Demand, Increase, Poultry, Production, Meat, Sector

1. Introduction

The overall meat production from animal sources includes

beef and veal, poultry, and sheep, excluding pork, seafood, and all other animal meats reported as 210.17 million metric ton (MT) in 2019, which dramatically increased from 73.14 million MT in 1990. The trend has reported a total of 3.58 percent annual growth, whereas poultry meat consumption shows a 5.18 percent increase per year (Memon et al., 2021). Poultry makes a considerable contribution to food security and nutrition that supplying energy, protein, and essential micronutrients to humans (Farrell, 2013). The increased demand for poultry products is expected to ensure the sector continues to grow in the future. The human population in the world is rapidly increasing and is projected to reach 9.7 billion people by 2050 (United Nations, 2019). The increased population leads to increases in food demand and supply in the market. Particularly in developing countries, poultry production is the fastest-growing sub-sector as compared to any other agricultural segment (World Bank, 2015). In smallholders as well as in both rural and urban areas, the poultry sector plays a vital

role in alleviating poverty, contributing to family income and nutrition (Bist et al., 2024).

It is reported that poultry meat occupied about 40 percent of the total global meat market in 2020, while egg production has increased by 150 percent over the last three decades (FAO, 2020). As per the available reports, Asia is the focal point driving this growth. China plays as the largest poultry egg producer, representing 38 percent of global egg output, while the United States plays a role as the largest poultry meat producer, having a capacity of 17 percent of global poultry meat production (FAO, 2023).

In Afghanistan, poultry production plays a crucial role in the agricultural sector, contributing significantly to the livelihoods of rural households and the family economy. Historically, the poultry sector in Afghanistan is more traditional, established with small scale operational units. The production potential of native breeds of poultry in Afghanistan is still very poor and has no significant improvement as compared to the 1960s. Reports indicate that before 1963, the native chicken growth performance was as slow as 0.769 kg body weight at the age of four months (Sahota and Bhatti, 2003a) and produced about 30 eggs per year (Sahota and Bhatti, 2003b).

However, the sector is gradually shifting from a traditional backyard production system to more intensive and commercialized practices. The market demand for poultry products continues to increase in Afghanistan. Various contributing factors, including the increased human population, an improved economy, and trends of urban living of people, are driving this growth in the poultry sector. By the way, the poultry sector supplies the dominant portion of protein. Contributing to food security (FAO, 2023). Several challenges hamper the poultry production development in Afghanistan, including inadequate infrastructure, limited access to veterinary services, feed shortages, and ongoing socio-economic instability. Severe epidemiological status followed by various disease outbreaks, particularly viral infection poses significant risks to production levels and farmers' performance (Hafez and Attia, 2020). Market instability, price variation, and sector resilience on the international market are the challenges the sector is facing. Ultimately, as Afghanistan moves towards economic recovery and agricultural commercialization and modernization, the poultry sector stands as a promising avenue for development and investment (World Bank, 2015).

This overview aims to address the current status, highlight the constraints, and predict the prospect of poultry production in Afghanistan so that contributes to future studies, policies and development strategies.

The lack of literature and data references about the poultry production sector in Afghanistan is a challenge to study in-depth and more accurately. However, this study can play a role as a starting point for conducting further studies.

2. The current profile of poultry production in Afghanistan

Indigenous poultry breeds of Afghanistan are well-adapted to local environmental conditions, has shown good resistance to prevalent diseases and fluctuating environmental factors. Nonetheless, the introduction of improved breeds and biosecurity measures has the potential to enhance productivity and sustainability within the sector, thus addressing food security and supporting nutritional outcomes for the Afghan population. The Afghan poultry sector is currently unable to respond to the local market demand sufficiently. As per the available report, the poultry products being imported are parallel to the increasing market demand in the country. The poultry products' import value was estimated about \$100 million annually from neighboring countries and from far distances (like Brazil, and the USA) in 2014 (Siddiky, 2017). The livestock sector contributes about 14 percent to the overall agriculture sector and provides about 3.3 million job opportunities (World Bank, 2016),

whereas the poultry subsector contributes about 4.81 percent to the agriculture and 9.84 percent to the livestock sector (Khatami et al., 2022).

Therefore, the poultry subsector provides about 380000 job opportunities in the country. MAIL (2024) also reported about 120000 direct and 300000 indirect employment opportunities provided across the country in this sector.

In Afghanistan, the poultry are being reared mainly using two major production systems, that is backyard and commercial poultry production (Siddiky, 2017; FAO, 2008). In some areas and/or country, the production systems are mainly divided into three major components which are backyard poultry, semi-commercial and commercial poultry production (Khatami et al., 2022). The free-range backyard poultry production system is mainly employed in rural areas plays important role as a source of income generation, family nutrition, jobless employment, women's empowerment and rural poverty alleviation in poor communities (Kawsar et al., 2013).

2.1. Backyard poultry production

The chicken indigenous native breeds play an important role in economies and nutrition in the most rural parts of Afghanistan. The backyard system plays an important dynamic role in the rural poor and disregarded community of people with respect to income and also nutritionally supports families with high-quality protein and essential amino acid sources (FAO, 2008).

Additionally, this practice nutritionally supports families using the always available fresh eggs and meat, which are essential components of a balanced diet. In the context of Afghanistan's challenging socio-economic environment, backyard poultry production represents a valuable strategy for poverty alleviation and resilience building within the communities. The backyard poultry production system is mainly based on the local indigenous chicken types that apply scavenging feeding practices with very low production potential. The extensive production system using traditional practices is associated with some constraints, such as disease outbreaks, feed shortages, feed imbalances, poor quality, inappropriate housing, and management systems (Emal & Muhsni, 2017). The flock size in a free-range rearing system is usually small and varies upon the investment capability, infrastructure, and production facilities. In a study in Kabul province, Paghman district, the flock size ranged from 3 to 50 birds, an average number of 26 birds, and a mean of 117 eggs produced per week (Nicnam & Ghafari, 2020). An assessment conducted from 2002 to 2004 showed that more than 13 million poultry were under production practices in Afghanistan, whereas 99 percent of them were raised as backyard poultry, which were mostly owned by women, and on average, 5.87 birds were owned per family (FAO, 2008; McMahon, 2008). The investment has gradually transferred from backyard production to commercialized and industrial farming systems in the last two decades.

2.2. Commercial poultry production

The commercial poultry production was initiated in Afghanistan when a new hybrid strain of birds was introduced to the Badam Bagh farm, Kabul, in 1963. Thereafter, due to home wars and internal conflicts, all the systems and strategies are demolished. However, during the last two decades, the poultry production sector moved from a backyard to a more commercialized pattern, and remarkable development has been observed. The poultry sector was expanded over the time with more investment and the establishment of more broiler and layer-rearing farms, hatcheries, and feed manufacturing units across the country. The commercial poultry production was the host for about 82000 direct employment jobs during 2018-2019 (Moore-Afghanistan, 2019). It is also reported that the poultry sector contributes 4.81 percent to agriculture and 9.84 percent to livestock sector growth. The investment rate in the poultry production sector tends to increase over the time. The initial investment in the commercial poultry production system was estimated to be 5.0 billion Af in 1986, 20.0 billion Af in 1992, 57.0 Af billion in 2001 (Chaudhry, 2001), and 200 billion AF in 2022 (Khatami et al., 2022).

In accordance with the report, a total of 8910 broiler and 982-layer farms were actively operating across the country in 2017 (Emal & Muhsni, 2017) in which about 56155778 birds were estimated to be under rearing practices (CARD-F, 2016). The recent report indicates that a total of around 11000 broiler poultry and 233-layer farms, 20 unit feed manufacturing plants, 28 unit hatcheries and 9 unit poultry of meat processing plants are actively operating across the country (Moore-Afghanistan, 2019) in this sector. Despite of the current investment and domestic production potential, the market demand can't be met. The poultry sector was projected to meet about 70 percent of meat and egg demand in the country market by 2024-2025 with 9-10 percent growth per annum (CARD-F, 20216; Khatami et al., 2022). Comprehensive Agriculture and Rural Development-Facility CARD-F) is an organization conducted an evaluation procedure titled "Assessment of the poultry value chain with a proposed vision for growth" for the national poultry value chain sector across the country in Afghanistan. The CARD-F reported the market demand for poultry meat to be 173000 MT (115292766 birds) per year in 2015. In contrast, this demand was reported by Moore-Afghanistan (2019) as 270000 MT and 1.05 billion for poultry meat and egg, respectively in 2019 which is about 57 per cent higher as compared to the estimation reported in 2015.

The poultry meat production in the country was reported as 182000 MT and the total capacity was estimated as 232000 MT (Moore-Afghanistan, 2019). The future demand for poultry meat in the country is projected to cross 232950 MT in 2024 (CARD-F, 2016). However, the recent production rate reported by MAIL (2024) as 219000 MT that is very close to the value projected in 2019, whereas the total market demand is estimated as 295000 MT. By the way, the current production potential can meet about 74 percent of the country's market demand for poultry meat. Khatami et al. (2022) reported that the poultry meat contribution to the total meat market in Afghanistan is estimated to be 19 percent in 2018 and increased to 25.8 percent in 2022, while it is projected to increase further in the upcoming future. The increasing demand for poultry meat is attributed to various factors such as an improved economy, urbanization (WHO, 2020), reduced access to other animal protein sources, 2.7 percent annual human population growth (World Bank, 2023) in the country, etc. Pakistan is reported to be the 11th largest poultry producer in the world with a capacity of 2.028 million MT meat and 19.170 billion eggs production per year (Hussain et al., 2024).

To meet the market demand, the poultry meat is being imported from the international market. The value of imported poultry meat increased from 16.9 million USD to 85 million USD from 2008 to 2012, while the value of imported eggs increased from 17.5 million USD to 29.6 million USD (World Bank, 2023). The imported meat and egg value was reported to increase further to 183 and 38 million USD, respectively in 2019 (Moore-Afghanistan, 2019).

Despite the poultry production sector shifting from the backyard system to commercialization as well as increased the imported meat quantity during recent years, the poultry meat and egg availability per capita is still deficient in the country. However, the poultry meat average consumption is different among the countries and nations. The global poultry meat average consumption is estimated at 13.6 kg per capita, ranging from 1.77 kg in India to 43.81 kg in the United States in 2014 (Vaarst et al., 2015). The average poultry meat and egg availability per capita in Pakistan is reported as 5 kg and 51 eggs per year which is also insufficient in comparison to the WHO standard recommendation that is 14.7 kg (36 percent of total meat consumption, Bruinsma, 2017) meat and 300 eggs (PPA, 2013). In Afghanistan, the average poultry meat consumption per capita is reported to be 23.53 gm per day or 8.5 kg (Our World in Data, 2018) or 6.5 kg (CARD-F, 2016) per year. This mass can meet only 44 percent requirement in comparison with WHO recommended poultry meat consumption level per capita, which is 14.76 kg per year (Kawsar et al., 2013). The total meat consumption per capita in the world is reported to be 41.3 to 45.5 kg, whereas out of this mass, 13.8 to 17.2 kg share is from poultry meat (Bruinsma, 2017). The data indicate that poultry meat could occupy about 36 percent of the total meat market in the world.

With the application standard recommendation, a total meat of 37.45 kg per capita per annum (102.3 gm per capita per day) is required so that to meet the optimum protein requirement in the body (WHO, 2023). If we consider Afghanistan's human population as 35 million, then the annual total meat requirement can be 1.306 million MT out of which 36 percent (Bruinsma, 2017) 470477 MT has to be supplied from poultry sources per year, whereas the poultry current production is estimated to be 219000 MT (MAIL, 2024) that can meet only 46.5 percent of the standard recommended requirement. Similar data is presented by CARD-F (2017) also Moore-Afghanistan (2019). With consideration the poultry meat contribution to the total meat market as 18.3 percent (FAOSTAT, 2024), then the poultry meat requirement is calculated as 239000 MT then the production reported by MAIL (20224) that is 219000 MT can meet about 92 percent of the country requirement. No data is available about poultry meat import value from the international market at the current time.

However, the available data regarding the meat consumption per capita in Afghanistan is varied. FAOSTAT reported the total meat consumption per capita in Afghanistan is known to be 9.3 kg, out of which 1.7 kg is poultry meat. The data indicate that poultry meat occupies only 18.3 percent of total meat consumption. The animal-origin protein availability per capita per day in Afghanistan is estimated as 10.2 gm; while this value in Pakistan is reported as 29.5 gm, and in the USA is estimated to be 84.3 gm (FAOSTAT, 2024). The majority of this protein may be sourced from meat, and a minor is from eggs and milk. Due to the higher cholesterol content of red meat, poultry meat consumption is predicted to increase further up to 50 percent by 2050. For this purpose, the red meat per capacity is recommended at no more than 98 gm per week (WHO, 2023).

Not enough data is available about egg production and consumption in the country. However, the average egg consumption per capita is reported to be 40 per year (CARD-F, 2016), while this value in Pakistan is reported to be 70-80 eggs per capita. The imported figure of eggs was reported as 812 million per year during 2018-2019 (Moore-Afghanistan, 2019).

3. Challenges

The poultry sector in Afghanistan is facing multiple challenges that hinder poultry development, which are categorized as follows. However, the unavailability of sufficient literature and data regarding the challenges against the sector is a problem regarding this writing and discussion.

3.1.Traditional management practices

However, biosecurity practices in poultry farming are considered the most cost-effective tool for preventing the spread of pathogens, parasites, and pests to and within the farms (Oyeniran et al., 2021). Despite this improvement, the poultry raising practices are still traditional, accompanied by low management skills and less knowledge in Afghanistan, as reported by different studies (Abozar et al., 2021; Samadi and Zadran, 2023). The situation could directly affect poultry raising management, production performance, and the farm economy. Khatami et al. (2022) conducted a study in Kabul province and found that the majority of the farmers are uneducated, and the hygiene practices in most (50–70 percent) of the farming system are poor or very poor. The author also reported that 27.66 percent of farmers do not use disinfectants on their farms for biosecurity purposes. The phenomenon contributes to the disease outbreaks, poor growth performance, increased mortality, and a poor farming economy. The same author reported a higher mortality rate (11-20 percent) and economic losses during production cycles due to disease outbreaks and market fluctuation. This situation automatically leads to farmers' poor (approximately 54 percent) satisfaction with the farms' performance (Shaiq et al., 2024). However, some of the researchers reported medium- to high-level biosecurity measures practices inside the poultry farms, and about 98 percent practices vaccination, as revealed through a study conducted across Kabul province.

However, inappropriate practices, farm inappropriate locations, insufficient pest control, and improper dead bird disposal as external biosecurity measures were also reported in the same study (Samadi and Zadran, 2023). The poor sanitation practices could exert detrimental effects on meat and egg quality, and cause food-borne diseases that impact the poultry production sector in Afghanistan (Faizy et al., 2022).

3.2. Poor infrastructure

The farm infrastructure plays a significant role in biosecurity and standard management practices that can directly impact the farming production performance and economy. Good management practices and standards can be applied only in a well-standard infrastructure. Poor ventilation that causes several health problems in poultry farms is reported in many farming systems (due to inappropriate infrastructure (Shaiq et al., 2024). Previous studies also indicate that effective ventilation can be maintained in a standard infrastructure, which contributes to reducing heat stress and mortality, improving feed conversion ratio (FCR), reducing disease outbreak incidence, and improving farming productive performance (Ali et al., 2015). Poor infrastructure is evidenced from the various observations in the field of poultry production sector in Afghanistan (Nicnam & Ghafari, 2020). This could directly impact the management standard application in the farming system. Some research reports also indicate inappropriate farm structure and location leads to poor biosecurity measures, access of wild birds, availability of rodents, wild animals such as cats and dogs interfering with the red zone, and feed spoilage due to inappropriate storage and preservation in farming systems (Samadi and Zarand, 2023).

3.3. Lack of technical expertise

The evidence from field experience and observation implication of the poultry production sector is also hindered by technical expertise shortcomings that lead to a lack or poor-quality veterinary services, poor consultation, disease outbreaks, increased birds' mortality, higher veterinary input expenses, and poor farming economy. A study conducted in Baghlan province showed that lack of technical expertise, farmers' lower education level, poor ventilation provision, and local residency were recognized to be the highly important factors affecting farm development and sustainability (Shaiq et al., 2024). Evidence from practical operations in the field shows poor experience and education level of lead farmers or laborers (Zrawar et al., 2023).

3.4. Diseases outbreaks

As per the available literature and field experience, poultry diseases are the major and frequently occurring factor that severely hindered the sector development in Afghanistan (Leslie et al., 2008; Sahab et al., 2020; Kariithi et al., 2021). The reports show that some factors, such as rodents, wild birds, and poor biosecurity, are the key players contributing to infectious and zoonotic disease outbreaks among poultry and animals that can contaminate water and feed resources in farming systems. (Meerburg and Kijlstra, 2007; Backhans and Fellström, 2012; Samadi and Zarand, 2023). As per the clinical experience and direct observation from the field, the frequently occurring diseases are infectious bursal disease (IBD), infectious bronchitis (IB), Newcastle disease (ND), and infectious laryngotracheitis (ILT). The farms are also witnesses to bacterial infections such as *Escherichia coli*, *Salmonella*, *Enterobacteria*, *Campylobacteria*, etc. Mycoplasma infections such as chronic respiratory disease (CRD) and coccidiosis are also major and clinically important diseases. All the above diseases could maintain their epidemiological status for a long period of time and can significantly affect farming performance.

3.5. Antimicrobial uncontrol use

Antimicrobials are being used mainly for therapeutic as well as subtherapeutic doses as growth-promoting agents in the livestock and poultry production sector (Azizi et al., 2024). The continuous and uncontrolled use of antibiotics, particularly as growth promoter agents, results in anti-microbial resistance development that poses significant risks to animal and human health (Mulchandani et al., 2023; Azizi et al., 2024). As per the evidence from the field of poultry production, antimicrobials are also being used in poultry farming without technical consultation and veterinary recommendations and guidance. The antibiotic is mainly being used for clinical treatment and prevention of bacterial infection as well as growth promoter agents. A study was conducted to evaluate the antibiotic use in commercial broiler chicken farms in Kandahar province. The result indicates that a total of 19 types of antibiotics are in use in poultry commercial farms for three main purposes (disease treatment, prevention, and growth of broiler birds). The antibiotics that were most commonly used were Colistin (78 percent), Amoxicillin (97 percent), Tylosin (83 percent), and Enrofloxacin (100 percent). The study also reported a total of 4.2 gm of antibiotic use per bird from day one to the market supply (Danish, 2024). This phenomenon can automatically result in microbial-resistant strain development, raising another challenge in this sector. Evidence from clinical experience shows that most of the antibiotics at the standard recommended dose are insufficient to control the bacterial infection, which is evidence of microbial resistance.

3.6. Input (feed and veterinary product) poor quality

The quality of poultry feed and veterinary products in Afghanistan has been a significant concern, adversely impacting the poultry production sector. Inadequate regulations and limited access to high-quality as well as certified ingredient resources have resulted in substandard feed formulations that compromise poultry productivity. The same challenge was reported through an importance-performance analysis (IPA) study conducted in Baghlan province (Abozar et al., 2021). Additionally, the improper and unsafe storage of the feed ingredients led to fungal infestation and mycotoxin production (Ochieng et al., 2021). The poor-quality veterinary input can further exacerbate the situation, leading to inappropriate treatments and increased disease susceptibility of the birds (Sherman, 2005). On the other hand, the unavailability of technical experts, research and testing laboratories, and infrastructure is another challenge that influences the quality evaluation of feed as well as medicine and vaccines. A study conducted in Kunduz province revealed significantly lower production performance of hens fed diet produced by local companies as compared to imported (Abozar et al., 2021).

3.7. End product price variation

The poultry products, particularly meat is highly exposed to market price variation as compared to any other commodities and agriculture products. The reasons may be attributed to the insufficient domestic supply and dependency on the international market. Because the demand has to be saturated from the international market which Pakistan market is the key player in this regards that is also also prone to seasonal price variation (Hussain et al., 2015), and this variation can directly impact the poultry market prices in Afghanistan.

For example, the day-old chicks' price during the hot season (May to August) is the lowest. During this season, the environmental temperature in Afghanistan is also higher, particularly in the west and southern regions. The environment temperature in the southern region during the months May to August ranges from 40 to 48 °C, which is extremely hot and can significantly affect the poultry production performance. During this season, due to increases in the infectious disease outbreak, chicks' mortality is increased from one hand, and from the other hand, demand for poultry in the market is also reduced. In the central, eastern, and northern regions of the country, the cold season ranges from September to May of the year.

During the cold season, particularly in the winter, the chick brooding practices and production costs are increasing due to farm temperature maintenance. Due to higher production costs, the poultry production is being decreased. This may be attributed to less or unavailability of energy sources to maintain the farm inside temperature at optimum level.

3.8. Farming production performance

Poultry farming production performance can be affected by various factors such as management style, animal welfare, nutrition, technology, etc. in the country. Currently, no reputed published literature is available to address the most predominant factors as well as their degree of affecting poultry farming. A study conducted in Parwan province indicates the Feed Conversion Ratio (RCR) to be 1.83, with 90.23 percent livelability, 1.9 kg average market weight, and a 9.77 percent mortality rate. From the production economy point of view, they also found that the feed, day-old chicks, and veterinary services expenses were 70.45, 6.98, and 3.44 percent of the total production cost. The cost-benefit ratio was reported to be 1:07 (Zrawar et al., 2023), while this value was reported by Samadi and Zadran (2023) as 1:0.48.

Prospects

The animal-sourced protein market tends to increase globally, and poultry production is expected to be one of the fastest-growing agricultural segments in the coming decades. It is also found from the reports that the livestock protein sources are converting from red to low cholesterol (chicken) meat (WHO, 2023). On the other hand, poultry production is the result of fast-food expansion, consumer preferences, competitiveness, and concerns over the safety of red meat (Charles, 2013). The increasing motivation of religiously preferred and the health benefits associated with poultry consumption positions are vital contributors to improving the dietary habits of the Afghan populace.

The increasing trend for poultry products (meat and eggs) demand in Afghanistan is also being regulated by the growing population, rising household incomes, and urbanization (WHO, 2020). The idea is also attributed by the increased trends of the initial investment of 5.0 billion Af in 1986 to 200 billion Af in 2022 (Khatami, et al., 2022).

As per the available literature, the Afghanistan human population is growing at 2.7 percent per annum (World Bank, 2023), while the poultry sector growth is estimated between 15 and 20 percent (Khatami et al., 2022) or 8-10 percent (CARD-F, 20216) per annum. Another study reported the poultry growth rate as 400 percent from 1990 to 2019, with an average of 13.8 percent per year (OECD, 2017). The current poultry meat production is reported to be 219000 MT (MAIL, 2024) with an average of 13.8 percent growth per year; then the projected production is calculated as 400332 MT by 2030.

Evidence from the literature and field activities indicates that the future of poultry production in Afghanistan holds significant promise, driven by the country's agricultural potential and the increasing domestic demand for poultry products. As Afghanistan continues to navigate its socio-economic challenges, the poultry sector presents an opportunity for enhancing food security, generating employment, taking share in the development of the national economy, and fostering rural development. As per the current context of the country, particularly for the poultry backyard system, both in rural and urban areas, poultry is a major asset and key in providing food security and income, poverty alleviation, and market participation (Mottet & Tempio, 2017). Furthermore, Afghanistan's diverse climate and agricultural landscape provide suitable conditions for poultry farming. The country's vast rural areas are conducive to both small-scale and commercial poultry operations.

Through equipping the poultry sector with modern technology and expertise and sustainable farming practices, Afghanistan can enhance its resilience production capacity. This approach not only preserves local biodiversity but also empowers farmers through the improved methodology practices and quality services. Investment in education and training for farmers is critical to the success of this sector. By equipping poultry farmers with modern techniques in biosecurity, nutrition, and veterinary care, disease outbreaks can be controlled with enhanced production efficiency. Furthermore, collaboration with international organizations and agricultural experts can facilitate the transfer of knowledge and improve access to high-quality feed and veterinary services. With the right investments in infrastructure and technology, the poultry industry can meet local demand efficiently while potentially opening avenues for exports to neighboring countries also. By aligning investment strategies with local needs and establishing a robust support system for farmers, the country can transform its poultry industry into a sustainable source of nutrition and economic opportunity. As Afghanistan strives for stability and prosperity, the advancement of poultry production stands out as a pivotal component of its agricultural strategy, as revealed by the Afghanistan National Development Strategy (2005). The development of the poultry sector is accompanied by a significant impact on the environment and is a large consumer of natural resources as well.

4. Conclusion

The demand for poultry products in Afghanistan is continuing to increase, which is attributed to factors such as an improved economy and urbanization. The investment in the commercial poultry production system is estimated at 200 billion Af in 2022. A total of 11000 or above broiler poultry farms are actively operating across the country that supply about 219000 MT of meat to the market, while the total market demand is estimated at 295000 MT in 2024. The subsector development is also hindered by various factors, such as the poultry farm's traditional management practices, poor infrastructure, lack of technical expertise, disease outbreaks, antimicrobial uncontrollable use, poor input quality, and the variation of end product prices. All these factors could affect the farming production performance. By equipping the poultry sector with modern technology and expertise and sustainable farming practices, Afghanistan can enhance its resilience with a projected poultry meat production capacity of 400332 MT by 2030.

Novelty Statement

This study is the first of its kind to attempt to reflect the status and literature available on the poultry production sector across the country by evaluating the current status, challenges and future opportunities.

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Food Safety in Afghanistan: Challenges and Measures Ensuring Safety – A Review

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Abstract

Food safety in Afghanistan involves a complex array of challenges, exacerbated by ongoing conflict, economic difficulties, and inadequate regulatory frameworks. Key concerns related to foodborne pathogens and chemical contaminants stem from water and soil contamination, along with poor hygiene practices. The lack of strong regulatory measures and their enforcement, combined with post-harvest losses and insufficient storage facilities, further complicates food safety in the country. To improve food safety, it is crucial to adopt a comprehensive approach that incorporates technological innovations, regulatory frameworks, and new resources. Utilizing digital technologies, precision agriculture, and advanced materials is expected to significantly enhance food safety protocols throughout the supply chain. Moreover, strengthening food inspection and quality control systems, raising public awareness and education about food safety practices, advancing food processing and preservation techniques, and establishing collaborative partnerships with international organizations are essential strategies to improve food safety in Afghanistan. This paper focuses on exploring the challenges of food safety, evaluating the potential implications, and examining the measures needed to ensure food safety. It highlights the importance of collaboration among government entities, non-governmental organizations, and international bodies to enhance food security and promote a culture of food safety. By addressing these issues through comprehensive strategies and sustainable practices, Afghanistan can work towards improving food safety, ultimately leading to better public health and well-being.

Keywords: Afghanistan, Food safety, Challenges, Measures.

1. Introduction

Recent evaluations indicate that the condition of food security and safety in Afghanistan continues to be a significant issue, attributable to a lack of adequate nutritious food availability, fragile infrastructure, limitations in capacity, challenges in data management, insecurity stemming from conflict, and insufficient investments that adversely affect health and local agricultural enterprises (Babu et al., 2021; Poole et al., 2018). The nation has historically encountered considerable obstacles in guaranteeing the availability of sufficient and nourishing food for its citizenry. A substantial segment of the populace resides beneath the poverty threshold, with rates of food insecurity escalating dramatically; for example, research indicates that as many as 70% of individuals in specific neighborhoods of Kabul are incapable of obtaining adequate food (Arshad et al., 2024). In addition to food insecurity, food safety is a major concern in Afghanistan (Khalid, 2016).

In conjunction with deficient food safety regulations and enforcement, inadequate food processing, improper storage, and insufficient handling practices culminate in the ingestion of contaminated and hazardous food items (Ebner et al., 2017). This phenomenon may result in the emergence of foodborne disease outbreaks, thereby exacerbating the difficulties encountered in the attainment of food security, especially within the poultry industry, where the dangers of contamination from pathogens and chemical residues continue to be a significant concern notwithstanding advancements in meat inspection practices (Faizy et al., 2022). Addressing these multifaceted challenges necessitates a commitment to long-term investment, the establishment of political stability, and the provision of international support to guarantee a sustainable and secure food supply for the Afghan populace.

Initiatives aimed at tackling these challenges are currently being pursued by both the Afghan government and various international organizations. Humanitarian organizations are actively engaged in the provision of food assistance, nutritional support, and livelihood opportunities for at-risk communities. Such initiatives encompass investments in agricultural development, the promotion of sustainable farming practices, the enhancement of food storage and transportation infrastructures, the delivery of nutritional aid to vulnerable demographics, and the facilitation of access to educational resources and opportunities for women involved in agriculture. Nonetheless, significantly greater efforts are essential to alleviate the ramifications of food insecurity and to secure long-term food safety within the context of Afghanistan. However, little research has been done to evaluate the current concerns regarding food safety in Afghanistan. In this review, we provide a comprehensive overview of the current food safety situation in Afghanistan. Furthermore, this study identifies existing knowledge gaps proposes avenues for future inquiry, and emphasizes the necessity of employing a multi-disciplinary approach to alleviate the public health risks posed by unsafe food, advocating for cooperative initiatives among food scientists, public health officials, and regulatory entities to enhance food safety and protect consumer health. In this study, we address the major challenges of food safety imposed by unsafe food in this country (Figure 1).

2. Methodology

2.1 Search Strategy

A systematic literature search was conducted in Web of Science (Core Collection), Scopus, and PubMed databases. The search terms used included “Afghanistan,” “food safety,” “challenges,” and “measures.”

The aim of this search was to identify peer-reviewed studies, reports, and relevant articles addressing food safety in Afghanistan, including the challenges encountered and the strategies implemented to mitigate these issues.

3. Food Safety Challenges

Food safety issues in Afghanistan are multifaceted, arising from a confluence of deficient infrastructure, pervasive food insecurity, and the widespread occurrence of foodborne pathogens. These challenges present considerable threats to public health and necessitate immediate intervention. The primary concern pertains to foodborne pathogens and chemical residues. For example, the poultry sector in Afghanistan encounters difficulties associated with foodborne pathogens and chemical contaminants, such as pharmaceuticals and pesticides, which demand rigorous oversight and collaboration among health authorities. The limitations of inspections at poultry processing facilities underscore the necessity for enhanced regulatory oversight to guarantee the safety of meat and eggs. The final concern revolves around food contamination risks.

Conventional food production practices, particularly concerning fruits, expose consumers to detrimental fungi such as Aflatoxin, which can result in serious health consequences.

The outbreaks within a British Role 1 facility in Afghanistan underscored potential food safety issues attributed to norovirus, the close interactions with the local populace, high population density, and insufficient infrastructure protocols (Makin et al., 2022). Potential food safety issues in Afghanistan are illustrated in Figure 2. While these issues are of paramount importance, it is equally crucial to contemplate the overarching context of persistent humanitarian crises and the imperative for international assistance to bolster food safety in Afghanistan.

3.1. Contamination of water and soil

The pollution of aquatic and terrestrial environments in Afghanistan presents substantial concerns regarding food safety, primarily attributable to the presence of heavy metals and nitrates, alongside the potential transference of contaminants to agricultural products, thereby affecting the safety and quality of food items and engendering health hazards for consumers. For instance, the infiltration of contaminants from urban agricultural runoff in Kabul results in nutrient depletion within both soil and water systems, thereby compromising food safety due to the possible contamination of crops with organic matter and nutrients (NPKC) and Co (Safi et al., 2016). Empirical research has indicated that the pollution of water sources and inadequate sanitation facilities in Afghanistan contributes to increased child mortality rates, underscoring the imperative need for access to potable water and enhanced sanitation practices to safeguard food safety (Ghafoori, 2022). The data of the population using at least basic drinking water services and sanitation services is depicted in Figure 3.

3.1.1. Heavy metal contamination

The application of wastewater for irrigation leads to the introduction of pollutants into the soil, thereby posing health risks through contamination of the food chain. In the context of Afghanistan, this scenario may precipitate food safety issues owing to the potential presence of pathogens, heavy metals (frequently originating from fertilizers and mining operations) (Singh & Steinnes, 2020), and the accumulation of organic pollutants (such as pesticides) (Yadav et al., 2023). The pollution of water sources in the Kabul aquifers with toxic metals including uranium (U), arsenic (As), and nickel (Ni) raises significant food safety concerns due to the risk of uptake by crops irrigated with tainted water (Mahaqi et al., 2021). Investigative studies reveal that the use of wastewater containing heavy metals, especially lead (Pb), for agricultural irrigation has resulted in heightened concentrations within both soil and crops, surpassing the safety thresholds established by the WHO and the FAO. In Kandahar, Pb concentrations in soil have been recorded at 43-83 mg/kg, while crops exhibited levels of 18-36 mg/kg, thereby elevating concerns regarding food safety due to the potential for bioaccumulation (Obaid et al., 2023). The contamination of soil by heavy metals such as cadmium (Cd), Pb, Ni, zinc (Zn), and copper (Cu) from airborne dust in Kabul's urban agricultural settings raises alarm regarding food safety due to the risks associated with the uptake of these contaminants by crops for human consumption. This implies a substantial action is required to reduce this level, to save consumer health.

3.1.2. Nitrate pollution

Nitrate pollution, predominantly arising from domestic sewage, is widespread in Kabul, with approximately 30% of water samples exceeding established safe levels (Mahaqi et al., 2021).

This elevated concentration of nitrates not only undermines the quality of drinking water but also poses risks when crops are irrigated with contaminated water, potentially resulting in the production of unsafe food items (Ebner et al., 2018). Excessive nutrient inputs in vineyards may lead to groundwater contamination, thereby presenting food safety challenges in Afghanistan. Moreover, the depletion of soil nutrients in cereal fields and garden areas further exacerbates these concerns (Safi et al., 2011).

3.1.3. Groundwater quality

The groundwater resources in regions such as Herat exhibit considerable contamination attributed to nitrates and heavy metals, as evidenced by a Water Quality Index that reveals substandard quality across numerous samples. The dependence on this compromised groundwater for irrigation intensifies food safety dilemmas, as agricultural produce assimilates these detrimental substances (Shakeri et al., 2022). The groundwater pollution in Kabul, Afghanistan, characterized by elevated nitrate and *E. coli* concentrations, engenders substantial food safety apprehensions, primarily due to the potential for waterborne pathogens and deficient water quality (Hamidi et al., 2023). The contamination of both water and soil in Afghanistan, encompassing elements such as arsenic, boron, and fluoride, poses significant food safety threats owing to the irrigation of crops with contaminated water, thereby adversely affecting the quality and safety of agricultural produce (Hayat et al., 2017). Inadequate municipal waste management practices in Kabul introduce risks, including the contamination of water supplies, potential injuries from waste, exposure to heavy metals, and the emergence of food and waterborne diseases stemming from ineffective solid waste management strategies (Yosufi, 2019). An investigation conducted on vegetables in Kabul city revealed alarming concentrations of heavy metals (Cd, Pb, Zn) alongside microbial contamination (Coliforms, *Ascaris*, *Entamoeba*) resulting from sewage irrigation, thereby presenting significant health hazards (Safi et al., 2011). While these investigations illuminate the critical contamination challenges impacting food safety in Afghanistan, it is imperative to contemplate the potential for remediation via enhanced water treatment technologies and sustainable agricultural practices. Addressing these pressing issues could alleviate the health risks of contaminated food sources.

3.2. Poor hygiene practices

In Afghanistan, inadequate hygiene practices substantially exacerbate food safety challenges, contributing to health crises such as cholera and foodborne diseases. Insufficient attention to food hygiene can precipitate food spoilage, adulteration, and the incidence of foodborne illnesses, thereby negatively influencing nutritional outcomes. Prevalent poor practices include insufficient hand hygiene, unsafe storage of water, and open defecation, which further amplify the incidence of diarrheal diseases, particularly among vulnerable demographics such as neonates, infants, children (notably those under five years of age), and the elderly (Chakrabarty et al., 2019). The convergence of inadequate sanitation, lack of access to clean water, and insufficient public awareness foster an environment conducive to disease transmission. Cholera, a severe diarrheal affliction, has seen a marked increase in Afghanistan, driven by poor sanitation and compromised water quality, with over 150,000 suspected cases documented in 2022 alone. The fecal-oral transmission pathway underscores the urgent necessity for the enhancement of hygiene practices to avert contamination (Ahmed et al., 2023). Research indicated that 15.8% of students at Kabul Medical University were afflicted with *ascariasis* attributable to the consumption of water from wells, street food, and unwashed vegetables (Mubarak et al., 2017).

A research investigation revealed that a mere 31% of individuals residing in slum conditions and only 11% of internally displaced persons (IDPs) engaged in handwashing with soap before consuming food, with an even lower percentage undertaking this practice post-defecation. This phenomenon exacerbates the transmission of diseases via fecal-oral pathways, thereby augmenting the incidence of diarrheal illnesses (Mubarak et al., 2016). Furthermore, the presence of informal settlements in Kabul contributes to a myriad of environmental challenges, including water contamination, air pollution, and the proliferation of infectious diseases, which collectively exacerbate concerns regarding food safety within Afghanistan (Ibrahimy, 2022). The occurrence of open defecation has been correlated with an escalation in diarrheal morbidity, particularly in contexts where communal toilet facilities are prevalent (Malik & Akhtar, 2020).

Additionally, the absence of adequate water storage methods fosters contamination, with a mere 41.9% of communities possessing secure water storage solutions (Hemat et al., 2017). Nevertheless, substandard hygiene practices in Afghanistan may precipitate food safety dilemmas by contaminating agricultural products throughout the stages of production, handling, and distribution, thereby posing significant threats to consumer health and overall food security (Walters & Groninger, 2014). The poultry sector encounters significant challenges from foodborne microorganisms and chemical residues, attributable to deficient monitoring and inspection protocols. Aflatoxin contamination in fruits represents a substantial health hazard, primarily arising from a lack of awareness regarding safe food production and storage practices (Amini & Dawi, 2021). An investigation conducted in the Herat province indicated that inadequate hygiene practices result in elevated bacterial contamination levels in raw milk, raising food safety issues such as increased coliform counts, adulteration, and the presence of antibiotic residues in milk samples (Ebner et al., 2016). Food safety challenges in Afghanistan also encompass incidents of hepatic veno-occlusive disease linked to pyrrolizidine alkaloids present in wheat flour, underscoring the critical importance of implementing safe food practices and agricultural interventions (Kakar et al., 2010). These issues are further exacerbated by socio-economic determinants, including high illiteracy rates and restricted access to sanitation facilities, which impede the efficacy of hygiene education and intervention strategies. Initiatives aimed at fostering community dialogue have demonstrated the potential to enhance hygiene practices, leading to notable decreases in the prevalence of diarrheal diseases. Improved access to handwashing amenities and secure water storage has been associated with favorable health outcomes. Despite these advancements, persistent poverty and economic volatility obstruct the attainment of comprehensive improvements in food safety, highlighting the necessity for continued international assistance and active community participation. Potential causes of poor hygiene practices in Afghanistan are illustrated in Figure 4.

3.3. Lack of regulatory frameworks and enforcement

The absence of comprehensive regulatory frameworks and their enforcement in Afghanistan substantially exacerbates concerns related to food safety, particularly in the poultry industry and more extensive agricultural practices. This predicament is intensified by the overlapping jurisdictions of governmental entities, insufficient training, and antiquated food safety protocols. The food safety infrastructure in Afghanistan is disjointed, lacking a consolidated regulatory body, which results in inefficiencies and ambiguity among stakeholders, thereby potentially heightening food safety risks stemming from unregulated food production, distribution, and consumption practices, in addition to neglecting traditional food safety methodologies that are entrenched in cultural practices (Nayak & Jespersen, 2022; Williams et al., 2023).

The existing institutions, including the Ministry of Public Health and the Ministry of Agriculture, frequently replicate efforts, thereby imposing administrative burdens without adequately mitigating food safety threats. Regulatory inspections are irregular and frequently lack the requisite thoroughness, with inspectors often inadequately equipped with contemporary food safety training. The deficiency of robust regulatory frameworks not only undermines food safety but also aggravates food insecurity, as substandard food safety practices can precipitate health crises that further destabilize agricultural output (Krishnan et al., 2019). The poultry sector, despite its developmental progress, continues to grapple with substantial challenges related to foodborne pathogens and chemical contaminants due to inadequate surveillance and enforcement (Khalid, 2015). Consequently, this situation permits issues such as elevated bacterial levels, coliform presence, and adulteration in raw milk, thereby compromising its quality (Ebner et al., 2016). Although some proponents contend that Afghanistan's agricultural capabilities could mitigate food insecurity, the prevailing regulatory and enforcement milieu presents formidable obstacles to the realization of this objective.

3.4. Post-harvest losses and inadequate storage facilities

Post-harvest losses, coupled with insufficient storage facilities, are substantial contributors to food safety challenges in Afghanistan, as they promote spoilage, diminish quality, and reduce the shelf life of harvested agricultural products (Adewoyin, 2023). The absence of adequate handling and storage techniques results in considerable waste, which exacerbates food insecurity while heightening the potential for contamination. The phenomenon of post-harvest losses leads to considerable wastage of fruits and vegetables, thereby adversely affecting food security and quality (Elik et al., 2019). Within the context of Afghanistan, post-harvest losses predominantly stem from substandard management practices, including inadequate sorting, grading, and packaging, which can culminate in losses approaching 40% in perishable crops such as apples (Amanullah et al., 2020). In the case of grains, these challenges engender safety concerns, manifesting as excessive moisture, insect damage, fungal growth, and aflatoxin contamination in stored food grains (Chattha et al., 2016). Variables such as pest infestations and insufficient storage facilities further exacerbate these losses, particularly within the domain of cereal grains (Gill et al., 2021). The lack of appropriate storage solutions escalates the risk of fungal contamination, particularly from Aflatoxin, which poses significant health hazards to consumers. Conventional food preservation techniques frequently prove inadequate in preventing such contamination, resulting in hazardous food products entering the market. The introduction of advanced storage facilities in China has demonstrated the capacity to reduce maize storage losses by 60%, thereby enhancing food security and safety. Comparable strategies could serve to alleviate post-harvest losses and bolster food safety in Afghanistan (Luo et al., 2022). Conversely, some researchers posit that enhancing education and awareness regarding food safety practices could mitigate these risks, indicating that community engagement may be instrumental in improving food security and safety in Afghanistan. The factors contributing to post-harvest losses are illustrated in Figure 5.

3. Consequences of Food Safety Challenges

Food safety concerns in Afghanistan exert significant ramifications, affecting public health (due to the prevalence of foodborne illnesses, as well as drug and chemical residues present in both plant and animal-derived products), economic viability (impeded economic progress), and food security (escalated rates of malnutrition and reliance on humanitarian assistance). The intricate relationship between inadequate food safety regulations pronounced food insecurity, and the widespread occurrence of foodborne pathogens engenders a precarious predicament for the Afghan populace.

3.1. Health risks and foodborne illnesses

The health threats and foodborne diseases prevalent in Afghanistan represent critical issues, primarily propelled by deficient food safety protocols (substandard sanitation and improper food handling techniques), tainted water sources (environmental pollution), and the widespread existence of deleterious pathogens (related to both foodborne and waterborne illnesses). These challenges are further intensified by post-conflict conditions and economic fragility, which obstruct effective governance and public health measures. Common pathogens such as *Salmonella*, *E. coli*, and *Listeria* are notably present in poultry and various food items. These pathogens can precipitate severe gastrointestinal disorders, manifesting symptoms including diarrhea and vomiting (Qamar et al., 2023). The presence of mycotoxins, particularly Aflatoxin in fruits, poses considerable health hazards, culminating in long-term health complications such as liver cancer. Inadequate municipal waste management in Kabul exacerbates water contamination and the transmission of zoonotic diseases, further complicating food safety (Yosufi, 2019). Contaminated water emerges as a primary contributor to foodborne diseases, with 20% of child mortality in Afghanistan ascribed to diarrheal diseases.

A study indicated that 43.9% of water samples were found to contain coliforms, while 24.3% were positive for *E. coli*, underscoring considerable public health hazards (Ebner et al., 2018). Literature reviews identify microbial contamination, chemical pollution, food adulteration, improper use of additives, mislabeling, genetically modified foods, and expired products as prevalent food safety risks that may pose health threats (Gizaw, 2019). A study highlighted that health risks in Afghanistan encompass exposure to microbial contaminants stemming from Traditional Closed-Loop Sanitation Systems, potentially resulting in waterborne diseases such as diarrhea, typhoid, and dysentery, thereby impacting food safety (Uddin et al., 2019). Notwithstanding these obstacles, there exists an urgent necessity for the enhancement of food safety standards and public health education to alleviate these risks. However, the absence of adequate infrastructure and resources persistently obstructs the implementation of effective interventions.

3.2. Economic losses and reduced market competitiveness

The phenomenon of food safety in Afghanistan exerts a considerable influence on economic detriments and market viability, predominantly through the channels of food insecurity, health hazards, and trade imbalances. The inadequacy of access to safe food exacerbates the cycle of poverty, as numerous households depend on humanitarian assistance, which ultimately stifles the expansion and competitiveness of local markets. Foodborne diseases, particularly those arising from poultry products and contaminated fruits, present grave health threats, culminating in elevated healthcare expenditures and diminished productivity. The widespread presence of pathogens and toxins, such as Aflatoxin, within food products further undermines consumer trust, consequently leading to diminished market demand and economic losses. Afghanistan's agricultural sector endures a persistent trade deficit, in part attributable to substandard food safety regulations that obstruct the exportation of high-quality goods. The economic ramifications of food safety challenges encompass potential financial losses and diminished market competitiveness stemming from health-related issues and waning consumer confidence, thus impacting stakeholders within Afghanistan (Adinolfi et al., 2016). Food safety deficiencies, including the absence of international certifications and standardized processing facilities, impede Afghanistan's agricultural export potential, resulting in economic detriment and diminished competitiveness among exporters (Rahimi & Artukoğlu, 2023). The enhancement of food safety measures could improve product quality, thereby augmenting competitiveness in the global marketplace. Conversely, although food safety challenges present substantial obstacles, some researchers posit that these issues also provide avenues for reform and investment within the agricultural sector, potentially yielding long-term economic advantages if addressed with efficacy. The elements contributing to economic losses and diminished market competitiveness are illustrated in Figure 6.

3.3. Negative impact on trust and consumer perception

Food safety concerns in Afghanistan critically erode consumer trust and perception, thereby influencing purchasing behavior and the overall dynamics of the market. The relationship between food safety and consumer confidence is of paramount importance, as evidenced by numerous scholarly investigations. Consumers tend to regard traditional butchered meat as both fresh and reliable, albeit lacking hygiene, whereas meat procured from supermarkets is perceived as more sanitary but raises apprehensions regarding its freshness and adherence to Halal standards (Nasiri et al., 2023). This dichotomy engenders a profound mistrust in formal institutions, prompting consumers to prefer informal markets despite the inherent safety risks. The poultry sector confronts significant food safety challenges, encompassing pathogens and chemical residues, which pose substantial public health hazards (Faizy et al., 2022). Detrimental effects on trust and consumer perception in Afghanistan stem from antiquated food safety practices, insufficient coordination among inspection agencies, and inadequate legislative measures that impede consumer confidence in food safety standards.

The disjointed regulatory framework, coupled with overlapping inspections, engenders confusion and distrust among consumers, thereby exacerbating the complexity of the food safety environment (Khalid, 2016). The absence of effective communication and transparency from regulatory authorities further intensifies consumer skepticism regarding food safety standards (Cha et al., 2020). Consumer trust in food safety can be adversely affected by a lack of transparency in food processing practices, resulting in negative perceptions. Enhancing consumer education regarding processing methodologies may facilitate the restoration of trust and acceptance (Meijer et al., 2021). Nevertheless, consumer perceptions regarding food adulteration may lead to diminished trust due to intentional contamination for economic advantage, thereby influencing food safety perceptions (Chousou & Mattas, 2021). While these findings highlight the adverse effects of food safety challenges on trust and consumer perception, it is crucial to recognize that certain consumers may still prioritize sensory attributes such as taste and freshness over safety, thus indicating a multifaceted relationship among these variables.

4. Measures to Ensure Food Safety

A comprehensive and multifaceted strategy that integrates technological innovations, regulatory frameworks, and avant-garde materials is imperative for the assurance of food safety. The amalgamation of digital technologies, precision agriculture, and cutting-edge materials has the potential to markedly improve food safety protocols throughout the entire supply chain. Literature reviews indicate that the strengthening of food inspection and quality control systems, the enhancement of public awareness and education concerning food safety practices, the promotion of advanced food processing and preservation methodologies, and the establishment of collaborative partnerships with international organizations are pivotal measures that could bolster food safety in a nation such as Afghanistan.

4.1. Strengthening of food inspection and quality control systems

The strengthening of food inspection and quality control systems is indispensable for the safeguarding of food safety. Robust measures not only shield consumers from foodborne threats but also augment the integrity of the food supply chain. The ensuing points, encompassing the significance of inspection and enforcement, technological innovations, and systematic methodologies, elucidate how these systems contribute to the assurance of food safety. Food inspections play a vital role in the identification and mitigation of foodborne risks, with governmental regulators utilizing an array of enforcement mechanisms such as detention and seizure to guarantee adherence to safety protocols. The frequency and caliber of inspections, coupled with the training of personnel and the capabilities of laboratories, significantly impact the efficacy of food safety initiatives (DeWaal et al., 2014). Adherence to rigorous veterinary and sanitary standards is paramount for ensuring the safety of animal-derived products, as mandated by regulatory authorities such as Rosselkhoznadzor (Organization, 2020). Multispectral imaging technology presents a non-destructive approach to the detection of contaminants and the assessment of food quality, encompassing the identification of pathogens and pesticide residues. The incorporation of sophisticated quality control apparatuses, such as pH meters and refractometers, is essential for sustaining precise measurements and ensuring food safety. Mass spectrometry methodologies, including MALDI-TOF MS, HRMS, IMS-MS, and AMS, are critical for the surveillance of microbiological contamination, pesticides, and veterinary pharmaceutical residues, thereby ensuring prompt and accurate food safety interventions (Domínguez et al., 2020). Additionally, pulsed UV technology presents a promising non-thermal strategy for the disinfection of food surfaces, thereby ensuring consumer safety through the effective decontamination of food products and the minimization of foodborne illness risks (Garvey & Rowan, 2019).

Initiatives aimed at bolstering food safety encompass the development of 3D-printed biosensors for the early detection of pathogens within the food supply chain, thereby enhancing screening efficacy and assuring food quality amidst the COVID-19 pandemic (Sharma et al., 2021).

The application of multiway analytical methods, such as PARAFAC and PARAFAC2, can enhance food safety by addressing analytical challenges, including the coelution of interferents and the optimization of analytical protocols for complex matrices (Ortiz et al., 2024). Graphene-based nano-sensors and intelligent food packaging systems augment food safety by facilitating the detection of pesticide residues and monitoring product freshness via active and intelligent packaging solutions, thus ensuring quality control and safety protocols (Sundramoorthy et al., 2018).

The advancement of a hyperspectral imaging system significantly augments food safety by facilitating the online identification of foreign contaminants within food products, thereby enhancing inspection protocols and quality control measures (Linowska & Garbacz, 2023). The application of Cold Plasma technology in the domain of food processing can substantially bolster food safety by diminishing bacterial populations, eradicating pests, and preserving bioactive compounds, which collectively improve the overall quality and safety of food products (Jiang et al., 2022). Digital innovations, including the Internet of Things (IoT) and Blockchain technology, are instrumental in enabling real-time monitoring and traceability of food items, thereby facilitating early detection of hazards and swift recall procedures in instances of contamination. Notably, the incorporation of Artificial Intelligence (AI) for predictive modeling serves to identify potential safety concerns before their escalation, thereby enhancing the overall management of food safety (Ali Eltabey, 2023). The implementation of comprehensive food safety and quality management systems is paramount in fostering consumer trust and augmenting competitiveness within the global marketplace (Lee, 2023). In regions such as Africa and Afghanistan, it is imperative to strengthen national food safety control systems through improved coordination and adherence to international standards to mitigate the prevalence of foodborne diseases (Kimanya, 2024). The execution of Food Safety and Quality Systems (FSQS) throughout value chains, encompassing production to distribution, is essential for ensuring the safety and quality of food by adhering to rigorous standards and instilling reliability within operational processes (Gordon & Gordon, 2020). Despite the promising nature of these initiatives, obstacles persist in the widespread adoption of these technologies and materials, particularly in developing regions where resources may be limited. Ongoing research and financial investment are critical for overcoming these challenges and advancing global food safety standards.

4.2. Enhancing awareness and education on food safety practices

The enhancement of awareness and education regarding food safety practices is of paramount importance for ensuring food safety in Afghanistan, where the prevalence of foodborne illnesses and food insecurity is significant. Effective public education initiatives have the potential to empower consumers, refine food handling practices, and ultimately protect public health. Public education campaigns can profoundly influence consumer behavior concerning food safety, promoting appropriate techniques for handling, storing, and preparing food. Collaborative endeavors among regulatory agencies, non-governmental organizations (NGOs), and public health institutions are vital for the successful implementation of effective educational strategies (Eruaga, 2024a). The poultry sector in Afghanistan confronts challenges posed by foodborne pathogens and chemical residues, thereby necessitating enhanced educational efforts directed toward both producers and consumers. Awareness of the risks associated with food contamination, such as Aflatoxin in fruits, is imperative for the prevention of health hazards. Education can mitigate food insecurity by augmenting knowledge about food safety, which is intrinsically linked to improved food utilization and stability.

An increase in educational attainment is associated with diminished concerns regarding food availability, thereby underscoring the necessity for widespread food safety education (Pakravan-Charvadeh & Research, 2020). For individuals, food safety assurance necessitates a comprehensive combination of cognitive and behavioral strategies, encompassing practices such as hand hygiene, temperature regulation, spatial separation, and thorough sanitation, as evidenced by the reviewed literature (Bulochova et al., 2024). Nonetheless, it is imperative to evaluate the attitudes, behaviors, and hygiene practices prevalent among socioeconomically disadvantaged parents (Carstens et al., 2022). Furthermore, the creation of educational posters, the dissemination of knowledge regarding the impact of climate change, and the advocacy of safe food handling protocols through precise and persuasive communication are essential (Cho et al., 2013). Within the food industry, the implementation of food safety protocols encompasses the training of food handlers in hygienic practices, the adoption of Good Manufacturing Practices (GMP), the establishment of Standard Operating Procedures (SOP), the adherence to Standard Operating Hygiene Procedures (SOHP), and the execution of Hazard Analysis Critical Control Points (HACCP) (Feitosa & Andrade, 2022). In the context of pandemics such as COVID-19, the potential strategies to uphold food safety consist of monitoring the health of personnel, enforcing hygiene protocols, utilizing protective gear, instituting rigorous visitor regulations, conducting frequent sanitation, practicing social distancing, and employing remote auditing techniques (Shahbaz et al., 2020). While the enhancement of awareness is of paramount importance, it is equally imperative to confront systemic challenges such as poverty and infrastructural deficiencies that exacerbate food insecurity and safety issues in Afghanistan.

4.3. Promoting food standard processing and preservation techniques

Promoting food processing and preservation methodologies in Afghanistan is indispensable for the augmentation of food safety, particularly in addressing foodborne pathogens and toxins. The amalgamation of contemporary technologies with traditional practices can substantially diminish health risks associated with food consumption. Sophisticated food processing techniques, including high-pressure processing, pulsed electric fields, and ultraviolet light, alongside the incorporation of probiotics, rapid microbiological methodologies, and hurdle technology, significantly enhance microbial safety while concurrently preserving nutritional integrity (Sami et al., 2023). Non-thermal technologies such as cold plasma and ultraviolet light have been demonstrated to prolong shelf life without compromising food safety (Pokharel et al., 2023). The fresh and dried fruits of Afghanistan are particularly vulnerable to Aflatoxin contamination, which presents severe health hazards. The application of efficacious preservation techniques can mitigate the prevalence of these deleterious fungi, thereby ensuring safer food products. The application of controlled atmospheres (CAs), modified atmospheres (MAs), and phosphine (PH₃) as viable alternatives to methyl bromide for pest management in stored cereals has also been documented (AHMDANI, 2009). The adoption of innovative food preservation strategies, including both thermal and non-thermal processing techniques, enhances food safety by inactivating microorganisms and enzymes while safeguarding the nutritional and sensory characteristics of food, thus aligning with product safety standards and extending shelf life, which in turn benefits food security in Afghanistan (Kapoor et al., 2023). Non-thermal technologies such as ultraviolet light, pulsed electric field, high-pressure processing, ultrasonication, cold plasma, and supercritical carbon dioxide are emerging strategies aimed at ensuring elevated food safety alongside improved food quality (Jadhav & Choudhary, 2024). Food preservation methodologies, encompassing heat transfer and moisture extraction, can significantly bolster food safety in Afghanistan by curtailing microbial growth and chemical interactions, thereby alleviating food wastage (Joardder et al., 2019). The evolution of sustainable food processing technologies aspires to augment food safety by reducing the reliance on chemical preservatives, preserving food integrity, and ensuring economic viability in Afghanistan (Chemat et al., 2017).

The application of ultrasound technology within food processing provides swift, reproducible, and efficient methodologies such as sterilization and extraction, thereby enhancing food safety through optimized processing practices in Afghanistan (Altaf et al., 2018). The Sous Vide (SV) technique, as elaborated in the discourse, improves food safety through meticulous heat distribution, elevating quality, nutritional value, and shelf stability while eradicating microorganisms, thus reinforcing food safety (Onyeaka et al., 2022). High-pressure processing (HPP) constitutes a non-thermal approach that proficiently eradicates foodborne pathogens and viruses, thereby enhancing food safety by prolonging shelf life without undermining nutritional or sensory attributes (Iqbal et al., 2022). The implementation of microwaves and radio waves in food processing and preservation can ameliorate food safety in Afghanistan by employing non-ionizing electromagnetic radiation to mitigate hazards and uphold food quality (Bhatt et al., 2020). Ozonation, an innovative bio-preservation method, strengthens food safety by effectively diminishing microbial populations within food commodities without compromising their nutritional or sensory characteristics, thereby benefiting food processing in Afghanistan (Barde et al., 2021). The formation of edible films incorporated with antiviral compounds can substantially diminish the transmission of foodborne viruses, thus providing an additional layer of protection for fresh produce (Leite et al., 2023).

The absence of comprehensive food safety legislation in Afghanistan necessitates the implementation of HACCP to standardize safety protocols throughout the food supply chain. Reinforcing regulatory frameworks and enhancing inter-agency coordination can significantly improve food safety oversight (Khalid, 2015). While progress in food processing and preservation is imperative, challenges such as insufficient infrastructure and regulatory deficiencies persist as substantial impediments to achieving comprehensive food safety in Afghanistan. Addressing these challenges is essential for unlocking the agricultural potential of the nation.

4.4. Collaboration with international organizations and partners

Collaboration with international entities and partners is of paramount importance for ensuring food safety in Afghanistan, especially in light of its persistent challenges related to food security and public health. Such collaboration enhances regulatory frameworks, augments monitoring systems, and fosters the exchange of knowledge among stakeholders. This partnership improves the establishment of unified standards, facilitates the sharing of expertise, and elevates regulatory practices across international boundaries.

4.4.1. International standards and policy harmonization

Entities such as WHO, FAO, European Food Safety Authority (EFSA), Global Food Safety Initiative (GFSI), Food and Drug Administration (FDA), World Trade Organization (WTO), International Food Safety Authorities Network, and Codex Alimentarius Commission (Savelli et al., 2021) are instrumental in the formulation of science-based food safety standards through cooperative endeavors among nations, which are crucial for Afghanistan to synchronize its regulatory framework with international standards (Havinga & Verbruggen, 2017; Tanne, 2011). These organizations assist in surmounting obstacles such as disparate regulatory systems and differing institutional capabilities, thereby promoting a cohesive strategy for food safety and facilitating the harmonization of food safety standards, which fosters consensus-building, knowledge dissemination, and resource allocation for the enhancement of global food safety (Eruaga, 2024b). International collaborations provide training for local inspectors and food safety specialists, addressing deficiencies in knowledge and competencies requisite for efficacious food safety management. Engagement with organizations such as the International Veterinary Organization (IVO) and the World Organization for Animal Health (OIE) contributes to the monitoring of foodborne pathogens and chemical residues in poultry, which poses a significant concern in Afghanistan (Faizy et al., 2022).

Partnerships with WHO, UNICEF, and Global Affairs Canada within Afghanistan's National Nutrition Surveillance Programme ensure the surveillance of maternal and child malnutrition, thereby augmenting food safety initiatives through methodical collaborations (Chinjekure et al., 2018). Improved communication and transparency among international collaborators enhance the surveillance systems for foodborne illnesses, which is imperative for public health. Global initiatives assist in mobilizing resources to address food insecurity exacerbated by conflicts and crises, such as the COVID-19 pandemic, thereby securing access to safe food (Islam et al., 2022).

4.4.2. Technological innovations

Technological advancements such as blockchain and the IoT improve traceability and monitoring within food supply chains, thereby enabling nations to adhere more effectively to international safety regulations. These innovations facilitate real-time data exchange, which is vital for prompt responses to food safety threats (Eruaga, 2024b).

4.4.3. Public-private partnerships

Collaborative efforts among governmental entities, industry stakeholders, and civil society organizations enhance resource mobilization and knowledge transfer, resulting in superior food safety management. Such partnerships are essential for effective surveillance and risk mitigation on a global scale (Eruaga, 2024b). In summary, the overarching themes encompass international collaboration, policy harmonization, the utilization of technologies such as blockchain and IoT, the adoption of risk-based methodologies, and the encouragement of public-private partnerships to establish effective surveillance and responsive strategies to ensure food safety. While international collaboration is paramount, challenges such as geopolitical tensions and varying levels of commitment among nations may impede progress. Addressing these challenges necessitates continuous dialogue and trust-building among stakeholders to strengthen food safety in Afghanistan. Some ways of collaboration with international organizations and partners that ensure food safety are illustrated in Figure 7.

Future Perspectives and Conclusion

Food safety in Afghanistan presents a multifaceted challenge that requires coordinated efforts across various sectors. Addressing infrastructure inadequacies, enhancing regulatory frameworks, building capacity, and promoting public awareness are essential steps toward ensuring food safety. While there are significant obstacles, the commitment from both local authorities and international partners provides a foundation for improvement. By focusing on these aspects and fostering collaboration, Afghanistan can move toward a safer food environment, ultimately contributing to better public health and economic stability. Future perspectives on food safety in Afghanistan are shaped by the need for regulatory reform, technological innovation, and consumer awareness. The current fragmented food safety system, characterized by overlapping responsibilities among various agencies, necessitates the establishment of a unified regulatory authority to enhance efficiency and effectiveness. Advanced technologies such as high-pressure processing, UV irradiation, and IoT can significantly improve food safety by enhancing microbial control and traceability. The integration of artificial intelligence and rapid detection methods can facilitate better risk management in food production. Addressing consumer trust and perceptions is crucial for improving food safety standards and practices. While these advancements present promising avenues for enhancing food safety, challenges such as cultural perceptions and infrastructural limitations remain significant hurdles to overcome.

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Impact of Climate Change on Food Security in Afghanistan

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Abstract

This study examines the serious threats that climate change poses to food security in Afghanistan, a nation already beset by severe socioeconomic problems. It draws attention to the detrimental effects of environmental changes on agricultural productivity and food delivery networks, including changed precipitation patterns, a rise in the frequency of extreme weather events, and rising temperatures. The study's objectives are to investigate the several ways that climate change affects food inaccessibility and to suggest workable methods to lessen these difficulties. The research synthesizes existing literature and data using a review methodology and content analysis to provide insights into the socio-economic impacts of climate change on food security. As a result, Unpredictable weather patterns and inadequate irrigation infrastructure significantly contribute to food inaccessibility in Afghanistan, exacerbated by climate change. Farmers face challenges in adapting due to rising food prices and limited access to financing, while poor transportation networks hinder food distribution, particularly in rural areas. To address these issues, targeted solutions are essential, including the improvement of irrigation techniques, diversification of drought-resistant crop production, and enhancement of transportation infrastructure. In conclusion, a multifaceted approach that combines sustainable agricultural practices, economic support systems, and robust climate research is crucial for improving food security and resilience against climate change. Recommendations include allocating funds for modern irrigation methods, diversifying crop varieties, enhancing transportation networks, and providing financial assistance through adaptable safety nets and credit options. Such measures are vital for significantly reducing food scarcity and enhancing overall food security in Afghanistan.

Keywords: Climate Change; Crops; Food Security; Food Inaccessibility; Irrigation

Introduction

Climate change in Afghanistan has led to severe water shortages due to its mountainous climate and desert-steppe climate. Climate changes have the most severe impacts (Nabavi & Mohammadi, 2024). Climate change poses a significant threat to food security in Afghanistan, particularly in hotspot areas, with inadequate data and inadequate government responses exacerbated by inaccessibility (Wheeler & Von Braun, 2013). The research aims to identify and address challenges related to food security in the face of climate change.

Afghanistan faces significant climate challenges, including changes in precipitation patterns, drought, and inadequate water supplies. These issues negatively impact agriculture and the country's economy (Khakimov, 2019). Climate change also affects forests, rangelands, and biodiversity, leading to natural disasters, drought, disease, and maladaptation of plants and animals.

Agriculture, which employs over 3 billion people worldwide, is crucial for food security and reduces food imports in developing nations, with 80% of the population in rural areas (Wijerathna-Yapa & Pathirana, 2022). Afghanistan ranked 171st food-secure country globally in 2015 due to food and nutrition insecurity, exacerbated by environmental disasters, poverty, and decades of internal and external conflicts (Akabay & Ahmadzai, 2020). Food security is crucial for global peace and development, and climate change is closely linked. The United States contributes significantly to the global food supply, exporting over 136 million mg. However, population growth and climate change are projected to negatively impact the four pillars of food security: availability, access, utilization, and stability (Mbow & Rosenzweig, 2020; O'Brien *et al.*, 2021). Afghanistan, a fragile country, is severely affected by natural disasters, particularly climate shocks like floods, due to its geography and environmental degradation. The population has become increasingly vulnerable, with over 16,000 deaths from earthquakes and floods since 1990 (The World Bank, 2014), Afghanistan experiences significant annual damages from flooding, earthquakes, and droughts, causing \$54 million in damages and \$3 billion in agricultural losses. Road closures and strong earthquakes cause frequent casualties (Ahmadzai & Morrissey, 2024). Afghanistan faces imminent economic collapse and humanitarian catastrophe due to climate change, and deteriorating environmental conditions. Socio-economic and political risks are arising from the refugee crisis and climate change's impact on conflict divisions (Aydin-Kandemir & Yıldız, 2023).

This country is among the most vulnerable nations due to its limited climate change mitigation capabilities, facing increased hazards like drought, desertification, and land degradation, with frequent natural disasters (Hizbullah & Omar, 2024). Climate change impacts food security, with studies showing increased insecurity. Afghanistan's conflict and price shocks have severe effects on household food security, with varying projections depending on the scenario (Oskorouchi & Sousa-Poza, 2021). Since 1960, Afghanistan has been significantly impacted by climate change, leading to dry land expansion, droughts, increased agricultural vulnerability, and a 1.8°C annual temperature rise, affecting health and increasing susceptibility to diseases (Azizi *et al.*, 2024).

Economic activity significantly impacts climate change, directly affecting agricultural production and food security (Parto & Mihran, 2014).

Climate change is linked to the food security crisis due to biodiversity changes, global warming, floods, droughts, desertification, and bush farming. It is a global threat and challenge, impacting mankind's way of living. Despite advancements in science, technology, and the internet, climate change has negative impacts on mankind and the environment (Sambo & Sule, 2023). Climate change is a growing concern globally, particularly in Africa, where it severely impacts agricultural land, thereby affecting food security (Masipa, 2017). Climate change impacts agricultural production systems through direct effects like temperature and rainfall changes, and indirect effects through changes in pollinators, pests, disease vectors, and invasive species (Gitz & Alexander, 2016). Food production and consumption contribute to climate change by destroying forests, generating waste, and leaving millions hungry, despite the industry's environmental impact (Cordeiro *et al.*, 2019; Reza & Sabau, 2022).

Climate change and weather extremes, such as temperature fluctuations, excessive rainfall, floods, and droughts, significantly impact crop production, attracting global attention from leaders, policymakers, NGOs, and international organizations (Chandio *et al.*, 2023). The IPCC's fifth assessment report highlights climate change's negative impact on crops, livestock, and fisheries, threatening agriculture and food security. Disasters in tropical areas disrupt food security, affecting communities employing 30 to 80 percent of the population in agriculture.

Climate change, caused by natural or man-made factors, impacts human life, society, livelihood, and food security.

It increases global temperature due to atmospheric gases and environmental factors impacting plant growth (Malhi *et al.*, 2021). Afghanistan's hydro meteorological data is unavailable due to civil wars and political instability, but neighboring climate trends show an average annual temperature increase of 0.6 degrees Celsius between 1960 and 2008 (Nabavi & Mohammadi, 2024). Climatic factors like precipitation, evaporation, humidity, and sunshine improve food security. Policymakers, communities, and aid providers should incorporate evidence-based technologies like zero tillage, integrated soil fertility management, drip irrigation, seed improvement, and indigenous knowledge (Yeboah *et al.*, 2021). The Intergovernmental Panel on Climate Change predicts South Asian temperatures will rise by over 2°C by the mid-20th century, increasing hot days and erratic rainfall. This makes the food system vulnerable to climate change variability. Sri Lanka's efforts to ensure food security have yielded mixed results (Esham *et al.*, 2018). Climate change impacts food security through factors such as availability, access, supply stability, and price instability in the food production process (Haque & Khan, 2022). The influence of climate change on food security in Afghanistan is examined in this review of the literature, with particular attention paid to how it directly affects food production, transportation, accessibility, and government actions.

Impact of Climate Change on Food Production

Climate change in Afghanistan has significantly impacted agricultural productivity, causing reduced crop yields and water scarcity. This vulnerability, coupled with fragile infrastructure, necessitates urgent adaptive measures to protect rural livelihoods and food security (Khalily, 2022). Environmental changes in Afghanistan, exacerbated by its mountainous terrain and underdeveloped infrastructure, significantly hinder food transportation and accessibility. Salman *et al.* (2017) highlight the challenges of climate-linked road transport, particularly during extreme weather, in ensuring reliable access to water and essential resources for agricultural activities. Furthermore, Poole *et al.*'s (2019a) study on Bamyān Province's food production and consumption highlights sustainability and seasonality challenges, exacerbated by climate change, and limited transportation access in rural areas.

Governmental and Policy Responses

According to a review by Azizi *et al.* (2024), the study underscores the urgent need for comprehensive sustainable development strategies, emphasizing the need for integrative policies to tackle both immediate and long-term challenges. Furthermore, Jawid and Khadjavi (2019) highlight the importance of extension services and community-based interventions in enhancing adaptive capacity, highlighting the need for robust governmental policies and frameworks.

Research Problem

Climate change poses a serious danger to Afghanistan's food security, particularly in hotspot areas where altered environmental conditions make it more difficult to move and get food. The issue is made worse by the absence of reliable data and practical solutions from governmental agencies, which creates major obstacles to tackling food inaccessibility. The objective of this study is to identify these issues and provide workable solutions to enhance food security in the context of climate change.

Climate change has a significant impact on Afghanistan's food security, influencing several facets of the food supply chain. Droughts, floods, and changing precipitation patterns are examples of environmental changes that impair food distribution networks and agricultural output. In rural and conflict-affected areas, where infrastructure is already inadequate, these disruptions are more severe (Safi *et al.*, 2024).

Objectives

- 1: To identify and categorize the various forms of food inaccessibility in Afghanistan as influenced by climate change.
- 2: To develop and recommend actionable solutions to mitigate food inaccessibility related to climate change effects.

Research questions

- Q₁: What are the various forms of food inaccessibility in Afghanistan that are influenced by climate change?
- Q₂: What actionable solutions can be developed and recommended to mitigate food inaccessibility related to the effects of climate change?

Materials and Methods

A review methodology was used in this study, which applied an inductive content analysis technique. The actions listed below have been carried out:

Gathering of Data: A variety of sources, including academic journal articles, official government reports and papers, and publications from non-governmental organizations (NGOs), were used to collect secondary data.

Examining Content: A content analysis was performed on the gathered data to find trends and themes about food inaccessibility and possible remedies. With this approach, the socioeconomic effects of climate change on Afghanistan's food security may be thoroughly understood. This method seeks to give a comprehensive analysis of the threats that climate change poses to food security and to provide evidence-based suggestions to Afghan stakeholders and policymakers. A similar method was used by other researchers (Salman *et al.*, 2017). It is essential to comprehend the complex effects of climate change on Afghanistan's food security in order to create workable solutions. Through the identification of specific difficulties and the proposal of practical remedies, this study seeks to support regional efforts to enhance food security. Policymakers, non-governmental groups, and international organizations striving for a resilient and food-secure Afghanistan will find the findings invaluable.

Results and discussion

1: Types of Food Inaccessibility in Afghanistan due to Climate Change

1.1 Environmental Factors:

A: Unpredictable Weather Patterns: Droughts and floods have increased as a result of temperature and precipitation changes, which have had a significant impact on crop choices and agricultural production. Severe drought in Afghanistan usually means two years in a row with little winter precipitation; it happens at least once every ten to fifteen years.

Unfortunately, there isn't any reliable hydro meteorological data accessible in Afghanistan because of recent civil wars and political unrest in the nation. Nonetheless, data on climate changes from nearby nations indicates that, between 1960 and 2008, Afghanistan's average annual temperature rose by 0.6 degrees Celsius. In arid and semi-arid nations like Afghanistan, the rise in temperature since 1960 has brought about a series of droughts, an increase in dry land, and increased agricultural susceptibility (Nabavi & Mohammadi, 2024).

B: Water Scarcity: Water shortages are a result of inadequate irrigation infrastructure and a reliance on rainfall, which makes it challenging for farmers to maintain animals and crops. Afghanistan does not technically have a shortage of water.

Inadequate resource management, policies, and formal dispute resolution mechanisms to lessen the effects of seasonal drought and floods compound the issue of inadequate water distribution and storage (Bose *et al.*, 2023).

Afghanistan's topography offers ample opportunity for the use of its abundant water resources. It is a pity that the country is unable to make use of its water resources. The four largest river networks (460 kilometres) are the Amu Darya, the ancient Oxus (which borders Central Asia and runs 1,100 kilometres through Afghanistan), the Helmand (1,300 kilometres), the Harirud (650 kilometres through Afghanistan), and the Kabul River. The only river to reach the ocean is the Kabul River, which joins the Indus River Basin of Pakistan. Numerous rivers and streams empty into the country's desert areas, where they evaporate and don't replenish the four main networks. Other streams and rivers only sporadically flow (Aydin-Kandemir & Yıldız, 2023)

One major worry raised by participants was the inaccessibility of a water supply. Even in cases where wells were present, the water pump was malfunctioning or the water was excessively salted. Participants compared this to kids who had diarrhoea all the time. It was difficult to get water through other channels, and the water that was acquired was of low quality (Parwak, 2019).

1.2 Economic Barriers:

A: Rising Food Prices: Due to rising food prices brought on by crop failures caused by climate change and economic uncertainty, many people cannot afford essential food staples. Both internal and foreign causes contributed to the sharp price rises that Afghanistan saw for various commodities and staple foods. The food price index rose by 40% over the fieldwork period of August 2007 to September 2008, with some of the biggest price rises (100%) observed in wheat, an Afghan staple (D'Souza & Jolliffe, 2012).

B: Limited Access to Credit: Farmers frequently lack the financial means to make investments in more efficient farming methods or to prepare for climate shocks. Insufficient irrigated land to expand the horticultural area is the main production side constraint. This is primarily due to the destruction and neglect of irrigation schemes during the three decades of conflict and insurgency. Other constraints include old orchards that require replanting, insecure property rights that discourage long-term investment, inadequate credit access, inadequate extension, and poor on-farm management of water, crops, and pests. Regarding marketing, producers have constraints in obtaining cold storage and refrigerated transportation, which are essential for numerous high-value yet perishable items (The World Bank, 2014).

1.3 Social and Infrastructure Challenges:

A: Poor Infrastructure: Food delivery is hampered by inadequate transportation networks, especially in rural areas, which makes food inaccessible during inclement weather. To achieve early development, it is essential to increase the irrigated area accessible for animal fodder, horticulture, and wheat. About 2 million hectares of crop land are currently irrigated annually; the only way to rapidly increase this amount is to continue restoring the infrastructure that was damaged during the conflict. Within ten years, irrigating an additional 500,000–700,000 hectares of land is a reasonable goal. Afghanistan has a long history of restoring irrigation systems; during the last 12 years, around 1.8 million hectares of irrigation systems have been restored, costing between US\$300 and US\$400 per hectare (US\$600 and US\$800 if tertiary canals are taken into account). Enhancing water use efficiency in farmers' fields is crucial, in addition to maintaining water conveyance infrastructure (The World Bank, 2014).

B: Health Issues: Food production and security are further impacted by the fact that health issues and malnutrition decrease the workforce force available for agricultural operations.

Participants named a number of variables linked to poor and deteriorating health. These elements include environmental issues, inadequate housing structures, restricted employment and means of subsistence, and human security (Parwak, 2019).

Farmers' resilience has increased as a result of an increase in non-farm revenue sources, such as those in commerce and transportation. Mobility has been facilitated, the selling of products and services has been made possible, and access to health and education has been made simpler by security improvements and the substantial presence of Afghan National Security Forces. In this situation, the threat of eradicating the poppy plant and the provision of wheat seed and fertilizer, contingent on reductions in poppy cultivation, gave the counter-narcotics effort in Helmand a political boost. However, by itself, these measures were insufficient to force communities to give up poppy cultivation or to maintain reductions in it over time (The World Bank, 2014).

2: Actionable Solutions to Mitigate Food Inaccessibility

2.1 Improving Agricultural Practices:

A: Investment in Irrigation: Enhancing water efficiency and decreasing reliance on precipitation can greatly boost agricultural productivity. To reduce water loss as much as possible cultivation using irrigation using modern techniques like sprinkler and drip irrigation. There are many various types of water-saving techniques available today, such as sprinkler and drip irrigation. In dry and semi-arid regions, drip irrigation is a nearly effective method of watering that can reach up to 90% of the area. The same quantity of water that is discharged from the ground is used annually for surface water irrigation, which uses 30,000 m³/hectares of surface water resources. Drip irrigation uses 529.056 m³/hectares of water per year. Surface water use for the entire 63.5 hectares is 1905000 m³, and drip irrigation uses 34547.356 m³ for the entire 65.3 hectares. 1870452.644m³ of water was saved (Shafaq and Gidde, 2019). For Afghanistan's industrial, agricultural, and electrical energy production sectors to grow, there must be enough water. Thus, given the growing effects of climate change, such advancements would remain a pipe dream for this nation (Nabavi & Mohammadi, 2024).

B: Diversification of Crops: Encouraging farmers to grow drought-resistant and less water-intensive crops can help adapt to changing climatic conditions. To address food inaccessibility, farm systems can be intensified,

new productive elements introduced, water and land use improved, staple yields improved, crop varieties and animal breeds introduced, efficient water use, soil health improvements, and pest control. Laser Land Levelling techniques in eastern Afghanistan reduced labor requirements, water demand, and yields for wheat, corn, and eggplant, while increasing water productivity and water productivity by 21%, 40%, and 38%, respectively (Khakimov, 2019).

2.2 Economic Support and Policy Recommendations:

A: Adaptive Safety Nets: Safety net programs can help households cope with food insecurity in the Afghan economy, which heavily relies on agriculture. Wheat, a major production crop and staple, contributes 57% to the caloric content of the average Afghan diet (D'Souza & Jolliffe, 2012).

B: Access to Credit and Financial Services: Expanding microfinance and credit access can help small-scale farmers invest in improved farming technologies, improve productivity, and transition from subsistence farming to large-scale commercial farming (Gedamu, 2020).

2.3 Infrastructure Development:

A: Enhancing Transportation Networks: Improving road infrastructure can enhance market access, ensure food delivery during emergencies, and reduce inventory costs by increasing maintenance and building redundancy in transportation networks (Kaiser & Barstow, 2022).

B: Community-Based Health (CBH) Initiatives: Mobile health clinics and nutritional support programs can address malnutrition-related health issues, improve community resilience, and enhance governance of Community-Based Health (CBH) programs at all health system levels (Food and Agriculture organization of United Nations, 2023).

2.4 Climate Adaptation Strategies:

A: Education and Training: Training farmers on climate-resilient agricultural practices can help manage climate change risks. Projects include dam construction, seed introduction, workshops, water canals, gardens, fertilizer, pesticides, terraces, and pasture re-greening (Jawid & Khadjavi, 2019).

B: Research and Data Collection: The Afghanistan Meteorological Authority (AMA) faces challenges in climate research and data collection, including limited capacity, reliance on expert knowledge, and limited resources. These issues hinder the development of effective policies to mitigate climate change's impact on food security in Afghanistan (Doosti & Sherzad, 2015). Afghanistan can enhance its food security amidst ongoing climate challenges by addressing food inaccessibility and implementing targeted solutions.

The results demonstrate the complexity of food inaccessibility in Afghanistan, which is mainly caused by social, economic, and environmental variables that are made worse by climate change. The production of agriculture has been greatly impacted by erratic weather patterns, which are characterized by an increase in floods and droughts. Similar to this, the data shows that Afghanistan's average yearly temperature has increased, which increases the country's susceptibility to droughts and makes agriculture more important. These factors are crucial for a country that mostly depends on agriculture for its food and stability (Poole *et al.*, 2019b; Quraishi, 2021).

It is not a shortage of water resources that causes water scarcity; rather, it is the result of insufficient irrigation infrastructure and subpar water management practices. Due to inadequate distribution networks and dependence on rainfall, many farmers do not have access to enough water to maintain their crops.

Similarly, other scholars note that the socioeconomic obstacles that restrict access to financial resources exacerbate the problem, driving up food costs and limiting farmers' capacity to adjust to climate shocks (Alam, 2015; Leal Filho *et al.*, 2022).

Furthermore, the delivery of food is made more difficult by Afghanistan's inadequate infrastructure, especially in rural areas with little access to markets. Malnutrition-related health problems make this worse by lowering the labor force that can be used for agricultural productivity. In contrast, the combination of these variables results in a vicious cycle of food insecurity that is challenging to escape, since households are unable to obtain cheap, wholesome food, which has a negative impact on their health and lowers agricultural productivity (Islam *et al.*, 2022; Torell & Ward, 2010).

Conclusion

To effectively address food inaccessibility in Afghanistan, a comprehensive strategy that addresses the underlying social, economic, and environmental issues is needed. Investing in irrigation and implementing water-efficient farming techniques, such as drip irrigation, can greatly increase agricultural productivity and climate change resilience. Furthermore, incorporating drought-resistant cultivars into your crop diversification will help reduce the hazards brought on by shifting weather patterns. To enable farmers to invest in more advanced farming technologies and techniques, economic support systems like flexible safety nets and easier access to loans are crucial. Improving transportation networks will make markets more accessible and guarantee that food reaches underserved communities, particularly in times of emergency.

Lastly, effective policies and strategies to increase food security in Afghanistan will be informed by robust climate research and data collection, as well as by education and training on climate-resilient practices. The literature continuously emphasizes how seriously climate change is affecting Afghanistan's food security. The necessity for effective legislative and policy solutions is highlighted by the direct consequences on agricultural productivity as well as the difficulties in food accessibility and transportation. In order to enhance food security despite the ongoing climate catastrophe, future research should concentrate on creating integrated adaptive solutions that blend local knowledge with scientific breakthroughs. Afghanistan can contribute to a more secure food future by putting these focused ideas into practice, reducing the effects of climate change, and building resilience within its farming communities.

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Study the Effects of Climate Change on Food Security

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Abstract

Nowadays, the issue of ensuring and improving food security is one of the greatest challenges facing developing countries. It is evident that supplying food for the growing population is related to the agricultural sector; but, evidence shows that climate change has had destructive negative effects on agriculture, and leading to food insecurity in many countries. Due to the importance of this issue, this study was conducted using a review-analytical method, and investigating library sources and related articles published in credible international journals. Therefore, by using the most important findings related to this research article, the impact of climate change on food security was analyzed, and a conceptual model was drawn. The findings showed that climate change through its impact on rainfall patterns, increase in temperature, the spread of pests and diseases, changes in water resources, impact on food systems and increase in inequality in societies, affects food security. The effects of climate change on food security can be reduced by implementing strategies for increasing the adaptation of agriculture to climate change, optimizing water resource management, promoting sustainable agriculture, strengthening agricultural infrastructure, and formulating national and international policies. This research can play a significant role in providing detailed insight to policymakers and practitioners about climate change and food security in developing countries, especially Afghanistan.

Keywords: Climate change, Food insecurity, Drought.

Introduction

Climate change is one of the greatest challenges facing humanity in the current century (Olabi & Abdelkareem, 2022), and its impacts on various aspects of human life, especially food security, are undeniable. Food security means everyone has access to sufficient, healthy and nutritious food for an active and healthy life. With climate change, patterns of precipitation, temperature, and weather conditions are changing significantly, which can profoundly affect agricultural production, access to water resources, and ultimately the food security of different countries (Malhi, 2021 & Kaur, 2021). Rising temperatures and weather phenomena such as droughts and floods can lead to reduced production of crops and fruits (Saqib et al., 2022). This reduction in production not only leads to increased prices and food shortages in global markets but can also provoke social and economic instability.

On the other hand, climate change can affect biodiversity and stress natural ecosystems (Williams, 2020; Newbold), which in turn can impact the food and nutrition resources available to humans. Moreover, vulnerable groups such as small-scale farmers and indigenous communities are more affected by climate change than others. These communities are heavily reliant on agriculture, and any changes in weather patterns can jeopardize their livelihoods. In arid and semi-arid regions of the world, the negative impacts of climate change will be very severe, because arid and semi-arid climates are more sensitive to environmental variability than other climates and are more vulnerable (Bannayan et al., 2010).

Wheat production in Afghanistan, as one of the main food resources of the country, plays a vital role in food security and safety. Wheat is not only the main source of carbohydrates for the population of this country but is also used as a base for many food products, including bread. Wheat provides about 50% of the daily protein of the people, and therefore, self-sufficiency. Wheat production is one of the most important economic goals of the country. Considering the economic and social situation of Afghanistan, ensuring food security through local wheat production, especially in rural areas, is of great importance. Climate change, including temperature increase, precipitation decrease and weather fluctuations, can directly affect wheat production. These changes may cause a decrease in crop yield, an increase in pests and diseases, as well as a change in planting and harvesting time. In addition, climate change can also affect access to water resources, which are essential for wheat farming. Therefore, it is necessary to understand and investigate the effects of climate change on the food security of the wheat crop in Afghanistan, to develop appropriate strategies to deal with these challenges and improve the country's food security (Ali Pour & Saei, 2023; Shiri, 2012).

Various studies have been published on food security and climate change. However, none of the previous studies, either domestically or internationally, have comprehensively reviewed the impact of climate change on food security while considering its most important consequences. Research has shown that climate change has significant negative effects on agricultural and livestock production, the spread of diseases, food systems, and water sources. Ebrahimi Khoshfi et al., (2013) found that climate change affects the growth periods of pests, diseases, and weeds, which in turn leads to reduced agricultural production and, consequently, decreased food security. Villier and Venbrunn (2013) stated in a research entitled the effects of climate change on global food security that due to the conditions of climate change and in order to reduce its damages, the need to design a "climate-smart food system" is felt. Stevanovic et al., (2016), focusing on the distributional effects of climate change in geographic regions and economic factors, showed that climate change causes a mostly positive trend in producer surplus and a negative trend in global consumer surplus at the end of the current century. Calvin et al., (2016) indicated that the consequences of climate change on agricultural performance would lead to changes in economic welfare, peaking in the 21st century. In a study, Gohar et al., (2019) found that climate changes increase reliance on additional irrigation times with groundwater, which raises the final value of groundwater irrigation; also, food prices increase, negatively impacting food security and reducing agricultural livelihoods. Alcamo et al. (2007) showed that climate change poses a serious threat to the production of major crops such as wheat, potatoes, corn, and barley in the country. In Iran, Momeni and Zibaei (2013) assessed the potential effects of climate change on the agricultural sector of Fars Province and found that in most cases, the welfare effects of climate change were positive, with impacts on producers being significantly greater than those on consumers. Nikouei (2012), in a study on sustainable water resource use and responses to food security goals, showed that optimal allocation and use of water resources would improve water consumption efficiency and food security. Barani and Karami (2019) examined the effects of climate change on per capita food consumption in agricultural ecological regions of Iran, indicating that total horticultural production decreases with rising temperatures, evaporation, transpiration, and wind speed, which consequently reduces per capita food consumption and food security. However, it can be said that climate change has significant negative effects on food security, and it is essential for policymakers and researchers to seek solutions to mitigate these adverse impacts. Given the importance of this issue, the present research aims to investigate various aspects of the impact of climate change on food security. This study can contribute to a better understanding of the existing challenges and solutions, leading to the development of effective strategies to combat the negative effects of climate change on food security.

Materials and Methods

According to the type of work method, this research is a review-analytical type that has been used to collect information from books and authentic scientific articles in the field of climate change and food security. So, regarding the issues of climate change and food security, more than (30) international authorities were used. Therefore, using the most important findings related to this article, the impact of climate change on food security was analyzed and a conceptual model was drawn in the field. It should be noted that considering the economic situation and the vulnerability of arid and semi-arid regions of developing countries due to climate change, the most important effects of climate change on food security have been deeply discussed and analyzed in the current research.

Result and Discussion

Climate change has profound and widespread effects on food security, some of its important effects are discussed below:

1. Changes in Precipitation Patterns

Changes in the amount and pattern of rainfall can lead to severe droughts or floods. These changes may result in reduced agricultural production and increased risk of hunger. In other words, shifts in precipitation patterns are one of the prominent effects of climate change, significantly impacting the environment, agriculture, and daily human life. These changes include both increases and decreases in rainfall. For instance, in some areas, precipitation may increase, while in others, it may decrease (Soltani et al., 2023). Additionally, the timing and intensity of rainfall may change across different seasons, leading to increased heavy rain in summer and droughts in winter. On the other hand, climate change can lead to an increase in the intensity of storms and sudden rains and floods. It is important to note that changes in precipitation patterns also affect surface and groundwater resources, potentially leading to challenges in supplying drinking and agricultural water. Altered rainfall patterns can also impact habitats and biodiversity, possibly leading to the extinction of certain species and negatively affecting food security (Kiani Ghaleh Sard et al., 2019).

3. Rising Temperatures

As a result of climate change, temperatures are rising, which in turn affects plant growth, harvesting times, and the quality of crops. Some regions may become unsuitable for cultivating certain types of crops. However, it can be stated that rising temperatures, as one of the consequences of climate change, have significant impacts on food security. For instance, increasing temperatures can lead to reduced agricultural production (Sustainable Development Goal, 2023; WHO, 2008). Recent studies and assessments indicate that if no action is taken to combat global warming, global agricultural production may decrease by about 15.9% by 2080 (Cline, 2017). Additionally, rising temperatures can reduce the nutritional quality of agricultural products, alter harvesting times, and impact the overall quality of crops. As temperatures rise, the water needs of crops increase, leading to higher irrigation demands and pest management costs, which in turn raise production costs. Consequently, the food supply chain is affected, resulting in increased poverty and inequality in society, with implications for migration and social tensions. As agricultural production declines due to rising temperatures and poverty expand, this can lead to migration from rural areas to cities or other countries, while competition for limited food resources can escalate social and political tensions (UNHCR, 2020). Therefore, rising temperatures pose a serious threat to global food security, necessitating immediate and effective actions in natural resource and agricultural management to mitigate its negative impacts.

3. Pests and Diseases

Climate change can facilitate the spread of pests and plant diseases, posing a serious threat to food security and food safety. According to estimates from the Food and Agriculture Organization (FAO), over 40% of agricultural products are lost annually due to damage from pests and plant diseases (FAO, 2020). Given that agriculture is a primary source of income in poor rural communities, this can lead to serious consequences such as increased hunger and poverty, putting plant health at significant risk (IPBES, 2019). Climate change and human activities have altered ecosystems and reduced biodiversity, paving the way for the emergence of new pests (FAO, 2020). For instance, (Ebrahimi Khoshfi et al.,) noted that climate change affects the growth periods of pests, diseases, and weeds, leading to reduced agricultural production and, consequently, decreased food security. However, the use of environmentally friendly methods, such as integrated pest management, can help control pest populations.

4. Changes in Water Resources

As a result of climate change, freshwater resources are affected, impacting irrigation and water supply for agriculture. In other words, climate change has extensive effects on water resources. With rising temperatures and decreasing rainfall, water resources are becoming limited, leading to more severe droughts. This situation leads to increased water stress and reduces the ability to supply water for communities. To address these challenges, it is essential to implement measures for the optimal management of water resources, improve water use efficiency, and promote the use of moderate water resources. It is important to note that international and inter-regional cooperation for coordinated management and sharing of water resources is crucial (Water, 2020; IPBES, 2019). Optimizing the use of water resources, preserving watershed margins, and implementing water resource management plans can help reduce the effects of drought and enhance water security. Effective water consumption management in agriculture improves the food security of farming households. Water scarcity and inefficient management of water resources are considered aggravating factors of food insecurity. Facing serious water resource shortages and significant food security challenges makes the effective use of limited water resources an international concern for governments and organizations (Moradi et al., 2014). Currently, agriculture is recognized as the largest consumer of water globally, with studies indicating that up to 70% of the world's freshwater resources are consumed by the agricultural sector (Mikhak et al., 2018). The lack of appropriate management of water resources in the future will lead to numerous consequences, the most severe of which will appear in the agricultural sector, affecting the food basket of rural households, a significant portion of which is derived from their own production. Consequently, food security, which is one of the primary macro-objectives of governments, will face a crisis. Water consumption management in agriculture impacts food security for farming households both directly and indirectly through product quality, changes in crop patterns, input productivity, production diversity, total yield, increased agricultural income, and self-consumption of agricultural products. For instance, Kang et al. (2017) found that water management through modern irrigation methods based on crop physiological responses, and improving the regional water productivity by integrative methods can improve the quality of fruits and vegetables and lead to higher profits for farmers.. Additionally, Valdes & Schiff (1990) concluded that access to sufficient water and the presence of appropriate irrigation systems enhance both the quantity and quality of farm production, which in turn increases income and elevates the food security level of farming households.

5. Impact on Food Systems

Climate change can disrupt food supply chains (Sustainable Development Goal, 2023; WHO, 2008) and lead to decreased food production.. This decrease is often due to the loss of income from farmers who lose their livestock and crops or suffer from reduced productivity (Albino et al., 2022). Additionally, climate change not only reduces agricultural output but also impacts supply due to farmers hoarding their products. A study by Udmale et al. (2014) showed that decreased yields of grains, horticultural products, livestock production, and loss of employment, all associated with reduced farmer income, were immediate economic effects of drought. Reduced agricultural production due to climate change leads to increased food prices. These rising prices can limit access to food for economically vulnerable communities, thereby threatening food security. However, it can be argued that climate change causes increases in the prices of essential food items due to reduced productivity and increased demand (Albino et al., 2022).

Climate change may also alter food access patterns. For example, droughts and floods can result in food losses and decrease individuals' ability to access food. Since climate variability affects food supply, it impacts food security through what is commonly referred to as "climate-induced food price changes." Higher food prices can pose a threat to food security, especially as many farming households are also food purchasers (Vosan et al., 2017). Furthermore, climate change affects input and output prices, as there may be a direct correlation between climate variations and local prices. These climatic changes certainly impact product yields. Additionally, even without changes in productivity, price changes can affect food security through shifts in purchasing power. Thus, the effects of climate variability are transmitted not only through production pathways but also via relative price changes. Climate change can lead to reduced diversity in food products and changes in consumption patterns. These changes may result in increased reliance on a few staple food items, posing greater risks to food security. In developing countries, lack of access to an adequate and diverse diet is a significant challenge for rural communities. The type of food in rural households' meals is typically determined by seasonal agricultural and livestock production. This indicates that rural populations may not pay sufficient attention to food diversity and nutritional value, or they may be unaware of it. This trend is exacerbated by decreasing household financial resources and climate change (Ahmadi et al., 2020). Low dietary diversity can negatively impact labor productivity, disrupt physical and mental growth, reduce physical ability, weaken immunity, increase susceptibility to various diseases, and raise child mortality rates among those under five years of age (Minja et al., 2021). Conversely, a more diverse diet that includes all food groups leads to healthier populations and supports optimal growth and development (Ouching et al., 2017).

Climate change impacts not only nature but also food supply chains, necessitating actions for adaptation and proper management. Some solutions for adapting to these changes include modifying agricultural practices, optimizing water resource use, promoting sustainable agriculture, and enhancing research in climatology and agriculture. Additionally, international cooperation is essential for better managing the impacts of climate change on global food systems (Sustainable Development Goal, 2023; WHO, 2008).

5. *Increasing Inequality*

The effects of climate change can exacerbate social and economic inequalities in society, particularly in economically weaker countries that rely on agriculture. In other words, climate change, as a global challenge, has profound impacts on various aspects of human life. One significant aspect of these impacts is the exacerbation of social and economic inequalities. Vulnerable communities are more affected by climate changes due to their limited access to resources and modern technologies. These communities often reside in areas with a high risk of natural disasters, making them particularly susceptible to the rapid impacts of floods, droughts, and storms (IPCC, 2022). Furthermore, climate change leads to increased income inequality. For instance, climate change can result in decreased agricultural production and rising food prices. This situation adversely affects low-income families, as they spend a larger portion of their income on food. Consequently, rising prices can exacerbate poverty and income inequality (World Bank, 2021). Moreover, climate change leads to migration and population displacement, as affected individuals move from one region to another. Those migrating from impacted areas may face serious challenges such as discrimination and lack of access to social services, which can further fuel social inequalities (UNHCR, 2020). Studies also indicate that climate change increases health inequalities within society, as rising temperatures and changing precipitation patterns may lead to higher incidences of infectious and chronic diseases. Vulnerable groups, including women and children, are particularly at risk of these threats, which can further exacerbate health disparities (WHO, 2019). Therefore, addressing the challenges posed by climate change to food security can help reduce the vulnerability of poor communities and promote social justice. According to the findings of this research, the following framework is presented.

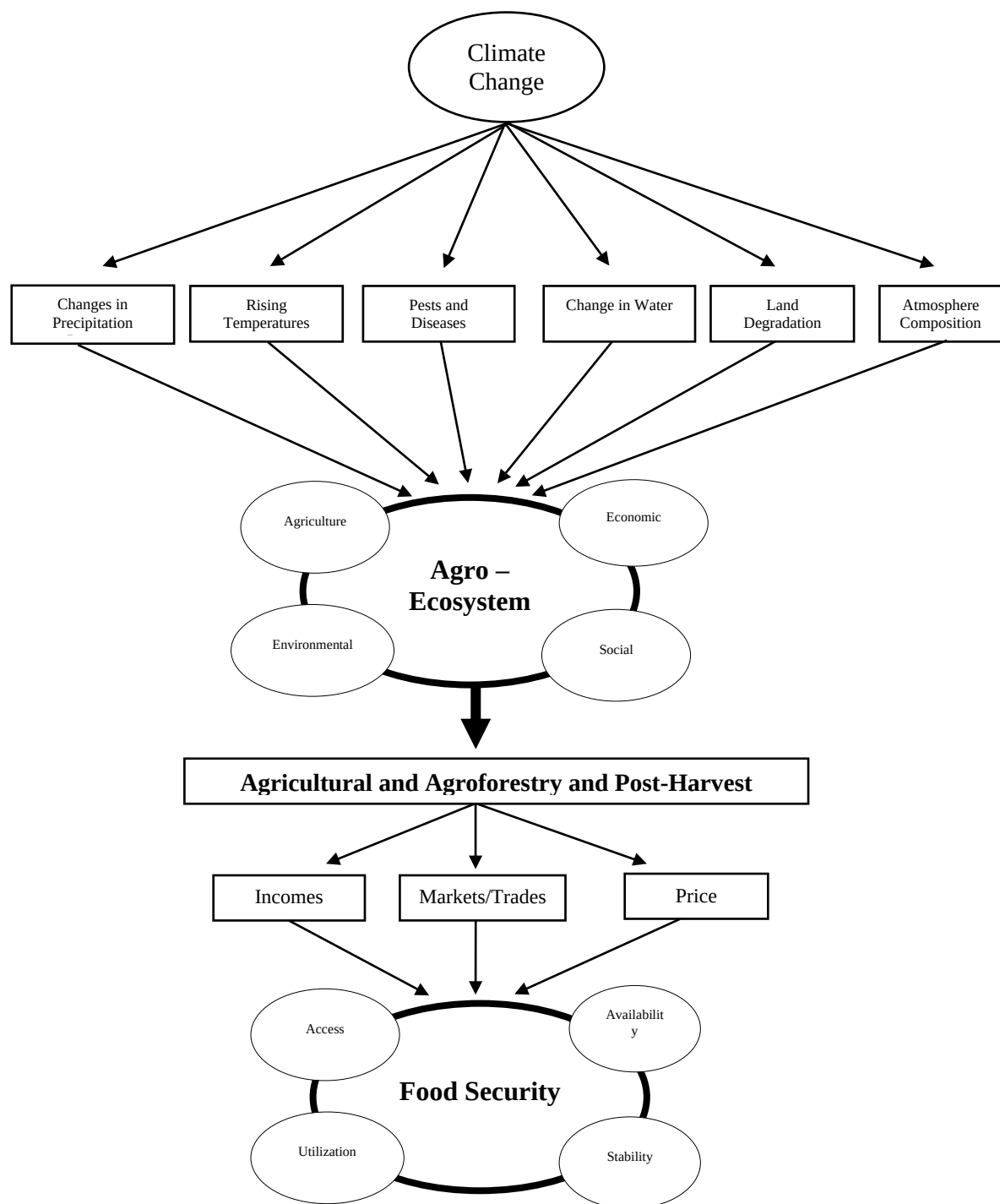


Figure 1. The Effects of Climate Change on Food Security

Conclusion

This study has analyzed the impact of climate change on food security through a review approach. The results indicate that climate change negatively affects agriculture, leading to a decrease in food production, which can seriously threaten food security in communities. Climate change influences food security through altered precipitation patterns, rising temperatures, pests and diseases, changes in water resources, increasing inequalities, and effects on food systems (such as reduced food availability, rising prices, decreased food diversity, and reduced access to food). The negative impacts of this phenomenon will be particularly severe for impoverished regions in developing countries, where approximately seventy percent of people are directly or indirectly reliant on agriculture, mostly in arid and semi-arid areas. Because arid and semi-arid climates are more sensitive to environmental variability than other climates and are more vulnerable. However, climate change presents a major challenge to global food security, necessitating immediate and effective actions in this sector. To manage the adverse effects of climate change on agriculture and food security, it is necessary to implement effective policies and solutions such as increasing the adaptation of agriculture to climate change, optimizing water resource management, promoting sustainable agriculture, strengthening agricultural infrastructure, increasing the resilience of communities and developing national and international policies. The following recommendations are proposed:

Increasing agriculture's adaptability to climate change is a requirement. Programs should be carried out in cases such as planting early varieties of plants and changing the production method from the pasture system to the mixed system and farm.

Optimum use of water resources, maintaining watershed margins and implementing water resource management plans can help reduce the effects of drought and increase water security.

One of the effective ways to reduce the negative effects of climate change on agriculture and food security is to promote sustainable agriculture, which includes the use of sustainable agricultural methods, preserving biodiversity, and improving the efficiency of natural resource consumption.

Strengthening agricultural infrastructure such as investment in irrigation infrastructure, access to agricultural product markets, and development of agricultural technologies can help increase production and food security of countries.

Increasing the resilience of rural communities, especially farmers, is a requirement. This action can be done through the diversification of economic activities, especially in rural areas, and the authorities should make continuous efforts in the field according to specific mechanisms.

To combat climate change, it is necessary to formulate and implement effective national and international policies and programs in the issues of investment and development of new irrigation systems, modified and high-yield seed technologies, insurance of agricultural products, training and capacity building of users, and sustainable land management.

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Effects of ultraviolet light radiation on food preservation

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Abstract

Due to the variety of foods and diversity of preservation methods. Food irradiation is one of the best methods at the moment. In this method of food preservation, food remains constant for extended periods by inactivating pathogenic microorganisms, thereby eliminating the causes of spoilage and extending its shelf life. Foods free of pathogenic bacteria, yeasts, molds, and insects; Control fruits and vegetables' ripening, aging, and germination. The UVC (200-280 nm) region, called the ultraviolet germicidal radiation, has high energy suitable for microbial inactivation. The lethal dose required for different microbes is varied. But the best dose in most foods is about 4 k Gray and the optimal disinfection wavelength is 254 nm. Several factors, including the operational settings of the UVC equipment, the traits of the microbes, and the composition, influence UVC radiation's effectiveness in food processing. Therefore, the application of UVC irradiation is an emerging non-thermal technique for the decontamination of food products. This review describes microbial properties, the required dose in food irradiation, and the fundamentals of using UVC radiation to inactivate pathogenic microbes for the decontamination of foods. At last, the current status of international regulations along the future challenges, are discussed in this context.

Keywords: UVC irradiation; keeping quality; disinfection; foods processing

Introduction

Producing safe, good-quality food products that do not pose any risk to consumer health, is one of the most critical challenges of the food industry. Therefore, food safety and security are the main priorities of the food production and storage sectors ([Fung, et al., 2018](#)). Food manufacturers are exploring various new technologies that could enhance or even replace traditional processing methods, aiming to produce high-quality food products. Conventional technologies (such as heat processing and pasteurization, cold plasma processing, ultrasound, radiofrequency heating, pulsed electric field, and high-pressure processing) are widely used for a wide range of food industries. However, those therapeutic technologies can change the physical properties (color, odor, texture, taste, etc.) or reduce the nutritional quality (loss of vitamins, fat oxidation, removal of proteins, inactivation of enzymes, etc.) Of the foods. Because the application of these methods generally requires high energy and capital costs, the development of innovative food processing techniques is the need of the time ([Singh et al., 2021](#))

Every year, many of our food sources are destroyed by spoilage or insect infestation. To solve the serious damages caused by these problems, since 1950, scientists have decided to use various methods of food storage, such as various thermal processing, Consumption of chemicals, fumigation, and similar. Irradiation is also used as a way to preserve foods.

In this process, UVC radiation causes the loss of microorganisms that infect foods or cause spoilage and destruction of foods stuff. Irradiation is known as a cold process, which increases the temperature significantly but doesn't leave any physical changes or sensory characteristics in most foods. For example, an irradiated apple is still crispy and juicy. Ultraviolet (UV) irradiation has become a promising technology for food processing in practical, real-world settings. It is commonly considered to be a non-toxic food processing method that does not have the adverse effects of more conventional options (e.g., thermal processing). UV light, especially UVC, which damages the DNA of pathogenic bacteria, and its powerful germicidal ability, are well known ([IAhmad, 2017](#)).

For the destruction of molecular chains, depending on the type of organism, a certain amount of UV light is required at the germicidal wavelength of 253.7 nm. Of course, the success in disinfecting surfaces by using UVC radiation greatly depends on the resistance and stability of materials that have to be disinfected. Generally, UVC radiation must directly hit the microorganisms to reach the lethal damage. If the organism is under the surface of the substance or is not in the direct path of UVC radiation, it will not be destroyed. ([Banrud and Moan J, 1999](#))

In many areas of application, UVC technology in the food industry has demonstrated greater effectiveness and cost-efficiency compared to traditional methods. Major global regulatory bodies, such as the United States Food and Drug Administration (US FDA) with its Hazard Analysis Critical Control Point (HACCP) system, Health Canada, and the European Union, have already approved the use of UV light for pathogenic control in the fruit juice processing and seafood industry. The assessment of UV light as a food processing method relies on factors such as the physical and chemical composition of the food being treated and the specifications of the UV equipment (such as UVC intensity and exposure time), microbial properties, and other commercial parameters. In addition, the UVC sensitivity of the relevant microorganisms is an important concern in microbial reduction in food matrices ([Hinds et al., 2019](#))

This review illustrates the fundamentals of using UVC radiation for food treatment and processing in terms of its principles, microbial inactivation mechanism, irradiation sources, treatment conditions, and potential for combination with other processing techniques. The purpose of this work is to study the process factors that apply control on the UV light treatment and processing for food safety. It also provides an overview of international as well as national regulation guides for the utilization of UV technology in food processing. The research was carried out with the following aims:

- Increasing the shelf life and storage length of food by irradiation method.
- Determining the antimicrobial area of UV light that has excellent and lethal disinfection properties against bacteria, fungi ,and viruses.

Literature review

Food irradiation began in the early 20th century. The concept was first proposed by the French physicist H. D. L. (Henri Desgranges), but the practical development and use of food irradiation were advanced significantly by scientists in the mid-20th century. In the 1920s, scientists began exploring the use of radiation for sterilizing food. The idea was to use radiation to kill bacteria and other pathogens, extend shelf life, and improve food safety ([Mikaelsen et al., 1971](#)).

The development of food irradiation technology was accelerated during World War II when researchers explored its potential for preserving food for troops.

In the 1950s, the U.S. Atomic Energy Commission supported research into food irradiation. In 1963, the U.S. Food and Drug Administration (FDA) approved the use of radiation for the treatment of certain foods. This was a significant step in formalizing the technology and establishing regulatory guidelines. The commercial application of food irradiation started to expand in the 1970s and 1980s. Countries like the United States, Canada, and Japan began adopting the technology more widely ([WHO., 2006](#)).

Materials and Methods

This systematic review followed the guidelines (flow chart and checklist) of the Preferred Reporting Items for Narrative Reviews and meta-analysis statements. Credible references and international sources that are globally acceptable to food security organizations have been utilized. I also analyzed and interpreted recent studies conducted by scientists in laboratories and applied them descriptively in this research. Search terms were used in Google Scholar, Scopus, and Science Direct databases.

Food irradiation

Food irradiation is one type of non-thermal technique in which food is subjected to a specific dose of non-ionizing radiations such as UV, visible light, infrared, radio waves, or ionizing radiations like gamma rays, X-rays and accelerated electron beams to destroy microbes like Virus, bacteria, etc. ([Pathak et al., 2018](#)).

Food irradiation involves using radiation to eliminate pests, such as microbes and insects, and prevent spoilage. This process is comparable to pasteurizing milk or canning fruits and vegetables, as it enhances food safety. Importantly, irradiation does not make food radioactive, nor does it alter its taste, texture, or appearance. The penetration of radiation into the material triggers the interaction of the radiation with the atoms or molecules of matter. Due to various physical processes, radiant energy is absorbed in the matter. The amount of absorbed energy in a substance is called the dose, denoted by the units of Gray G (the amount of absorbed energy per unit mass) ([Nair and Sharma, 2016](#)).

Ultraviolet non-ionizing radiation, specifically UV-C, is employed to reduce microbial populations in foods as an alternative to chemical decontamination. It has been approved for use as a disinfectant in the treatment of products' exterior surfaces. (US-FDA, 2002). The purpose of food irradiation is to increase the shelf life and improve the safety and germicidal Features of the product. The beams used to remove microorganisms should have low wavelengths because such shorter-wavelength rays have a more destructive effect on microorganisms ([Sommers & Fan, 2008](#))

The anti-microbial effect of UVC

The UV region is located in the electromagnetic spectrum (100–400 nm) between the visible and X-ray regions. This wavelength range includes four different regions: (a) the UVA region (315–400 nm) has the longest wavelength and lowest energy; (b) the UVB region (280–315 nm) has medium wavelengths which can lead to skin tanning, sunburn, and even skin cancer; (c) the UVC region, also known as the UV-germicidal irradiation range (200–280 nm), possesses high energy levels ideal for microbial inactivation; and (d) the vacuum UV region (100–200 nm) which can be absorbed by almost all substances but is transmittable only in a vacuum ([Song et al., 2016](#)).

Among all the UV spectral regions, the UVC region is very popular due to its excellent and deadly germicidal properties against bacteria, fungi, and viruses. The mechanism of the destructive action of UVC is the ability to disrupt and burst DNA / RNA in microbial cells to alter cell metabolism and reproduction, which ultimately leads to cell death.

The harm to genetic material occurs mainly through the production of dimers between pyrimidine nucleotide molecules in the nucleic acid backbone. The formation of those dimers (Cyclobutane pyrimidine dimers, CPDs, and pyrimidine photoproducts) disrupts the natural set of DNA and other cellular functions of microorganisms. CPD is usually formed between thymine's (TT), cytosine (CCs), or based on cytosine/thymine (CT), depending on the nucleotide composition. These molecules disrupt normal RNA transcription and DNA replication, causing mutations and eventually leading to cell death.

Non-ionizing UV radiation can cause breaks in chemical bonds and can induce molecular photochemical reactions. All nutrition and toxicological studies that were undertaken showed the absence of any harmful effects of ions, excited atoms, and molecules generated during irradiation. (Bintsis et al., 2000). DNA damage by irradiation of undesirable microorganisms found in food leads to their inactivation. The amount of energy can be controlled to achieve the desired effects in terms of conservation while maintaining the quality, safety, and nutritional properties of the food. The biological effects of UV radiation depend on the wavelength and exposure time (Sorica et al., 2014).

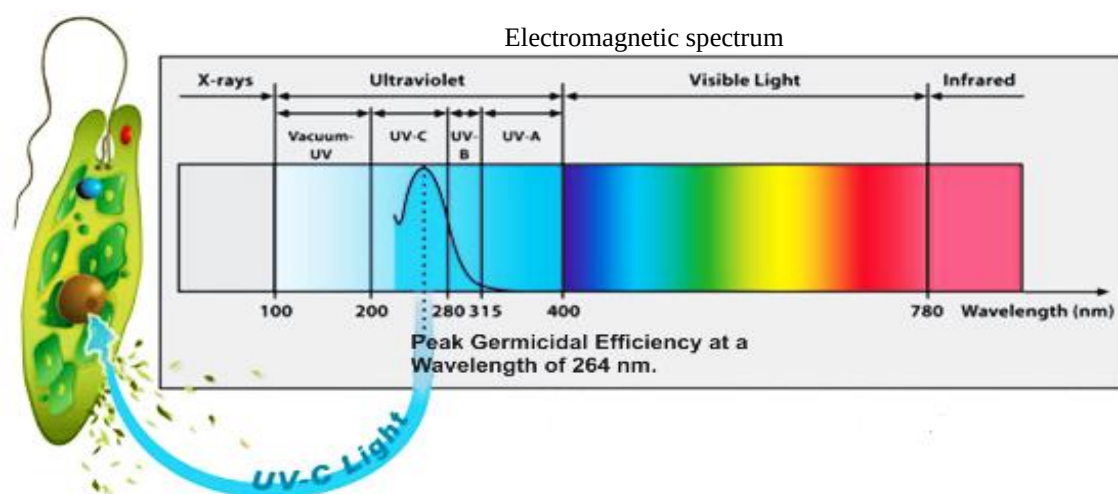


Figure 1: Curve of germicidal efficiency of UV radiation on pathogens depending on the wavelength (nm) (Sorica et al., 2014).

Figure 1 shows the wavelength range of 260–270 nm is regarded as the most lethal because this energy is highly absorbed by the nucleic acids of microorganisms. The nucleic acids usually absorb wavelengths ranging from 200–300 nm, with a peak absorbance at 260 nm (within the UVC region). UVC light at 254 nm is considered the optimal wavelength for achieving maximum germicidal action. UVC radiation has proven effective in inactivating a broad spectrum of foodborne pathogenic bacteria, including *Escherichia coli*, *Listeria*, *Salmonella*, *Staphylococcus*, *Bacillus*, *Clostridium*, *Yersinia*, *Aeromonas*, *Cladosporium*, and *Alicyclobacillus*, as well as spoilage bacteria. Such as *Lactobacillus*; spoilage yeasts (*Saccharomyces cerevisiae*, *Zygosaccharomyces bailii*); and molds (*Neosartorya fischeri*). The presence of these microbes—bacteria, fungi, yeasts, and even viruses—in food has been linked to foodborne infections and diseases. An example is the microorganism *Escherichia coli* in food liquids such as fruit juices, alcoholic beverages, and milk; raw meat; honey bees; and Fresh products such as raw fruits and uncooked vegetables. Causes Diseases such as Hemorrhagic diarrhea, abdominal cramping, pain or tenderness, nausea and vomiting, kidney failure, and urinary infections (Singh et al., 2021).

Required dose in food irradiation

The Irradiation dose is different for various foods and has been determined for many food products within less than 10 k Gy.

For pasteurization of food products we use 1 up to 10 k Gy irradiation dose, and for sterilization can be used above 10 k Gy dose of irradiation ([Indiarto & Qonit, 2020](#)).

In some food products for the disposal of insects, the irradiation process can be performed at a dose of less than 1 k Gy. To prevent the germination of potatoes and onions, a dose of less than 0.5 k Gy is required. Also, to delay the arrival of fruits, products can be irradiated at a dose of less than 0.3 k Gy ([Placek et al., 2004](#)).

Equipment parameters and UVC processing

To inactivate microbes and maximize process efficiency and penetration of UVC light into food items, especially liquid food products; choosing a UVC source with the optimum wavelength is very important. UVC antimicrobial lamps such as low-pressure (254 nm line) high-pressure lamps (broadband line) and mercury lamps and Excimer lamps (207, 222 nm) hold great promise in food applications. However, exposure to mercury vapor emitted by these lamps can cause serious damage to health.

A krypton-chlorine Excimer lamp emitting radiation at 222 nm shows higher bactericidal activity than conventional 254 nm mercury lamps against the prevalence of foodborne bacteria. Moreover, UVC radiation generated from pulsed xenon lamps, which emit light at regular time intervals, can provide more instantaneous energy intensity than conventional mercury lamps ([Koutchma et al., 2008](#)).

Currently, the use of UVC light-emitting diodes (LEDs) that emit monochromatic UVC light is a great choice in food applications due to its compact size, portability, high efficiency, and long lifetime. Wavelength is another main parameter that plays a role in microbial inactivation in UVC food processing. UVC has greater lethality to microorganisms near the peaks of DNA absorption. The emission of the wavelength depends on the choice of a UVC source/lamp. In UVC light applications, various equipment and devices are used to achieve the desired level of microbial inactivation for solid and liquid food products. Applying UVC light to liquid foods, such as alcoholic beverages or milk, requires specially designed reactors; while simple UVC containers can be used to disinfect solid foods such as fruits and fresh produce ([Koutchma, et al., 2004](#)).

In Figure 2, the main factors that affect the success of UV-C processing are presented as well as a general representation of the reactor chamber.

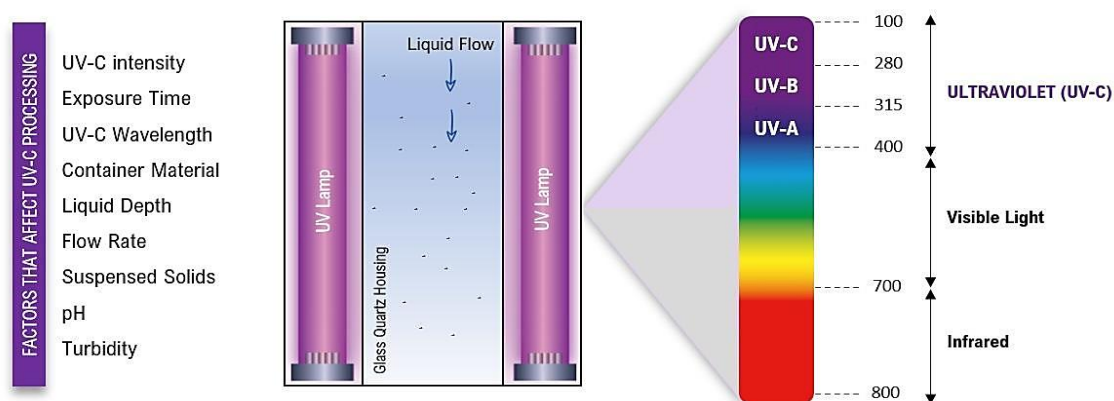


Figure 2 : Reactor chamber UV-C processing for liquid foods and the main factors that affect the process ([Tchonkouang et al., 2023](#)).

Microbial characteristic

An important factor that affects the efficacy of UVC for food treatment is the sensitivity of the targeted microorganisms to UVC light. When designing a treatment process, complete UVC knowledge of decimal reduction / inactivating microorganisms is required.

Accurate quantification of radiation is critical for microbial inactivation in any UVC light experiment. The disinfection produced by UVC light energy directed on a single microbial population can be expressed as follows: $N_t/N_0 = e^{-k.E.\Delta t} = e^{-k.D}$

Where N_t/N_0 Is the fraction of surviving microbes (N_0 and N_t are the initial and final microbial populations, respectively, after time Δt); k is the microbe-dependent inactivation constant; E is the effective germicidal irradiance received by the microorganism ($\mu\text{W cm}^{-2}$); and D is the UVC dose, i.e., amount of radiant energy applied to a particular area in a particular time (mJ cm^{-2}) ([Murata et al., 2013](#)).

The antimicrobial action of UVC radiation is expressed in terms of the dose (D) of UVC intensity flux, which depends on the intensity/current (I) of UVC and the exposure time (t), as determined by the following equation: $D(\text{mJcm}^{-2}) = I(\mu\text{Wcm}^{-2}) \times \text{time(s)}$

The UVC flow rate is the total radiant flux that passes through the unit area in all directions, and this must always be determined exactly at the location of the exposed food sample. However, the energy fluence does not indicate the actual radiation energy absorbed by the food ingredients ([Schindl et al., 2001](#)).

A large amount of radiant flux produces a high dose of UV that will provide an efficient microbial inactivation process. The radial model is one of the most important models for evaluating the delivery of UVC current to microorganisms, which is shown below:

$$I(r) = (P_L / 2\pi r) \cdot e^{-\alpha \cdot r}$$

Where $I(r)$ is the UVC fluence rate at radial distance r from the lamp; P_L is the UV power emitted per unit arc length of the lamp, and α is the absorption coefficient (cm^{-1}) ([Singh et al., 2021](#)).

Studies also revealed that the smallest cells are more resistant to UVC radiation because of the amount of light absorbed by each cell. Additionally, molds and yeasts are more resistant as compared to other microbes as they have different cell membranes, thicknesses, and a smaller number of pyrimidine bases ([Atilgan et al., 2021](#)).

Food product features

The performance of microbial inactivation depends on the composition of the food product being treated. For liquid foods, UVC light penetration is related to color, optical density, viscosity, turbidity, (PH), thickness, and chemical composition. UVC penetration in fruit juices and other liquid products is generally limited because of their high optical density. Additionally, UV absorbance and turbidity are two key optical properties that significantly impact the effectiveness of UVC treatment. Differences in the absorption coefficient (α) of liquid foods are observed between different components that absorb light differently. Fruit juices and beverages have low UVC light transmission capacity, which can reduce the antimicrobial effectiveness of radiation. Clear liquid foods have lower absorption coefficients than pulp juices or food matrices with suspended solids ([Sorica et al., 2014](#)).

Because increasing the amount of α reduces the ability of UV light to penetrate the food, a high α value reduces the antimicrobial efficiency of any delivered UVC dose. Therefore complete information and characterization of the absorptive characteristics of liquid food items and juices are thus vitally important when estimating the required UVC dose. The presence of suspended solids and soluble components in the food matrix can also attenuate the effects of UVC radiation by inducing light scattering, absorption, and reflection. Some effects of ultraviolet (UV) light on food products are presented in Table 2. Which shows the dose of UV light, UV region, and observed effect on Fruit/Vegetable preservation ([Koutchma et al., 2008](#)). _

Table 2: Effect of different UV radiation on nutritional and physico-chemical properties of various fruits and vegetables.

Fruit/Vegetable	Treatment	Time and Dose	Observed Effects	Reference
Grapes	UV-C and UV-B	3.6 kJ/m ²	- pH, TA & TSS not adversely influenced during storage - Significant increment in anthocyanin (0.24 g kg⁻¹) and flavanol content by 9.40% & 19.56% at 14 days of storage by UV-C treatment compared to UV-B treated and controlled samples	Sheng et al., (2018)
'Phulae' Pineapple	UV-C light	10 min & 13.2 kJ/m ²	- Vitamin-C content increased with storage up to 28 days at 10 °C then gradually decreased (1.79 ± 0.04) - TFC of peel enhanced (20.75 ± 0.07c) at 28 days of storage	Sari et al., (2016)
Broccoli florets	UV-B light	1.5 kJ/m ² (hermetic)	- Yellowing of broccoli florets delayed by storage in the dark at 4 °C - During storage at 4 °C for 14 days: - Respiration rate increased - AA increased by 7% - Total glucobrassicin increased by 18% - Glucoraphanin increased by 11%	Duarte-Sierra et al., (2020)
Peaches	UV-B, UV-C light & combination of both	0.36 kJ/m ² , 0.72 kJ/m ² & 10 min 20 mins	- UV-B & UV-C alone or in combination inhibited the increase in TSS of the samples - Compared to UV-B, TSS inhibition was more in UV-C irradiated fruit UV-C treated peaches maintained high vitamin-C content (8%) compared to UV-B treatment - At the end of the storage period, a loss of more than 28% of vitamin C was observed in controlled samples compared to the treated ones	Abdipour et al., (2019)
Fresh-cut spinach leaves	UV-B light	0.6 kJ/m ² & 10 min	Storage period decreases TSS (6.4%) compared to controlled samples (8.25%)	Kasim and Kasim (2017)
Button Mushrooms	UV-C	1 kJ/m ²	Highest GDHB, GHB and TPC was found in gill	Wu et al., (2016)
Apple skin	UV-B light	36 h 219 kJ/m ² &	- TFC & TPC were reduced but at the end of the storage period, an accumulation of TPC was observed as compared to controlled samples - AA, Anthocyanins, and Hydroxycinnamic acids (38%) were increased and maintained at the time of storage - No significant effect was found on dihydrochalcone	Assumpcao et al., (2018)
Mangoes	UV-B	5 kJ/m ² for 4 h	- AA and polyphenol content were increased - Reduction was observed in the rate of ion leakage and MDA content	Jaing et al., (2015)

Current status of international legislation and regulations

The potential utility of UV light, as an emerging food processing technique, has attracted much attention. Specific international and national organizations, including the US Food and Drug Administration, the US Department of Agriculture (US FDA), and the European Food Safety Authority (EFSA), have already approved the use of UV rays to control microorganisms in food products. US FDA regulations do not mention any minimum/maximum UV dose to be applied during food processing. Instead, these criteria should be established on a case-by-case basis, under good manufacturing practices. In addition, the FDA expects the maximum dose applied to food products to be economically acceptable due to the costs associated with UV irradiation. In 2000, the US FDA amended the Food Additive Regulation to guide the safe use of UV at 253.7 nm. These modifications can help reduce human pathogens and microorganisms in fruit juices. Low-pressure mercury lamps, which emit 90% of the light emission at a wavelength of 254 nm, are the preferred source of UV light ([Komolprasert, 2016](#)).

The Food Safety and Standards Authority of India (FSSAI) defines novel food as "a food item for which standards have not been specified but is not considered unsafe, Provided that such foods do not contain any of the foods and ingredients prohibited by this law".

In six jurisdictions, UV-treated foods are new foods, including the European Union, the United Kingdom, Canada, Australia, New Zealand, and China. Complete knowledge of the legislation and regulations of each country can support equipment manufacturers in bringing their products and technology to market quickly and at a lower cost ([Pisanello & Caruso, 2018](#)).

Result and discussion

UV-C ultraviolet non-ionizing radiation reduces microbial populations in foods as an alternative to chemical decontamination. It has been approved for use as a disinfectant for treating exterior surfaces. Proper control of pathogens and perishable microorganisms in food products is a prerequisite for promoting food safety and maintaining health standards for complete and good health. UV light therapy is an economical and eco-friendly technology; that has shown very high potential in the food industry. UVC irradiation is an emerging non-thermal method for decontaminating food products. This technology is the best way to inactivate pathogenic and perishable microorganisms, in beverages and food products. Also, disinfecting foods by UVC does not produce any chemical waste or toxic products.

Combining UV light with other techniques (hurdle technology) is also considered today. Despite several advantages related to the UVC technique, certain difficulties can limit the large-scale application in the disinfection of food products. For example, the efficiency of microbial inactivation with UVC light is mainly influenced by the physical properties of the food. The low penetration power of UVC to treat food products with large areas requires higher dosages. Such long food irradiation of UVC can affect food quality. Therefore, for successful inactivation of microbes in different food products, UV doses and optimizing exposure time should be considered.

Comparing the disinfection effect of UVC light with other methods, it was found that there is no better disinfection method than UVC light. Other disinfectant methods which use chemical materials are time-consuming and laborious, as well as harmful to workers and the environment. In addition to the permissible limits specified by regulatory authorities (FDA), before application on a larger scale, they must be accurately tested and examined on a lower scale. Methodological work in microbial inactivation studies; it is also important to inspect how pulsed optical or UV LED technology can affect the nutritional quality and sensory characteristics of the food being treated. Issues related to ozone production, economic facilities, and the safety of workers should also be considered shortly.

Conclusion

To prevent fruits and vegetables from microbial contamination, irradiation is the best reported method because ultraviolet light has antiseptic properties. When food is exposed to UV light, specifically in the UV-C region, most microbes are deactivated, which helps to prolong the food's shelf life. UVC irradiation processing effectiveness of food is influenced by many factors, like the operational parameters of the UVC equipment, characteristics of the microbes, and the composition of the food material. These elements play a key role in the UVC treatment. Among these, a UV-C wavelength of 254 nm is particularly effective for decontaminating food compared to other wavelengths.

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Current Status and Sustainable Solutions to Food Security: A Case Study in Paktika

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Abstract

One of the major problems affecting Afghanistan's growth is food insecurity. The study's objectives were to assess Paktika's present level of food security and propose sustainable solutions to Afghanistan's food security issue. A study including one hundred individuals from Sharana (center of Paktika) and three other districts was carried out in the province of Paktika. The study discovered that there were 23569 cases of malnutrition in the first quarter of 1402, based on a mix of field observations and surveys. Of those surveyed, 92 % had little food options, 97 % were unable to eat their favorite meals, and 86% were concerned about their family members' lack of food. Afghanistan's food security can be enhanced by raising productivity in agriculture, providing funds for agricultural education and training, diversifying the sector, opening up markets, utilizing modern technology, developing infrastructure, strengthening capacity, promoting microfinance, supporting good governance, and funding research.

Keywords: [Agricultural production, Climate Change, Food security, Malnutrition, Sustainable solutions]

Introduction

For there to be sustained food production and access for individuals, groups, and society as a whole, there must be food security. Additionally, it supports population, economic, political, cultural, and intellectual growth (Yerlan, et al., 2023). The FAO's 1974 proposal for food security aims to ensure everyone has access to safe, nourishing food, a human right that protects against malnutrition and maintains a balanced diet (Okoko et al., 2023). Since 2020, global food insecurity has worsened due to factors such as COVID-19, economic shifts, climate change, commodity price variations, diseases, pests, and regional wars (Jiang and et al., 2023). Prices of food fluctuate greatly, especially in developing countries, and this has an impact on food security (Tasleem and et al., 2023). Implement modern irrigation techniques, reduce water usage in crops, and transition to dry farming to mitigate the effects of climate change on food security (Marzban et al., 2023). In Afghanistan 80% of people living in rural areas, agriculture is their main source of income, which is essential for the nation's food security and economic growth (Kawasaki et al., 2012). Malnutrition is a pressing issue that cannot be addressed by a single sector, and the absence of cross-sector cooperation poses a significant challenge (Levitt and Pelletier, 2011). Various problems, such as natural catastrophes, conflict, infrastructure, land ownership disputes, contaminated water, and insufficient health and education systems, make it difficult for people in underdeveloped countries to acquire food security (Berman et al., 2013).

Hunger hinders a nation's economic, social, and political development due to factors like insufficient production, storage, processing, climate change, natural disasters, weak policies, and uncontrolled population (Ilaboya et al., 2012).

Food insecurity leads to costly, chronic diseases like overweight, obesity, and mental illness in adults, poor growth and development in children, dental caries, socioemotional impairment, and behavioural issues (Booth and Pollard, 2020).

In 2007, more than 42% of Afghans lived in poverty, and until 2014, 78.2% of households in urban areas will continue experience food shortages (Kakar et al., 2019). Therefore, the study showed Paktika's current degree of food security and proposed sustainable solutions for food security.

Materials and Methods

The study used both primary and secondary sources, such as field observations, questionnaires, and data from the General Office of Nutrition's Public Health Directorate of Paktika, as well as journals, papers, and conference proceedings. The questionnaire for this study was adapted from Coates et al. (2007). The data collected from the questionnaires was descriptively evaluated, and the results were used to support the study's desired findings. The questionnaires were translated into Pashto, Afghanistan's indigenous language, so that respondents could easily understand them and provide the proper responses. The questionnaire, which comprised closed-ended questions, was distributed to 100 citizens of Sharna, the administrative center of Paktika, as well as the three districts of Muta Khan, Orgon, and Khair Kot. A descriptive analysis of the obtained results was carried out using SPSS 24. The research analysis strategy was frequency and percentage.

Results and discussion

In order to measure food insecurity, this study uses a questionnaire containing nine occurrence and frequency-of-occurrence questions. All family members, including adults, children, and adolescents, are addressed by the questions, which encompass perceptions of food vulnerability and behavioural reactions without making a distinction between adults and children. The HFIAS (Household Food Insecurity Access Scale) occurrence questions, which concentrate on three food insecurity categories, examine household members' attitudes or actions over the previous four weeks.

Table (1): Summary of Questionnaire Results

Three domains of food insecurity	Questions	Parameters	Survey participants responses	
		Rarely = once or twice, Some times =three to ten times and Often = more than ten times in the past four weeks	Frequency	Percentage
Anxiety and uncertainty about the household food supply	Did you worry that your household would not have enough food?	Never Rarely Sometimes Often Total	14 31 39 16 100	14.0 31.0 39.0 16.0 100.0
Insufficient Quality (includes variety and preferences of the type of food)	Were you or any household member not able to eat the kinds of foods you preferred because of a lack of resources?	Never Rarely Sometimes Often Total	3 30 39 28 100	3.0 30.0 39.0 28.0 100.0
	Did you or any household member have to eat a limited variety of foods due to a lack of resources?	Never Rarely Sometimes Often Total	8 35 34 23 100	8.0 35.0 34.0 23.0 100.0
	Did you or any household member have to eat some foods that you really did not want to eat because of a lack of resources to obtain other types of food?	Never Rarely Sometimes Often Total	15 23 35 27 100	15.0 23.0 35.0 27.0 100.0
Insufficient food intake and its physical consequences	Did you or any household member have to eat a smaller meal than you felt you needed because there was not enough food?	Never Rarely Sometimes Often Total	9 36 35 20 100	9.0 36.0 35.0 20.0 100.0
	Did you or any household member have to eat fewer meals in a day because there was not enough food?	Never Rarely Sometimes Often Total	10 35 32 23 100	10.0 35.0 32.0 23.0 100.0
	Was there ever no food to eat of any kind in your household because of a lack of resources to get food?	Never Rarely Sometimes Often Total	9 35 30 26 100	9.0 35.0 30.0 26.0 100.0
	Did you or any household member go to sleep at night hungry because there was not enough food?	Never Rarely Sometimes Often Total	31 29 22 18 100	31.0 29.0 22.0 18.0 100.0
	Did you or any household member go a whole day and night without eating anything because there was not enough food?	Never Rarely Sometimes Often Total	38 25 21 16 100	38.0 25.0 21.0 16.0 100.0



Figure 1: Patients with malnutrition at Paktika Central Hospital

According to the table (1), 86% of respondents are concerned about the food insecurity of their family members. 97% find it difficult to eat their chosen foods, 92% consume a limited variety of foods and 85% consume undesirable foods. 91% consume smaller meals and 90% consume fewer meals per day as a result of food shortage. 90% of households lack food due to lack of resources, 69% went hungry at night, and 62% went without food all day and night in the past four weeks.

According to the unpublished report of General Office of Nutrition (Paktika Public Health Directorate) in the first quarter of the 1402 solar year (Hamal, Sawar, Jawza, and Sarathan), there were 7830 PLW (Pregnant and Lactating Woman), 6788 MAM (Moderate Acute Malnutrition), 8495 OPD SAM (Severe Acute Malnutrition), and 456 IPD SAM positive cases of malnutrition in Paktika. With the financial assistance of WFP and UNICEF, 6202 PLW, 4836 MAM, 8377 OPD SAM, and 363 IPD SAM patients have received treatment. As reported by Ahmadzai (2014), children in Afghanistan have the highest rates of chronic malnutrition in the world. 72% of Afghan children under five are deficient in micronutrients like iron and iodine, with 34% of them being underweight and suffering from chronic malnutrition. Restoring horticulture in Afghanistan will strengthen the country's economy, give up to 80% of its people jobs, and improve food security (Yousufi, 2016). Green biotechnology is a promising and significant potential solution to address food insecurity (Nasser et al., 2021). Increasing agricultural production, enhancing science and technology, facilitating market access, rural off-farm opportunities, capacity building, gender-sensitive development, adequate storage facilities, bioethanol/diesel production, and good governance can significantly improve food security (Ilaboya et al., 2012). Effective macroeconomic management is crucial for ensuring social welfare (Nwalie, 2017). To encourage the gradual improvement of long-term household food security, governments should provide an extensive package of public goods (Hendriks, 2015).

Conclusion

Food security aims to ensure everyone has access to safe, nourishing food, a human right that protects against malnutrition and maintains a balanced diet. Food insecurity hinders a nation's economic, social, and political development due to factors like insufficient production, storage, processing, climate change, natural disasters, weak policies, and uncontrolled population. In Paktika 86% of respondents of the survey are worried about the food insecurity of their family members. 97% find it difficult to eat their chosen foods, 92% consume a limited variety of foods and 85% consume undesirable foods. According to the study findings there were 7830 PLW, 6788 MAM, 8495 OPD SAM, and 456 IPD SAM positive cases of malnutrition in Paktika. There are several economic ways to improve food security in Afghanistan. Here are some potential strategies:

increased agricultural production, improving infrastructure, investing in agricultural education and training programs, improving infrastructure, diversification of agriculture, market development, green biotechnology, strengthening value chains, capacity building, microfinance support, good governance, and investing in research.

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Zinc Fertilization Assessment on Productivity and Safety of Maize, Rice, and Wheat Grain Production

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Abstract

Zinc (Zn) is one of the essential micronutrients for all organisms, including humans. In farmland, Zn deficiency is one of the main reasons for low productivity and quality of cereal crops, which ultimately results Zn deficiency in consumers. Maize, rice, and wheat crops are the most consumed grain sources that remained more sensitive to Zn deficiency. For these crops, sufficient availability of Zn in farmland is required for healthier growth and development. Zn fertilization is effective strategy for increasing crop productivity and enhancing Zn concentration in mention crops. Depending on soil fertility and cultivated crop variety, soil application and/or foliage spray of Zn fertilizer in the range of 5–30 kg/ha and/or 0.2–2%, respectively, which is the most desirable and effective application technique with high grain yield and maximum Zn concentration in grains. Zn fertilization boosts grain yields of maize, rice, and wheat, respectively, up to 65, 130, and 43%, whereas Zn accumulation in grains has increased up to 57, 38, and 80%. Since Zn is a heavy metal and its unsuitable availability may cause hyper-accumulation in soil-plant systems beyond the safe limit (<60 mg/kg), constant evaluation of the environmental contamination is required.

Key Words: Food, Maize, Zinc, Wheat, Rice, Health

Introduction

Zinc (Zn) is one of the important minerals for all plants and animals, including humans. This is the second most essential trace element in the human body after iron (Fe), which is involved in several structural, regulatory, and physiological functions of plants and humans (Elsayed et al., 2022; Obaid et al., 2022). Zn insufficiency affects nearly 20% of the world's population, particularly mothers with newborn babies, children under the age of five, and the elderly (Cakmak & Kutman, 2018; Johansen & Ekelund, 2018; Khanet et al., 2022).

Despite the high importance of Zn, soil Zn deficiency is one of the major agricultural problems that could have negative effects on food security and safety, as well as consumer health. (Amanullah et al., 2020; Liu et al., 2020). Soils deficient in Zn account for 30 to 50% of all arable land (Zhang et al., 2019), and crops produce roughly 60% of the targeted yield when a Zn deficiency is present (Amanullah et al., 2020). Recently, research has shown that Zn fertilization is more efficient in water-deficient zones, such as Afghanistan, because the input reduces irrigation requirements and increases plant tolerance to drought as well (Elshamly et al., 2024). Zn-enriched grain production (particularly maize, wheat, and rice) may be safe and suitable for consumer health. Zn-enriched grain production should be produced under optimal farming conditions and agronomic practices to achieve the highest Zn level.

In cereal production, Zn application is a more suitable solution to produce adequate Zn-enriched production, including low-phytate content in the products (Khan et al., 2022; Prahara et al., 2021). Many factors control the availability and content of Zn in soil followed in productions and consumers, such as Zn status in culture media, agronomic practices, nutrient management, plant verity and root system, Zn fertilization, soil condition and amendments, and consumer health status (Obaid et al., 2022; Saleem et al., 2022). Several studies reported that nutrient management, including Zn fertilization, is a well-known, easiest, economic, and safe technique of Zn-enriched grain production, including low phytic acid in the production (Elsayed et al., 2022; Hui et al., 2022; Obaid et al., 2022). Good agronomic practices' management, including Zn input, improves soil Zn availability, plant productivity, and quality, and improves an adequate amount of Zn in the maize-, wheat-, and rice-based diets that lastly remediate Zn deficiency risks of the humans.

Nutritional value of maize, rice, and wheat productions

Cereal productions are important diets and vital energy sources for animals and humans. From cereal, maize (*Zea mays* L.), wheat (*Triticum aestivum*), and rice (*Oryza sativa*) are three important staple grain foods in many countries for livestock, poultry, and humans (Cakmak, 2008; Liu, et al., 2020; Poutanen et al., 2022; Rawat et al., 2023), which supply around 51 and 47% of calories of protein, respectively (Poutanen et al., 2022). It was reported that over three-fourths of the world's grain production is generated from maize, wheat, and rice (Singh, 2022). These crops' productions are multipurpose groups that are produced for food, beverage, dietary fiber, fodder, hay, forage, and industrial resources such as starch, phytochemicals, alcohol, glue, ethanol fuel, oil, bread, etc. (Leff & Foley 2004; Liu et al., 2020).

The total annual production of cereal grain is estimated at around 2,500.0 and 4.83 million metric tons worldwide and in the Afghanistan, respectively (World Bank, 2024). The productivity and quality of maize, rice, and wheat productions needed to be further enhanced in order to ensure food security and food safety (Table 1, 2). According to the Zn level, one hundred grams of each of these crops grains contains about 1.6–2.5 mg of bioavailable Zn (on a dry weight basis), which accounts for about 15–30% of a human's daily Zn requirement (Bevis & Hestrin, 2020; Obaid et al., 2022; Reinberg et al., 2021). Even though these products are high in calories and protein but have low Zn levels in the products, offering a barrier for consumer health. In general, the required safe level of Zn, defined by the FAO and WHO, for food is less than 60 mg/kg in crop production (FAO/WHO, 2015; Obaid et al., 2022), whereas the Zn level was not exceeded by 37 mg/kg even in Zn-enriched grains of milled and non-milled products of these crops (Reinberg et al., 2021). However, Zn insufficiency is a common occurrence in these crops, and these crops are more sensitive to soil Zn deficiency (Khan et al., 2022). Consequently, Zn fertilization could be an effective agronomic approach that improves maize, rice, and wheat productivity as well as Zn grain bioavailability up to the expected level (>40 mg/kg).

Table 1 Annual required enhancement of maize, rice, and wheat productions in Afghanistan

Crop	Annual Productions by Million Metric Ton	Required Enhancement (%)	References
Maize	0.27	25.0	Elham et al. (2023), Sharifi et al., (2024)
Rice	0.59	34.9	Ariana (2020)
Wheat	5.00	28.6	Salam (2024)

Zn Functions, Intake Levels, and Controlling Factors in Human Body

Zn is the second most commonly essential trace element in the human body after iron (Fe), and it may be found in bone, skeletal muscle, the brain, the liver, and skin (Hara et al., 2017; Obaid et al., 2022).

Zn is necessary for the biological system to function properly, as it acts as a catalytic, structural, cofactor in enzymatic reactions, vitamin A metabolism, membrane stabilization, and regulatory ion in the homeostatic mechanism. It also has a role in immune responses, oxidative stress, apoptosis, fetal growth and development, and the ageing process (Cabrera-Soto et al., 2018; Ryu & Aydemir, 2020). Insufficient Zn has been linked to poor pregnancy outcomes, growth retardation, early mortality, immune system malfunctions, neurobehavioral disorders, and lately, the inability to fully recover from COVID-19 (Khan et al., 2022).

Human Zn deficiency is a main problem worldwide. A range of metabolic problems arise in the body when the homeostatic mechanism is interrupted by severe Zn deficiency (Himoto & Masaki, 2018). In studies (Dumrongwongsiri et al., 2020), Zn supplementation from breast milk has been shown to be important for newborn growth and development and brain function. Zn supplementation can significantly reduce the risk and severity of pneumonia (Obaid et al., 2022). Because they are more prone to age-related diseases and have immunological and sensory deficiencies, the elderly require a high Zn intake (Obaid et al., 2022).

The amount of Zn required by the human body varies depending on age and gender, and the daily recommended intake (DRI) based on age and gender is different. Children and adults require 1.1–11.2 and 3.0–19.0 mg Zn/day, respectively, although pregnant and lactating women require much more (25–30 mg/day) (Manzeke et al., 2019). The DRI of Zn for people over the age of 70 is 11 mg/day, while for men and women it was counted about 8 mg/day (Cabrera-Soto et al., 2018). At the range of 2–4 g, Zn is found in the human body and is dispersed through plasma (Gammoh & Rink, 2017). Zn is distributed within the cytoplasm, nucleus, and cell membrane by Zn transporters, which strictly regulate cellular and subcellular Zn homeostasis once it is absorbed from meals by the small intestine (Hara et al., 2017). Unlike Fe, the human body cannot store Zn via a specialized storage system, thus requiring a sufficient daily intake of Zn-enriched foodstuffs (Trame et al., 2018). The two main factors that control Zn bioavailability in the human body are Zn quantity and Zn availability in foodstuffs (Obaid et al., 2022). The bioavailability of Zn is also linked with other components such as phytic acids, dietary fiber, tannin, lignin chelates Zn, polyphenols, and oxalate (Castro-Alba, Lazarte, Bergenståhl, & Granfeldt, 2019). These non-digestible plant ligands were responsible for Zn movement, absorption, and translocation (Akhtar et al., 2018). Phytate (myoinositol hexaphosphate) is a common biochemical that controls Zn bioavailability in meal (Pramitha et al., 2020). When the ratio between phytic acid and Zn (PA: Zn) in grain exceeds 15:1, the absorption rate of Zn is reduced in the digestive system, hence leading to Zn deficiency (Obaid et al., 2022). Up to 18% less phytic acid is present in grains when zinc is applied (Alikhani et al., 2023).

Biological Functions of Zn in Plant

Zn is an essential micronutrient for plant growth and development. It is involved in several physiological and biochemical processes. It serves as a catalyst for the activation of more than 300 enzymes (Elsayed et al., 2022; Noulas et al., 2018). Furthermore, Zn is an important cofactor for several enzymes in biochemical pathways in plants (Heerema et al., 2017). Zn is also improving plant photosynthesis, growth, and productivity, as well as being involved in several protective functions of plants.

Zn function in protein and enzyme synthesis

Zn is essential for plant protein and enzyme synthesis and stabilization. It's an integral part of approximately 1200 proteins. It is required for DNA regulation and RNA synthesis, as well as protein-protein interactions (Alloway, 2008; Khan et al., 2018).

Zn is required for DNA transcription factor function and structure, as well as the stability of several regulatory proteins such as Zn-fingers, Zn-clusters, and Ring finger domains (Broadley et al., 2007; Kathpalia & Bhatla, 2018; Shyam 2020). The amount of protein is considerably reduced, but the composition is nearly similar. The mechanisms by which Zn deficiency affects protein production are thought to be RNA reduction and ribosome distortion and reduction (Alloway, 2008).

Zn is required as a cofactor for many enzymes' activity, such as carbonic anhydrase, alcohol dehydrogenase, glutamic dehydrogenase, L-lactic dehydrogenase, malic dehydrogenase, D-glyceraldehyde-3-phosphate dehydrogenase, D-lactate dehydrogenase, Aldolase, carboxypeptidase, alkaline phosphatase, superoxide dismutase, RNA polymerase, Ribulose bi-phosphate carboxylase, and phospholipase (Alloway, 2008). The carbonic anhydrous (CA) enzyme is essential for plant growth that involve in CO₂ dehydration and catalysis process. CA increases CO₂ absorption per leaf surface unit, photosynthesis, and biomass production. This enzyme's activity is inhibited in plants suffering from Zn deficiency (Marschner, 1995; Suganya et al., 2020). CA activity, chloroplast photochemical activity, chlorophyll content, and changes in chloroplast structure can all have a negative impact on photosynthesis (Shyam, 2020).

Zn for chlorophyll contents and photosynthesis

Zn also improves chlorophyll contents and photosynthesis. Zn's participation in the activity of some enzymes, such as the carbonic enzyme, which is required for chlorophyll biosynthesis (Sabir & Sari, 2019). Additionally, the role of Zn in photosynthesis enzymes (carbonic anhydrase) and photochemical processes of photosystems could explain why Zn treatment increases photosynthetic rate (Bouain et al., 2014; Sabir 2019). Zn also improves the pigment chlorophyll, which is a key component of photosynthesis. Zn application had a positive effect on chlorophyll content when compared to untreated plants (Munirah et al., 2015).

Zn Effect on Plant Growth and Productivity

Zn is a component of important growth regulators, such as Indole Acetic Acid and Gibberellic Acid. These hormones are important for the development of plant leaves (Drissi et al., 2017). According to Wasaya et al. (2017), enhancing the leaf length and width could possibly be due to the role of Zn in cell division. As a result of Zn's beneficial effect on the chlorophyll, leaf area, and photosynthesis rate, Zn has an important role in improving plant biomass and productivity (Elsayed et al., 2022; Li et al., 2020; Liu et al., 2020).

Organs require Zn, such as flowering, male and female gametogenesis, zygote production, and seed development. Microsporogenesis, pollen grain formation, pollen fertility, and seed setting all require a sufficient level of Zn (Shyam, 2020). Under Zn-deficient conditions, plants produce less pollen, resulting in a higher percentage of empty grain locations (Castillo-González et al., 2018; Liu et al., 2017).

Zn Protective Function in Plant

Zn has an essential role in the lignin and suberin synthetic processes, which produce antioxidants to increase the cell wall strength to protect the plant from pathogens' attack. It is required for several enzymes to participate in plant defiance systems, such as ADH and SOD enzymes (Cakmak, 2000; Zhang et al., 2016). Zn participates in reactive oxygen species (ROS) detoxification, which has a very harmful effect at high concentrations on organisms because it oxidizes the lipids, oxidizes proteins, damages the nucleic acid, inhibits enzymes, and ultimately causes cell apoptosis (Cakmak, 2000; Shyam, 2018; Zhang et al., 2016).

Zn levels and availability influences in farming soil

Zn is one of the metallic and more active elements in the soil solution, typically not extant in absolved form (Zn^{2+}) that reacts with different constituents and produces complexed compounds in soil. In the farmland, Zn deficiency is a worldwide issue that has a negative impact on agricultural productivity and quality (Amanullah et al., 2020; Liu et al., 2020). Deficient Zn soils have DTPA-extractable Zn levels of less than 0.5 mg/kg (Lindsay & Norvell, 1978; Liu et al., 2020). In the soil, several factors negatively affect Zn absorption and accumulation in edible parts. In the soil, the low amount of available Zn and high pH levels (> 7) are the mean factor that reduces required Zn. Meanwhile, high content of organic matter, CaCO_3 , and soil type and also reduces Zn availability (Alloway, 2009; Pfaender et al., 2017). Sand, calcareous, saline, and wetland soils that are tightly compacted, contain substantial organic matter, and have high levels of phosphates and nitrogen is among the soil types that are susceptible to Zn deficiency (Saleem et al., 2022).

Zn Agronomic biofortification

Plant biofortification is an effective way to increase the crop yield and nutrient concentration in plants (Obaid et al., 2022; Waters & Sankaran, 2011). Plant biofortification has two methods: plant breeding and agronomic biofortification (Obaid et al., 2022). Kumssa et al. (2015) suggest that, fertilizer application (especially Zn fertilization) is one of the easiest, quickest, and most cost-effective methods of agronomic biofortification.

Agronomic biofortification is a direct and cheap method of improving the nutritional content of food (Marques & Kraft, 2021; Obaid et al., 2022). The effective biofortification plan should increase grain productivity with a high Zn concentration in the grain (Table 2). Spraying, soil application, and seed coating techniques are beneficial in Zn-deficient soils as they enhance the plant's ability to absorb more micronutrients directly, which will significantly improve the crop's growth and yield (Obaid et al., 2022). From different fertilization methods soil application (5-30 kg/ha) plus foliage spray ($\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$, 0.2-2%) are most effective and desired application techniques with high grain yield and maximum Zn concentration in grains.

Zn Fertilizers and Application Method

Zn fertilizer application is the primary method of combating Zn deficiency in soil-plant systems. Different sources of Zn fertilizers are used to overcome soil Zn deficiency. ZnSO_4 (Zn 22-36%), ZnO (Zn 50-80%), and ZnCl_2 (Zn 50%) and chelating sources such as Na_2ZnEDTA (Zn 8-14%) and NaZnHEDTA (Zn 6-10%) are common inorganic Zn fertilizer sources (Loneragan & Webb, 1993; Montalvo et al., 2016). Zn fertilizer can be applied by several methods, such as foliar sprays, soil application, and/or seed treatment of Zn salts (Alloway, 2009). Zn fertilizer application, as a soil application, is an easy and effective way to grow some plants, such as maize, rice, and wheat (Elsayed et al., 2022; Islam et al., 2021; Nayak et al., 2023).

Table 2 At Zn deficient soils, Zn Application increases grain yield and Zn concentration of maize, rice, and wheat crops

Crop	Location	Increases in grain yield	Zn conc. in grain	References
		(%)		
Maize	China	19.7	56.6	Elsayed et al. (2024)
	A meta-analysis	17.0	25.0	Mutambu et al. (2023)
	Argentina	64.6	54.8	Martínez-Cuesta et al. (2021)
Wheat	Bangladesh,	15.9	36.8	Khan et al. (2023)
	Pakistan	25.5	36.7	Khan et al. (2023)
	Iran	43.0	19.0	Alikhani et al. (2023)
Rice	Pakistan	11.0	28.0	Akmal et al. (2023)
	Pakistan	130	77.0	Shah et al. (2023)
	Bangladesh	30.9	25.8	Islam et al. (2021)
	Pakistan	22.4	79.7	Mehmood & Hussain (2023)
	Kashmir	47.6	80.4	Hussain et al. (2018)

Conclusion

Zn deficiency in soil is an effective reason that reduces maize, rice, and wheat production and Zn bioavailability in grain. Zn fertilization is used to overcome soil Zn deficiency problems. Thus, Zn fertilization could be an effective agronomic approach that improves maize, rice, and wheat productivity as well as Zn grain bioavailability up to the expected level (>40 mg/kg). Concerning soil fertility and cultivated crops, Zn fertilization as soil application in the range of 5–30 kg/ha and/or 0.2–2% foliage spray are the most effective and desired application techniques with high grain yield and optimum Zn concentration in grains. Zn fertilizer application improves productivity of maize, rice, and wheat in the range of 17-65, 11-130, and 15-43%, respectively. Meanwhile, the application increased Zn concentrations in the range of 25-57, 19-38, and 25-80% in the maize, rice, and wheat grains, respectively. Zn salts, such as $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$, ZnO , and ZnCl_2 , are Zn fertilizers that can be used as sprays, soil applications, and seed treatments, while soil application is an easy and effective method to improve productivity and Zn concentration of grain. High-accumulation of Zn as a heavy metal in soil and plant edible parts could be toxic for plant and human health. Therefore, the balance between improving crop productivity, Zn bioavailability using Zn fertilizers and its effect on soil contamination and the environment still needs more investigation.

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Nutrient Management in Pearl Millet under Conservation Agriculture in arid ecologies

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Abstract

Pearl millet (*Pennisetum glaucum* L.) is a major cereal crop of semi-arid and arid regions, cultivated on nearly 31 million hectares across more than 30 countries in Asia, Africa, and Latin America. Global annual production exceeds 15 million tonnes, with India contributing almost half of the total output. Pearl millet supports the food security and livelihoods of over 30 million resource-poor people, particularly in drought-prone environments. However, productivity in rainfed systems remains low and unstable due to frequent droughts, limited biomass recycling, low soil organic matter, multi-nutrient deficiencies, nutrient depletion, sub-optimal fertilizer use, and poor nutrient use efficiency. As a result, yields in rainfed areas are only one-third to half of those achieved under irrigated conditions. These constraints are further intensified by rising food and energy costs, declining water resources, soil degradation, desertification, biodiversity loss, and climate variability, posing serious risks to food security. Conservation Agriculture (CA) has emerged as an effective pathway for sustainable intensification by improving nutrient use efficiency, conserving soil and water, enhancing soil carbon sequestration, reducing production costs, and stabilizing yields. Nutrient management under CA-based pearl millet systems offers a resilient strategy to enhance productivity while promoting long-term environmental sustainability.

Key words: Conservation agriculture, Nutrient management, semi-arid and arid ecologies, cropping system

INTRODUCTION

More than 90 million desperately poor people depend on pearl millet for food and income. They generally live in the drier parts of Africa and Asia, places where most other crops just won't grow and local farm households literally have nowhere else to turn for food security. Fortunately, pearl millet is not just a resilient and dependable source of energy, but also a good source for other dietary needs, especially micronutrients. Pearl millet covers an estimated 31 million hectares worldwide and is grown in more than 30 countries located in the arid and semi-arid tropical and subtropical regions of Asia, Africa and Latin America. The crop is well adapted to agricultural areas that are afflicted by severe drought, poor soil fertility, and high temperatures. It also grows well in soils with high salinity or low pH. Because of its tolerance to such challenging environmental conditions, it is often found in truly marginal areas where other cereal crops, such as maize or wheat, can't survive (ICRISAT, 2019). Pearl millet accounts for about 50% of the total global production of millets. India is the largest single producer of the crop, both in terms of area (9.3 million hectares) and production (8.3 million tons).

The West and Central Africa region has large areas under millets (15.7 million hectares), of which more than 90% is pearl millet. The crop is cultivated on more than 2 million hectares in the Eastern and Southern Africa region (GOI, 2019).

Pearl millet is largely grown as a rainy season crop under rainfed conditions in Asia and Africa. Under these conditions, it is often grown as a component of intercropped or mixed cropping systems with legumes, such as chickpea, mustard, wheat, barley, pigeon pea, groundnut and cowpea, or with such cereals as sorghum and maize. On the other hand, it is rarely grown in mixed or intercropped systems, except in the very dry areas of Northwest India (Bana *et al.*, 2013).

In the Cerrado Savannah region of Northeast Brazil, pearl millet is grown as a mulch crop in no-till soybean systems – taking advantage of its tolerance to the acidic subsoil to produce a dense mulch that limits weed growth, prevents soil erosion, and recycles soil nutrients recovered from depth. And in central Asia it is being tested as a rotational crop after wheat to increase cropping intensity and incomes, and to limit soil erosion.

Due to its superior adaptation (compared to all other tropical cereals) to drought, soil salinity, soil acidity, and high temperatures, not to mention its food, feed and fodder values, opportunities exist for pearl millet to make inroads in new niches in Central Asia, the Middle-East, Australia and the Americas where preliminary trials have yielded encouraging results, especially with respect to its forage value. It also has potential for wider use in conservation agriculture in all conditions (Jat *et al.*, 2017).

Pearl millet based cropping system

The term cropping system refers to the crops, crop sequences and management techniques used on a particular agricultural field over a period of years. It includes all spatial and temporal aspects of managing an agricultural system. Historically, cropping systems have been designed to maximize yield, but modern agriculture is increasingly concerned with promoting environmental sustainability in cropping systems. Pearl millet is generally grown in areas where the available moisture is very less so it is followed by crops which require less water. Pearl millet-based cropping systems are well suited in India under limited water conditions and are preferred by the farmers because of attractive price of chickpea, mustard *etc.* (Parihar *et al.*, 2013). effective pearl millet based cropping systems are pearl millet-chickpea, pearl millet-mustard, pearl millet-wheat, pearl millet-barley and pearl millet-pigeon pea.

Constraints and solutions

The area where pearl millet is practiced characterized by low productivity and high variation in yields due to the cumulative effect of many constraints like frequent drought, low soil organic matter, multi-nutrient deficiencies, depletion of nutrients by crops, low nutrient use efficiency *etc.* are the major constraints in reducing productivity in the rainfed areas. Because of the mentioned reasons the productivity of rainfed area is only 1/3rd of the irrigated areas (Bana *et al.*, 2013).

Soils from arid and semi-arid regions are generally low in moisture, organic matter and have consistently been depleted of nutrients due to continuous cropping (Singh *et al.*, 2007). The problem of soil fertility depletion in India is a result of intensive cultivation and imbalanced and inadequate fertilizer recommendations. As a consequence, the incidence of multi-nutrient deficiencies has recently been documented (Dwivedi *et al.*, 2006).

Conservation Agriculture has been emerged as a key route to sustainable cropping systems during recent time.

The benefits arising from the ease of nutrient use efficiency, crop management, energy/cost/time savings, and soil & water conservation led to widespread adoption of conservation agriculture. In addition, Conservation agriculture–based nutrient management practices has proved to produce more at less cost, enhance nutrient use efficiency, reduce environmental pollution, improve soil health and growing evidence suggests that CA increases crop yields and builds-up soil carbon and also stability of crop yield and yield attributes in dry climates (Pretty and Bharucha, 2014).

Nutrient management and its antagonistic effect

Nutrient management is the science and practice directed to link soil, crop, weather, and hydrologic factors with cultural, irrigation, soil and water conservation practices to achieve optimal nutrient use efficiency, crop yields, crop quality, and economic returns, while reducing off-site transport of nutrients that may impact the environment. Furthermore, it reduces contamination to waterways by plant nutrients chiefly nitrate nitrogen and phosphorus, nitrate nitrogen levels that are sometimes elevated in ground water, reduce toxic level of macro and micro nutrients, avoid excess use of fertilizers inputs in order to reduce cost of production and antagonistic effect of nutrients (Oborn *et al.*, 2003).

Nutrient uptake antagonism refers to the competition between nutrients for uptake by plants. The two nutrients, often ions with the same charge, are said to be antagonistic with regard to the other. The excess amount of nitrogen can reduce potassium and calcium in the soil and excess amount of potassium reduces nitrogen, calcium and magnesium in the soil. Similarly, excess amount of phosphorus reduces zinc, iron and copper in the soil and so on (Rietra *et al.*, 2017).

Virtuous fate of Nitrogen and Phosphorus management

Nitrogen fertilizers improve the amount of grain produced per unit land, but nitrogen runoff and volatilization pollute water and air. Furthermore, the major grain crops use only about 40% of the applied fertilizer the rest is lost to the air, water, and soil microbes. Shallow-rooted annual and perennial plants frequently have iron and zinc deficiencies caused by excessive phosphorus. P can become water-soluble and mobile, entering surface waters and causing algae and other undesirable plants to grow. This reduces water quality and desirable fish and aquatic plants (science daily, 2018).

Results and Discussions

Conservation agriculture is almost the new agronomic intervention in the field of agronomy, so very less researches have been conducted for nutrient management in pearl millet–based cropping systems. Nonetheless, we have collected some results and findings regarding the mentioned topic.

1. System uptake of N, P and K kg ha⁻¹ as influenced by residue management in pearl millet based cropping system

Nitrogen uptake is significantly higher by pearl millet crop under residue retention (158.3 kg ha⁻¹) as compare no residue (121.4 kg ha⁻¹) plots. The pearl millet crop uptake more nitrogen (141.7 kg ha⁻¹) under Pearl millet-chickpea cropping system compared to pearl millet-mustard (136.8 kg ha⁻¹) and pearl millet-wheat (103.2 kg ha⁻¹) cropping systems, respectively. Similarly, potassium uptake is also significantly higher by pearl millet where residue is retained (161.4 kg ha⁻¹) as compare no residue incorporation (139.6 kg ha⁻¹). The pearl millet crop uptake more K (176.3 kg ha⁻¹) under Pearl millet-mustard cropping system as compare to pearl millet-chickpea (158.6 kg ha⁻¹) and pearl millet-wheat (162.7 kg ha⁻¹), respectively.

However, phosphorus was slightly affected by residue management and was at par in all pearl millet cropping based cropping systems (Amgain *et al.*, 2019). Similarly, Moisture management and zinc (Zn) fortification affected NPK uptake by pearl millet crop. The highest NPK uptake was recorded by narrow bed and furrow + 2.5 tonnes ha⁻¹ crop residue followed by flat bed + 5 tonnes ha⁻¹ crop residue. Likewise, Zn fortification to pearl millet improved NPK uptake by pearl millet. The uptake of Nitrogen (107.5 kg ha⁻¹) and K (140 kg ha⁻¹) is higher at 5 kg ha⁻¹ Zn. However, uptake of P (36.9 kg ha⁻¹) is at par with 5 and 2 kg ha⁻¹ Zn respectively, due to phosphorus antagonism effect with Zn (Choudhary *et al.*, 2016).

2. Effect of tillage and residue management on productivity of pearl millet-mustard cropping system

Residue retention and zero tillage are the basic principles of conservation agriculture which enhance both micro biological life and moisture retention in the soil, optimize soil temperature and reduce contaminant level of toxic nutrients by augmenting nutrient use efficiency. Consequently, yield and yield attributes improves under conservation agriculture (Bahan and Behera, 2014).

The grain yield, by-product yield and biological yield (kg ha⁻¹) are significantly affected by residue retention as compare to no residue retention. The grain yield of pearl millet is ominously higher at conventional tillage with 4 tonnes ha⁻¹ residue (2302 kg ha⁻¹) followed by zero tillage 4 tonnes ha⁻¹ residue (2261 kg ha⁻¹). However, the by-product yield (7578 kg ha⁻¹) and biomass yield (9839 kg ha⁻¹) are higher at zero tillage with 4 tonnes ha⁻¹ residue followed by conventional tillage 4 tonnes ha⁻¹ residue (Choudhary *et al.*, 2016). Some studies showed that the yield increases year by year under conservation agriculture and it remains constant under conventional tillage (Sepat *et al.*, 2018).

3. Effect of nitrogen management on system productivity of pearl millet-mustard cropping system, protein content and protein yield of pearl millet

Nitrogen (N) is so vital because it is a major component of chlorophyll, the compound by which crops converts sunlight energy to chemical form in order to produce sugar from H₂O and CO₂ (*i. e.*, photosynthesis). It is also a major component of amino acids, the building blocks of proteins. Without proteins, plants wither and die. Some proteins act as structural units in plant cells while others act as enzymes, making possible many of the biochemical reactions on which life is based.

System productivity of pearl millet-mustard cropping system, protein content and protein yield of pearl millet were highly affected by nitrogen levels.

The system yield (4.69 ton ha⁻¹), protein content (11.3%) and protein yield (285 kg ha⁻¹) were significant higher at 75 kg N ha⁻¹ as compare to all other treatment combinations (50 kg N ha⁻¹ and control) respectively, (Bamboriya *et al.*, 2017). Similarly, seed yield, stover yield and harvest index of mustard under conservation agriculture based pearl millet-mustard system were affected by N level at two splits (basal application and side dressing). Significantly, higher seed yield (1776 kg ha⁻¹), stover yield (5558 kg ha⁻¹) and harvest index (24.2%) were obtained from 60 kg ha⁻¹ N (30 kg N at basal application and 30 kg N at side dressing) as compare other combinations (Saber *et al.*, 2017).

4. Zinc fortification on protein content and zinc content

Zinc (Zn) fortification to pearl millet affects protein content, and Zn content. Significantly, higher protein content (10.91%) obtained from 2.5 kg Zn ha⁻¹ that at par with 5 kg Zn ha⁻¹ application. However, Zn content in both grain and stover were affected ominously.

The highest Zn content in grain (38.12 mg kg⁻¹) and stover (27.86 mg kg⁻¹) was found where 5 kg Zn ha⁻¹ were applied. Similarly, Zn fortification to chickpea affects protein content percentage, and Zn content. Meaningfully, higher protein content (10.88%) was attained from 2.5 kg Zn ha⁻¹ application. Conversely, Zn content in both grain and stover were affected gloomily. The highest Zn content in grain (36.48 mg kg⁻¹) and stover (26.52 mg kg⁻¹) found significant where 5 kg Zn ha⁻¹ were applied (Choudhary *et al.*, 2016).

5. Effect of sulphur application on 1000-grain weight and productivity of pearl millet under pearl millet–Indian mustard cropping system

Sulfur is one of the six macronutrients required by crops and is found in the amino acids cysteine and methionine and in a variety of metabolites. When one considers that sulfur in crops is only 3% to 5% as abundant as nitrogen, it is perhaps understandable that sulfur assimilation has been less well studied (Brunold and Rennenberg, 1997).

Sulphur application ominously affect 1000-grain weight and productivity. The highest 1000-grain weight (8.5 g) was gotten where 45 kg S ha⁻¹ was used. However, grain yield (2.22 t ha⁻¹) and stover yield (7.51 t ha⁻¹) obtained where 30 kg S ha⁻¹ was applied (Choudhary *et al.*, 2016).

Conclusion

Indeed, more than 90 million desperately poor people depend on pearl millet for food and income. Pearl millet–based cropping systems under conservation agriculture can enhance food production sustainably. In general pearl millet and pearl millet–based cropping systems remove considerably very high amount of nutrients from the soil / field which need to be replenished either through chemical fertilizers or organic sources of nutrients including crop residue recycling.

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Food Security and Sustainable Development Goals (SDGs)

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ABSTRACT

The United Nations (UN)¹ Agenda 2030 represents set of strategies for sustainable development which was approved by the UN in September 2015, and divided into a framework of 17 Sustainable Development Goals (SDGs)². Food security is related to all of the United Nations SDGs. The main focus of this paper is to understand the relationship of food security with SDGs. The integration of food security as an explicit part of the sustainability agenda would go a long way towards such a goal. Food security is defined as a situation that exists when “all people, at all times have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life”. Improved food security governance based on sound, equitable, and sustainable food systems that benefit from modern information and sustainable and equitable agricultural technologies is essential for countries to meet the SDGs. Results show that there is a positive relationship between food security and SDGs. This paper is based on secondary data collected from 1990 to 2024.

Keywords: Food, security, Sustainable, development, goals,

INTRODUCTION

The 2030 Agenda for Sustainable Development, spearheaded in 2015 by the United Nations (UN) and agreed upon by its 193 Member States, includes 17 Sustainable Development Goals (SDGs) with 169 associated Targets and a Global Indicator Framework.¹ Each Member State is committed to accomplishing the SDGs via international and domestic resources and collaboration, in order to realize a more resilient and sustainable global society. As a successor to the Millennium Development Goals (MDGs), initiated by the UN in the year 2000 with a focus on the developing world, the 2030 Agenda is inclusive and universal, acknowledging that improvement is needed in every socioeconomic domain around the world. While the MDG Agenda largely targeted social change, the 2030 Agenda aims for social, economic and environmental progress. (Ministry of economy, 2021).

One of the goals of the Millennium Development Goals (MDGs) is to achieve food security by 2015, though this has not been achieved as almost 1 billion people still suffer from hunger and almost 2 billion are under-nourished according to Food and Agriculture Organization (FAO,2002). The SDGs is an expansion of the Millennium Development Goals that is aimed at transforming the world over the next fifteen (15) years. It has seventeen goals as against eight for MDGs. Two of the goals are eradicating poverty and providing food security for all (Elver, 2015).

Food security may be understood as the access by all people at all times to food sufficiency for a healthy life while food insecurity is the lack of access to enough food leading to poverty.

¹ United Nation

² Sustainable Development Goals

Food security is dependent on the sustainability of food supply while poverty is regarded as the root cause of food insecurity. (Mukhtar, F. B. and Haruna, U 2018).

World leaders converged at a millennium summit at the United Nations Headquarters in New York in 2000, to discuss global problems which includes food security, at the end of the summit, they agreed to work together to find a lasting solution to the problems. During the summit, poverty was considered to be the root cause of food insecurity, it was then agreed to reduce global poverty rate to half by 2015. This led to the formulation of Millennium Development Goals ³(MDGs). At the end of 2015, the MDGs were expanded to 17-point Sustainable Development Goals and this includes eradicating hunger and poverty. The Sustainable Development Goals (SDGs), officially known as Transforming our World: the 2030 Agenda for Sustainable Development is a set of seventeen aspirational "Global Goals" with 169 targets between them. It is spearheaded by the United Nations and it involves its 193 Member States, as well as global civil society groups. The highlight of the seventeen SDGs (<https://en.un.org/sustainabledevelopment-goals>) is given in this section.

- 1. No Poverty** - End poverty in all its forms everywhere.
- 2. Zero Hunger**- End hunger, achieve food security and improve nutrition and promote sustainable agriculture.
- 3. Good Health and Well-being** - Ensure healthy lives and promote well-being for all at all ages.
- 4. Quality Education** - Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.
- 5. Clean Water and Sanitation** - Ensure availability and sustainable management of water and sanitation for all.
- 6. Affordable and Clean Energy** - Ensure access to affordable, reliable, sustainable and modern energy for all.
- 7. Decent Work and Economic Growth** - Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all.
- 8. Industry, Innovation and Infrastructure** – Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation.
- 9. Reduced Inequalities** - Reduce income inequality within and among countries.
- 10. Sustainable Cities and Communities** - Make cities and human settlements inclusive, safe, resilient and sustainable.
- 11. Responsible Consumption and Production** - Ensure sustainable consumption and production patterns.
- 12. Climate Action** - Take urgent action to combat climate change and its impacts by regulating emissions and promoting developments in renewable energy.
- 13. Life Below Water** - Conserve and sustainably use the oceans, seas and marine resources for sustainable development.
- 14. Life on Land** - Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.
- 15. Peace, Justice and Strong Institutions** - Promote peaceful and inclusive societies for sustainable development. Provide access to justice - for all and build effective, accountable and inclusive institutions at all levels.

³ Millennium Development Goals

16. Partnerships for the Goals - Strengthen the means of implementation and revitalize the global partnership for sustainable development. These seventeen set of goals are expected to be used by United Nation's member states to frame their agenda and policies over the next fifteen years (Mukhtar, F. B. and Haruna, U 2018).



Figure 1. The 17 Sustainable Development Goals

RESEARCH METHODOLOGY

This research employs a library-based methodology, which involves the collection, analysis, and interpretation of information from existing sources. The study primarily relies on secondary data obtained from academic books, peer-reviewed journals, governmental and non-governmental reports, and reputable online databases. The qualitative nature of this method enables a comprehensive understanding of the topic by synthesizing insights from a wide range of scholarly materials.

Through systematic literature review, the research identifies relevant theories, models, and previous findings related to food security and the Sustainable Development Goals (SDGs). The collected data is critically evaluated to highlight trends, challenges, and gaps in existing knowledge. This approach allows the researcher to build a solid theoretical framework and support the analysis with well-established academic evidence.

While the study does not involve fieldwork or empirical data collection, the depth and breadth of the reviewed literature ensure the reliability and academic rigor of the findings.

RESULTS AND DISCUSSIONS

The 2030 Agenda for the Sustainable Development Goals (SDGs) represents a common framework of international cooperation to promote sustainable development.

Nutrition is the key point for the SDG 2 'End hunger, achieve food security and improved nutrition and promote sustainable agriculture and is an essential component for achieving many of the other targets overall, the nutritional aspects of the SDGs aim to promote healthy and sustainable diets and ensure food security globally.

The result shows that there is a positive relationship between the SDGs and Food Security. Based on data, nutrition represents an important pillar of efforts designed to facilitate achievement of Sustainable development goals.

The SDGs include a significant number of interconnected objectives related to food. SDG 2 focuses explicitly on food by seeking to end hunger, achieve food security and improved nutrition and promote sustainable agriculture.

Food Security and Sustainable Development Goals (SDGs)

1. Concept of Food Security

The concept of Food security is a dynamic theory that, over the years, has policy and research steadily. The concept of Food security has a long history starting from the first half of the 1970s when the world's food crisis occurred (Clay, 2002).

Food security is such a complicated topic that it is impossible to measure directly it, and a number of integrated novel scopes and analytical stages. The new food security dimension has always been analyzed. This ongoing evolution of the food security concept represents a broader recognition of the complexities of definition in public of proxy methods that have been proposed. The most widely used food security measures are asset of four aspects of food security nutritional status and coping strategies (Mohamed, 2017; Atara et al., 2019) and also Several studies noted that the most desirable measure of food security measurement on four major food security – availability, access, utilization, and stability (Maxwell, 2013, Atara et al., 2019; FAO, 2000; FAO, 1996). Numerous definitions have been suggested to describe the concept of food security; approximately more than 200 definitions of food security and 450 indicators of food security (Mughal and Fontan Sers, 2020).

However, a definition that seems to be considered comprehensive is FAO's (FAO, 2000). Aware of the literature definition FAO⁴ generally conceptualized, Food security is terms used to define that people in the household have access to adequate food both in quantity and quality. Food security issues have gained prominence and greatly focused on international national household, and individual levels with advances in time and magnitude of the problem. Such innovative research has contributed to the redefinition of the breadth and depth of the idea of food security (Duffour, 2009). Hence different institutions and organizations, in various ways defined food security. Based on (FAO, 2008) food security is a condition that reached the international, national, household, and individual levels when "all people, at all times, have physical and economic access to sufficient safe and nutritious food that meets their dietary needs and food preference for an active and healthy life.

On the other side, some developed countries defined food security as financial ability. The Canadian government food security research center defined food security as "household food insecurity due to financial constraints has adequate or insecure access to food" (PROOF, 2017). The Agricultural Department of the United States defined food security as "To ensured access to adequate food, healthy living," which demonstrated that a household is classified as marginally, moderately, or severely food insecure according to their ability to buy food (Hamilton, 1997). Food security definition in recent studies as sufficient access to and availability of food for the family to meet the minimum energy needs as recommended for an active and healthy life (Hussein, 2013). Thus, a household is considered food insecure when the consumption decreases below 80 % of the daily minimum recommended caloric allowance intake amount for daily activity and safe person. Food insecurity contains low food consumption and a lack of access to food. Also, poor resilience in front of shocks is an indicator of food insecurity (Mohamed, 2017). In total, food insecurity includes low-quality food, variability in access to food, and livelihood vulnerability strategy that creates adequate food in good times, but it is not robust against shocks.

The four pillars of food security

1. Physical availability of food: Food availability addresses the “supply side” of food security and is determined by the level of food production, stock levels and net trade.

⁴ Food and Agriculture Organization

2. Economic and physical access to food: An adequate supply of food at the national or international level does not in itself guarantee household level food security. Concerns about insufficient food access have resulted in a greater policy focus on incomes, expenditure, markets and prices in achieving food security objectives.

3. Food utilization: Utilization is commonly understood as the way the body makes the most of various nutrients in the food. Sufficient energy and nutrient intake by individuals are the result of good care and feeding practices, food preparation, diversity of the diet and intra-household distribution of food. Combined with good biological utilization of food consumed, this determines the nutritional status of individuals.

4. Stability of the other three dimensions over time: Even if your food intake is adequate today you are still considered to be food insecure if you have inadequate access to food on a periodic basis, risking a deterioration of your nutritional status. Adverse weather conditions, political instability, or economic factors (unemployment, rising food prices) may have an impact on your food security status.

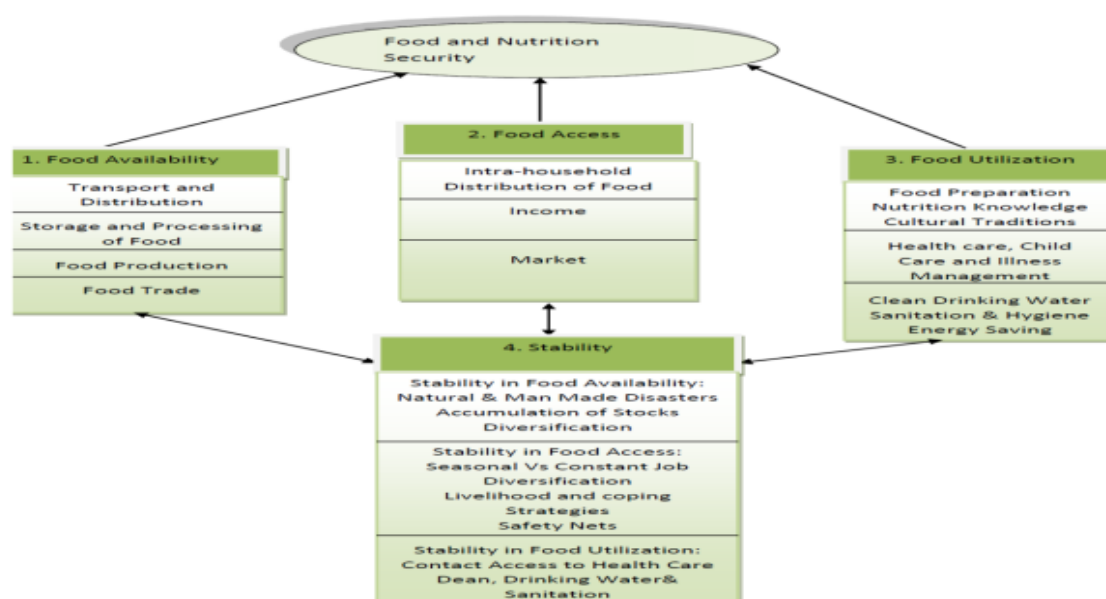


Figure 2. The four pillars of food security

2. Food security and its relationship to the SDGs

Attaining food security and sustainable food production are elements of Sustainable Development Goal 2. SDG2 has three components: (1) End Hunger and Achieve Food Security (Target 2.1) (2) End all forms of malnutrition (Target 2.2) (3) Promote Sustainable Agriculture (Targets 2.3-2.5) Progress towards meeting the End Hunger component of Target 2.1 is assessed using a measure curated by the Food and Agriculture Organization (FAO) called the Prevalence of Undernourishment (PoU). In brief, FAO tracks, on an annual basis, food production and trade. This allows FAO to calculate per capita caloric availability. Separately it calculates minimum caloric requirements. Caloric requirements are affected by age, sex, weight, and activity levels. FAO takes all these into account when constructing, on a country-by-country basis, minimum caloric requirements. Lastly, FAO estimate how caloric availability is distributed within a country this distribution, when compared to caloric requirements, generates an estimate of the number and prevalence of undernourished individuals (FAO, 2015). The End Hunger Target 2.1 will be achieved when this measure of undernourishment falls to zero.

Progress towards achieving the food security component of Target 2.1 is measured through FAO's Food Insecurity Experience Scale (FIES) (FAO, 2016a). The FIES is based on the idea that food insecurity is not a binary state.

Instead, it exists on a continuum that begins with concern that household resources are not sufficient to meet food needs, to coping strategies such as reducing diet quality and diversity, to skipping meals and ultimately going whole days without eating. Work done around the globe shows that these are universal responses to food insecurity (Corbett, 1988; Radimer, Olson and Campbell, 1990; Radimer et al., 1992; Devereux, 1993; Coates 2013; Ballard, Kepple and Cafiero, 2013; FAO 2016). Based on this universality, FAO developed a simple eight question survey module which is now administered in more than 140 countries around the globe. Generally, households who answer affirmatively to one or more questions are considered to have some form of food insecurity; four or more of these questions are considered moderately-or-severely food insecure; and households that answer affirmatively to seven or eight are considered severely food insecure (FAO, 2016).

The SDG2 Target 2.1 for global food security will be met when the prevalence of any food insecurity falls to zero. We end this section by noting two additional points. First, the focus of this paper is on Target 2.1, working towards all SDG2 targets is immensely important. Meeting Target 2.2 - end all forms of malnutrition with particular focus on wasting (acute undernutrition) and stunting (chronic undernutrition) - is both intrinsically valuable (good nutrition for all is a good thing) and instrumentally valuable. Child wasting is associated with increased risk of avoidable death due to infectious diseases and so ending wasting will reduce infant and child mortality. Chronic undernutrition causes neurological damage. As a result, chronically undernourished children attain fewer grades of schooling and learn less than their better nourished peers. As adults, they earn lower incomes and are at increased risk of being poor (Hoddinott et al, 2013). Thus, meeting Target 2.2 will contribute to SDG1 (Ending Poverty). Good nutrition requires both good health (and good access to health services) and access to biologically adequate consumption of food, both in quantity (calorie) and quality (micronutrient) terms. Achieving Target 2.1 (ending hunger and food insecurity) thus contributes to Target 2.2.

CONCLUSIONS

The SDGs offer an opportunity to address the major challenges facing humanity in ways that will not make things worse in trying to make things better. Food security is moving rapidly up the global agenda as information emerges on the high and multiple burdens and the many interactions with other societal goals such as no Poverty, nutrition and clean water.

The Sustainable Development Goals (SDGs) include a significant number of interconnected objectives related to food. SDG 2 focuses explicitly on food by seeking to “end hunger, achieve food security and improved nutrition and promote sustainable agriculture”, but multiple other goals relate to challenges in the food system. SDG 1 focuses on poverty reduction, where agriculture and food has a key role to play. Sustainable agriculture plays a central role in achieving SDG 6 on water, SDG 12 on sustainable consumption and production, SDG 13 on climate change adaptation and mitigation and SDG 15 on land use and ecosystems. Sustainable management of fisheries also features prominently in SDG 14 on marine resource and oceans.

RECOMMENDATIONS

1. Sustainable intensification increases food production, ensuring the long-term potential of agricultural resources (e.g. soil, water, plants and livestock) and maintaining their environmental functions. These practices include sustainable tillage, precision resources management, crop residues and cover crops for soil protection as well as cropping system diversification. However, as these practices are not adopted widely, countries should promote them.

2. Transitions to more sustainable and healthy diets, i.e. more plant-based with minimum animal-source food, reduce global mortality and agriculture-related GHG emissions. Therefore, countries need to facilitate diet changes through policy instruments and soft measures,

including taxes on unhealthy foods and subsidies on healthy ones.

3. Avoiding food loss and waste saves resources used to produce food, reduces food systems' environmental impacts and enhances local, regional and global food security. Various technologies and soft measures are available to reduce food loss or waste.

4. Connecting producers with business is key to sustainable food systems. Linking young farmers to sustainable finance and private sector leaders to access needed finance and mentorship will transform these youths into competent and confident business leaders.

5. Regional and local food systems will ensure food availability during difficult times, enhance local employment, especially for women and youth, and reduce food transport emissions. Thus countries can promote the regionalization of food systems by implementing appropriate policies subsidies, and carbon tax.

6. Social protection and empowerment are required for vulnerable populations to ensure their food security in difficult times.

Disruptions in food systems caused by climate change, weather extremes or conflicts can result in food insecurity. Social protection includes food subsidies, cash transfers, agriculture insurance, farmer's pension and employment guarantee, and universal income.

7. Urban and per-urban agriculture can increase the resilience of regional and local systems. Urban and per-urban agriculture contributes to food availability and accessibility, reduces poverty, improves nutrition, provides a series of ecosystem services, e.g. reducing heat stress and carbon sequestration, and fosters the circular economy.

8. Investment in research, innovation, and extension services needs to be increased, particularly in agro ecological approaches, sustainable production practices, game-changing emerging technologies, locally appropriate business model development and financing mechanisms. Countries should invest in building their capacities for integrating data, analytics, and assessments, supporting evidence-based policies to ensure food security.

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Deepening Poverty and Regional Disparities in Afghanistan: A Call for Targeted Interventions

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Abstract

Afghanistan has witnessed a resurgence of poverty after the recent governmental changes. The regional distribution of the poor population remains to be determined, presenting an obstacle to formulating targeted poverty alleviation policies and initiatives. This study endeavors to bridge this knowledge gap and elucidate the current regional inequalities in poverty within Afghanistan. Utilizing the Multiple Indicators Cluster Survey (MICS) dataset for 2022–23, this analysis employs the Multidimensional Poverty Index (MPI) methodology. The findings reveal a pronounced escalation in the MPI, the poverty headcount ratio, and the intensity of poverty relative to the year 2020. In addition, Afghanistan has experienced regression in seven indicators associated with the five Sustainable Development Goals, except access to electricity and potable water. Education—specifically, years of schooling and school attendance—and nutrition are the predominant factors contributing to the overall MPI. A significant disparity is observed between rural and urban areas and among provinces across all nine indicators of the MPI. For example, the central, northeastern, and northern regions exhibit elevated poverty rates concerning the drinking water indicator. In contrast, the southern, western, and northwestern regions display the highest poverty rates concerning the education indicator. Consequently, rural areas necessitate specialized policy interventions to address the heightened rates of poverty and inequality compared to urban locales. Moreover, indicator-specific and geographically focused, tailored poverty reduction initiatives are imperative to address the multifaceted determinants of poverty in Afghanistan.

Keywords: Multidimensional poverty Index, poverty, Inequalities, Afghanistan

Introduction

While significant efforts have been made to eradicate poverty globally, millions still face its harsh realities. Estimates suggest that over 1.1 billion people across 111 countries struggle with poverty, with 18% being acutely and multidimensionally poor. Furthermore, 730 million people reside in middle- or low-income countries, highlighting the geographically concentrated nature of poverty. South Asia alone accounts for one-third of the global poor, emphasizing the regional inequalities (UNDP & OPHI, 2023). In Afghanistan, nearly half of the population was classified as being multidimensionally poor (OPHI, 2023; World Bank, 2024) even before the COVID-19 pandemic, which increased the level of poverty around the world (Alkire, Nogales, Quinn, & Suppa, 2021), specifically, the collapse of administration in Afghanistan exacerbated further.

To address this complex issue effectively, policymakers require sophisticated tools that capture poverty's multifaceted nature. Traditional poverty measures, often focused solely on income or the cost of basic needs (Streeten, 1979),

fail to capture the whole picture, particularly in developing countries where illiteracy, poor sanitation, and inadequate access to basic necessities are widespread. These limitations may result in an underestimation of the true extent of poverty and impede the development of effective interventions aimed at eradicating regional inequalities. Alkire and Foster (2011) introduced the Multidimensional Poverty Index (MPI), a comprehensive measure that captures deprivations across multiple dimensions, such as health, education, and living standards, to address these shortcomings. While some studies propose adding more indicators like the natural environment and social variables (Cheng, et al., 2024) as mentioned, three domains are broadly accepted indicators for MPI analysis. This approach allows for a more nuanced understanding of poverty and facilitates the development of targeted interventions to address specific deprivations in various locations. Moreover, the MPI's ability to decompose data by region is crucial for implementing effective regional development policies and tackling inequalities. Furthermore, the MPI can be utilized for individual-specific analyses, revealing the disproportionate impact of poverty on vulnerable segments of households (Vijaya, et al., 2014) and ultimately the population.

Globally, MPI is being applied to analyze the poverty level and bring about new debates on the extent and intensity of inequalities at national, sub-national, regional, and individual levels. While global MPI analysis reports give a snapshot of poverty worldwide yearly, its country-specific in-depth analysis reveals the inequalities in poverty (Alkire et al., 2022; 2023). The MPI assists with area-based policy implications and program impact evaluation in sub-national and regional analysis. Moreover, different segments of the population seem to be affected differently; for instance, cast-based multidimensional poverty analysis among children revealed the existence of inequalities across India (Pradhan, et al., 2023). In addition, regional and ethnic-based disparities of poverty in the case of Malaysia (Rongen et al., 2024) and Afghanistan (Trani, Kuhlberg, Cannings, & Chakkal, 2016) point to the socioeconomic and geographic side of poverty. Therefore, a sub-national level analysis is needed to identify the segments of the population that are most deprived, which is of paramount importance in regional poverty and inequality policy initiatives.

While there is a well-established literature on the extent of multidimensional poverty within and among countries for policy implications, the ground for multidimensional inequality must be addressed. Inequality analysis usually takes income (Hornok & Raeskyesa, 2024) or economic growth as the basis for the study at the national and sub-national levels, which could underestimate the multifaceted nature of deprivation and, thus, inequality in developing states. In addition, poverty analysis with MPI has different dynamics than income-based analysis. For instance, the MPI approach being applied to analyze the multidimensional energy poverty (MEP) in China, which revealed to have different dynamics compared to income poverty (Wang & Lin, 2022), as well as in the Indian case, that uncovers inequality (Sadatha & Acharyab, 2017). Moreover, the MPI contributors differ based on the level of socio-economic indicators of each country. For instance, education is the highest contributor to MPI in rural deprived areas of China (Guo et al., 2022). Meanwhile, the MPI values of Nigerian women are more bound to the dimension of living standards (Jerumeh, 2024). Therefore, regional inequalities of poverty would have their contributors, which could be of paramount importance for targeted policy implications within each country for a better and just society.

However, some efforts have been made to identify the inequality in multidimensional poverty, especially in Afghanistan (Trani et al., 2016), but without accounting for serious poverty measures such as child mortality, nutrition, access to electricity, and years of schooling. These indicators are among critical deprivation factors that could enlarge regional inequalities if not addressed.

In addition, provincial-level multidimensional inequality analysis is needed to carve inequality and poverty alleviation initiatives more accurately.

Additionally, country-specific analysis is required to track SDG achievements, quantify MPI with different indicators, and pinpoint the regional inequalities based on various indicators.

This paper focuses on Afghanistan, a country grappling with conflict, natural disasters, and political instability. These factors undoubtedly contribute to its high poverty rates, which in turn translates into more socio-economic challenges, such as child marriage and child labour (Ehsan et al., 2021), that transfer the poverty between generations and changes to be chronic. We employ the MPI framework, utilizing data from the Multiple Indicator Cluster Survey (MICS 2022-23), to construct a comprehensive picture of poverty inequality at the national, regional, and provincial levels. Our analysis examines explicitly three key domains: health, education, and living standards in 9 indicators. There is also the flexibility to use more indicators based on research purposes (NSIA, 2019). However, we use the standard comparable way MPI indicators are used.

This paper, which incorporates nutrition data not available in previous MICS surveys of Afghanistan, provides a complete understanding of poverty, especially food utilization, while focusing on provincial-level inequalities. Moreover, it aims to achieve several key objectives. First, we will identify the most deprived areas and indicators within Afghanistan, aiding in developing targeted poverty alleviation initiatives. Second, by comparing our findings with previous MPI analyses, we will assess the country's progress towards achieving the Sustainable Development Goals (SDGs) established by the United Nations, which is one of the main accessories of MPI (Alkire et al., 2023). This comparison will reveal setbacks or improvements, allowing policymakers to adjust interventions accordingly and allocate resources efficiently. Ultimately, our analysis will contribute valuable insights for policymakers seeking to achieve the 7 UN SDGs in Afghanistan, such as SDGs 1-4, 6, 7, 10, and 11 (details provided in the data section).

This paper's results, informed by MPI, reveal a pervasive spread of poverty across Afghanistan and significant spatial inequalities. The gap in MPI between rural and urban areas remains substantial, with rural populations experiencing a considerably higher burden of poverty. This disparity is further underscored by the fact that 75% of the population resides in rural areas, where a staggering 75% are classified as poor. Additionally, the MPI in rural regions is double that of urban areas, highlighting the greater depth of poverty in these communities. Consequently, addressing rural poverty requires immediate and targeted interventions.

Regional inequalities in poverty also emerge from the data. Provinces with major cities, except for Kandahar, exhibit significantly lower poverty levels than their less urbanized counterparts. This observation suggests the presence of regional disparities in multidimensional poverty. Furthermore, school attendance and nutrition indicators are key contributors to the overall MPI. These indicators have significantly deteriorated since the disruption of government stability. The decline in nutritional well-being mirrors a broader decline in food security and utilization across the country. This can be attributed mainly to the economic downturn, which has compelled households to reduce consumption expenditure drastically. The overall poverty situation appears to have significantly deteriorated compared to 2020 and earlier years, demanding urgent action to reverse this negative trend.

This paper offers several critical contributions to understanding poverty dynamics in Afghanistan and informs policy interventions.

Firstly, it demonstrates how recent political and military upheavals have impacted food security and utilization and adversely affected Afghan citizens' well-being across multiple dimensions. Overall, poverty indicators have worsened considerably since 2020, highlighting a decline in living standards nationwide. Secondly, the analysis identifies education as a significant factor contributing to the rise in MPI. Without addressing this issue, poverty is likely to persist and worsen in the future. Finally, while national poverty levels are alarmingly high,

regional inequalities region-indicator-based targeted policy interventions to support the most deprived areas.

Materials and Methods

Data

The data for this study was drawn from the Afghanistan Multiple Indicator Cluster Survey (MICS) conducted between September 2022 and February 2023. The survey employed a two-stage cluster sampling design across all 34 provinces, stratified by rural and urban areas. Probability proportional to size sampling design was used at the first stage to select primary sampling units (enumeration areas, EAs) from a sampling frame based on 2019 National Statistics and Information Authority satellite imagery. A total of 982 EAs were selected, and 24 households were systematically sampled from the household listing within each EA, resulting in a target sample of 23,568 households. However, data collection was impossible in 10 EAs due to security constraints, yielding a final sample of 23,213 households (99.8% response rate).

Data collection utilized computer-assisted personal interviewing (CAPI) on CS Pro software (version 7.7) and a dedicated MICS data management platform. The global MICS program procedures and standards were adapted for Afghanistan. Before full-scale implementation, CAPI was piloted in Kabul city to ensure data quality and address potential issues.

The fieldwork involved 34 teams: four interviewers, one measurer, and a supervisor. Due to security concerns, data collection was interrupted for six weeks from mid-November to December 2022.

All adult participants gave informed verbal consent. For children aged 5-17, consent was obtained from a male adult household member. All interviewees were informed of the survey's voluntary nature and assured of data confidentiality and anonymity in disseminating findings.

The survey utilized four questionnaires: Households, Women (15-49), Children under Five, and Children (5-17). Response rates exceeded 98.8% for all questionnaires. More information on survey design, data collection, and data processing could be achieved from the MICS 2022/23 detailed report (UNICEF, 2023). After data cleaning and removing unreal values, this analysis used 22,923 households.

Method

Variables' description

The Alkire-Foster (AF) method is a multidimensional poverty measurement approach encompassing a dual cut-off system. This system identifies individuals experiencing poverty based on the number of deprivations they face (within dimensions) and the intensity of those deprivations (across dimensions). The AF method typically employs 10 indicators across three domains: health, education, and living standards, with equal weights.

The health domain consists of two indicators: nutrition and mortality. The nutrition indicator, based on WHO Child Growth Standards (*igrowup* STATA ado file) (WHO, 2022), assesses weight-for-age (underweight), weight-for-height (wasting), and height-for-age (stunting) z-scores in children under five. Households with at least one child falling two standard deviations below the median z-score in any of these indicators are classified as deprived. Additionally, mortality deprivation is determined if a child under 18 has died in the household within the five years preceding the survey. Due to the unavailability of data on child deaths specifically, the AF method allows for classifying households as deprived if any child has died within the past five years. Deprivation in the educational domain is measured by two variables: level of education and school attendance.

A household is considered deprived of education if none of its ten or older members have completed primary education (defined as six years of schooling in Afghanistan). Moreover, school attendance deprivation applies when none of the household's children attend school up to grade 8.

Living standards are assessed through five indicators in the third domain. Lack of access to electricity, improved drinking water (as defined by SDG guidelines, or located at least a 30-minute round trip from home), and improved sanitation facilities (either unimproved or shared with other households) all classify household members as deprived. Furthermore, housing deprivation is measured by the construction materials used for walls, roofs, and floors. Finally, asset deprivation considers the lack of ownership of household appliances like TVs, radios, phones, computers, refrigerators, cars, bikes, rikshaws, motorbikes, and animal carts.

The above MPI indicators are related to 7 SDGs out of 17 goals. The overall index is a proxy for no poverty (SDG 1). At the same time, the nutrition indicator is set to quantify zero hunger (SDG 2), and child mortality accounts for health and well-being (SDG 3). In contrast, the whole domain 2 (school attendance and years of schooling) is dedicated to quality education (SDG4). Moreover, drinking water and sanitation cover SDG 6, while access to electricity indicates affordable and clean energy (SDG7) goals, and housing is a proxy for sustainable cities and communities (SDG 11). In addition, by decomposing the analysis on a regional basis, we can analyze the inequalities within Afghanistan, which serves SDG 10 (reduce inequality) (UN, 2015).

However, the AF method allows for flexibility in indicator selection. New variables can be added or removed based on data availability and research objectives. In this study, due to the unavailability of the cooking fuel variable in the Afghanistan MICS2022/23 data, the analysis utilizes the remaining nine indicators described above.

The Alkire-Foster (AF) method employs an identification threshold (k) to pinpoint multidimensionally poor households. This threshold represents the minimum number of deprivation indicators a household must lack to be classified as multidimensionally poor. Considering our use of nine indicators in this study, any household deprived of at least three (or 33%) indicators will be categorized as multidimensionally poor. Additionally, the MPI with more cut-offs is reported to acknowledge the severe cases of poverty with higher deprivations.

Multidimensional poverty index

To consider who is poor or not, the multidimensional approach takes a threshold to measure the level of well-being at the household or individual level.

In the multidimensional poverty index, individuals' achievements are measured regarding given cut-offs. However, using cut-offs with a unidimensional approach, such as income, which aggregates the accomplishments into a single binary variable, will result in the loss of information. In contrast, there is a commonly used union approach to poverty identification. In this approach, an individual or household will be classified as poor, if at least deprived in one dimension.

$$\rho(y_i; z) = 1 \text{ if and only if } c_i \geq 1, \quad i = 1 \dots d \quad (1)$$

In equation 1, ρ is the multidimensional poverty index of a person from y_i achievements given z deprivation cutoffs, and c_i is the number of dimensions that a person is being deprived of.

However, the problem arises when many dimensions classify most of the population as poor. Therefore, there are better approaches than this for distinguishing and targeting the most deprived population. In contrast, the intersection approach of multidimensional identification is used to classify a person as poor if only the person is deprived in all dimensions.

$$\rho(y_i; z) = 1 \text{ if and only if } c_i = d, \quad i = 1 \dots \dots d \quad (2)$$

This approach will identify a particular group of poor while leaving others non-deprived in classification. The union and intersection approaches are in both far extremes, either 1 or d. To solve the issue, an alternative approach is to have intermediate cut-off points for c_i , Something between 1 and d. As a result, a person is classified as multidimensionally poor whenever the number of dimensions that person is deprived being more than the cut-off k:

$$\rho_k(y_i; z) = 1 \text{ if whenever } c_i \geq k, \quad k = 1 \dots \dots d \quad (3)$$

In contrast, if the number of dimensions lies below the cut-off point, that person is no longer multidimensionally poor. It is called the dual cut-off approach due to the dependency of ρ_k to within dimension or deprivation cutoff (z) and between dimension or poverty cutoff (k). Before Alkire and Foster (2011) applied in various cases (Mack & Lansley, 1985; Gordon et al., 2003); however, the properties and axioms needed to be explored.

Calculating poverty with MPI

The MPI approach needs to consider the incidence and intensity of poverty in calculating poverty. The incidence of poverty (H) is the proportion of the population that is multidimensionally poor. In addition, the intensity of poverty (A) is the average dimension in which the population is multidimensionally poor.

$$H = \frac{\sum_{i=1}^n \rho_k(y_i, z)}{n} = \frac{q}{n} \quad (4)$$

The above equation will identify the number of people who experienced multidimensional poverty, analogous to income-based poverty identification. Hence, it possesses both pros and cons that are easy to calculate, while unchanged if a poor person becomes deprived in a new dimension. In addition, to know the share of each dimension in poverty, H is not enough.

The analysis includes the intensity of deprivation (A) to address the above issue.

$$c_i(k) = \rho_k(y_i; z) \quad i = 1 \dots \dots n \quad (5)$$

Where $c_i(k)$ is the censored vector of deprivation counts, hence $c_i(k)/d$ is giving the possible deprivations suffered by a poor person :

$$A = \frac{|c_i(k)|}{qd} \quad (6)$$

Thus, if a poor person becomes deprived in a new dimension or a non-poor person becomes deprived, it could be detected by A. MPI is constructed as below:

$$MPI = A * H \quad (7)$$

The MPI possesses decomposability, replication invariance, symmetry, poverty focus, deprivation focus, weak monotonicity, and dimensional monotonicity. Further proof and related information could be achieved from (Alkire & Foster, 2011). However, certain drawbacks need to be taken into account. First, the poverty status of poor people is not affected by improvement in the non-deprived dimension, and a non-poor person is not classified as poor due to drops in a deprived dimension. Second, the equal weighting scheme used widely in MPI analysis does not consider the significance of specific indicators that may vary across space. Therefore, alternative weightings are being proposed (Pasha, 2017). However, that has not been concretely established and has not received much attention in MPI analysis.

To extract the results, we have applied the *mpitb* toolbox (Suppa, 2023) in STATA 17, which uses the AF approach corrected for complex survey design.

To check the reliability and robustness of the estimates, an alternative toolbox proposed by Pacifico and Poege (2017) under the *mpi* command is also being used. Furthermore, the related robustness and scope details of MPI can be found in more detail in Alkire and Santos (2014).

Results and discussion

Descriptive statistics

Table 1 presents the descriptive statistics of the variables used in this paper. Housing is the most deprived indicator, with 92.4%, followed by school attendance and sanitation. In contrast, access to electricity is the least deprived among Afghanistan's citizens. Similar patterns of deprivation are observed in other least developed nations. For example, in countries like Chad and South Sudan, housing deprivation often exceeds 80%, and sanitation indicators show similarly high levels of deprivation, while access to electricity remains relatively low, with figures typically below 50% (UNDP, 2023; WFP, 2023). These comparisons highlight the critical challenges Afghanistan faces in terms of basic infrastructure and human development. In addition, over half of the households are classified as nutritionally deprived, which is a sign of food insecurity at the household level, which translates to lower values of nutritional measures. Moreover, housing, sanitation, and assets are related much more to households' economic ability than public goods such as education and access to electricity and drinking water, which the government should provide. In addition, compared to previous MPI analysis with the 2015/16 dataset, Afghanistan recorded a mere increase in drinking water and access to electricity incorporated with SDGs 6 and 7. In contrast, other SDGs such as no poverty (SDG1), nutrition (zero hunger -SDG2), child mortality (health and well-being - SDG3), education (quality education - SDG4) and housing (sustainable cities and communities - SDG11) the rollback occurred, which dragged away Afghanistan to provide better living conditions for the citizens.

Table 1 Descriptive Statistics

Domains	Indicators	Weight	Mean	SD
Health	Child Mortality	0.167	0.172	0.378
	Nutrition	0.167	0.511	0.500
Education	School Attendance	0.167	0.668	0.471
	Years of schooling	0.167	0.400	0.490
Living Standard	Access to electricity	0.067	0.146	0.353
	drinking water	0.067	0.407	0.491
	sanitation	0.067	0.655	0.475
	Housing	0.067	0.924	0.264
	asset	0.067	0.382	0.486
Observations	Total individual observations	196,889		
	Total Households	22,923		

Source: Authors calculations from MICS 2022-23 of Afghanistan

SD- stands for standard deviation

MPI results at the national level

The Empirical analysis in Table 1 illustrates the overall worsening of poverty in Afghanistan in nearly a decade. Based on DHS 2015/16, the proportion of multidimensionally poor or poverty headcount ratios was 55.9%, 21.2%, and 66.9% (in national, urban, and rural, respectively) (OPHI, 2023). In contrast, our findings indicate that 65.6%, 36.2 and 75.5% (in national, urban, and rural, respectively) in 2022/23 are poor.

This is an increase of over 10% in poverty across Afghanistan in just less than a decade. Moreover, while the overall MPI was 0.272 in DHS2015.16, it increased to 0.371 in MICS2022/23, again nearly a 10% increase. In addition, multidimensional poor households experience 37.1% of total possible deprivations. Additionally, poverty in the rural areas, which consists of $\frac{3}{4}$ of the population, is alarming at $\frac{3}{4}$ being multidimensionally poor. As a result, the overall poverty conditions in Afghanistan got worse in less than a decade, which may be due to the COVID-19 pandemic and the governmental changes, which dragged the country away from achieving sustainable development goals indicated by the UN (UN, 2015). The urban-rural inequalities persist, and Afghanistan did not make any progress to achieve SDG 10 or decrease the gap.

Table 1: Multidimensional Poverty Index of Afghanistan based on MICS 2022/23

Level of Analysis	MPI	Intensity of poverty	Poverty headcount ratio	Population share
National	0.371	56.6%	65.6%	100%
Urban	0.177	48.8%	36.2%	25.2%
Rural	0.436	57.8%	75.5%	74.8%

Source: Authors calculations from MICS 2022/23 of Afghanistan

The results in Table 1, despite giving an overall picture of the multidimensional poverty in the country, fall short of being used for targeted policymaking because three domains and nine indicators drive the index. Therefore, reporting the contribution of each domain and indicator to overall poverty is essential for any policy-making initiative to target specific deprivation.

The results reported in Table 2 indicate high contributions from school attendance and nutrition to overall MPI. In domains, education, with 0.41, is the highest contributor to the overall MPI, which follows the paths of the previous analysis (NSIA, 2019) with higher values. This result reflects the economic meltdown and recent political changes in the country. To help with nutrition, the UN has been involved with unconditional food and money transfers to households in Afghanistan since August 2021.

Table 2 Contribution of each indicator to MPI at the national level

Indicator	MPI	
	Indicators	Domains
Domain 1		
Child mortality	0.071	0.263
Nutrition	0.192	
Domain 2		
School Attendance	0.241	0.407
Years of schooling	0.166	
Domain 3		
Electricity	0.024	0.330
Drinking water	0.054	
Sanitation	0.084	
Housing	0.112	
Asset	0.056	
Total	1.000	1.000

Source: Authors estimation from MICS 2022/23 of Afghanistan

The results reported in the above two tables use the global MPI cut-off of 33.33%, which means that a person or household will be classified as multidimensionally poor if deprivation occurs in three indicators out of nine. By disaggregating the data by urban and rural areas in Figure 1, we can see how these indicators contribute differently to poverty in each setting.

However, the patterns between rural and urban settings remain nearly constant compared to DHS2015/16, which has higher poverty levels. The inequalities are widening in some indicators like drinking water and assets, while access to electricity reveals an improvement in both settings (OPHI, 2023). This shows that poverty is a structural inequality between urban and rural settings. For example, housing, sanitation, and school attendance are severe factors of poverty in rural areas compared to urban settings; in comparison, the access to electricity is similar. Recognizing these differences is crucial for crafting effective policies to reduce inequalities and poverty. By tracking these inequalities with MPI in specific areas (urban or rural), we can gauge the effectiveness of policy implications in alleviating poverty. This allows for targeted adjustments to policies, ensuring they address the root causes of poverty in each context.

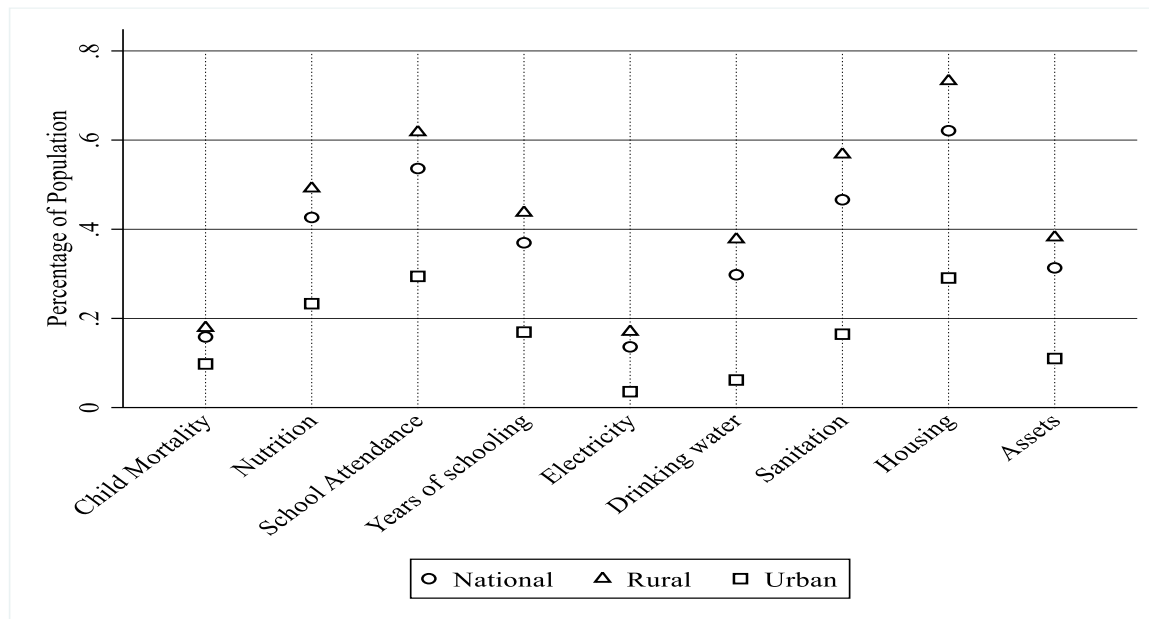


Figure 1 Censored deprivation decomposed by residence area

MPI results at sub-national level

Disaggregation at the provincial level (Admin Level 2) is implemented for a more granular area-based analysis, which is crucial for targeted poverty reduction policies. The results of this provincial analysis are presented in Table 3 and Figures 5 and 6.

Table 3 reveals significant disparities in multidimensional poverty across provinces. Zabul emerges as the most deprived province, with 91% of its population classified as multidimensionally poor. Helmand and Badghis follow closely behind. Conversely, Kabul, Panjshir, and Balkh exhibit the lowest levels of deprivation. Interestingly, the difference in the MPI value of Kabul (most non-deprived) is half of Panjshir (second-least deprived), while the difference in most deprived provinces is minimal. This suggests a potential concentration of poverty in specific regions. Furthermore, 15 out of 34 provinces have a lower MPI than the national average, highlighting the need for geographically targeted interventions. Moreover, previous MPI analysis, using data from 2016/17 (using different indicators and domains), reveals that the most deprived provinces were Badghis, Nooristan, Kunduz, and Zabul (NSIA, 2019). Compared to our findings, the MPI levels are increased.

Table 3 Provincial-level MPI in Afghanistan

Provinces	MPI	H	A	Population share
Zabul	0.579	91.0%	63.6%	1.3%
Helmand	0.558	87.8%	63.5%	7.0%
Badghis	0.549	88.0%	62.4%	2.2%
Nooristan	0.545	89.3%	61.0%	0.5%
Ghor	0.524	87.9%	59.6%	2.5%
Kandahar	0.519	84.0%	61.7%	4.8%
Urozgan	0.517	87.2%	59.2%	1.5%
Faryab	0.490	78.6%	62.3%	3.9%
Samangan	0.489	82.6%	59.2%	1.5%
Farah	0.488	79.8%	61.2%	1.8%
Paktika	0.484	86.5%	56.0%	1.6%
Badakhshan	0.441	79.7%	55.3%	3.5%
Kapisa	0.438	78.3%	56.0%	1.3%
Sar-e-pul	0.423	73.7%	57.4%	1.8%
Baghlan	0.410	75.4%	54.4%	2.6%
Kunduz	0.390	68.1%	57.2%	3.4%
Laghman	0.388	71.2%	54.5%	1.9%
Kunar	0.382	69.4%	55.1%	1.5%
Ghazni	0.372	66.4%	56.0%	3.0%
Maidan Wardak	0.370	69.4%	53.4%	1.8%
Paktiya	0.365	69.1%	52.8%	2.0%
Nangarhar	0.355	67.0%	53.0%	6.6%
Takhar	0.352	65.4%	53.8%	3.3%
Khost	0.343	67.9%	50.5%	2.7%
Logar	0.342	63.8%	53.6%	1.3%
Nimroz	0.341	64.1%	53.2%	1.0%
Jawzjan	0.330	60.1%	54.9%	2.3%
Daikundi	0.316	59.6%	53.0%	2.2%
Herat	0.315	55.8%	56.5%	8.1%
Parwan	0.307	58.4%	52.5%	2.3%
Bamyan	0.299	59.5%	50.3%	1.1%
Balkh	0.230	43.2%	53.1%	5.0%
Panjshir	0.216	45.2%	47.7%	0.3%
Kabul	0.128	28.0%	45.7%	12.6%

Notes: H- poverty headcount ratio, A- intensity of poverty

Based on Figure 2, the contribution of indicators varies across 34 provinces of Afghanistan, with some similarities. For instance, child mortality does not contribute to provincial MPI in Kapisa and Baghlan, while it is high in Balkh, Bamyan, and Herat provinces. In contrast, nutrition and education are contributing more or less equally across provinces in Afghanistan. Moreover, access to electricity and drinking water differs across provinces.

While access to drinking water is not a significant contributor to MPI in Logar, Nangarhar, and Paktika, it is a significant issue for the remaining 31 provinces that must be addressed. Therefore, the findings in Figure 5 point to different levels of development in various indicators across Afghanistan.

At the same time, some problems are country-wide, like education and education, which need to be addressed in nation-wide policy implications; some of the issues are much more local and call for specially curved targeted policies.

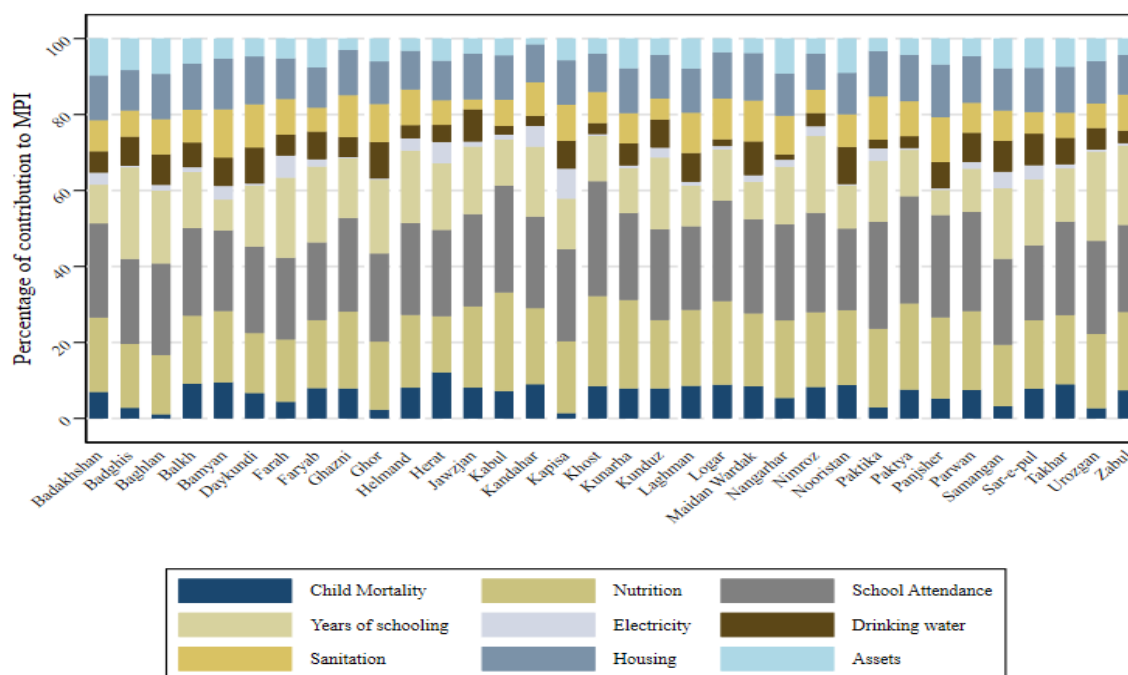


Figure 2 Contribution of each indicator to overall provincial MPI

Figure 3 draws the MPI at a provincial level in Afghanistan. Apart from Kandahar, the MPI is low in extensive urban settings such as Kabul, Balkh, Herat, and Nangarhar, while it's high in mountainous, hard-to-reach provinces such as Zabul, Ghor, Badghis, Nooristan, and Helmand. In addition, regional maps are made for every indicator to create a general view and show the regional disparity clearly.

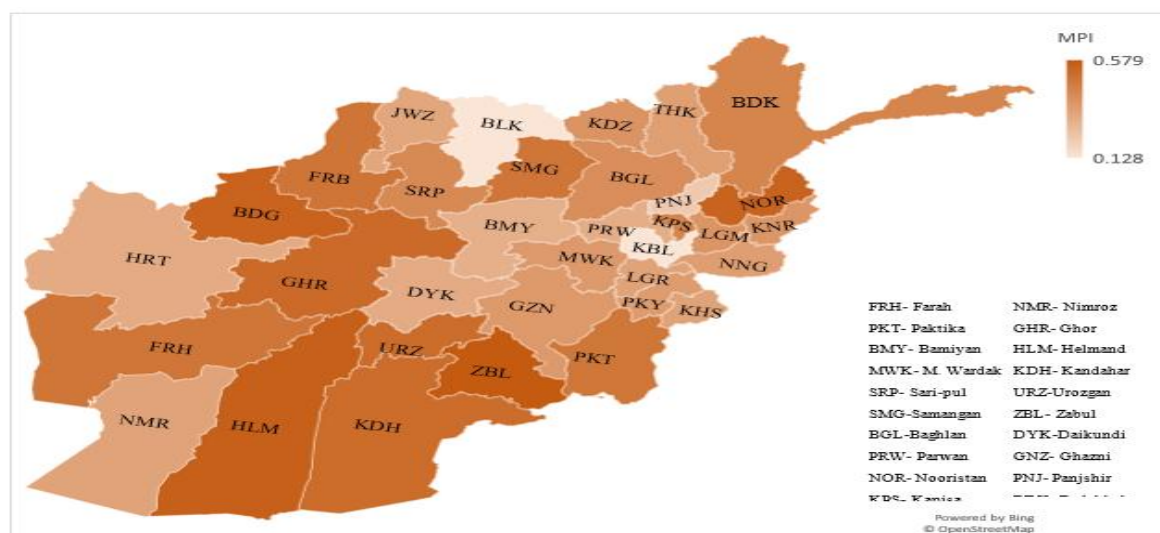


Figure 3 Provincial level MPI in Afghanistan as different from the national level

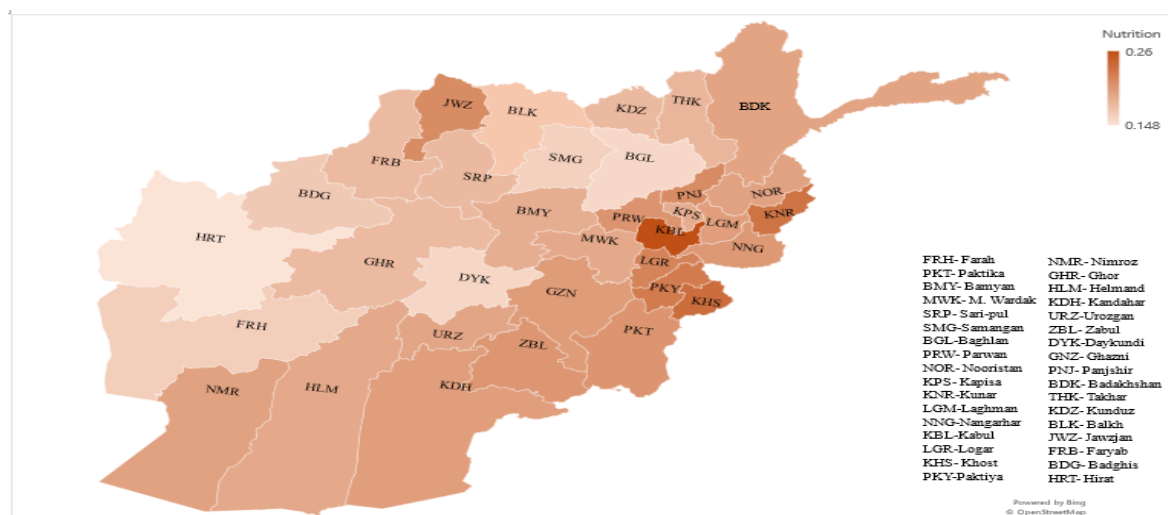


Figure 4 Provincial-level inequalities in nutritional poverty in Afghanistan

Figure 4 reveals provincial-level disparities in nutritional poverty based on the MPI in Afghanistan. East, southeast, and central Afghanistan, along with Jawzjan and Badakhshan from the north and northeast, have the highest level of nutritional poverty. In contrast, Baghlan, Samangan, Hirat, and Daykundi have the lowest. The south, southeast, and northeast have the lowest level of school attendance. The southern provinces especially have the highest poverty rates regarding school attendance.

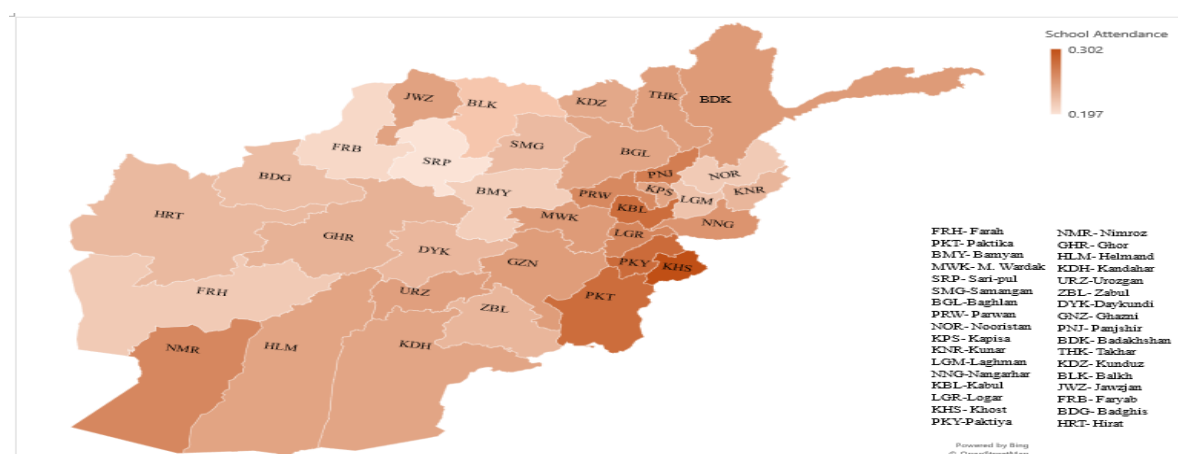


Figure 5 Provincial-level inequalities in school attendance poverty in Afghanistan

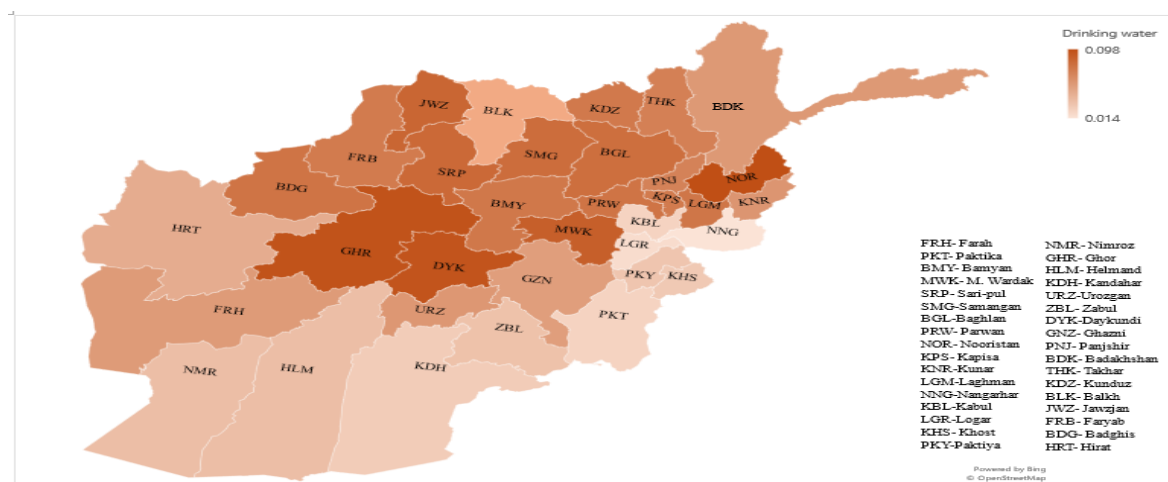


Figure 6 Provincial-level inequalities in access to drinking water poverty in Afghanistan

However, south and southeast Afghanistan have the lowest poverty rates regarding access to drinking water and asset holdings. While drinking water is a primary concern in central Afghanistan, asset holdings remain a significant burden to Afghanistan's east, northeast, and Northern provinces. This could be related to the lower economic base in these provinces, which forced them to live with minimal assets.

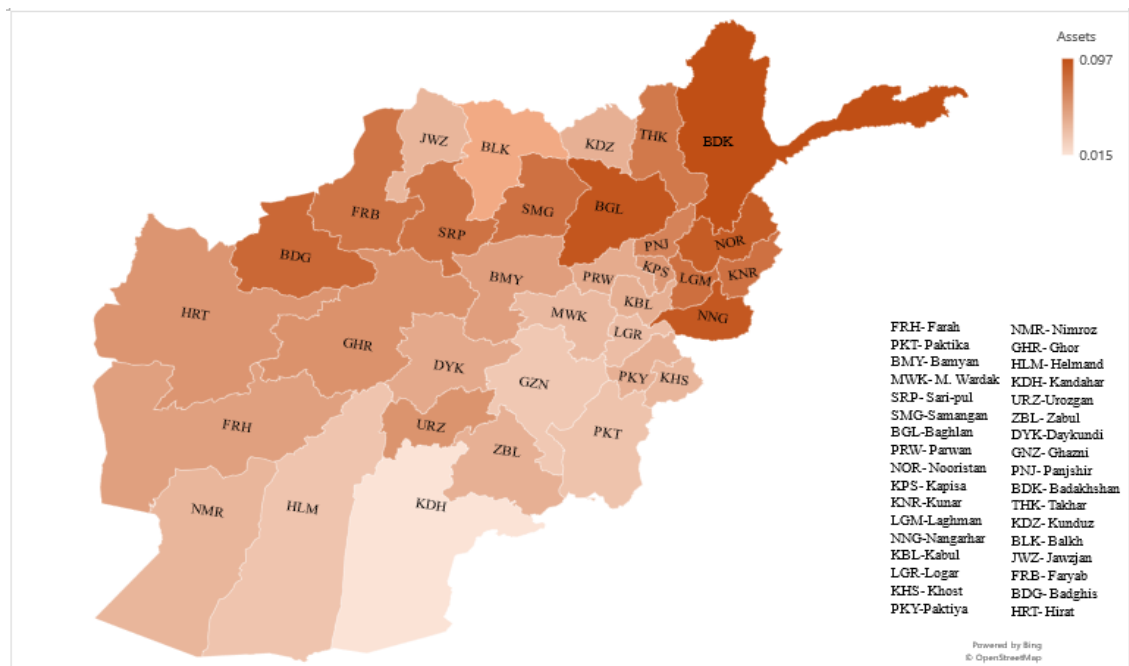


Figure 7 Provincial-level inequalities in assets holding poverty in Afghanistan

Conclusion

This paper analyses the changes in poverty in Afghanistan after the political changes in the country utilizing the MICS-2022-23 data set. Moreover, by comparing the results from the current analysis with previous MPIs, we aimed to navigate between various SDGs to uncover the achievements and drawbacks across time and space. This will allow policymakers to adjust new plans and allocate resources more efficiently to locations and indicators requiring extra attention to leave people out of poverty. Moreover, this paper, which incorporates nutrition data not available in previous MICS surveys, provides a more complete understanding of poverty in Afghanistan, especially food utilization. Ultimately, our analysis will contribute valuable insights for policymakers seeking to achieve the first UN SDGs in Afghanistan.

The overall MPI indicators used in this analysis are related to 8 SDGs. The overall index is a proxy for no poverty (SDG1), while the nutrition indicator is set to quantify zero hunger (SDG2). In addition, child mortality accounts for health and well-being (SDG3), and the whole domain two is dedicated to quality education (SDG4). Moreover, drinking water and sanitation cover SDG 6, while access to electricity indicates affordable and clean energy (SDG7), and housing is a proxy for sustainable cities and communities (SDG11).

The results indicate that access to drinking water and electricity improved compared to 2016, while the conditions got worse in other indicators. It is a sign of rollback in 6 indicators incorporated with 4 SDGs, namely increased poverty (SDG1), increased hunger (SDG2), worse off education (SDG4), and increased deprivation in housing (SDG11) (OPHI, 2023). In contrast, it is impossible to compare the mortality with previous studies due to the unavailability of the data in the past.

By decomposing the MPI over urban/rural and admin 2-level analysis, we can investigate the overall inequality in the country.

This part serves SDG 10, which calls for reducing disparities within and among countries. Unfortunately, Afghanistan could not progress in reducing inequality between rural and urban or among 34 provinces from a regional perspective. Rural areas, with $\frac{3}{4}$ of the population, are multidimensionally poorer than urban settings.

Among indicators, the most significant contribution to overall MPI comes from school attendance, years of education, and nutrition. Considering the current educational policy, the overall condition will worsen even further. Because of half the population, girls are banned from attending school above 6th grade. This will translate into further deprivation in the next generation, and multidimensional poverty will be transferred between generations. In contrast, nutrition's immense contribution reflects the country's overall economic melting down after the administrative changes. The vast amounts of aid distributed by the UN agencies (WFP, 2023) may have averted some of the risks, but the overall condition signals the rise of deprivation in this indicator.

In conclusion, Afghanistan has recorded a high increase in overall poverty in the aftermath of the recent political changes. In addition, inequalities persist between rural and urban areas, as well as among provinces. Some places are better in one indicator while worse off in another. The existing disparities call for realistic, indicator, and area-based poverty reduction policies to improve the quality of life in Afghanistan.

Recommendation

The following recommendations aim to address the multifaceted nature of poverty in Afghanistan, targeting the specific drivers of inequality in education, nutrition, infrastructure, and regional disparities.

- Targeted Education Reforms in Rural and Underdeveloped Regions**
 Given the significant disparities in education indicators, particularly in the southern, western, and northwestern regions, it is essential to implement targeted education reforms. These should focus on improving school attendance, increasing years of schooling, and enhancing educational infrastructure in rural and impoverished provinces. Programs that provide incentives for teachers to work in these regions and initiatives to reduce barriers to schooling (such as transportation or safety concerns) should be prioritized.
- | | | | |
|------------------|--------------------|----------------|-----------------|
| Localized | Nutritional | Support | Programs |
|------------------|--------------------|----------------|-----------------|

 With nutrition being a major contributor to the Multidimensional Poverty Index (MPI), a region-specific approach to addressing food insecurity is critical. Nutritional programs should be designed to target high-poverty areas, particularly in rural regions, by providing food assistance, promoting sustainable agricultural practices, and improving access to balanced diets. Additionally, integrating nutritional education into school curricula could improve long-term health outcomes.
- Improving Access to Basic Infrastructure: Water and Sanitation**
 The central, northeastern, and northern regions exhibit higher poverty rates related to access to drinking water. Therefore, it is essential to prioritize investments in water and sanitation infrastructure in these regions. Policies should focus on expanding clean water access through community-based solutions and improving sanitation facilities to reduce health disparities and increase overall well-being.
- Urban-Rural Disparity Reduction through Economic Diversification**
 Rural areas are experiencing disproportionately higher poverty and inequality. To address this, targeted economic development policies should focus on diversifying rural economies beyond agriculture. This can include promoting local small businesses, improving access to microfinance for rural entrepreneurs, and creating job opportunities in sectors such as handicrafts, agro-processing, and tourism.

These interventions should be tailored to local resources and capacities.

- **Tailored, Region-Specific Poverty Alleviation Policies**
Given the stark regional disparities in poverty levels and the MPI indicators, it is crucial to design geographically focused poverty alleviation strategies. Regional variations in poverty should be carefully considered when creating policies, with interventions tailored to the specific needs of different provinces. This can involve decentralized decision-making, where local authorities are empowered to design and implement poverty reduction initiatives based on local data and circumstances.

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Climate Change and Food Security in Rural Afghanistan: Impacts, Adaptation Strategies, and Policy Implications

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Abstract

This study examines the impact of climate change on food security and adaptation strategies in rural areas of Afghanistan. As a cornerstone of sustainable development, food security, particularly in developing countries like Afghanistan, which rely heavily on agriculture, is influenced by complex factors, including climate change. Using qualitative and quantitative methods, this research analyzes the existing challenges and identifies effective strategies for addressing these changes. The findings reveal that persistent droughts and temperature fluctuations have reduced agricultural production and food insecurity, profoundly affecting rural households' livelihoods. Additionally, this study identifies local strategies for adapting to these challenges and emphasizes the need for policy interventions. The results of this research can serve as a scientific basis for informed decision-making on food security and sustainable agriculture in Afghanistan.

Keywords: *climate change, food security, rural areas, Afghanistan*

Introduction

Food security, as a fundamental pillar of sustainable development and community well-being, refers to the provision of sufficient, healthy, and accessible food for all members of society. In developing countries like Afghanistan, where a significant portion of the population resides in rural areas and relies heavily on agriculture, food security is not limited to agricultural production but is also influenced by a complex set of factors, including climate change (Yar, 2024; Yar & Zazia, 2024). As one of the most significant challenges of the 21st century, climate change has dramatically altered precipitation patterns, temperatures, and environmental conditions, profoundly affecting food production systems (Caron et al., 2018). In Afghanistan, the effects of climate change are particularly evident in rural areas (Rahmani et al., 2021; Yar & Zazia, 2024). Persistent droughts, diminishing water resources, and changes in growing seasons are among the consequences of climate change that have directly impacted agricultural production. These changes have not only limited rural households' access to food resources but also negatively affected the sustainability of the agricultural economy. Especially in regions where the tools and infrastructure necessary to cope with these changes are insufficient, rural food security is at serious risk (Kc et al., 2022; Yar & Zarghani, 2024). Given these challenges, the introduction of adaptation strategies designed based on the specific conditions of each region can be one of the most effective approaches to addressing the adverse effects of climate change. Adaptation strategies consist of a set of actions and policies aimed at reducing the vulnerability of rural communities and enhancing their resilience to climatic changes. Therefore, studying the impact of climate change on food security in Afghanistan and examining adaptation strategies in this context can contribute significantly to improving living conditions in rural areas and reducing the risks associated with climate change (Palanivel & Shah, 2021).

This research aims to investigate the challenges posed by climate change in rural areas of Afghanistan, analyze the impact of these changes on food security, and introduce effective strategies for adaptation. Given the importance of agriculture to Afghanistan's economy and the strong

dependency of rural areas on this sector, the results of this study can serve as a tool for informed decision-making and the development of sustainable policies aimed at enhancing food security (Yar & Zazia, 2024). The main objective of this study is to examine the impacts of climate change on food security in rural areas of Afghanistan and identify adaptation strategies that can help mitigate the negative effects of these changes. This research is based on the hypothesis that rural households employ various methods and strategies to cope with climate change and its impacts on food security, which require detailed identification and analysis.

To achieve these objectives, this study raises the following questions:

What are the specific impacts of climate change on food security in rural areas of Afghanistan?

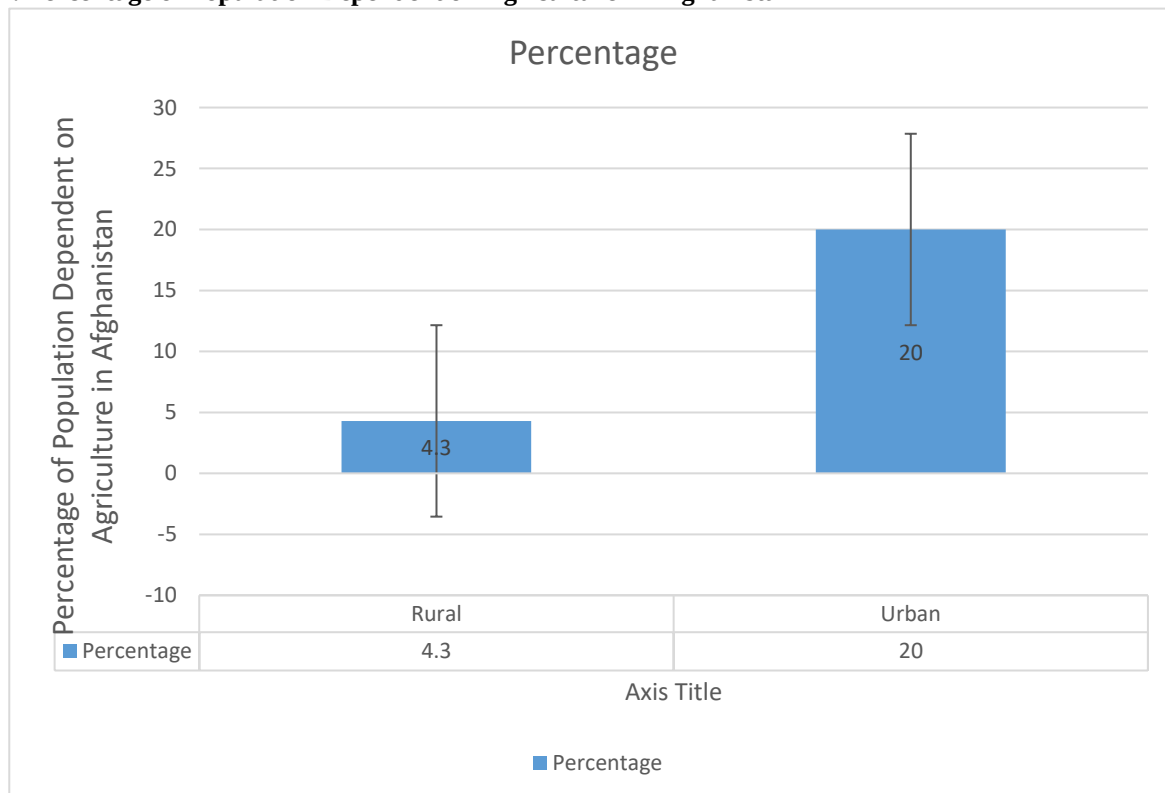
What strategies do rural households use to adapt to climate change and enhance their food security?

What factors influence the success or failure of these strategies?

This study utilizes both qualitative and quantitative methods, collecting data through interviews with farmers and analyzing statistical data. This approach allows for a comprehensive examination of the topic and the presentation of valid and documented findings. Moreover, this research aims to identify the strengths and weaknesses of existing strategies and provide recommendations for strengthening the resilience of rural households to climate change. This study can serve as a valuable resource for decision-makers and policymakers in the fields of food security and sustainable agriculture in Afghanistan. The findings of this research not only contribute to a better understanding of the current situation but also guide the designing of effective, evidence-based policies aimed at improving food security and sustainable resource management in Afghanistan.

Problem Statement

Climate change, as one of the serious and global challenges of the 21st century, has profoundly affected food security in developing countries, particularly Afghanistan. With its unique geography and extreme climatic fluctuations, including recurrent droughts and unpredictable rainfall, Afghanistan faces significant crises in providing sufficient and high-quality food. Approximately 80% of the country's population relies on agriculture, especially in rural areas, where there are substantial challenges to ensuring food security. This issue has not only led to reduced agricultural production and food diversity but has also increased poverty and social insecurity (Rahmani et al., 2021; Verma et al., 2024; Yar, 2024). Furthermore, the economic and social instabilities resulting from climate change exacerbate food security challenges in Afghanistan (Yar et al., 2024). Many households struggle to meet their basic needs, making it imperative to examine the impacts of climate change on food security and identify adaptation strategies that could help mitigate these effects (Belay et al., 2024).

Chart-1: Percentage of Population Dependent on Agriculture in Afghanistan

Research Significance

The significance of this research is evident in several aspects:

1. **Raising Awareness:** This study analyzes the effects of climate change on food security in Afghanistan, contributing to the broader public and scientific understanding of the issue. Increased awareness of the various dimensions of this problem can facilitate more effective discussions and policymaking.
2. **Developing adaptation strategies:** By identifying and examining local and indigenous strategies employed by rural households to cope with climate change, this research contributes to the improvement of effective approaches to food security and resource management.
3. **Supporting Policy Development:** The results of this study can serve as a scientific foundation for the formulation and enhancement of food security and sustainable agriculture policies in Afghanistan. Policymakers can use these findings to design programs aimed at improving livelihoods and increasing the resilience of rural households.
4. **Strengthening Resilience:** This research identifies the strengths and weaknesses of existing strategies in rural areas that can help strengthen households' resilience to climate change and improve their living conditions. Overall, this study is a necessary step toward a better understanding of the status of food security and the effects of climate change in Afghanistan, serving as a reliable resource for informed and evidence-based decision-making in this area.

Literature Review

Food security and climate change are recognized as two critical and interconnected domains in the study of sustainable development and environmental geography. In recent years, numerous studies have examined the impacts of climate change on food security, as climatic shifts directly affect agricultural production, natural resources, and access to food across different regions of the world. This section reviews and analyzes previous research related to climate change, food security, and adaptation strategies in rural areas,

particularly in developing countries like Afghanistan (Yar & Yasouri, 2023). One significant study in this field is the research conducted by (Al et al., 2008), which indicates that climate change in countries with agriculture-dependent economies, such as Afghanistan, leads to reduced agricultural productivity and increased instability of food resources. The study emphasizes that decreased rainfall and changes in seasonal patterns reduce crop yields, thereby threatening rural food security.

(Singh et al., 2020) explored the impacts of climate change on agriculture and food security in South Asian countries. This study highlights that temperature variations and changes in rainfall patterns have severely negative effects on agriculture in arid and semi-arid regions such as Afghanistan. It also emphasizes the need for adaptation strategies to mitigate the adverse effects of these changes on food security.

The study by (Adger et al., 2003) focuses on the social and economic aspects of climate change impacts, stating that adaptation is a key strategy for addressing these effects. The study suggests that adaptation should not only include agricultural techniques and natural resource management but also pay broader attention to social and economic dimensions. It highlights the role of empowering local communities and increasing their participation in decision-making processes as part of adaptive strategies.

Research related to Afghanistan also emphasizes the importance of adaptation strategies. Omerkhil, in their study on the impacts of climate change in rural Afghanistan, concluded that frequent droughts, one of the main consequences of climate change, are a major factor in the destruction of rural livelihoods and the deterioration of food security in the country. They recommend that comprehensive policies on water resource management, modern agricultural techniques, and infrastructure improvements be implemented to enhance rural food security.

Additionally, (Morton, 2007) analyzed adaptive strategies in vulnerable regions and showed that using modern agricultural techniques, such as conservation agriculture and sustainable water management systems, can help mitigate the negative effects of climate change on food security. He emphasizes that the success of these strategies requires close collaboration among governments, international organizations, and local communities.

Finally, a study by (Change, 2001) examined global adaptation strategies and demonstrated that reducing the impacts of climate change on food security requires tailored strategies based on the geographical, economic, and social conditions of different regions. The research highlights the role of innovative technologies, such as digital and data-driven agricultural systems, in improving food security.

The existing literature shows that the impacts of climate change on food security are multidimensional, requiring comprehensive consideration from perspectives such as natural resource management, agricultural policies, social empowerment, and modern technologies. The present study, by examining the specific conditions of rural areas in Afghanistan and

offering adaptive solutions based on previous studies, seeks to provide innovative contributions to this field.

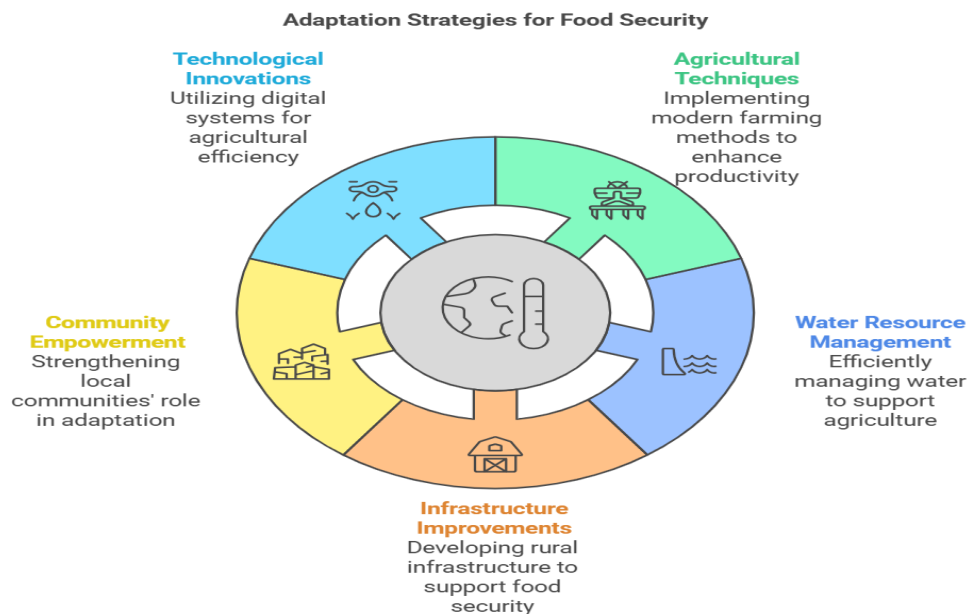


Figure-1: Food Security and Climate Change: An Analysis of Adaptation Strategies in Rural Afghanistan

Theoretical and conceptual framework

The theoretical and conceptual framework of this research is developed to explain the relationship between climate change and food security, based on existing theories related to climate change, food security, and adaptation strategies. This framework helps us gain a better understanding of the factors influencing food security and how rural communities adapt to climate change. The main theories utilized in this section include "adaptation theory" and "resilience theory" in response to climate change and the concept of "food security."

1. **Adaptation Theory:** Adaptation theory, as one of the key theories in climate change studies, refers to a set of actions and strategies adopted by communities, countries, or systems to cope with the effects of climate change. The primary goal of adaptation, according to this theory, is to reduce vulnerability to the adverse impacts of climate change and increase resilience and capacity to deal with these changes (Adger et al., 2005). This research employs adaptation theory as the primary framework to analyze different strategies in Afghanistan's rural areas. In this context, adaptation refers to changes in agricultural practices, water resource management, and the use of modern technologies to address the negative consequences of climate change and maintain food security. Adaptation theory also emphasizes the role of local community participation and government policies in designing and implementing effective adaptation strategies.

2. **Resilience Theory:** Resilience is another key concept in the theoretical framework of this research, which refers to the capacity of communities or systems to recover from crises and maintain their essential functions and structures.

According to resilience theory, social and environmental systems must be able to adapt to climate change while maintaining their sustainability (Folke, 2006). In this study, resilience refers to the ability of rural households and communities in Afghanistan to maintain food security in the face of climatic shocks such as droughts, floods, or temperature fluctuations. Previous research has shown that rural resilience depends on various factors such as access to natural resources, local infrastructure, and social capacity to cope with crises (Cutter et al., 2008).

Therefore, this study examines the factors that can enhance the resilience of Afghan rural households against climate change.

3. Food Security Concept: Food security is a fundamental concept in this research and refers to the ability of individuals to access sufficient, safe, and nutritious food to maintain a healthy and active life. According to the Food and Agriculture Organization ([Al et al., 2008](#)), food security is achieved when all people, at all times, have access to enough food to meet their nutritional needs.

Numerous studies have shown that climate change is one of the greatest threats to global food security, especially in developing countries that rely heavily on agriculture ([Wheeler & von Braun, 2013](#)). In this research, food security is used as a measure to assess the impacts of climate change on rural Afghan communities and their access to food. The study aims to demonstrate how changes in rainfall patterns, rising temperatures, and declining water resources threaten the food security of rural households.

4. Social-Ecological Systems Model: The social-ecological systems model addresses the interaction between social and environmental factors within a complex system. This model emphasizes that changes in one part of the system (e.g., climate change in the environmental sector) can directly affect other parts of the system (e.g., food security in the social sector) ([Berkes et al., 2000](#)). In this study, the social-ecological systems model was used as a framework to analyze the interrelationships between climate change and food security in Afghan rural communities. This model helps us better understand the dynamics between natural resources, agriculture, and social welfare in the face of climate change.

5. Vulnerability Theory: Vulnerability theory refers to the degree to which a system or community is susceptible to external risks and shocks, such as climate change ([Turner & Zhou, 2023](#)). According to this theory, the more vulnerable a system is, the more severe the negative impacts of climate change will be. In this study, vulnerability theory is used to analyze factors that can weaken food security in Afghanistan in the face of climate change, including lack of resilient infrastructure, weaknesses in agricultural policies, and economic poverty. The theoretical and conceptual framework of this research combines adaptation theory, resilience theory, food security concepts, the social-ecological systems model, and vulnerability theory to provide a comprehensive analysis of the impacts of climate change on food security in Afghanistan. This framework helps us understand the multifaceted effects of climate change on rural production and livelihoods and offers effective adaptive solutions to confront these challenges.

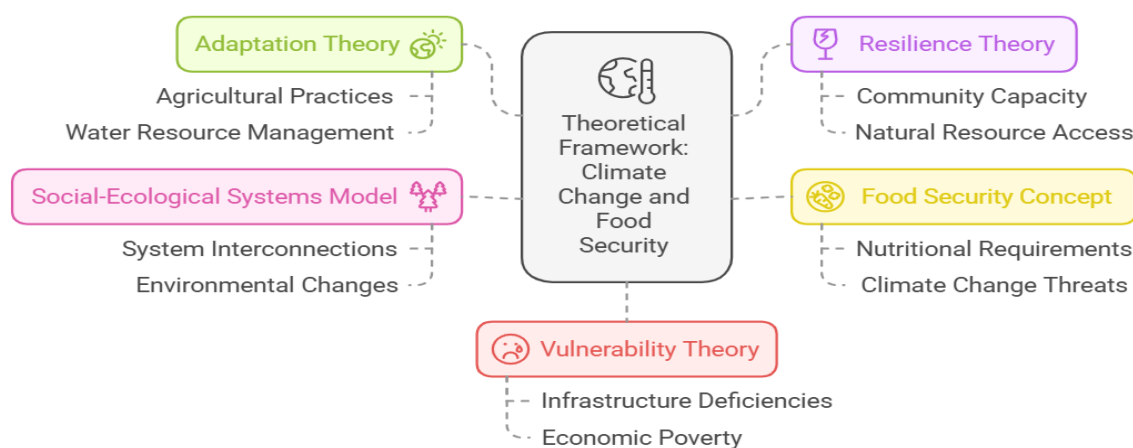


Figure-2: Theoretical and Conceptual Framework: Climate Change and Food Security

Methodology

This research employs a mixed-methods approach (both quantitative and qualitative) to examine the impacts of climate change on food security and identify adaptation strategies in rural areas of Afghanistan. This approach allows us to conduct a comprehensive analysis by using quantitative data to explore general patterns and qualitative data to gain deeper insights into the experiences and challenges of rural communities.

The study population includes rural households in various regions of Afghanistan that are directly affected by climate change. Stratified random sampling was used to select the samples, allowing us to cover different households from areas with diverse climatic and geographical conditions. The sample size is determined using Cochran's formula to ensure a representative and adequate sample for statistical analysis.

The following tools will be used for data collection:

Structured Questionnaires: The questionnaires include both closed and open-ended questions regarding food security, the impacts of climate change, and adaptation strategies. These questionnaires are designed to measure the perspectives and experiences of rural households concerning climate change and its impact on food security.

Semi-structured Interviews: To collect qualitative data, interviews will be conducted with local leaders, farmers, and experts in the fields of climate and food security. These interviews aim to provide deeper insights into the existing challenges and local strategies for coping with climate change.

Secondary Data: Available data, including climate statistics, agricultural production data, and official reports from governmental and international organizations such as FAO and WFP, will be utilized. This secondary data will aid in the detailed analysis of climate change impacts on a broader scale. The data analysis process will include the following steps:

Quantitative Data Analysis: Data from the questionnaires will be analyzed using statistical software such as SPSS or STATA.

Statistical tests such as t-tests, multiple regression, and analysis of variance (ANOVA) will be used to analyze relationships between variables and assess the impacts of climate change on food security.

Qualitative Data Analysis: The data obtained from interviews will be analyzed using thematic content analysis. This method will help identify patterns, key themes, and adaptation strategies used in rural communities. The interviews will be carefully coded to extract significant themes related to climate change and food security.

To ensure the validity and reliability of the research tools, the following steps will be taken:

Content Validity: The questionnaires and interviews will be reviewed by experts in climate change and food security to ensure adequate coverage of the research content.

Reliability Testing: Cronbach's alpha test will be used to assess the reliability of the questionnaires, helping to ensure that the data is measured consistently without random errors.

Triangulation Method: To increase validity, the triangulation method will be used, meaning data from multiple sources (questionnaires, interviews, and secondary data) will be analyzed to address a single issue. This method enhances the credibility of the research results and considers various perspectives.

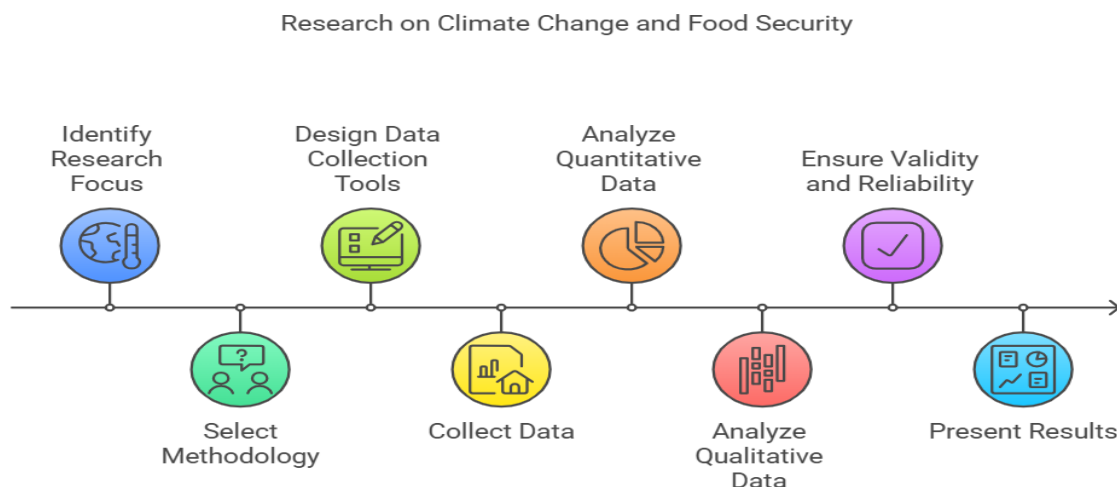


Figure-3: Impacts of Climate Change on Food Security in Rural Afghanistan: A Mixed-Methods Approach

This research methodology, using a mixed methods approach and combining quantitative and qualitative tools, provides a comprehensive analysis of the impacts of climate change on food security in rural Afghanistan and explores adaptation strategies. Careful selection of samples, questionnaire design, and data analysis allow us to achieve valid and reliable results that can contribute to future policymaking and actions related to food security and climate change.

Results & Findings

In this section, the findings of the research are presented based on data collected through quantitative and qualitative methods. The results include statistical analyses of quantitative data and content analysis of qualitative data. This section is accompanied by tables, charts, and detailed explanations to provide readers with a clear and thorough understanding of the results. The research explores the effects of climate change on food security and analyzes the adaptation strategies used in rural areas of Afghanistan.

1. Quantitative Results

1.1. Impact of Climate Change on Agricultural Production According to the data gathered from questionnaires, the average agricultural production in the surveyed areas has significantly declined over the past decade. Multiple regression analysis indicates that temperature fluctuations and reduced rainfall have had the greatest impact on the decrease in agricultural output. The table below shows the changes in the production levels of key crops (wheat, barley, rice, and corn) in the surveyed areas:

Table 1: Impact of Climate Change on Agricultural Production

Crop Type	Production Before Climate Change	Production After Climate Change	Percentage Decrease
Wheat	50000	20000	30%
Barley	30000	20000	33%
Rice	20000	15000	25%
Corn	40000	25000	37.5%

This reduction in agricultural output is directly related to the increasing severity of droughts and temperature fluctuations. The results show that rural households have experienced difficulties in accessing food due to these changes.

1.2. Household Food Security Index: The household food security index was measured using global standards such as the Food Insecurity Experience Scale (FIES). The results of this index indicate that over 60% of households have experienced varying degrees of food insecurity in the past two years.

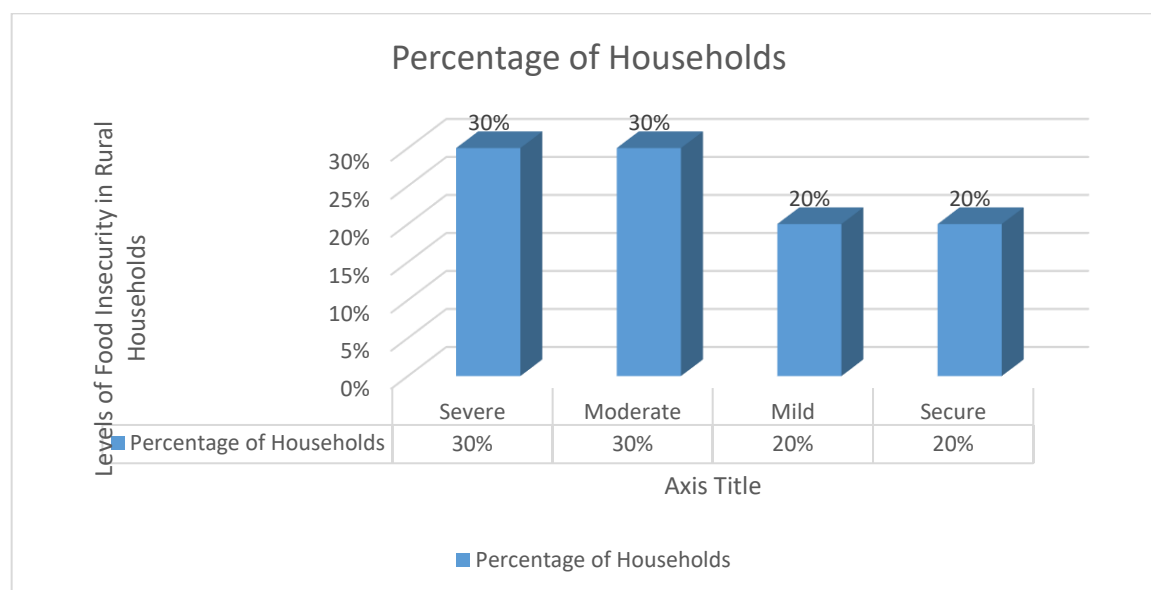


Chart-2: Levels of Food Insecurity in Rural Households

As shown, a significant percentage of households are facing severe and moderate food insecurity. These findings confirm that climate change has directly affected households' access to food.

1.3. Adaptation strategies employed: Respondents to the questionnaires mentioned various strategies for adapting to climate change. An analysis of the data shows that the most commonly used strategies include:

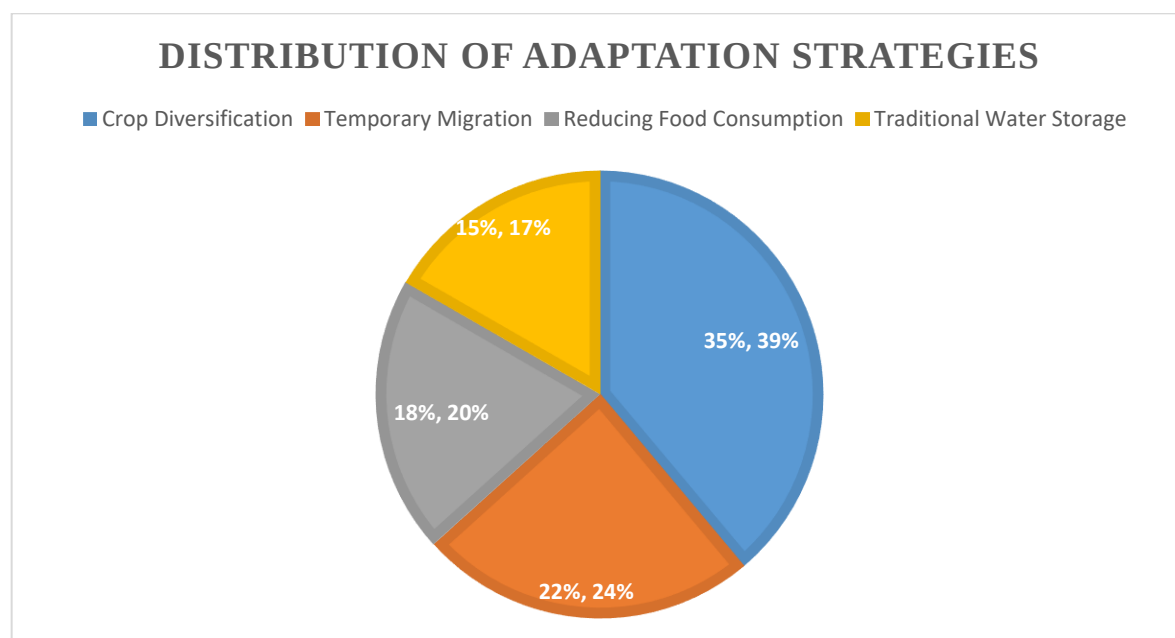


Figure-4: Distribution of Adaptation Strategies

2. Qualitative Results

2.1. Households' Experiences of Climate Change: In semi-structured interviews, most rural households emphasized that climate change has seriously affected their lives in recent years. Some of the responses included the following:

Reduced access to agricultural water: Rural households mentioned that decreased rainfall and reduced water resources have left their agricultural land barren. One farmer stated, "Our water supply has decreased to one-third of what it used to be, and we even face challenges in accessing drinking water."

Increased temperature fluctuations: Many interviewees referred to extreme temperature changes, which have damaged crops, especially during harvest time.

2.2. Local Strategies for Coping with Climate Change: In another part of the interviews, several local strategies for coping with the effects of climate change were identified. These strategies mainly relied on traditional and indigenous knowledge, such as the use of traditional water storage methods, which were highlighted as one of the most important survival mechanisms in the face of droughts.

3. Mixed-Methods Analysis: By simultaneously analyzing quantitative and qualitative data, it was found that the adaptation strategies employed by rural households are primarily driven by economic pressures and reduced income resulting from climate change. Overall, the findings indicate that while rural households use various strategies to respond to climate change, these measures alone are insufficient, and there is a need for policy interventions and government support. The results of this study confirm that climate change has had significant negative impacts on the food security of rural households in Afghanistan. Additionally, the adaptation strategies employed by households have not yet fully compensated for these negative effects. Based on these findings, it is recommended that food security and climate change adaptation policies be strengthened at the national level and additional support measures be provided to rural communities.

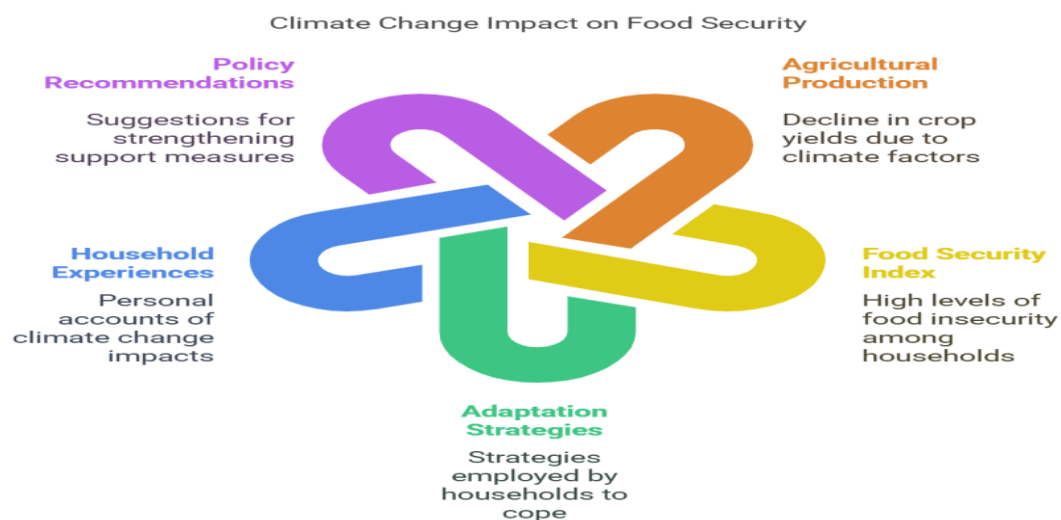


Figure-4: Research Findings on Climate Change and Food Security in Rural Afghanistan

Discussion and Interpretation

In this section, the research results are interpreted and analyzed in light of the literature and theoretical framework. The findings indicate that climate change has significantly affected food security in rural areas of Afghanistan, and households have adopted various methods to adapt to these changes. The following is a discussion of the results, comparing them with previous studies and the theoretical framework.

1. Alignment of Results with the Literature: The findings of this study align with previous research on the effects of climate change on food security. Studies conducted by (Adger et al., 2005) and (Al et al., 2008) also demonstrate that climate change leads to reduced agricultural production and increased temperature fluctuations, which directly impact the food security of rural households.

Our results similarly show a significant decline in the production of key crops in rural Afghanistan, primarily due to droughts and decreased rainfall (Yar et al., 2024). Previous studies have emphasized the importance of crop diversification and the use of modern irrigation techniques as effective strategies to combat the effects of climate change (Smith et al., 2014). In this study, crop diversification was identified as one of the primary strategies employed by rural households in Afghanistan to cope with climate change.

This indicates that Afghan rural households, much like other regions globally, are resorting to similar traditional methods, though these measures alone are insufficient and require the enhancement and application of modern agricultural technologies.

Table-3: Comparison of Agricultural Production Decline in Afghanistan and Other Developing Countries

Country	Percentage Decline
Afghanistan	30-37.5%
Ethiopia	20-25%
India	15-20%

2. Newly Identified Factors: One innovative aspect of this research is the identification of indigenous and local strategies for coping with climate change. The results show that Afghan rural households employ traditional methods such as water storage and temporary migration as coping mechanisms. While previous studies have largely focused on modern solutions, this research demonstrates that indigenous methods can also complement modern approaches.

The study also revealed that some households have adapted by reducing food consumption and changing their dietary patterns. This finding, rarely explored in previous research, highlights the importance of cultural and economic factors in the adaptation to climate change.

3. Comparison of Results with Theoretical Framework: In the theoretical framework of this study, the models of adaptation and resilience were used as the basis for analysis. According to resilience theory, communities should be able to maintain and strengthen their structures when facing crises and changes (Walker et al., 2004). The results show that despite severe resource limitations, rural households have managed to achieve a level of resilience through various strategies.

However, the findings also indicate that the current resilience of these households is at risk due to the drastic reduction in water and financial resources. Nonetheless, the use of indigenous knowledge and local strategies suggests the existence of resilience foundations that can be strengthened with appropriate policy interventions.

4. Results and Food Security Improvement: This research clearly shows that climate change is one of the primary drivers of food insecurity in rural areas of Afghanistan. The results can assist decision-makers and policymakers in designing more effective policies to address these changes, taking into account the local experiences and strategies of rural communities. The findings also emphasize the importance of education and capacity-building for farmers in utilizing modern agricultural techniques and resource management.

Overall, the suggested strategies for improving food security and addressing climate change include:

Strengthening modern agricultural practices: Based on the findings, the use of modern irrigation and agricultural techniques can improve agricultural production and consequently enhance food security.

Capacity-building and farmer education: Educating and empowering farmers to adapt to climate change and adopt new technologies will play a crucial role in reducing their vulnerability.

Government and international support: The current strategies employed by rural households are insufficient on their own, and greater support is needed from both government and international organizations.

This research demonstrates that climate change has had widespread negative impacts on food security in rural Afghanistan, and households are employing a combination of traditional and modern strategies to address these challenges. However, broader interventions and institutional support are necessary to improve food security and strengthen the resilience of these communities.

Conclusion

This study has shown that climate change has had a significant negative impact on food security in rural areas of Afghanistan, and rural households face numerous challenges in confronting these changes. The findings highlight the importance of adaptation strategies in these communities and show that although these strategies are not sufficient on their own, they play a critical role in increasing farmers' resilience to climate crises.

The results of this research can provide a solid foundation for food security policies in Afghanistan. Policymakers should consider these findings when developing programs for sustainable agriculture, increasing farmer capacity, and improving water resource management infrastructure. Additionally, the research underscores the importance of international cooperation to combat climate change and learn from the experiences of other countries.

This study faced some limitations, including the difficulty of accessing comprehensive and accurate data from remote areas of Afghanistan. Future research should focus on gathering more extensive field data and conducting a more in-depth examination of indigenous and local strategies to contribute to the development of knowledge in this field.

Overall, the findings of this study not only contribute to improving food security policy in Afghanistan but also enrich the scientific literature on climate change and food security in developing countries.

Recommendations

Based on the results of this study and the analysis, several practical and policy recommendations are suggested to mitigate the negative impacts of climate change on food security in rural Afghanistan:

- 1. Promote sustainable agricultural practices:** To combat the effects of climate change, sustainable agriculture using modern technologies such as efficient irrigation systems and drought-resistant farming methods should be promoted and developed in rural areas. Government incentives for farmers using these methods could be effective.
- 2. Increase crop diversity:** Due to climate change and fluctuations in agricultural production, diversifying crops in rural Afghanistan can reduce the risks associated with declining yields of certain key crops. Supportive policies for farmers to grow diverse crops, particularly those resistant to climate change, are essential.
- 3. Capacity-building and farmer education:** One of the most important strategies for coping with climate change is to educate farmers about resource management and the use of modern agricultural techniques. Regular educational programs can enhance farmers' skills and knowledge, leading to increased productivity and reduced vulnerability.
- 4. Strengthen early warning systems and disaster management:** Establishing and strengthening early warning systems to inform farmers about climate risks and natural disasters such as droughts and floods will help them respond more quickly to these events and reduce damages.
- 5. Invest in irrigation infrastructure and water resource management:** One of the biggest challenges in addressing climate change is water resource management.

Investments in modern irrigation infrastructure, water storage, and water purification can increase farmers' resilience to water shortages.

6. Enhance regional and international cooperation: Regional and international cooperation to combat climate change and reduce its impact on food security should be strengthened. Afghanistan can benefit from the experiences of other countries in addressing climate change and join regional networks to exchange knowledge and expertise.

7. Financial and social support for vulnerable households: Establishing special financial funds to support vulnerable households in rural areas, especially during natural disasters, can help reduce their vulnerability. This support should include low-interest loans, agricultural subsidies, and agricultural insurance provisions.

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Meat Borne Parasitic Zoonotic Diseases and its Public Health Significance

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Abstract

The significance of meat-borne pathogens in worldwide disease transmission and food safety is critical for public health. Meat-borne parasitic zoonotic diseases are a global concern that has a considerable impact on human health and have economic ramifications, making them an important public health issue. Although the overall incidence rate is dropping, it continues to harm local public safety. Increasing populations, poverty, and international trade in food and animal feed are contributing to worsening food safety issues in the 21st century. These factors, combined with climate change, are having a detrimental impact on the safety of food and drinking water worldwide. Parasitic meat-borne diseases can spread from one host to another. The route of infection may be water-based, foodborne, or through the route. They have been identified as Neglected Tropical Diseases (NTDs), causing diseases in over one billion people worldwide, but have received little attention from the public health community. To investigate potential causes of its high prevalence in some areas, validated detection methods such as survival/infectivity assays and consensus molecular typing protocols are required. These methods are essential for developing quantitative risk assessments and effective control measures. Enhanced awareness and adherence to food safety guidelines are essential to reduce the burden of meat-borne parasitic diseases globally. This review will cover the current state and epidemiological trends in meat-borne parasite infections.

Key Words: Meat borne, parasites, significant, public health

Introduction

Food is essential for people, but it can also be a source of disease transmission if contaminated with harmful microbes (bacteria, viruses, or parasites) or chemicals/toxins. Every year, billions of people are exposed to food-borne diseases (FBDs), and millions become ill as a result. Many people die as a result of eating unsafe foods (WHO, 2016). Parasites are organisms that feed on and protect other living species known as hosts. They can be spread from animal to human, human to human, or human to animal. Several parasites have been identified as major causes of foodborne and waterborne diseases (Bhatia et al. 2016). Meat-borne parasitic diseases represent a significant public health concern globally, primarily transmitted through the consumption of infected or undercooked meat. These diseases are caused by various pathogens, including protozoa and helminths, which can lead to severe health complications in humans (USDA, 2017). Parasites live and spread within the tissues and organs of infected humans and animals, and are frequently expelled in faeces (EFSA, 2024).

Meat is an important source of protein and a lucrative product in low-income countries (Clonan et al., 2018). Zoonoses are diseases that are naturally transmitted between vertebrate animals and humans (Gupta et al., 2018). These diseases may be more severe in young people, pregnant women, and people who are elderly or have a compromised immune system (WHO, 2015 & 2016).

Children who survive some of the most serious FBDs may experience delayed physical and mental development, which can have a long-term impact on quality of life. There are over 250 diseases caused by food (FBDs), according to the Centres for Disease Control and Prevention (CDC). In 2010, 420,000 people died as a result of eating contaminated food, and one out of every ten people became ill each year (WHO, 2015). Children under the age of five (who make up 9% of the world's population) suffer a third (30%) of the burden of FBD, leading to 33 million disability-adjusted life years (DALYs) (WHO, 2015).

These zoonotic foodborne parasites could pose a serious concern to human health if infected tissue is consumed undercooked or raw, as well as the safety of animal-derived foods (Sithithaworn et al., 2006., Dorny et al., 2009; Jenkins et al., 2013 and Murrell, 2013). As a result, controlling meat-borne parasites is a top priority for quality assurance in slaughterhouses and food processing facilities. On the other hand, governments incur less cost from the diagnosis and prevention of parasite-infected animal-derived foods than from the treatment of parasitic infections. According to the (WHO), parasite infections caused 48.4 million cases and 59,724 deaths each year, resulting in 8.78 million Disability Adjusted Life Years (DALYs), with 48% of these parasitic diseases being foodborne (Chavez et al., 2021). The prevalence of certain parasites in food supply varies by country and area. Parasitic zoonoses have a direct impact on human health and livestock production. Meat-borne zoonoses are less common in developed countries as compared to developing countries as the proportion of processed meat out of meat produced is very low in developing countries (Zhou et al. 2008, Bhatia et al. 2016).

In comparison, vector-borne infections account for more than 17% of all infectious diseases and kill over 700,000 people each year (Anisuzzaman et al., 2023). Recently, the (WHO) and the World Organisation for Animal Health (WOAH) estimated that 60% of human diseases have an animal origin, 75% of emerging infectious diseases, such as COVID-19, originate from animals, and 80% of bioterrorists use zoonotic pathogens, demonstrating the economic impact of zoonotic diseases (Haider et al., 2020).

A "top ten" list of foodborne parasites of greatest global concern was reported by the Food and Agriculture Organisation (FAO) and the (WHO) in July 2014. These parasites infect tissues and cause clinical symptoms, affecting the health of millions of people (FAO, 2014). Based on the parasite load in humans, the FAO-WHO ranked the "top ten" foodborne parasites. The "top ten" foodborne parasites with the same examples from which sources man can be infected are as shown in (Table. 1).

(Table.1): Top ten foodborne parasites with their transmission ways.

No	Name of the Parasites	Sources of infections
1	<i>Taenia solium, saginata</i> (pork and beef tapeworm)	Contaminated meat (beef & pork) water and food
2	<i>Echinococcus granulosus</i> (hydatid worm or dog tapeworm)	vegetables, fruits, and other food infected with the eggs of the hydatid worm or handling dogs
3	<i>Echinococcus multilocularis</i> (a type of tapeworm)	vegetables, fruits, and other food infected with the eggs of the hydatid worm or handling dogs
4	<i>Cryptosporidium</i> spp (protozoa):	1. In uncooked meat products, water, fruit juice, and milk
5	<i>Entamoeba histolytica</i> (protozoa)	In uncooked infected meat products, water, and sexual transmission
6	<i>Trichinella</i> spp. (pork worm)	In pork, dogs, foxes, horses, wild boars, walruses, and birds
7	Opisthorchiidae (Trematoda, family of flatworms):	In freshwater fishes
8	<i>Ascaris lumbricoides</i> (small intestinal roundworms)	contaminated food, water, vegetables, environment
9	<i>Trypanosoma cruzi</i> (protozoa, Chagas diseases)	mainly insect vector-borne disease, but maybe also from contaminated food and drinks
10	<i>Toxoplasma gondii</i> (protozoa)	In the meat of small ruminants, pork, beef, and their organs, as well as unpasteurized milk and cheese from goats or contaminated vegetables and other food, soil, etc.

Study Objectives

1. To identify major parasites transmitted through meat.
2. To understand their epidemiology and impact on human health.
3. To highlight prevention and control measures.

Methods and Materials:

A literature review was conducted using keywords related to meat-borne parasites, zoonotic diseases, and public health. and a comprehensive literature search was conducted to gather relevant information on meat-borne parasitic zoonotic diseases and their public health significance. The search focused on peer-reviewed journals, books, reports, and other credible sources were used.

Result and Finding:

Zoonoses by flatworms or flukes

Particularly in Asia and worldwide, food-borne flatworms, including intestinal flukes (*Echinostoma* spp., *Fasciolopsis buski*, *Heterophyes heterophyes*), lung flukes (*Paragonimus* spp.), liver flukes (*Clonorchis sinensis*, *Opisthorchis* spp., *Fasciola* spp.), and water-borne schistosomiasis, are serious public health issues (Anisuzzaman et al., 2021; Anisuzzaman and Tsuji, 2020; Labony et al., 2020 and Labony et al., 2022). Humans can be infected by foodborne trematode

infections from about 100 different species. The primary finding was that there are almost 56 million foodborne trematode infections worldwide. Approximately 7.9 million of these have serious effects, and 7158 of them die each year (Fried & Abruzzi, 2010; Duthaler, & Utzinger, 2010).

Cholelithiasis, cholestasis, cholangitis, cholecystitis, cirrhosis and biliary and liver abscess, pancreatitis, hepatitis, and, as a most serious result, cholangiocarcinoma of the bile duct can all be brought on by *Clonorchis sinensis* and *Opisthorchis viverrini* (Keiser and Utzinger, 2009). According to the International Agency for Research on Cancer, *Clonorchis sinensis* is a group 1 biological carcinogen and is thought to be a cause of cholangiocarcinoma, a kind of liver and bile duct cancer (Bouvard et al., 2009).

Thirty-three trematode species have been implicated in the transmission of disease to humans through fish eating. An estimated 665000 DALYs are caused by foodborne trematode infections worldwide each year (Paul et al., 2014). Schematic diagram of transmission and diagnosis of zoonotic foodborne parasites is shown in Figure.1 (Reza et al., 2017). In the Middle East and Asia, particularly in the Philippines, Indonesia, Thailand, the People's Republic of China, Japan, and the republic of Korea, diseases associated with these parasites which are contracted by eating raw, marinated, or improperly cooked fish are commonly recorded. Inflammation, ulceration, and necrosis may result from a high concentration of these parasites in the small intestine. *Clonorchis sinensis* and *Opisthorchis spp.* are significant fish-borne and parasitic diseases of humans, while not being marine fish parasites [WHO, 2019].

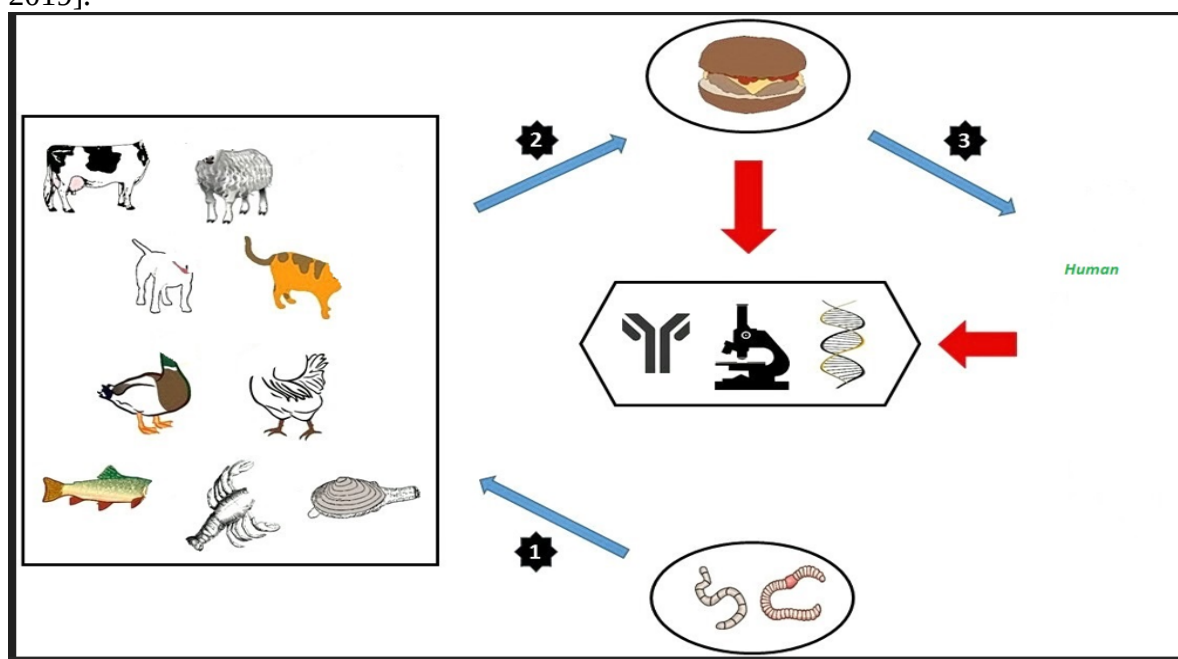


Figure-1 Schematic diagram of transmission and diagnosis of zoonotic foodborne parasites. Blue arrows show: (1) Transmission of parasites to animals, (2) transmission of parasites to animal-derived foods, and (3) transmission of parasites from animal-derived foods to humans. The red arrow shows the possibility of a diagnosis of zoonotic foodborne parasites by direct microscopic, serologic, and molecular-based methods (Reza et al., 2017).

Zoonoses by tapeworms

Cyclophyllidea and *Pseudophyllidea* are the two orders into which tapeworms are classified.

Around 3000 species in the largest order, *Cyclophyllidea*, which consists of the "classic" tapeworms (Anisuzzaman et al., 2023). The zoonotic tapeworms that usually infect humans are *Taenia solium*, *T. saginata*, *Echinococcus granulosus*, *E. multilocularis*, and *Diphyllobothrium latum*. Human health can suffer significantly as a result of human cysticercosis. The life cycle of taeniasis in animals and humans is shown in (Figure. 2).

The central nervous system, muscles, skin, and eyes can also host the larvae (cysticerci) (WHO, 2024b). The disorders known as neurocysticercosis (NCC) occurs when cysts form in the brain. Severe headaches, blindness, convulsions, and epileptic seizures are among the potentially lethal symptoms (WHO, 2022). In around two months, the larvae develop into adult worms that can survive for several years; often, there are only one or two adult worms. Although they can grow up to 25 meters in length, adult *T. saginata* tapeworms usually measure 4 to 12 meters (Chelsea M and William A., 2023).

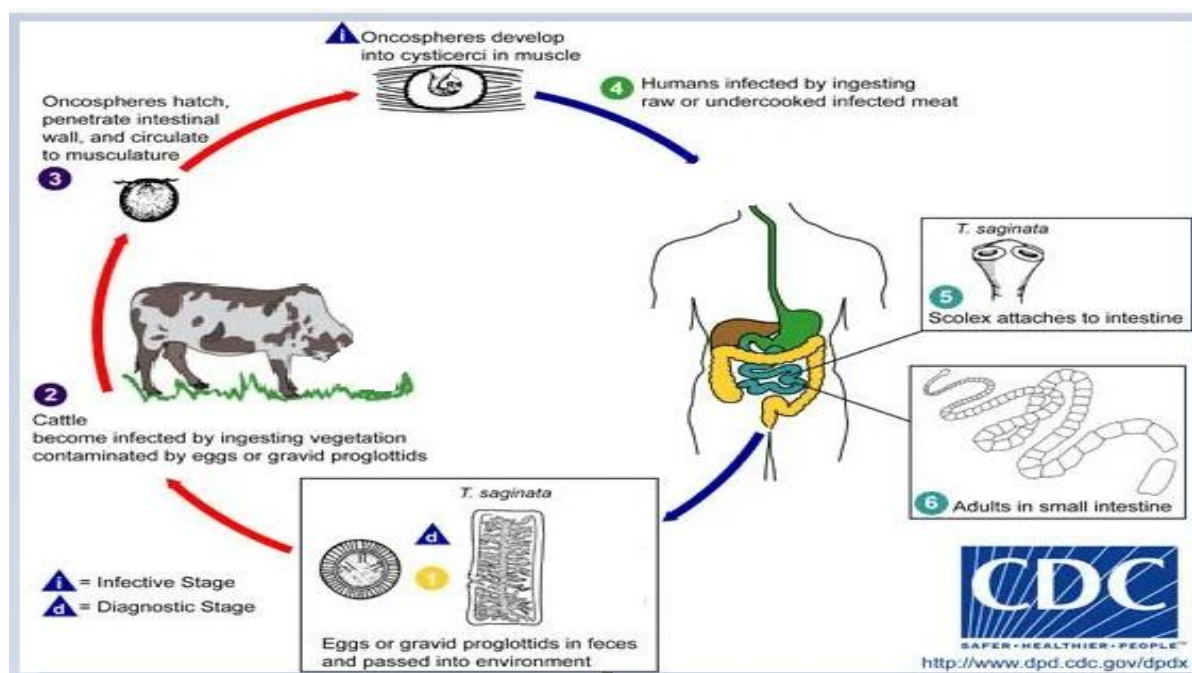


Figure 2. The life cycle of taeniasis in animals and humans. <https://healthjade.net/taeniasis/>

The parasite *Diphyllobothrium latum*, a Cestode, is the cause of diphyllobothriosis. Man's small intestine is host to *Diphyllobothrium latum*, which causes anaemia and gastrointestinal disorders. The eggs are liberated through faeces in water (Muhammad et al., 2023). Eating undercooked fish that have pleurocercoid larva can infect a person. It has been found that the pleurocercoid is not destroyed by salting, pickling, or smoking and hence remains contagious to humans (WHO, 2024).

Fish-associated human cestode infections are mostly found in nations that consume raw, marinated, or undercooked fish, such as Alaska, the United States, Canada, Scandinavia, Japan, Chile, Peru, and Russia (Praveen et al., 2015). At least 13 species of *Diphyllobothrium* have been reported from humans worldwide, with infections by *D. latum* and *D. dendriticum* being the most common (Adams and Rausch., 1997). Rausch and Hilliard recorded six species of *Diphyllobothrium* from humans in Alaska, with *D. latum* being the most common (Mohammad et al., 2023).

Eating raw or undercooked seafood is a major risk factor for this zoonotic disease (Scholz et al., 2019).

Human encroachment into the host fish's natural habitat and human waste contamination of water are related causes. The best ways to avoid diphyllbothriasis are post-harvest management, such as proper fish processing and food preparation common (Mohammad et al., 2023).

Zoonoses by roundworms

Nematodes are the most well-adapted parasitic worms and can be found in many types of environments, including freshwater, marine, soil, arctic and tropical. According to a recent investigation, there are over 30,000 nematode species, classified into 2271 taxa and 256 families. Humans may be exposed to nematodes from approximately 342 different species (Aibinu et al., 2019). Gastrointestinal nematodes affect almost half of the world's population. Different species of roundworms are spread by meat, particularly red meat, and a variety of fish species, especially freshwater fish (Anisuzzaman et al., 2023).

The most common nematode illness that affects people is anisakiasis, which can be transmitted via fish. The species most commonly linked to human illness is *Anisakis simplex* (Francisco and Rocío, 2020). There have been no reports of adult worms infecting humans; the infections are caused by the worms' larval stages. The worms are naturally occurring parasites of marine mammals, which are the definitive hosts of *Anisakis simplex*, including porpoises, dolphins, and whales (Francisco and Rocío, 2020).

Eating raw, improperly cooked, salted, pickled, or smoked herring (*Clupea harengus*), cod (*Gadus spp.*), mackerel (*Scomber spp.*), salmon (*Oncorhynchus spp.*), or squid (*Todarodes spp.*) exposes humans to larval *Anisakis simplex* (Bhatia et al., 2016). The stomachs of the marine mammalian definitive hosts contain adult *anisakids*. The female worms' eggs pass through their faeces and develop in the ocean. The larvae are discharged and travel through the digestive system before entering the mesenteries, viscera, or muscle after being consumed by a fish or squid paratenic host. The larvae may penetrate the gastrointestinal tract and cause disease in humans who consume the paratenic hosts, which are contaminated fish (Mattiucci et al., 2022). The symptoms may resemble an acute abdomen, gastric ulcer, or tumor. The majority of infections are treated by surgically removing the parasites or by using forceps during fibre-optic endoscopy. Abdominal pain, fever, nausea, vomiting, and other symptoms are common in men (Francisco and Rocío, 2020).

Common reservoirs of parasitic zoonoses

Animals (herbivores and carnivores) and birds frequently serve as reservoirs and play a role in the spread of infections to humans, leading to increases in zoonoses (Anisuzzaman et al., 2023). These diseases are now seen as One Health issues due to the involvement of several sources, and the One Health strategy is currently a desirable method of controlling zoonotic infections. The goal of One Health is to optimize and sustainably balance the health of people, animals, and ecosystems through a unified, integrated approach (Anisuzzaman et al., 2023). Nowadays, it includes environmental, animal, and human health, all of which are interdependent and closely connected. Addressing future health risks and food insecurity can assist accomplish the Sustainable Development Goals (SDGs) (Carlotta et al., 2023). This can be achieved through the engagement of several sectors and a transdisciplinary approach in various disciplines and communities. A One Health strategy is necessary since these zoonotic illnesses also kill and sick cattle (Anisuzzaman et al., 2023). Through the food chain and vectors, parasites are spread from the environment to a variety of hosts, such as humans, animals, and birds.

More than 200 zoonotic diseases actually threaten the world's population and cause significant financial losses (Shrivastava et al., 2015).

In comparison, vector-borne diseases account for more than 17% of all infectious diseases and cause more than 700,000 deaths annually (Gupta et al 2018 and Anisuzzaman et al., 2023). Four steps for the prevention of zoonotic infections are shown in (Figure 3). These can be caused by parasites, bacteria, or viruses. In particular, malaria, a mosquito-borne disease, is estimated to cause 247 million cases worldwide, resulting in more than 619,000 deaths in 2021 alone (Abuga et al., 2021).

The (WHO) and the (WOAH) recently estimated that 60% of human diseases have an animal origin, 75% of emerging infectious diseases, such as COVID-19, originate from animals, and 80% of bioterrorists use zoonotic pathogens, clearly indicating the economic impact of zoonotic diseases (Anisuzzaman et al., 2023).

Out of the 20 NTDs classified by the WHO and CDC, 13 are parasitic, showing their global effect (WHO, 2023). Parasitic diseases are found all throughout the entire globe, from the rainforest to the desert, although they are most widespread in the tropics and subtropics (Anisuzzaman, 2020). It is estimated that approximately 25% of the world's population suffers from one or more parasitic infections, with food and vector-borne parasitic zoonotic diseases being the most concerning (Lindahl and Grace, 2015).



Figure. 3. Four steps for prevention of zoonotic infections <https://douglaspublichealthnetwork.org/food-safety/>

Prevention and Control:

Prevention and control options in the food chain detecting and removing contaminated carcasses from the food chain (or treating lightly infected carcasses) is one of the major preventive measures for taeniasis (Coster et al., 2018).

As previously stated, this aim is complicated by the lack of meat inspection in certain highly endemic locations, and even if adopted, lightly contaminated corpses may still enter the food chain (Pozio, 2020).

At the end of the food chain, the consumer may play an important role as well. Dietary habits have a significant influence on the inactivation of viable *cysticerci* in cattle. As for other FBPs, excellent cooking methods, avoiding raw/undercooked beef consumption practices play a significant role in reducing the level of risk of exposure, leaving a significant role (Pozio et al 2020). Of course, actions aimed at the human host, such as treating tapeworm carriers, preventing open defecation, or managing sludge on pastures, are highly relevant (Coster et al., 2018).

Raising awareness among people can be effectively achieved through conducting seminars and training programs.

These initiatives help educate communities on food safety practices and empower them to implement preventive measures in their daily lives (Reza et al., 2017). Educating fish-eating communities about parasitic diseases from fish consumption is crucial. Thorough and proper cooking of meat, specifically to a temperature above 140°F (60 °C) for at least five minutes, plays a key role in disease control. Always measure meat temperature with a cooking thermometer to ensure safety (Bhatia et al. 2016).

Proper hand hygiene is also vital for preventing the spread of diseases. Always wash your hands after using the bathroom and before handling food. When traveling to areas with poor sanitation, avoid foods that might be contaminated by human feces and steer clear of raw or inadequately cooked beef meat (WHO, 2022).

Providing laboratory facilities for the identification of parasitic agents is crucial for effective disease control. These facilities enable accurate diagnosis and help in developing targeted treatment and prevention strategies. Diseases can also be controlled through proper investigation and monitoring. The inspection of animals and meat helps reduce the risk of spreading tapeworms (Praveen et al., 2015).

Conclusion

The development of priorities for a national public health system is a competition and resources to food borne parasitic zoonoses are generally handicapped by lack of good health and economic impact data. It is critical to have updated knowledge on the frequency of zoonotic parasites and the risk factors related to human infection. This will help in more effective implementation of the strategic control program. The increased incidence of established parasitic zoonoses and the growing evidence of emerging parasitisms give cause for concern to various stakeholders in public health. Every year, millions of individuals suffer worldwide, and the issue is exacerbated in developing countries, causing social and economic burdens. Meat-borne parasitic diseases pose a significant threat to public health, necessitating comprehensive surveillance, education, and intervention strategies to mitigate their impact. The interplay between human behavior, food handling practices, and the biological characteristics of these parasites underscores the complexity of controlling these infections. Enhanced awareness and adherence to food safety guidelines are essential to reduce the burden of meat-borne parasitic diseases globally.

The lack of adequate slaughtering facilities and practices contributes significantly to meat-borne zoonoses. Poverty, unsanitary living conditions, a lack of education, poor personal cleanliness, and occupation contribute to the prevalence of parasitic infections.

The veterinarian's role is critical in working with medical and public health specialists to achieve the joint goal of reducing the health and economic risks posed by foodborne parasites. And new diagnostic procedures will provide further instruments for this in the future.

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Vulnerability and Dynamics of Food Poverty in Afghanistan: A Synthetic Panel Analysis Approach

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Abstract

While poverty remains a significant challenge for policymakers, its dynamics and the vulnerability of the population to livelihood shocks are often overlooked in Afghanistan. Furthermore, poverty is typically measured in monetary terms, and the data quality is usually low. This paper takes a unique approach to address these issues, applying synthetic panel analysis to three rounds of household surveys between 2011 and 2020, using calorie and protein per capita intake as the key-dependent indicators. The findings reveal a high prevalence of chronic food poverty in Afghanistan when measured by protein compared to calorie intake. Moreover, there is a large proportion of the population suffers from transient food poverty. To address food poverty in Afghanistan, curving special policies to address chronic and transient poverty expected to be more effective than generalized interventions. The higher prevalence of chronic food poverty requires redemptive policy reforms to improve households' livelihood and food security conditions.

Keywords: Climate change, food poverty, vulnerability, synthetic panel, Afghanistan

1 Introduction

The high prevalence of poverty and food insecurity in developing nations remains a significant challenge for policymakers and governments (FAO, IFAD, UNICEF, WFP, & WHO, 2023). However, the dynamics of poverty, which is important to distinguish between chronic and transit poverty, is largely understudied and could potentially be used for improved policy initiatives, especially in resource-scare settings. Moreover, it's helpful for governments to track trends to assess the impact of poverty reduction policies over time. Yet, crude numbers such as poverty headcount ratio and proportion of the food-insecure population between surveys do not fully capture the real dynamics. Some households likely escaped poverty and food insecurity. In contrast, others were deprived, a reality that is not detectable by comparing means at the survey level between years or analyzing cross-sectional data in resource-scare settings. In addition, some portion of the population remains poor over time, indicative of chronic poverty and food insecurity. Distinguishing between transitory and chronic food insecurity is crucial and could lead to improved policy initiatives, requiring distinct strategy applications (Dang & Ianchovichina, 2018).

Longitudinal datasets are crucial tools for analyzing poverty and food insecurity dynamics. For instance, (Letta, Montalbano, & Tol, 2018) analyzed the impact of higher temperatures on food insecurity in Tanzania between 2008 and 2013 in a panel analysis. Their analysis revealed differentiated implications based on the household's initial food consumption level. The poorest (with the lowest initial food consumption) households were affected negatively compared to the richest, which cross-sectional datasets could not detect.

This shows the differentiated impact of livelihood shocks based on consumption quintile level. Results of panel data analysis of Ethiopian rural households indicate that rainfall variability affects food security. However, social safety nets such as food aid rations didn't improve food security (Hunnes, 2015), which points to chronic food insecurity.

Such problems need structural intervention to enhance food security rather than shallow social safety net programs, which apply to transitory food insecurity.

However, the mentioned paper does not differentiate between chronic and transitory food insecurity. In contrast, the panel data analysis of Cambodian rural household food security between 2013 and 2014 indicates that having nonfarm activities increases the level of access, utilization, and stabilization of food (Do, Nguyen, & Grote, 2019). Such activities are addressing chronic food security better by empowering households.

Long-term initiatives to improve livelihood could treat chronic food insecurity and poverty; any shock affecting such livelihood sources would be devastating. For instance, shocks such as the COVID-19 pandemic affected food security negatively in the Nigerian panel of households. The impact was higher on the nonfarm workers due to large-scale lockdowns and decreased labor force participation (Amare, Abay, Tiberti, & Chamberlin, 2021). However, the unavailability of data and measurement techniques made it nearly impossible to make any inferential analysis of such shocks on both transitory and chronic food insecurity in resource-scarce least developed countries. Moreover, the high level of attrition and limited national representativeness make the panel data unreliable in developing nations, especially in the case of the existence of such datasets.

Afghanistan, a developing country, lacks longitudinal household-level data to measure poverty and food insecurity dynamics over a longer period. As a result, understanding poverty and food insecurity dynamics is overstated, undermining the proper policy implications for addressing this problem. The potential implication of uncovering the dynamics of poverty and food insecurity is as significant as the issue itself. The findings of such research are of utmost importance for policymakers, providing crucial insights for policy formulation and implementation to meet both transitory and chronic poverty and food insecurity.

In contrast, new approaches, such as the synthetic panel method proposed by Dang et al. (Dang H.-A., Lanjouw, Luoto, & McKenzie, 2014), suggest solving this issue using repeated cross-sectional datasets readily available in most developing countries. Early validation analyses indicate that synthetic panel datasets estimate poverty with good precision when compared to real panel datasets in the cases of Indonesia and Vietnam. The poverty estimates of true panel datasets lie between the synthetic panel method's upper and lower bound estimates. For instance, the transition from poor to poor is 7.3 in Indonesia using the 1997-2000 true panel dataset. In contrast, the synthetic panel analysis has a lower bound of 13.6 and an upper bound of 5.4. Similarly, another validation study took the opportunity of panel datasets of Chile, Peru, and Nicaragua (Cruces, et al., 2015), indicating that the results of true panel data lie in the 95% confidence interval of the synthetic panel approach. The results show that the transition from poor to poor in the panel dataset of Chile between 1996 and 2006 was 4.64, while the synthetic panel results show 5.35 and 2.61 for lower and upper bounds, respectively, which is quite overlapping. Another study reached the same conclusion using data from Turkey (Limanli, 2021).

Despite resulting in a good approximation of estimates, the distance between the lower and upper bounds is very large. To solve this issue, Dang and Lanjouw (Dang & Lanjouw, 2023) proposed the point (parametric) estimates to more accurately address this issue. However, the parametric method is less accurate in developed countries (H'erault & Jenkins, 2019) than in developing countries' validation case studies (Dang & Lanjouw, 2023). Therefore, parametric and non-parametric (point and bound estimates, respectively) applications are needed for a good estimate. The synthetic panel analysis mostly focuses on poverty analysis from a monetary perspective.

However, in this study, we incorporate the notion into the analysis of food poverty and related vulnerability mobilities using nutrient intake at the household level. Therefore, we can distinguish between chronic and transitory cases of food poverty and vulnerability mobilities across time. The results are of paramount importance to combat food poverty, whether preemptive or redemptive policy choices ([Barrett, 2005](#)). Social safety nets are the preemptive policy, which aims to prevent the non-poor or transient poor population from falling into chronic poverty, such as relief assistance and unconditional aid. Redemptive policy intervention aims to lift chronically poor populations out of poverty with interventions such as land reform, microfinance, etc. Therefore, it's crucial to distinguish between these two kinds of poverty to tailor specific and effective policy intervention, which is missing in the case of Afghanistan.

To fill the above knowledge gap, this paper applies the synthetic panel method to three rounds of household-level datasets of Afghanistan between 2011 and 2020. Instead of per capita income, as used in the literature, calorie, and protein per capita intakes are used as proxies for food insecurity.

This paper contributes to the literature: First, the analysis fills the knowledge gap of the absence of true panels to determine the policy implications for addressing food insecurity mobility and vulnerabilities in Afghanistan. Second, besides the dynamics of food poverty, the paper also provides the dynamics of vulnerability to food poverty, and the latter is as important as the former.

2 Data and methods

2.1 Data

This study covers a decade-long repeated cross-sectional data from household surveys in Afghanistan. The surveys are the National Risk and Vulnerability Assessment 2011/12, the Afghanistan Living Conditions Survey 2016/17, and the Income and Expenditure & Labor Force Survey 2020. These surveys were fairly collected based on the two-stage stratified sampling design from the same pool of primary sampling units across Afghanistan. Details about the survey are given elsewhere ([CSO, 2011-2012, 2014; CSO, 2021](#)).

The datasets cover large themes and gather information on household socio-economic characteristics. The main part of the mentioned datasets is the detailed household food consumption module, which is non-replaceable in each round of surveys and gives in-depth details on food security indicators. The module covers the households' food consumption a week before the interview. For synthetic panel analysis, which requires a cohort age of household head, we use the range of 20-70 in Afghanistan. In contrast, this range is between 25 and 70 in the literature, with some variation, such as 25-65 in the [Dang et al. \(Dang H.-A., Lanjouw, Luoto, & McKenzie, 2014\)](#) analysis. However, given the reality of Afghanistan's household formation and dissolution, our choice is well in line. Twenty percent of our sample household's heads are above 65 years old. Limiting the range will lead to the loss of the poverty dynamics in this vulnerable cohort.

2.2 Methods

2.2.1 Variables' description

The dependent variables are calories and protein per capita. These two variables are calculated based on every survey's household food consumption module using the procedures described in ([Smith & Subandoro, 2007](#)) and nutrient values reported in ([Sabry & Rizek, 1982](#)) for the Middle East. The amount of each food item multiplied by the calorie and protein contents and summing for all items for each household. Then, to have a comparable nutrient per capita, the overall calorie and protein were calculated for each household, divided by adult equivalent household size and seven days. The values over 12000 kcal/capita/day and under 500 kcal/capita/day were removed from the dataset to reach a better realistic observation based

on consumption.

Our research proposes using food consumption variables as a practical and effective alternative to income and monetary poverty. This approach offers distinct advantages. First, it eliminates the need for different poverty lines yearly, as the mean nutrient intake remains universally accepted and constant over time. Second, it provides a more realistic reflection of households' experiences, from their access to food to their ability to lead a nutritious life.

The practicality and effectiveness of this approach are key strengths of our research, instilling confidence in its potential and assuring the audience of its reliability.

The calorie and protein poverty lines, taken from the definition of the UN as the level of calorie and protein deficiencies, are 2100 kcal/capita/day and 50 gr/capita/day, respectively.

2.2.2 Synthetic panel approach

The absence of longitudinal data in developing nations has led to unawareness of poverty and food insecurity dynamics, especially over time. In contrast, there has been a surge in cross-sectional data with fairly good frequencies in recent years. To utilize this opportunity, Dang et al. (Dang H.-A. , Lanjouw, Luoto, & McKenzie, 2014) Proposed applying a synthetic panel approach by using time-invariant observable characteristics of households on cross-sectional data. To begin with, we are using the two variables of food consumption, namely calorie and protein per capita.

$$y_{ij} = \beta'_j x_{ij} + \varepsilon_{ij} \dots \dots \dots I$$

Where, y_{ij} , stands for the household's food consumption (calories and protein) in period j ($j=1,2$), x_{ij} represents the households' time-invariant observable characteristics. β'_j Denotes the parameter to be estimated and ε_{ij} represents the error term for household i in period j .

To estimate the proportion of households who were poor in period 1 but were non-poor in period 2, given a poverty line of z_j :

$$P(y_{i1} < z_j \text{ and } y_{i2} > z_j) \dots \dots \dots 2$$

However, the first difficulty is that y_{i1} and y_{i2} are unknown, and we cannot estimate pinpoints. Therefore, it is possible to obtain bounds. Therefore, the above equation 2 could be rewritten as:

$$P(\varepsilon_{i1} < z_j - \beta'_1 x_{i1} \text{ and } \varepsilon_{i2} > z_j - \beta'_2 x_{i2}) \dots \dots \dots 3$$

The main properties of equation 3 rely on the joint probabilities of ε_{i1} and ε_{i2} , which captures the part of households' food consumption that has not been explained by x_{i1} and x_{i2} in both periods. However, the mobility of food insecurity depends on the correlation of ε_{i1} and ε_{i2} , the higher the correlation, the lower the mobility and visa vis.

This method has two major assumptions: First, the population under the study being sampled in both survey rounds is the same. This means there are no major concerns about the high death and birth rates and the high influx and outflow of migration. Second, both error terms ε_{i1} and ε_{i2} are positive dependent quadrants. It employs the non-negative correlation of the error terms. Based on the pseudo-panel analysis, we can restrict the household head age to 20-70 years and apply it to both survey rounds to satisfy these assumptions (Rongen, 2021; Dang H.-A. , Lanjouw, Luoto, & McKenzie, 2014).

We could estimate the upper and lower bounds of poverty and vulnerability mobility based on the assumptions above. Equation 3 estimates the upper bound when the error terms are completely independent of each other with zero correlation. Specifically, we can estimate the upper bound of food poverty mobility as follows:

To estimate the movement out of food poverty:

$$P(y_{i1}^{2U} < z_1 \text{ and } y_{i2} > z_2) = P(\varepsilon_{i2} < z_1 - \beta'_1 x_{i2}) - P(\varepsilon_{i2} < z_2 - \beta'_2 x_{i2}) \dots \dots 4$$

To estimate the movement into food poverty:

$$P(y_{i1}^{2U} > z_1 \text{ and } y_{i2} < z_2) = P(\varepsilon_{i2} > z_1 - \beta'_1 x_{i2}) - P(\varepsilon_{i2} > z_2 - \beta'_2 x_{i2}) \dots \dots 5$$

In equations 4 and 5, y_{i1}^{2U} stands for estimated consumption in round 1 of households sampled in round 2, and U stands for upper bound.

The lower bound coefficients could be estimated using equation 3 when both error terms correlate perfectly.

To estimate the movement out of food poverty:

$$P(y_{i1}^{2L} < z_1 \text{ and } y_{i2} > z_2) = P(\gamma \varepsilon_{i2} < z_1 - \beta'_1 x_{i2}) - P(\varepsilon_{i2} < z_2 - \beta'_2 x_{i2}) \dots \dots 4$$

To estimate the movement into food poverty:

$$P(y_{i1}^{2L} > z_1 \text{ and } y_{i2} < z_2) = P(\varepsilon_{i2} > z_1 - \beta'_1 x_{i2}) - P(\gamma \varepsilon_{i2} > z_2 - \beta'_2 x_{i2}) \dots \dots 5$$

Where, y_{i1}^{2L} stands for the food poverty estimations of households in round 1 survey in round 2, and L stands for the lower bound and $\gamma = \sqrt{\frac{\text{Var}(\varepsilon_{i1})}{\text{Var}(\varepsilon_{i2})}}$.

This method also assumes bivariate normal distribution for error terms in years 1 and 2. Therefore, by calculating the correlation of the error terms ρ , the estimation of food poverty mobilities is possible. For instance, the likelihood of the food insecure households in round 1, being food insecure in round 2 is calculated as:

$$P(y_{i1}^{2L} > z_1 \text{ and } y_{i2} < z_2) = \theta\left(\frac{\text{Log}(z_1) - \beta'_1 x_{i1}}{\sigma_1}, \frac{\text{Log}(z_2) - \beta'_2 x_{i2}}{\sigma_2}, \rho\right) \dots 6$$

In equation 6, θ represents the bivariate normal cumulative distribution function, ρ is the correlation of error terms and z_1 and z_2 stands for the food poverty lines of years 1 and 2, respectively (H'erault & Jenkins, 2019; Dang H.-A., Lanjouw, Luoto, & McKenzie, 2014).

Besides the poverty analysis, there are also vulnerable segments of the population. One should indicate the vulnerability line to analyze vulnerability, which requires two steps: First, a vulnerability range is chosen, from which the appropriate vulnerability index is drawn. Second, we empirically solve the vulnerability line from the equation below:

$$\Gamma = P(y_{i2} \leq z_2 | z_1 < y_{i1} < v_1) \dots \dots 7$$

In equation 7, Γ stands for the probability of vulnerability. The vulnerability line shows the highest food consumption among currently food secure households, with a probability of falling into food poor conditions. Given two food consumption thresholds, we can extend this to analyze the mobilities across categories (Dang & Ianchovichina, 2018). For instance, the percentage of households in period one who experienced an improvement in their welfare and escaped food poverty in period two but remained vulnerable could be estimated by:

$$\begin{aligned} \Gamma(y_{i1} \geq z_1 \text{ and } z_2 \leq y_{i2} < v_2) \\ = \theta_1\left(\frac{z_1 - \beta'_1 x_{i2}}{\sigma_{\varepsilon 1}}, \frac{v_2 - \beta'_2 x_{i2}}{\sigma_{\varepsilon 2}}, \rho\right) - \theta_2\left(\frac{z_1 - \beta'_1 x_{i2}}{\sigma_{\varepsilon 1}}, \frac{z_2 - \beta'_2 x_{i2}}{\sigma_{\varepsilon 2}}, \rho\right) \dots 8 \end{aligned}$$

Equation 8 represents the proportion of food-poor households in period 1 who move to the middle class of food security with vulnerable conditions.

3 Results

3.1 Descriptive statistics

The descriptive statistics reported in Table 1 cover the cohort of households with heads between 20 and 70 years old. The overall deterioration and recovery from 2011 up to 2020 mimic the realities of Afghanistan's economy.

However, calorie deficiency is higher in 2020 compared to 2011, which may indicate an unequal recovery for the poorest of the population. In contrast, protein deficiency nearly affected half of the population under study in 2016/17, while the recovery decreased the level to 37.9, which is still higher compared to the beginning of our data sets. Therefore, chronic and transitory food insecurity could be detected from these volatilities of food consumption.

Table 1 Descriptive statistics

Variable	2011/12	2016/17	2020
Calorie per capita	3507.405 (1755.196)	3273.222 (1707.151)	3527.257 (1878.350)
Calorie deficiency	0.146 (0.354)	0.202 (0.401)	0.150 (0.357)
Protein per capita	69.008 (40.025)	61.258 (40.911)	67.805 (40.113)
Protein deficiency	0.333 (0.471)	0.502 (0.500)	0.379 (0.485)
Observation	19,887	18,852	17,020

Note: Standard deviations are in parentheses

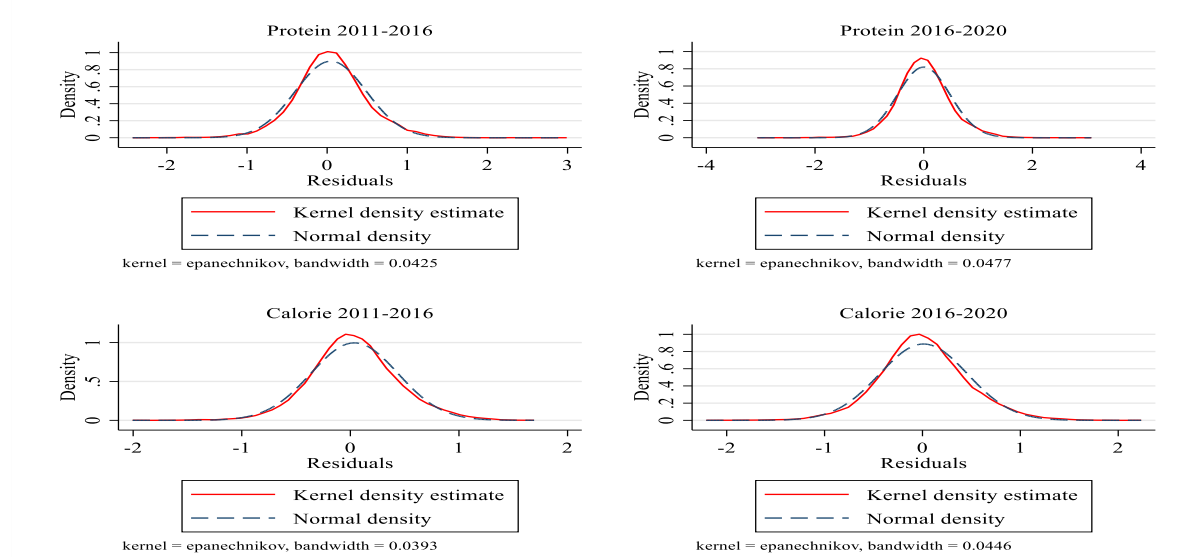


Figure 1 Normality test of residuals

One of the assumptions of the synthetic panel model is the normal distribution of error terms. Figure 1 clearly indicates the normality of error term for models using either calorie or protein intake.

3.2 Food Poverty Mobility Estimates

3.2.1 Food poverty mobility based on calorie deficiency

The food poverty mobility analysis in Table 2 is based on the 2100 kcal/capita/day food poverty line. Both parametric (point) and non-parametric (bound) estimates are being reported. Based on non-parametric estimates of joint probabilities, the proportion of households who were poor in 2011 remained poor in 2016 between 9.7% and 3.7%, with a point estimate of 7.7%. This means that the chronic food-poor population in Afghanistan was around 8% between 2011 to 2016. The proportion of households left out of food poverty at the same time period is between 3.8% and 9.7%, with a point estimate of

7.4%. In contrast, the proportion of households who moved into food poverty (non-poor, poor) is nearly double that of households left out of poverty. This points out the increase in transitory food poverty in Afghanistan in the population of the selected age range at the time span under the study. The conditional probabilities of 2011/12-2016/17 show the probability of households being in food poverty in period 2, given the base period 1. For instance, poor to poor indicates the probability of being poor in year 2 is between 71.6% and 27.5%, with a point estimate of 51%, given that the households were also poor in 2011/12.

This indicates that half of the poor population in 2011/12 was still food-poor in 2016/17 and could be classified as a chronic food-poor population. In contrast, the results reported in Table 2, models 4-6, represent a different path compared to the previous period of models 1-3. While chronic food poverty persists at around 8%, the transition from poor to non-poor is twice that of the previous period. This may be due to the good weather conditions in Afghanistan during the 2018- 2020 period. The transition from non-poor to poor slows down at around 8.4%, indicative of fragile conditions. The results of conditional probabilities are also indicative of recovery. The likelihood of being poor in 2020 for those poor in 2016 is 37.3, much lower than 51% in the previous period. While the transition from poor to non-poor shows an increased probability. In addition, the transition from non-poor to poor is two-thirds of the last period.

Table 2 Food poverty mobility estimates - synthetic panel based on calorie intake

Variables	Non-parametric		Parametric	Non-parametric		Parametric
	LB *	UB *		LB *	UB *	
Joint probabilities	(1)	(2)	(3)	(4)	(5)	(6)
Poor, poor	0.097	0.037	0.077	0.117	0.035	0.084
Poor, non-poor	0.038	0.097	0.074	0.096	0.163	0.141
Non-poor, poor	0.105	0.166	0.144	0.033	0.116	0.084
Non-poor, non-poor	0.759	0.701	0.705	0.754	0.686	0.692
Conditional probabilities						
Poor to poor	0.716	0.275	0.510	0.551	0.177	0.373
Poor to non-poor	0.284	0.725	0.490	0.449	0.823	0.627
Non-poor to poor	0.122	0.191	0.169	0.042	0.144	0.108
Non-poor to non-poor	0.878	0.809	0.831	0.958	0.856	0.892
Observations	18,742	18,742	18,562	16,886	16,886	16,519

Note: It is estimated using a poverty line of 2100 kcal/capita/day in all years. Non-parametric refers to bound, while parametric refers to point estimates. Models 1-3 present the results of 2011/12- 2016/17, and models 4-6 cover the results of 2016/17- 2020

*LB- lower bound and UB upper bound for non-parametric estimations

Moreover, the total number of poor people in 2011/12 was 0.151, while the number increased to 0.221 in 2016/17, corresponding to the rise in poverty in 2016/17. The total number of poor people in 2016 was 0.225, while the number dropped to 0.168 in 2020, corresponding to the rise in non-poor people in 2020.

These findings show transient and chronic food insecurity based on calorie intake in the second decade of the 21st century. While transient food poverty indicates mobilities, the chronic food-poor population remains unchanged or increased. This shows the poor targeting of chronic food poverty in Afghanistan or the unavailability of such programs to solve the issue.

3.2.2 Food poverty mobility based on protein deficiency

To add more dimension to the results presented in Table 2, protein-based deficiency analysis is added as lower than 50gr/person/day as food-poor. The results of food poverty mobility based on protein deficiency are reported in Table 3, indicating heightened food poverty compared to calorie intake. While chronic food poverty based on calorie intake is around 8%, it's around 22% in 2011/12- 2016/17 and 26% in 2016/17- 2020 based on protein per capita and deficiency. Moreover, the transition to food poverty and out of it is much more volatile based on protein per capita. The recovery from food poverty

compared to the first year is around 9% in the 2011/12- 2016/17 period with a lower bound of 2.6% (Table 3, columns 1-3). In contrast, the mobility out of food poverty gained momentum in 2016/17 – 2020, with 20.6% of the poor population classified as non-poor with a lower bound of 15.3 (Table 3, columns 4-6).

Table 3 Food poverty mobility estimates - synthetic panel based on protein intake

Variables	Non-parametric		Parametric	Non-parametric		Parametric
	LB *	UB *		LB *	UB *	
Joint probabilities	(1)	(2)	(3)	(4)	(5)	(6)
Poor, poor	0.285	0.178	0.215	0.332	0.198	0.256
Poor, non-poor	0.026	0.108	0.091	0.153	0.256	0.206
Non-poor, poor	0.218	0.325	0.243	0.047	0.181	0.123
Non-poor, non-poor	0.471	0.388	0.451	0.468	0.365	0.414
Conditional probabilities						
Poor to poor	0.917	0.621	0.703	0.684	0.436	0.554
Poor to non-poor	0.083	0.379	0.297	0.316	0.564	0.446
Non-poor to poor	0.316	0.456	0.350	0.092	0.332	0.229
Non-poor to non-poor	0.684	0.544	0.650	0.908	0.668	0.771
Observations	18,742	18,742	18,562	16,886	16,886	16,519

Note: Estimated using a poverty line of 50 gr/capita/day in all years. Non-parametric refers to bound, while parametric refers to point estimates. Models 1-3 present the results of 2011/12- 2016/17, and models 4-6 cover the results of 2016/17- 2020

*LB- lower bound and UB upper bound for non-parametric estimations

Conditional probabilities indicate that the likelihood of the poor population of 2011/12 remaining poor in 2016/17 is around 0.70, in bounds between 0.92 and 0.62 (Table 3, columns 1-3). In contrast, this probability decreases to 0.55 with bounds of 0.68 and 0.44 in 2016/17 and 2020 (Table 3, columns 4-6). The likelihood of mobility out of poverty is around 0.3, given that households were poor at the beginning of the 2011/13 time period, while it has momentum in 2016/17 – 2020 by a likelihood of 0.45 with bounds of 0.32 and 0.56. Similarly, falling back to food poverty in 2011/12- 2016/17 is around 0.35, while it decreases to around 0.23. These two mobilities demonstrate a decreasing pattern of transient food poverty. This may be due to the economic recovery between 2016 and 2020 and the favorable weather conditions of 2018 and 2020.

Based on parametric, joint probabilities, The total population share of the poor in 2011/12 was 0.306, 0.458 in 2016, and 0.379 in 2020, indicative of an increase and then a decrease in poverty statistics.

3.3 Vulnerability to Food Poverty Estimates

3.3.1 Vulnerability to food poverty based on calorie consumption

Vulnerability to food poverty was analyzed to address another important aspect of food security besides poverty mobility. The results are presented in Tables 6 and 7 for 2011-2016 and 2016-2020.

Based on estimations provided in Table 5, vulnerability to food poverty (calorie per capita) is not a big problem. However, poverty increased between 2011 and 2016, comparing 13.7% in column 4 with 20.2% in column 1 or joint probability. Based on conditional probability, around one-fifth of the poor and vulnerable in 2011/12 remained poor in 2016/17, indicative of chronic food insecurity. In contrast, parametric estimates show that 6.8% of the vulnerable population in 2011/12 became poor in 2016/17. Moreover, the vulnerable population increased between surveys from 22.2% to 26.9%. Additionally, based on conditional probabilities or parametric estimates, one-third of the given vulnerable in 2011/12 fell back to poverty, one-third remained vulnerable, and one-third experienced improved caloric consumption (Table 6, parametric estimates).

Table 6 Food Poverty Mobility and Vulnerability Estimates 2011-2016 Based on Calorie per capita

Variables	Poor in 2016/17	Vulnerable in 2016/17	Secure in 2016/17	Total
	(1)	(2)	(3)	(4)
Joint probabilities	Non-parametric upper-bound estimates			
Poor in 2011/12	0.038	0.001	0.098	0.137
Vulnerable in 2011/12	0.001	0.000	0.002	0.002
Secure in 2011/12	0.163	0.003	0.695	0.861
Total	0.202	0.004	0.795	
Conditional probabilities				
Given poor in 2011/12	0.276	0.005	0.720	1.000
Given vulnerable in 2011/12	0.254	0.006	0.740	1.000
Given secure in 2011/12	0.190	0.004	0.807	1.000
Observation	19,374			
Vulnerability index	0.25			
Joint probabilities	Parametric estimates			
Poor in 2011/12	0.079	0.047	0.030	0.156
Vulnerable in 2011/12	0.068	0.074	0.080	0.222
Secure in 2011/12	0.075	0.148	0.400	0.622
Total	0.221	0.269	0.510	1.000
Conditional probabilities				
Given poor in 2011/12	0.506	0.302	0.193	1.000
Given vulnerable in 2011/12	0.305	0.334	0.362	1.000
Given secure in 2011/12	0.120	0.237	0.643	1.000
Observation	19,103			
Vulnerability index	0.3			

Note: Estimated using a poverty line of 2100 kcal/capita/day and a vulnerability line of 2110 kcal/capita/day.

The estimates reported in Table 7 overall reflect the improvement in food security and decreased poverty level between 2016 and 2020, with 22.9% (column 4) vs. 14.9% (column 1) of poor. Moreover, conditional probabilities of non-parametric estimates show that apart from one-fifth of the vulnerable in 2016/17 who fell back to poor situations, the remaining four-fifths experienced an improvement in their calorie consumption. The estimated parametric model also confirms this improvement over the mentioned period. Moreover, the food-secure population in 2016/17 remained largely secure in 2020, which shows the persistence of food security improvement.

Table 7: Food Poverty Mobility and Vulnerability Estimates 2016-2020

Variables	Poor in 2020 (1)	Vulnerable in 2020 (2)	Secure in 2020 (3)	Total (4)
Joint probabilities	Non-parametric upper-bound estimates			
Poor in 2016/17	0.041	0.001	0.188	0.229
Vulnerable in 2016/17	0.001	0.000	0.003	0.004
Secure in 2016/17	0.107	0.001	0.658	0.767
Total	0.149	0.002	0.849	
Conditional probabilities				
Given poor in 2016/17	0.177	0.003	0.820	
Given vulnerable in 2016/17	0.181	0.003	0.816	
Given secure in 2016/17	0.140	0.002	0.858	
Observations	17,479			
Vulnerability index	0.18			
Joint probabilities	Parametric estimates			
Poor in 2016/17	0.087	0.056	0.116	0.259
Vulnerable in 2016/17	0.040	0.042	0.136	0.218
Secure in 2016/17	0.040	0.062	0.421	0.523
Total	0.168	0.160	0.672	
Conditional probabilities				
Given poor in 2016/17	0.336	0.218	0.446	
Given vulnerable in 2016/17	0.185	0.192	0.623	
Given secure in 2016/17	0.077	0.119	0.805	
Observations	17,105			
Vulnerability index	0.18			

Note: Estimated using a poverty line of 2100 kcal/capita/day and a vulnerability line of 2110 kcal/capita/day.

3.3.2 Vulnerability Based on Protein Per Capita Consumption

Protein consumption per capita is also added to the analysis to examine food poverty differently. The conclusion indicates similar vulnerabilities for 2011/12 and 2016/17 years. However, the food-poor population increased from 29.6% to 50.3% in 2016/17. This is due largely to the economic meltdown and large-scale natural disasters during this period (Table 8, non-parametric joint probabilities). Moreover, based on conditional probabilities of non-parametric estimates, more than half of the vulnerable population in 2011/12 was classified as poor in 2016/17, two times higher than food poverty based on calorie intake. This behavior of trading off the quality and quantity of food has been recorded in the wake of livelihood shocks. Additionally, one-fifth of the population given poor or vulnerable in 2011/12 stayed vulnerable in 2016/17. In addition, around one-fifth of the secure in 2011/12 fell back to the vulnerable condition, while 42% were classified as poor in 2016/17 (Table 8, non-parametric conditional probabilities). The parametric estimates present the same patterns of poverty and vulnerability as well.

Table 8 Poverty Mobility and Vulnerability Estimates 2011-2016 based on protein intake

Variables	Poor in 2016/17 (1)	Vulnerable in 2016/17 (2)	Secure in 2016/17 (3)	Total (4)
Joint probabilities	Non-parametric upper bound estimates			
Poor in 2011/12	0.185	0.059	0.052	0.296
Vulnerable in 2011/12	0.103	0.040	0.050	0.193
Secure in 2011/12	0.215	0.096	0.199	0.511
Total	0.503	0.196	0.301	
Conditional probabilities				
Given poor in 2011/12	0.625	0.200	0.174	1.000
Given vulnerable in 2011/12	0.532	0.209	0.259	1.000
Given secure in 2011/12	0.421	0.189	0.390	1.000
Observation	18,742			
Vulnerability index	0.53			
Joint probabilities	Parametric estimates			
Poor in 2011/12	0.207	0.015	0.096	0.318
Vulnerable in 2011/12	0.023	0.002	0.018	0.043
Secure in 2011/12	0.231	0.030	0.378	0.639
Total	0.461	0.047	0.492	
Conditional probabilities				
Given poor in 2011/12	0.651	0.047	0.305	
Given vulnerable in 2011/12	0.534	0.051	0.414	
Given secure in 2011/12	0.362	0.046	0.591	
Observation	18,473			
Vulnerability index	0.53			

Note: Estimated using a poverty line of 50 gr/capita/day and a vulnerability line of 63 gr/capita/day. Cells give the fraction of the population in the selected age range in each of the nine categories.

The food poverty condition in 2016-2020 follows the same path as calorie intake but with higher proportions. From 52.6% poor in 2016/17, half remained poor in 2020, while 11% fell into the vulnerable condition. In contrast to the vulnerable population of 18.8% in 2016/17, 8.7% experienced an improvement in their food security condition (Table 9, non-parametric joint probabilities). However, the improvement from vulnerable conditions to food security is not as obvious as calorie intake. It is still indicative of recovery, but from the population given vulnerable in 2016/17, one-third is poor, one-fifth is vulnerable, and 46% are food secure (Table 9, non-parametric conditional probabilities).

Based on parametric estimates, nearly half of the population under study was classified as poor in 2016/17, which is staggering compared to one-fourth of the calorie intake reported previously. The total poor in 2020 was 37.9%, indicative of a good recovery but still very high compared to calories (Table 9, parametric joint probabilities).

Table 9 Non-parametric Poverty Mobility and Vulnerability Estimates Upper bound 2016-2020

Variables	Poor 2020	in Vulnerable 2020	in Secure 2020	Total
	(1)	(2)	(3)	(4)
Joint probabilities	Non-parametric upper bound estimates			
Poor in 2016/17	0.225	0.107	0.194	0.526
Vulnerable in 2016/17	0.065	0.035	0.087	0.188
Secure in 2016/17	0.088	0.052	0.145	0.286
Total	0.379	0.194	0.426	
Conditional probabilities				
Given poor in 2016/17	0.428	0.204	0.368	
Given vulnerable in 2016/17	0.348	0.188	0.464	
Given secure in 2016/17	0.309	0.182	0.508	
Observations	16,886			
Vulnerability index	0.35			
Joint probabilities	Parametric estimates			
Poor in 2016/17	0.260	0.024	0.247	0.531
Vulnerable in 2016/17	0.017	0.002	0.029	0.048
Secure in 2016/17	0.102	0.016	0.303	0.421
Total	0.379	0.042	0.579	
Conditional probabilities				
Given poor in 2016/17	0.490	0.045	0.465	
Given vulnerable in 2016/17	0.350	0.044	0.605	
Given secure in 2016/17	0.243	0.037	0.719	
Observations	16,519			
Vulnerability index	0.35			

Note: Estimated using a poverty line of 50 gr/capita/day and a vulnerability line of 63.

4 Discussion

This chapter analyzes mobility and vulnerability to food poverty using datasets covering the second decade of the 21st century in Afghanistan. Due to the unavailability of panel datasets, we lack knowledge on the mobility of poverty, especially food poverty in Afghanistan. The synthetic panel approach proposed by Dang et al. (Dang H.-A., Lanjouw, Luoto, & McKenzie, 2014) is being applied to overcome this challenge.

The findings show a high prevalence of chronic food poverty in Afghanistan, especially when measured by protein intake, which follows prior literature (Sugiharti, Esquivias, Shaari, Jayanti, & Ridzuan, 2013). Two distinct policies could be applied to combat food poverty: preemptive and redemptive (Barrett, 2005). Therefore, social safety nets such as unconditional food transfers, which have been in force for the last decade, will not solve this issue. Such kind of interventions are beneficial for transitory food poverty while preventing the non-poor from falling into chronically poor conditions. To lift chronically food-poor people out of poverty, the government needs to frame policy implications to improve their livelihood, or structural policy reforms such as increasing irrigated land and investing in agriculture are needed.

The comparison between calorie and protein intake shows that households are more food-poor when measured by the latter than the former,

pointing to the level of trade-off between food quality and quantity in the face of livelihood shock. This behavior of households when facing livelihood shocks has previously been documented in the literature on food security in Afghanistan (D'Souza & Jolliffe, 2014; Oskorouchi & Sousa-Poza, 2021).

5 Conclusion

The overall results indicate the existence of chronic food poverty in Afghanistan, and the proportion is higher when measured by protein intake. Most mobility is between the poor and the non-poor, while vulnerability remains very low, with a high prevalence of poor-to-poor conditions in each panel. This shows the stickiness and poverty trap in the poor segment of the population. Therefore, the main objective and initiative that could help to lift food-poor people out of poverty is to address chronic and transient food poverty with various policy points.

The higher prevalence of chronic food poverty requires redemptive policy reforms to improve households' livelihood and food security conditions. Relying only on social safety nets just prevents the vulnerable and non-poor segments from falling into chronic food security while not doing much to lift chronically food-poor households.

6 Limitations of the model

These results apply to the cohort of households with heads in the 20-70 age range. Our analysis results are not applicable to the remaining below and above this age range. The second limitation is that it assumes that the population that surveys conducted remains stable between two points of the panel. Excessive migration in or out, higher death or birth rates, or other factors could bias estimates.

7 Recommendations

1. **Targeted Interventions:** Policymakers should design targeted interventions that specifically address the distinct challenges associated with chronic and transient food poverty. For instance:
 - **Chronic Food Poverty:** Implementing long-term strategies focused on improving household livelihoods and food security, such as enhancing agricultural productivity, providing access to education, and supporting job creation.
 - **Transient Food Poverty:** Developing short-term relief measures, such as food aid or cash transfers during periods of crisis, to help households cope with temporary shocks.
2. **Improving Data Quality:** Efforts should be made to enhance the quality and comprehensiveness of data collection on poverty and food security. This can be achieved by:
 - Investing in robust survey methodologies.
 - Ensuring regular monitoring and evaluation to better understand the evolving nature of poverty.
3. **Nutritional Focus:** Given the emphasis on protein intake as a critical indicator, policies should prioritize nutritional outcomes alongside caloric intake. This could involve promoting diverse diets and improving access to nutrient-rich foods.
4. **Cross-Sector Collaboration:** Addressing food poverty requires a coordinated approach that involves various sectors, including health, education, and agriculture. Collaborative efforts can lead to more holistic and sustainable solutions.

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Exploring the Efficacy of Botanical Insecticides for Managing Red Flour Beetle (*Tribolium castaneum*) in Stored Grains: A Sustainable Approach to Food Security

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Abstract

The increasing global population is contributing to a growing food security crisis, with stored agricultural products facing significant threats from insect pests. Among these pests, red flour beetle (*Tribolium castaneum*) is one of the most destructive, infesting a wide range of stored grains and processed food products. This pest causes considerable damage to food quality and quantity, leading to significant economic losses in both developed and developing countries. In developing regions, up to 30% of stored grain can be lost to insect infestations. Afghanistan faces significant pest pressure, especially in the absence of widespread integrated pest management (IPM) practices. Traditional pest control methods, such as synthetic chemical pesticides, are commonly used but present environmental and health risks, particularly in resource-limited settings. The use of botanicals could help control pest populations without harming the environment, beneficial insects, or human health. Afghanistan has diverse ecosystems with a range of plant species that could serve as the basis for developing botanicals. This paper reviews the effectiveness of various plant-based treatments for controlling *T. castaneum*, emphasizing their potential as environmentally friendly alternatives to chemical pesticides. As a result, there is a growing interest in exploring safer, more affordable alternatives. Recent research has focused on plant-derived products, which have demonstrated insecticidal and repellent properties against *T. castaneum*. Botanicals such as neem, eucalyptus, turmeric, garlic, lemongrass and citrus have shown potential for controlling this pest. Such natural protectants could significantly improve food security, particularly in subsistence farming communities where access to costly chemical pesticides is limited.

Keywords: Food security, *Tribolium castaneum*, Botanical Insecticides, Sustainable Pest Management

Introduction

The increasing global population is leading to a food crisis. Under these circumstances, food and agricultural products must be stored and shielded from insect contamination using various materials, like synthetic chemical pesticides (Chaubey, 2007). Pest contamination is a major issue for stored food products, affecting them from the time of harvest through to storage. Ensuring food security largely relies on the proper storage and safeguarding of grain commodities worldwide. These stored grains are continuously vulnerable to pest infestations (Islam, 2017). Pests in stored products cause significant losses in both the quality and quantity of post-harvest food grains. In developed countries, post-harvest losses due to insects, mites, rodents, and microbes in stored grains are estimated at 10%, while in developing countries, the losses can range from 10% to 30% (Ahmady et al., 2016). It has been estimated that over

one-third of food products are lost to various pests during post-harvest storage (Tripathi et al., 2009).

Insect infestations during storage represent a particularly serious issue, especially in developing countries. Among the pests that affect stored goods, the Red Flour Beetle, *Tribolium castaneum*, is one of the most widespread and destructive. It feeds on a range of stored grains and products, including peas, beans, cocoa, nuts, dried fruits, and spices, with milled grain products like flour being its most favored food source (Mishra et al., 2012). According to the 2011 survey reports from the Plant Protection and Quarantine Department (PPQD) of Ministry of Agriculture, Irrigation and Livestock (MAIL) of Afghanistan, losses caused by storage pests such as *Rhyzoperha dominica*, *Trichoderma granarium*, and *Tribolium castaneum* are estimated to exceed 30% for rice, flour, beans, and oilseeds in storage (NGOLLO, 2011). These pests are particularly drawn to grains with high moisture content, where they promote mold growth and produce an unpleasant, musty odor.

Various insect control methods have been assessed to protect grain and reduce reliance on chemical insecticides. A significant issue with chemical insecticides is the residue they leave on food grains, which can pose health risks to consumers. According to Islam (2017), *Tribolium castaneum* (red flour beetle) ranks 19th among the top 20 insecticide-resistant arthropods, with 132 recorded instances of resistance. This highlights the urgent need to find alternatives that can replace these harmful chemicals. To address these challenges, exploring alternative pest control methods is crucial. Botanical pesticides, which protect stored grains from pests, offer numerous benefits. These include being easily produced by farmers and being more affordable. More than 120 plant species and their products have been identified for controlling stored grain insect pests. Recent studies have reported various plants with insecticidal and repellent properties against the red flour beetle (Padin et al., 2013; Sagheer et al., 2014; Bilal et al., 2015; Nattuduraj et al., 2015). With the growing interest in medicinal plants, this review discusses the potential of eco-friendly and cost-effective methods for managing the red flour beetle, focusing on recent research into phyto-derivatives in the 21st century.

Description of Red Flour Beetle

A significant secondary pest in food storage areas, particularly in warmer regions of the world, is commonly known as the Red Flour Beetle, Rust Red Flour Beetle, or simply Flour Beetle. Its taxonomic classification is as follows: Phylum: Arthropoda; Class: Hexapoda (Insecta); Order: Coleoptera; Family: Tenebrionidae (CABI, 2007).

The eggs are tiny (microscopic), whitish, and cylindrical, with flour remnants sticking to their surface due to a sticky substance that coats the eggshell (Devi and Devi, 2015; Li and Arbogast, 1991). The larvae are small and brownish-white, growing to about 4-5 mm in length when fully mature. These larvae can be distinguished from other species by their two pointed, well-defined, segmented ends.

The pupa of *Tribolium castaneum* lacks a cocoon, is inactive, and does not feed, typical of all holometabolous insects. It gradually changes from yellowish-tan to brown (Beeman et al., 2012). The average body length for male pupae is around 3 mm with a width of 1 mm, while female pupae typically measure 4 mm in length and 1.15 mm in width (Devi and Devi, 2015). Adult beetles range from 2.3 to 4 mm in length (Hill, 2002) and are red-brown in color (Baldwin and Fasulo, 2014). The antennae consist of eleven segments, with the last three segments slightly enlarged compared to the gradual four segments in *T. confusum* (Baldwin and Fasulo, 2014). Males have a setaceous lesion on the ventral surface of the front femur (Haines, 1991). The compound eyes are partially horizontally divided by a backward projection of the head (Anonymous, 1986). According to CABI (2007), the red flour beetle (*Tribolium castaneum*) can be easily confused with the confused flour beetle (*Tribolium confusum*). Distinguishing between the larvae of these two species is particularly challenging.

While the adults of both species are similar in size and color, there are several key differences that set them apart.

Biology and Life Cycle

Under optimal conditions, the life cycle of *T. castaneum* is typically very short, taking about 20 days to complete (Haines, 1991). The cycle begins when mature female adults lay eggs on or between stored products. These females have a long lifespan, surviving up to three years, and can lay between 400-500 sticky, white eggs, which hatch within 1-2 weeks (Abdullahi et al., 2019).

The larvae are active feeders and tend to hide in cracks and crevices of stored products, using these areas for shelter when disturbed. The larvae can be identified by their distinctive two pointed, segmented ends. Under favorable conditions, the beetle can produce 4-5 generations per year (Rees, 1996; Abdullahi et al., 2019).

The duration of the larval stage is primarily influenced by the availability, type, and quality of food, as well as the environmental conditions, particularly temperature and relative humidity (Haines, 1991). Different studies report varying lengths for the larval period, with averages ranging from 12.9 days (Haines, 1991), to 12-13 days (Howe, 1956), and even 70-80 days (Devi and Devi, 2015). Each larval instar also has distinct characteristics that help differentiate it from the others (Devi and Devi, 2015).

The pupae of *Tribolium castaneum* do not form a cocoon and remain inactive, not feeding, similar to other holometabolous insects. The duration of the pupal stage differs between sexes, with males undergoing pupation for 6-7 days, while females take 7-9 days (Devi and Devi, 2015). Abdullahi et al. (2019) reported an average pupal duration of 4 days, which aligns closely with the 4.5 days found by Haines (1991). Arpitha (2021) observed an 8-day pupal period. Thus, the average pupal period is generally considered to be around 6-7 days.

Host Range and Damage

Tribolium castaneum is one of the most widespread pests of stored products (Fedina and Lewis, 2007; Bachrouch et al., 2010;), known for its polyphagous feeding habits (Bachrouch et al., 2010). It attacks a wide range of stored products and their by-products (Obeng-Ofori and Reichmuth, 1999). This pest is commonly found on wheat and wheat flour, and it often causes significant damage to processed cereal-based foods such as biscuits, nuts, beans, pasta, cornflakes, and even dried fruits (Hussain et al., 1996; Kheradpir, 2014; Devi and Devi, 2015). Wheat flour is considered its preferred food source (Lu et al., 2010; Kheradpir, 2014). Additionally, it has been reported to infest groundnuts/peanuts (Rao et al., 2010), as well as other cereals like maize, rice, and sorghum, along with their flours (Ajayi and Rahman, 2006). Other studies have documented *T. castaneum* in a variety of products including beans, dried flours, pasta, spices, cocoa beans, chocolate, dried pet food, dried museum specimens, yam, cassava (Ajayi and Rahman, 2006; Tettey et al., 2014), pearl millet (Lale and Yusuf, 2000; Ahmed et al., 2010), wheat grain (White and Lambkin, 1988), soybean meal (Cox and Simms, 1978), and other stored grains and grain products (Nadeem et al., 2012) across the globe.

Damage caused by *T. castaneum* typically results in both a reduction in quantity and a decline in quality (Bachrouch et al., 2010). Infestation is often visible through the presence of adults on the grain surface, and extensive damage is seen in grains that are already broken or holed, or those affected by other pests.

Both larvae and adults contribute to the damage. Infested products usually contain frass, carcasses, and exuviae, and the grain often turns grey with a strong, unpleasant odor due to the release of benzoquinones, a defensive chemical from their prothoracic and abdominal glands,

making the product unfit for human consumption (Lale, 2002; Devi and Devi, 2015). Both larvae and adults feed on the surface of grains and processed foods, causing severe damage, though larvae primarily affect the germ of wheat grains (White and Lambkin, 1988).

These forms of damage lead to significant losses, both in terms of reduced value and the additional costs for pest control measures, such as pesticides and expensive, pest-proof packaging (Obeng-Ofori and Reichmuth, 1999; Lale and Yusuf, 2000). Therefore, there is a pressing need to develop more affordable and safer control methods for this pest that can be applied across its entire host range, which would greatly improve food security, particularly for subsistence families with limited resources who cannot afford the high costs of insecticides and other protective measures.

Botanical Insecticides

Since the beginning of the 21st century, researchers have increasingly turned to plants as a source of safer, more affordable, and locally accessible botanical substances for managing the red flour beetle. Botanical pesticides are natural plant extracts or products used against insects, thereby suppressing their biology and development, which may lead to their death (Negbenebor and Nura, 2024). Recent studies have highlighted the effectiveness of various plant-derived materials in controlling this pest (Padin et al., 2013; Sagheer et al., 2014; Bilal et al., 2015; Nattuduraj et al., 2015; Joel, 2015; Saeed et al., 2016). Using plant materials as traditional protectants for stored products is a longstanding practice that has been used worldwide (Talukder, 2009). Typically, this protection involves mixing grains with plant-based protectants (Tapondjou et al., 2002).

Botanicals are chemical compounds derived from plants that serve as insect repellents, feeding and oviposition deterrents, and disrupt the biochemistry, physiology, and behavior of insect pests. A variety of spice crops, including chili, garlic, turmeric, and ginger, as well as plants like neem, bakaino, century plant, undi, China berry, and lac tree, have been effectively used to control insect pests (Shukla et al., 2007). Srinivasan (2008) notes that many plant-based substances have been thoroughly tested and found to be effective in preventing infestations by various stored-grain insect pests.

Various plant-derived substances have been reported to exhibit harmful bioactivity against all life stages of *T. castaneum*, and have been used with varying success to control this pest on different stored products. For example, Ahmed et al. (2010) found that *Annona squamosa* L. powder provided the best protection for stored millet against *T. castaneum* infestation. Additionally, powders from neem (*Azadirachta indica* Juss) seeds, turmeric (*Curcuma longa* L.) rhizomes, and sweet flag (*Acorus calamus* L.) have shown promising potential for managing *T. castaneum* (Iqbal et al., 2015).

A laboratory study was conducted to evaluate the toxic effects of acetone and water extracts from *Eucalyptus globulus*, *Vitex negundo*, *Datura fastuosa*, and *Aphanamixis polystachya* against the red flour beetle, *Tribolium castaneum*. The results indicated that all four plants were toxic to the insect (Begum and Sarker, 2010).

Garlic (*Allium sativum*) has been found to repel *T. castaneum*, with its oil being particularly effective in killing both *T. castaneum* and *Sitophilus zeamais*, and reduce fungal contamination in wheat storage (Ho, 1996; Batta, 2014).

In Southeast Asia, eucalyptus is a locally available plant with a wide range of species known for their medicinal properties.

This plant has demonstrated repellent and inhibitory effects against the red flour beetle (*Tribolium castaneum*) (Saeed et al., 2016; Haq et al., 2005; Mishra et al., 2012; Fathi and Shakarami,

2014). Additionally, citrus peel, seeds, seed extracts, and decoctions have been found to contain acidic properties that repel adult red flour beetles when used in higher concentrations (Abdullahi et al., 2011; Iram et al., 2013; Bilal et al., 2015).

An experiment was conducted to assess the effects of plant extracts and insecticides on the mortality of adult *Tribolium castaneum*. Among the botanical treatments, neem leaf powder caused the highest mortality followed by eucalyptus leaf powder (Krishna and Yadav, 2023). The insecticidal properties of neem against various insect pests have also been studied by Sharma (1999) and Khattak et al. (1996). Sahayaraj and Paulraj, 2000 found that neem leaf extract was the most effective repellent against *T. castaneum* on groundnut seeds. Additionally, neem (*Azadirachta indica* Juss) seeds, turmeric (*Curcuma longa* L.) rhizomes, and sweet flag (*Acorus calamus* L.) powders have all shown considerable potential in managing *T. castaneum* (Iqbal et al., 2015). Peppermint (*Mentha piperita*), Cinnamon (*Cinnamomum verum*) and Citronella (*Cymbopogon nardus*) can be used to repel insects like ants, moths, and weevils in wheat storage, while also protecting against mold and fungal growth there (Jalali and Nikbakht, 2011; Sahu and Sahu, 2014; Liew and Yong, 2017).

Other plant products that have shown strong bioactivity against *T. castaneum* include camphor, *Peganum harmala* L., citrus essential oils, neem (*Azadirachta indica*) seed kernels, and fruit powder extracts of *Citrullus colocynthis* L. (Xie et al., 1995; Obeng-Ofori et al., 1998; Jbilou et al., 2006; Nadeem et al., 2012; Bilal et al., 2015). Neem oil, turmeric powder, and mustard oil), as well as *C. longa* leaf oil, have also been shown to have insecticidal effects (Chander et al., 1992; Khattak et al., 2001; Tripathi et al., 2002).

Other plant oils such as those from coconut, sunflower, sesame, and mustard have demonstrated similar properties (Obeng-Ofori and Reichmut, 1999). Additionally, garlic oil (*Allium sativum* L.), essential oils from *Evodia rutaecarpa*, *Lippia rugosa* L. (Lamiaceae), *Hyptis spicigera* Lam. (Verbenaceae), and essential oils from the rhizomes of *Zingiber zerumbet*, *Alpinia conchigera*, and *Curcuma zedoaria*, along with their major components like camphor, camphene, 1,8-cineole, α -humulene, isoborneol, α -pinene, β -pinene, and terpinen-4-ol, as well as *Nicotiana tabacum* and *Salsola banyosma*, have all been reported to exhibit insecticidal effects on *T. castaneum* (Ho et al., 1996; Liu and Ho, 1999; Kouninki et al., 2007; Suthisut et al., 2011; Sagheer et al., 2013).

Mode of action of Botanical Insecticides

The mode of action of a botanical insecticide refers to the specific biochemical processes through which it affects insect pests, typically by interfering with particular enzymes, proteins, or biological systems (Bloomquist et al., 2008). Essentially, it describes how the insecticide causes physiological disruptions at its target site. The action of a botanical insecticide depends on its ability to act as both a contact and systemic poison. Some botanicals function as neurotoxins, inhibiting the acetylcholinesterase enzyme, which in turn disrupts the action of the neuromodulator octopamine (Priestley et al., 2003; Houghton et al., 2006). Botanicals can also serve as repellents, disrupt mating and sexual communication, act as sterilants, retard growth, deter oviposition, serve as antifeedants, or act as lethal toxins, ultimately causing insect mortality (Odeyemi et al., 2008; Negbenebor and Nura, 2024). These insecticides can be applied as powders or plant extracts to control various insect species in grain storage (Makanjuola, 1989). Different plant parts are utilized as protectants for stored grains (Lale, 1992).

The toxicity of botanical extracts varies based on factors such as the chemical composition of the extract, its source (e.g., stem, root, or oil), the season and ecological conditions, extraction methods, solvents used, and extraction time (Lee et al., 2001).

Exposure of insect larvae to botanical pesticides can prevent moulting, causing many insects to die before they reach the pupal stage, which effectively stops their development into adults (Charleston et al., 2005). In summary, the mode of action of a botanical pesticide can include one or more of the following mechanisms:

1. Blocking respiratory passages
2. Acting through contact toxins or impairing digestion
3. Preventing reproduction by reducing hemocyte count, damaging organelles, and destroying plasma membranes
4. Detering feeding by blocking receptors for feeding stimulants or stimulating deterrent receptor cells, or both
5. Repelling insects or altering their behavior
6. Inhibiting growth by blocking a morphogenetic peptide hormone, affecting ecdysteroid and juvenile hormone levels.

Conclusions

In conclusion, the global population growth and increasing demand for food have exacerbated the challenge of food security, particularly due to the significant losses caused by stored product pests such as red flour beetle (*Tribolium castaneum*). These pests, responsible for considerable damage to stored grains and food products, not only lead to the loss of food quality and quantity but also create economic burdens, especially in developing countries. While chemical insecticides have been the traditional means of pest control, their associated health risks and environmental concerns underscore the urgent need for safer, more sustainable alternatives.

Botanical insecticides present a promising solution, offering eco-friendly, cost-effective, and locally available options for managing red flour beetle infestations. Various plant-derived substances, such as those from neem, turmeric, garlic, and eucalyptus, have demonstrated notable efficacy in controlling *T. castaneum* at various life stages. These botanicals provide a valuable tool for integrated pest management, particularly in regions where access to chemical pesticides is limited or where their use is not viable. Given the promising results from recent studies, the potential of medicinal plants and their derivatives for stored grain protection should be further explored and developed. By embracing these natural alternatives, we can reduce reliance on harmful chemicals, mitigate post-harvest losses, and ultimately enhance food security in an environmentally sustainable manner. Future research should focus on optimizing the application of these botanicals, understanding their mechanisms of action, and developing strategies to integrate them effectively into pest management systems, thus improving both the quality and availability of food across the globe. With the support of international partners, local research initiatives, and farmer education programs, botanicals could play an important role in promoting sustainable agriculture in Afghanistan.

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Zn Biofortification and Zn Solubilizing Bacteria: A Sustainable Approach to Improve Wheat (*Triticum aestivum* L.) Productivity and Nutritional Quality

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Abstract

Wheat plays a critical role in ensuring food security in the world, including in Afghanistan. However, when grown in soil with low zinc (Zn) availability, wheat productivity and quality are negatively affected, resulting in reduced grain yield and poor bioavailability of Zn. Field experiments were conducted using a factorial randomized block design using three wheat genotypes (G₁-TRB-72-311 synthetic hexaploid, G₂-TRB-89-348 advanced line, G₃-Pirsabak-19 approved variety) and four Zn application methods (AM₁: no Zn application, AM₂: seed priming with Zn 0.5%, AM₃: soil application of Zn 10 kg/ha, AM₄: foliar application of Zn 0.5%). The experiment also explored the use of Zn solubilizing bacteria (BF₀: without bacteria, BF₁: with bacteria). The results exhibited that wheat genotypes, Zn application methods, and the presence of Zn solubilizing bacteria significantly influenced various growth and yield parameters. Additionally, Zn content, protein content, and gluten content in the grain were affected. Among the treatments, TRB-72-311 with 0.5% foliar Zn application and the presence of Zn solubilizing bacteria demonstrated the best performance, exhibiting improved growth, yield characteristics, higher grain yield (5.07 t/ha), greater straw yield (6.88 t/ha). Moreover, the combination resulted in high grain Zn content (37.95 mg/kg), protein content (12.7%), and gluten contents (24.9%). Based on these findings, selecting of Zn efficient wheat genotype with foliar Zn application and Zn solubilizing bacteria application enhance yield and nutritional quality to eradicate malnutrition both in the research area and abroad.

Keywords: Zn Biofortification, Zn Solubilizing Bacteria, Productivity, Quality

Introduction

Food production and security are prominent concerns in this era, given the continuous growth of the global population. As clearly stated in the United Nations' second Sustainable Development Goal (UN-SDG2), achieving the eradication of all forms of starvation by 2030 is a formidable task due to time constraints, substandard international health conditions, and the socioeconomic aspects of hunger. Nonetheless, it remains a necessary endeavor (Fanzo et al., 2021). In this context, hidden hunger, a widespread universal issue, affects billions of individuals worldwide. Hidden hunger is characterized by a severe deficiency of vitamins and micronutrients (Biesalski, 2021; Abbaspour and Kelishadi, 2014).

Wheat (*Triticum aestivum* L.) stands out as the predominant staple cereal in terms of production and cultivated area, providing approximately 70% of the daily calorie intake for people (Cakmak, 2008). In Pakistan, wheat serves as the primary staple food; however, it is deficient in bioavailable zinc (Zn) (Rehman et al., 2020). Excessive reliance on wheat production in Zn-depleted soils leads to Zn malnutrition and diminished Zn bioavailability (Cakmak, 2008; Khalili et al., 2023). Recently, there has been a noticeable decline in the potential yield of common wheat in terms of both productivity and quality. This decline raises serious concerns about future food production and security worldwide (Khalili et al., 2024). The decrease in wheat yield per hectare can be attributed to a loss of wheat diversity and imbalanced fertilization, particularly the inadequate application of micronutrients. Nonetheless, the limited inherent diversity can be explored within the existing germplasms, as wheat genotypes exhibit variations in growth, yield, and quality. Consequently, diversifying new wheat genotypes through selective breeding could be a viable solution for enhancing productivity and grain quality. Thus, it becomes imperative to replace local, old, and low-yielding wheat genotypes with newly developed and promising ones (Khalili et al., 2023).

Simultaneously, it is worth noting that approximately 50% of cereal-growing soils worldwide have low Zn availability, with the situation being even worse in Pakistan, where 70% of soils are Zn deficient (Khalili et al., 2023; Kausar et al., 2001). This deficiency results in reduced Zn content in grains. To address this issue, Zn fertilizers can be applied through seed treatment, soil application, or foliar application, in addition to utilizing Zn solubilizing bacteria. Seed treatment involves soaking the seeds in a solution containing specific amount of element for a specific time (Farooq et al., 2012). Seed priming with Zn has proven to be the most cost-effective method for increasing economic yield and net revenue (Zulfiqar et al., 2020). Zn applied to soil enhances crop development and increases seed Zn content (Khalili et al., 2023; Khan et al., 2003). Foliar application of Zn is particularly useful when soil conditions limit root uptake. The highest grain Zn content and Zn bioavailability were observed with foliar Zn application, followed by soil application (Khalili et al., 2023; Zulfiqar et al., 2020). The use of Zn solubilizing bacteria (ZSB) is another alternative approach. Incorporating ZSB as an inoculant is a cost-effective and environmentally friendly option for Zn bio-fertilization. These bacteria have the ability to solubilize Zn by producing organic acids in the soil, which leads to a decrease in soil pH and the sequestration of Zn cations (Rasul et al., 2019). Wheat grain yield was most effectively improved when ZSB was used in combination with Zn seed priming and soil application. Furthermore, grain Zn concentration and Zn bioavailability were enhanced by applying Zn to the soil and foliage in conjunction with ZSB (Rehman et al., 2018).

Considering the concerns, this study aims to assess the impact of Zn fertilization along with ZSB application on the growth, yield, grain Zn concentration, and quality of wheat grain to address hidden hunger and ensure food security and safety.

Materials and Methods

Experimental site, design and field management

Two field experiments were conducted during the winter season at the Agricultural Research Institute (ARI) Tarnab, Peshawar, in Khyber Pakhtunkhwa, Pakistan, with the first experiment carried out in the years 2021-2022 and repeated in 2022-2023. The research site is located at latitude of 34°00' N and a longitude of 71°69' E, with an elevation of 309 m above sea level..

The soil at the experimental site had a texture composed of sand, silt, and clay 2, 88, and 10%, respectively. Its pH was 8.1, electrical conductivity (EC) was 0.48dS/m, organic content was 0.46 %, calcium carbonate (CaCO₃) content was 6.75%, nitrogen content was 0.086 mg kg⁻¹, phosphorus content was 9.03 mg kg⁻¹, potassium content was 87 mg kg⁻¹, and Zn content was 0.98 mg kg⁻¹.

The experiments followed a randomized complete block design (RCBD) with a factorial arrangement having three replications. The study involved three variables: (A) Three wheat genotypes: G₁ - TRB-72-311 synthetic Hexaploid (SHW), G₂ - TRB-89-348 advanced line, and G₃ - Pirsabak-19 approved variety (PS-19). (B) Four Zn application methods: AM₁ - No Zn application control, AM₂ - Zn seed priming (0.5%), AM₃ - Zn soil applied (Zn 10 kg/ha), and AM₄ - Zn foliar spray (Zn 0.5%) at heading stage of crop. Using Zn source of ZnSO₄·7H₂O. (C) BF₀ - No ZSB application and BF₁ - ZSB (*Bacillus* sp. Strain AZ6 (accession number KT221633) application. Prepared ZSB solution of strains was obtained from the Institute of Soil & Environmental Sciences, University of Agricultural Faisalabad. The ZSB was applied to the soil before sowing (5 liter/ha).

The field was prepared by plowing it twice with a cultivator, after that by a rotavator to break up clods and pulverize the soil. Each plot had a size of 3 m x 1.8 m, containing six rows. The wheat crop was planted by hand hoe with a 30 cm row-to-row distance and a 3 m row length, using a 120 kg seeds/ha. The recommended dose of NPK fertilizers (120:90:60 kg/ha) were applied using urea, di-ammonium phosphate (DAP), and sulfate of potash as the fertilizer sources. Half amount of the recommended dose of N and the whole amount of P and K were applied at the time of sowing, while the remaining N dose was split equally and applied during the first and second irrigation.

Observations and chemical analysis

The parameters related to plant growth, such as height of plant, leaf area index (LAI), tillers per square meter, chlorophyll content index (CCI) by Using of (OPTI-SCIENCES CCM-200 plus) a handheld chlorophyll content meter, length of spike, spikes per square meter, grains per spike, and test weight, were recorded. Grain and straw yields per square meter were also measured and converted to tons per hectare. Grain Zn concentration was determined through wet digestion using atomic absorption spectrophotometry, following the procedure defined by (Tsonev and Fernando 2012). The plant samples were kept for pre-digestion overnight and were digested for 1 h at a temperature of 320°C until they were colorless. The seeds were estimated using the turbidimetric method, while N was determined after acid digestion and there after steam distillation by Kjeldahl's method. Gluten content in wheat flour for each treatment was determined using the hand wash method (AACC, 2000).

$$LAI = \frac{\text{total leaf area (cm}^{-2}\text{)}}{\text{Ground area (cm}^{-2}\text{)}} \quad \text{I}$$

$$\text{Grain Zn conc. mg/kg} = \frac{\text{AAS reading}}{\text{weight of sample}} \times \text{volume of extract (ml)} \quad \text{II}$$

$$\text{Protein (\%)} = \% \text{ N} \times 5.7 \quad \text{III}$$

Statistical analysis

The data from two years were analyzed using on ANOVA test with the Statistix 8.1 software. Post hoc comparisons of treatment means were conducted using Fisher's Least Significant Difference (LSD) test at a significance level of $p \leq 0.05$ to identify and distinguish differences between treatments.

Results

Growth parameters

The experiments showed significant effects of genotype (G), application methods (AM), and biofertilizer (BF) on plant height, number of tillers per square meter, leaf area index (LAI), and chlorophyll content index (CCI). The highest plant height (107.00 cm) was recorded in G₁ with AM₄ and B, while the lowest (91.50 cm) was observed in G₃ under AM₁ and BF₀.

The maximum number of tillers per square meter (401.83) was found in G₁ with AM₃ and BF₁, and the minimum (279.47) in G₃ under AM₁ and BF₀. For LAI, the highest value (4.43) occurred in G₁ with AM₄ and BF₁, while the lowest (2.47) was noted in G₃ under AM₁ and BF₀.

The chlorophyll content index (CCI) was highest (33.07) in G1 with AM3 and BF1, and the lowest (21.00) in G3 under AM1 and BF0. The interactions of $G \times AM$ and $AM \times BF$ were significant for most traits, while the three-way interaction ($G \times AM \times BF$) showed no significant effect.

Table 1 The average plant height, LAI, No. of tillers and chlorophyll content index (CCI) of wheat as affected by genotypes, Zn application methods and Zn solubilizing bacteria (ZSB) over two years studies

Treatment			Plant height	No. of	LAI	CCI
G	AM	BF	(cm)	tillers/m ²		
G ₁	AM ₁	BF ₀	96.79 ^{j-m}	303.50 ^{hij}	3.44 ^{ef}	21.50 ^j
		BF ₁	98.66 ^{f-j}	322.58 ^{fg}	3.39 ^{ef}	24.37 ^{ghi}
	AM ₂	BF ₀	94.79 ^{k-n}	331.57 ^f	3.15 ^{fg}	24.37 ^{ghi}
		BF ₁	99.71 ^{efg}	386.42 ^{abc}	3.49 ^{de}	27.37 ^{def}
	AM ₃	BF ₀	100.72 ^{def}	371.16 ^{cde}	3.96 ^b	29.53 ^{bcd}
		BF ₁	104.65 ^{bc}	401.83 ^a	3.79 ^{bcd}	33.07 ^a
	AM ₄	BF ₀	105.33 ^{ab}	395.71 ^{ab}	4.08 ^b	29.37 ^{cde}
		BF ₁	107.00 ^a	400.00 ^{ab}	4.43 ^a	32.25 ^{ab}
G ₂	AM ₁	BF ₀	92.00 ^{op}	290.83 ^{ijk}	2.89 ^{ghi}	21.33 ^j
		BF ₁	94.50 ^{mn}	301.66 ^{hij}	2.84 ^{ghi}	23.17 ^{hij}
	AM ₂	BF ₀	93.91 ^{no}	319.76 ^{fgh}	3.21 ^{ef}	24.27 ^{ghi}
		BF ₁	99.07 ^{fgh}	352.81 ^e	3.30 ^{ef}	25.63 ^{fgh}
	AM ₃	BF ₀	97.00 ^{h-k}	363.66 ^{de}	3.26 ^{ef}	25.05 ^{fgh}
		BF ₁	101.62 ^{de}	397.33 ^{ab}	3.15 ^{fg}	26.67 ^{efg}
	AM ₄	BF ₀	97.25 ^{hij}	386.66 ^{abc}	3.52 ^{cde}	30.90 ^{abc}
		BF ₁	102.83 ^{cd}	398.16 ^{ab}	3.83 ^{bc}	31.27 ^{abc}
G ₃	AM ₁	BF ₀	91.50 ^p	279.47 ^k	2.47 ^j	21.00 ^j
		BF ₁	92.00 ^{op}	288.59 ^{jk}	2.50 ^j	22.00 ^{ij}
	AM ₂	BF ₀	94.21 ^{no}	308.38 ^{ghi}	2.61 ^{ij}	24.90 ^{fgh}
		BF ₁	96.75 ^{i-l}	323.24 ^{fg}	3.14 ^{fgh}	25.33 ^{fgh}
	AM ₃	BF ₀	94.75 ^{lmn}	353.16 ^e	2.83 ^{hi}	23.33 ^{hij}
		BF ₁	98.91 ^{f-i}	392.83 ^{ab}	3.31 ^{ef}	25.90 ^{fgh}
	AM ₄	BF ₀	98.33 ^{g-j}	381.34 ^{bcd}	3.25 ^{ef}	24.33 ^{ghi}
		BF ₁	98.50 ^{f-j}	392.83 ^{ab}	3.98 ^b	28.67 ^{cde}
LSD (0.05) for interactions						
G×AM			1.69	12.20	0.25	2.23
G×ZSB			1.19	NS	0.17	NS
AM×ZSB			1.38	9.96	0.20	NS
G×AM×ZSB			NS	NS	NS	NS

Yield attributes

The experiment revealed significant effects of genotype (G), application methods (AM), biofertilizer (BF), and their interactions on spike length, number of spikes per square meter, number of grains per spike, and 1000-grain weight.

For spike length, the maximum value (20.19 cm) was observed in G1 with AM4 and BF1, while the minimum (9.60 cm) was recorded in G3 under AM1 and BF0. The number of spikes per square meter was highest (385.00) in G1 with AM4 and BF1, and lowest (239.61) in G3 under AM1 and BF0. The highest number of grains per spike (58.24) was found in G1 with AM4 and BF1, while the lowest (39.80) was noted in G3 under AM1 and BF0. For 1000-grain weight, the maximum value (52.91 g) was recorded in G1 with AM4 and BF1, followed by G2 with AM4 and BF1 (51.71 g), whereas the minimum value (37.27 g) was observed in G2 under AM1 and BF0. Significant interactions were found for $G \times AM$ and $AM \times BF$ for most traits, while the three-way interaction ($G \times AM \times BF$) was non-significant except for spike length.

Table 2 The average spike length, no. of spike, no. of grain in spike and 1000 grain weight of wheat as affected by genotypes, Zn application methods and Zn solubilizing bacteria (ZSB) over two years studies

Treatment		Spike length (cm)	No. spike (m ⁻²)	No. of grains spike ⁻¹	1000 grains weight (g)	
G	AM					BF
G ₁	AM ₁	BF ₀	11.37 ^{jkl}	295.33 ^g	41.54 ^k	40.04 ^{jk}
		BF ₁	11.73 ^{h-k}	319.37 ^f	47.20 ^{c-f}	45.62 ^{fgh}
	AM ₂	BF ₀	12.50 ^{g-j}	290.07 ^{gh}	44.79 ^c	46.21 ^{e-h}
		BF ₁	13.51 ^{efg}	330.73 ^{ef}	48.69 ^c	47.98 ^{de}
	AM ₃	BF ₀	14.16 ^{b-e}	273.63 ^{hi}	48.28 ^c	45.74 ^{fgh}
		BF ₁	15.19 ^{bc}	343.61 ^{de}	52.00 ^b	50.58 ^{bc}
	AM ₄	BF ₀	15.39 ^b	355.03 ^{cd}	51.33 ^b	48.72 ^{cd}
		BF ₁	20.19 ^a	385.00 ^a	58.24 ^a	52.91 ^a
G ₂	AM ₁	BF ₀	10.17 ^{lm}	250.83 ^{jkl}	41.28 ^{kl}	37.27 ^l
		BF ₁	10.51 ^{klm}	248.75 ^{jkl}	43.59 ^{ij}	41.04 ^{ij}
	AM ₂	BF ₀	11.54 ^{ijk}	261.76 ^{ijk}	42.61 ^{jk}	42.27 ⁱ
		BF ₁	11.55 ^{h-k}	285.63 ^{gh}	45.62 ^{fgh}	44.61 ^h
	AM ₃	BF ₀	12.78 ^{fgh}	361.59 ^{bcd}	45.93 ^{fgh}	45.13 ^{gh}
		BF ₁	12.45 ^{g-j}	371.04 ^{abc}	47.76 ^{cde}	46.85 ^{d-g}
	AM ₄	BF ₀	13.88 ^{def}	373.41 ^{abc}	47.97 ^{cd}	45.74 ^{fgh}
		BF ₁	14.11 ^{cde}	378.39 ^{ab}	48.64 ^c	51.71 ^{ab}
G ₃	AM ₁	BF ₀	9.60 ^m	239.61 ^l	39.80 ^l	38.28 ^{kl}
		BF ₁	10.53 ^{klm}	242.63 ^{kl}	42.40 ^{jk}	39.78 ^{jk}
	AM ₂	BF ₀	11.31 ^{jkl}	260.87 ^{ijk}	42.63 ^{jk}	40.50 ^{ij}
		BF ₁	11.99 ^{hij}	263.44 ^{ij}	46.27 ^{efg}	42.33 ⁱ
	AM ₃	BF ₀	12.71 ^{f-i}	257.41 ^{i-l}	46.49 ^{def}	45.20 ^{gh}
		BF ₁	13.31 ^{efg}	283.50 ^{gh}	48.42 ^c	46.31 ^{e-h}
	AM ₄	BF ₀	13.54 ^{efg}	322.21 ^f	44.32 ^{hi}	47.28 ^{def}
		BF ₁	14.88 ^{def}	318.83 ^f	48.03 ^{cd}	48.71 ^{cd}
LSD (0.05) for interactions						
G×AM			0.93	14.66	1.36	1.43
G×ZSB			0.66	10.37	0.96	1.01
AM×ZSB			0.76	11.97	NS	1.17
G×AM×ZSB			1.32	NS	NS	NS

Yield

The experiment showed significant effects of genotype (G), application methods (AM), biofertilizer (BF), and their interactions on grain yield, straw yield, and biological yield. For grain yield, the highest value (5.35 t ha⁻¹) was observed in G₂ with AM₄ and BF₁, followed closely by G₁ under AM₄ and BF₁ (5.07 t ha⁻¹). The lowest grain yield (3.38 t ha⁻¹) was recorded in both G₂ and G₃ under AM₁ and BF₀.

Straw yield was maximum (6.88 t ha⁻¹) in G₁ under AM₄ and BF₁, while the minimum (4.23 t ha⁻¹) was observed in G₃ with AM₁ and BF₀.

Biological yield was highest (12.02 t ha⁻¹) in G₂ under AM₄ and BF₁, and the lowest (7.61 t ha⁻¹) was recorded in G₃ under AM₁ and BF₀. Significant interactions for G × AM and G × BF were observed for grain yield, straw yield, and biological yield, while AM × BF was non-significant except for biological yield. The three-way interaction (G × AM × BF) was significant for grain yield and biological yield but non-significant for straw yield. Biofertilizer application (BF₁) consistently improved all yields compared to BF₀ across genotypes and application methods.

Table 3 The average grain, straw and biological yield of wheat as affected by genotypes, Zn application methods and Zn solubilizing bacteria (ZSB) over two years studies

Treatment			Grain	Straw	Biological
G	AM	BF	yield (t ha ⁻¹)	yield (t ha ⁻¹)	yield (t ha ⁻¹)
G ₁	AM ₁	BF ₀	3.85 ^{fg}	4.89 ^{jk}	8.74 ^{gh}
		BF ₁	4.27 ^d	5.47 ^{e-h}	9.74 ^{de}
	AM ₂	BF ₀	4.47 ^{cd}	5.67 ^{def}	10.14 ^d
		BF ₁	4.95 ^b	6.27 ^b	11.21 ^{bc}
	AM ₃	BF ₀	4.28 ^d	5.84 ^{cd}	10.11 ^d
		BF ₁	5.06 ^b	6.65 ^a	11.71 ^{ab}
	AM ₄	BF ₀	4.66 ^c	6.06 ^{bc}	10.71 ^c
		BF ₁	5.07 ^b	6.88 ^a	11.95 ^a
G ₂	AM ₁	BF ₀	3.38 ^j	4.46 ^{lm}	7.84 ^{jk}
		BF ₁	3.61 ^{hi}	4.68 ^{kl}	8.29 ^{hij}
	AM ₂	BF ₀	3.75 ^{gh}	4.86 ^{jk}	8.61 ^{hi}
		BF ₁	4.04 ^{ef}	5.14 ^{ij}	9.18 ^{fg}
	AM ₃	BF ₀	3.94 ^{fg}	5.26 ^{hi}	9.20 ^{fg}
		BF ₁	4.29 ^d	5.58 ^{d-g}	9.87 ^{de}
	AM ₄	BF ₀	4.39 ^d	5.70 ^{de}	10.09 ^d
		BF ₁	5.35 ^a	6.67 ^a	12.02 ^a
G ₃	AM ₁	BF ₀	3.38 ^d	4.23 ^m	7.61 ^k
		BF ₁	3.40 ^{ij}	4.50 ^{lm}	7.90 ^{jk}
	AM ₂	BF ₀	3.47 ^{ij}	4.53 ^{lm}	8.00 ^{jk}
		BF ₁	3.55 ^{hij}	4.64 ^{kl}	8.19 ^{ij}
	AM ₃	BF ₀	4.26 ^{de}	5.32 ^{ghi}	9.57 ^{ef}
		BF ₁	4.33 ^d	5.43 ^{e-i}	9.76 ^{de}
	AM ₄	BF ₀	4.41 ^{ij}	5.38 ^{f-i}	9.79 ^{de}
		BF ₁	4.30 ^d	5.56 ^{d-h}	9.86 ^{de}
LSD (0.05) for interactions					
G×AM			0.16	0.23	0.37
G×ZSB			0.11	0.16	0.26
AM×ZSB			NS	NS	0.30
G×AM×ZSB			0.23	NS	0.53

Grain quality

The experiment revealed significant effects of genotype (G), application methods (AM), biofertilizer (BF), and their interactions on Zn content, protein content, and gluten content. Zn content was highest (37.95 mg kg⁻¹) in G₁ under AM₄ and BF₁, while the lowest (27.87 mg kg⁻¹) was observed in G₂ under AM₁ and BF₀. Protein content reached its maximum (13.12%) in G₁ under AM₄ and BF₁, and the minimum (9.45%) was recorded in G₃ under AM₁ and BF₀. For gluten content, the highest value (24.04%) was found in G₁ under AM₄ and BF₁, whereas the lowest (17.27%) occurred in G₁ under AM₁ and BF₀. Significant interactions for G × AM, G × BF, and AM × BF were observed for Zn content, protein content, and gluten content.

The three-way interaction (G × AM × BF) was significant only for protein content but not for Zn or gluten content. Biofertilizer application (BF₁) consistently improved Zn, protein, and gluten contents compared to BF₀ across genotypes and application methods.

Table 4 The average grain Zn concentration, protein and gluten content of wheat as affected by genotypes, Zn application methods and Zn solubilizing bacteria (ZSB) over two years studies

Studies Treatment					
G	AM	BF			
G ₁	AM ₁	BF ₀	28.23 ^l	10.46 ^{h-k}	17.27 ⁱ
		BF ₁	31.94 ^{gh}	11.49 ^{c-g}	19.39 ^{cde}
	AM ₂	BF ₀	30.76 ^{ij}	10.88 ^{e-j}	17.31 ^{hi}
		BF ₁	33.83 ^{de}	10.69 ^{g-k}	19.94 ^c
	AM ₃	BF ₀	32.76 ^{fg}	12.13 ^{bc}	18.51 ^{d-h}
		BF ₁	34.88 ^{bc}	11.65 ^{c-f}	22.30 ^b
	AM ₄	BF ₀	34.75 ^{bcd}	12.84 ^{ab}	19.61 ^{cd}
		BF ₁	37.95 ^a	13.12 ^a	24.04 ^a
G ₂	AM ₁	BF ₀	27.87 ^l	10.11 ^{jkl}	17.83 ^{ghi}
		BF ₁	31.56 ^{hi}	10.67 ^{g-k}	18.09 ^{f-i}
	AM ₂	BF ₀	32.01 ^{gh}	10.84 ^{f-k}	18.27 ^{e-i}
		BF ₁	34.78 ^{bcd}	10.94 ^{efghi}	19.37 ^{cde}
	AM ₃	BF ₀	32.48 ^{gh}	10.61 ^{hijk}	18.77 ^{c-g}
		BF ₁	33.95 ^{cde}	10.78 ^{ghijk}	19.65 ^{cd}
	AM ₄	BF ₀	32.72 ^{fg}	11.19 ^{defgh}	19.83 ^c
		BF ₁	34.21 ^{cde}	12.41 ^{bc}	21.26 ^b
G ₃	AM ₁	BF ₀	28.42 ^l	9.45 ^l	17.92 ^{f-i}
		BF ₁	29.47 ^k	10.33 ^{ijk}	17.76 ^{ghi}
	AM ₂	BF ₀	30.53 ^j	10.05 ^{kl}	19.07 ^{c-f}
		BF ₁	32.20 ^{gh}	11.70 ^{cde}	18.81 ^{c-g}
	AM ₃	BF ₀	33.56 ^{ef}	10.48 ^{hijk}	18.61 ^{d-g}
		BF ₁	32.40 ^{gh}	10.94 ^{efghi}	19.48 ^{cd}
	AM ₄	BF ₀	33.93 ^{cde}	10.69 ^{ghijk}	17.65 ^{ghi}
		BF ₁	35.54 ^b	11.79 ^{cd}	18.78 ^{c-g}
LSD (0.05) for interactions					
G×AM			0.71	0.54	0.91
G×ZSB			0.50	0.38	0.64
AM×ZSB			0.58	0.44	0.74
G×AM×ZSB			NS	0.77	NS

4. DISCUSSIONS

The experimental results strongly support the hypothesis that Zn biofortification, in combined with Zn-solubilizing bacteria (ZSB), significantly enhances growth, yield attributes, and nutritional quality across three wheat genotypes. Plant height increased by 13.1%, leaf area index (LAI) by 44.2%, tiller density by 301.3%, and chlorophyll content index (CCI) by 34.9% compared to the control (Table 1). These improvements underscore the essential role of Zn in enhancing wheat growth, likely through increased auxin synthesis, which promotes cell division and elongation of plant internodes (Khan and Qasim, 2007).

Significant differences were also observed among wheat genotypes and Zn application methods, with foliar Zn application demonstrating the highest effectiveness in improving plant height and LAI. These findings are in agreement with Ghasal et al. (2017)[17], who reported variations in growth parameters across wheat varieties and highlighted the positive influence of Zn application compared to control.

Yield attributes and grain yields also increased significantly with Zn and ZSB applications. Spike length improved by 52.45%, spike density by 37.76%, grains per spike by 31.66%, and 1000-grain weight by 27.80% over the control (Table 2). The combined application of foliar Zn and ZSB showed the greatest effects, corroborating earlier findings by Paramesh et al. (2020) and Ghasal et al. (2017)[17, 18], who reported significant enhancements in wheat yield attributes due to Zn fertilization. Grain yield increased by 33.33%, straw yield by 38.51%, and biological yield by 36.31% with foliar Zn application and ZSB in synthetic hexaploid wheat compared to the control (Table 3). These observations align with results from Khalili et al. (2023), Majd et al. (2015), and Ghasal et al. (2017)[6, 17, 19], which highlighted significant yield improvements among genotypes and Zn application methods. The role of seed coating with Zn in further enhancing yields has also been emphasized by previous studies[4, 6]. Notably, the interactions of ZSB with genotypes significantly influenced yield components, while other ZSB interactions did not produce significant effects. These findings highlight the importance of genotype selection, Zn application methods, and biofertilizer use in determining grain, straw, and biological yields.

Zn biofortification also improved grain nutritional quality. Grain Zn concentration increased by 25.11%, protein content by 27.97%, and gluten content by 25.45% under foliar Zn application with ZSB in synthetic hexaploid wheat compared to advanced lines and control varieties (Table 4). The higher Zn content reflects efficient Zn mobilization to the grain, consistent with findings by Zhang et al. (2010)[20], who reported greater increases in grain Zn concentration under foliar Zn application compared to soil application. Paramesh et al. (2020)[18] attributed this efficacy to the rapid absorption and translocation of foliar-applied Zn.

Biofertilizers, particularly ZSB, played a critical role in improving nutrient uptake and grain Zn concentration, as observed in studies by Khalid et al. (2022) and Naz et al. (2016)[21, 22]. These studies emphasized the contribution of ZSB to enhanced Zn availability and uptake, which aligns with the present results. Khalili et al. (2023), Ghasal et al. (2017), and Prasad et al. (2012)[6, 7, 17, 23] also reported similar findings, demonstrating the synergistic effects of Zn and biofertilizers on improving wheat nutritional quality.

The observed increases in Zn uptake also contributed to higher grain protein content, as supported by Rehman et al. (2020) and Gao et al. (2012)[5, 6, 24]. Zn is essential for enzymatic processes, protein synthesis, and carbohydrate metabolism, which directly influence grain quality. These findings highlight the dual benefits of Zn biofortification in enhancing wheat productivity and nutritional quality, offering a promising strategy to address micronutrient deficiencies and improve food security. The results align with studies by Paramesh et al. (2020) and Ghasal et al. (2017)[6, 17, 18], which underscore the critical role of Zn application in improving grain protein content and overall crop quality. The enhanced nutritional profile achieved through Zn biofortification provides an effective solution to tackling micronutrient deficiencies, ultimately improving human health outcomes.

Conclusion

The study demonstrates that Zn biofortification, coupled with Zn-solubilizing bacteria, is a promising approach to improve wheat growth, yield, and nutritional quality. Significant enhancements in growth parameters, yield attributes, yield, and grain nutritional quality in terms of grain Zn, protein and gluten content obtained from 0.5% foliar application with Zn solubilizing bacteria in TRB-72-311 synthetic hexaploid wheat genotype, highlights the effectiveness of this strategy in addressing hidden hunger and improving food security. The findings underscore the importance of selecting appropriate Zn efficient wheat genotypes and Zn application methods to maximize benefits. This sustainable approach offers a viable solution for increasing wheat productivity and enhancing its nutritional value, contributing to global efforts to combat micronutrient deficiencies.

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Food Safety and Security Assessment in Street Food Shops of Pul-e-Alam City, Logar Province, Afghanistan

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Abstract

This study, aimed at examining the status of street food vendors, was conducted using a qualitative analytical method. Semi-structured interviews were employed as the research tool, and purposeful interviews were conducted with 9 street food vendors in the city of Pul-e-Alam. The results revealed that street food vendors in Pul-e-Alam face several challenges. Among these are the lack of proper facilities and equipment to protect food from contamination, especially food left over from one day to the next. Additionally, there is a severe shortage of drinking and washing water, and vendors lack access to proper sanitation facilities. Wastewater from washing is disposed of in the street gutters. Furthermore, the vendors have not received any professional or health-related training from relevant authorities, such as the municipality, Ministry of Public Health, Standards and Norms Authority, and other related institutions. Food evaluations are generally carried out monthly by various organizations, particularly the provincial authorities, Ministry of Public Health, municipality, Ministry of Economy, and the Directorate of Industries and Food. These evaluations are mostly conducted through simple observation, and evaluators do not have the necessary tools or equipment to test the quality and safety of the food. In contrast, previous studies in other countries have shown that the food from such vendors is regularly tested using advanced equipment. Additionally, in other countries, street food vendors receive training from municipal authorities and public health agencies on how to maintain food safety and protect customers from potential contamination.

Keywords: Pul-e-Alam City, Municipality, Shop, Food Safety

Introduction

Food security and safety are of paramount importance in any society, as neglecting them essentially means neglecting the health of its citizens. Nowadays, in cities, in addition to standard hotels and restaurants, a number of street food vendors are also involved in food preparation and sales. These vendors generally have fewer resources compared to hotels and restaurants. Research has shown that in many countries, the consumption of fast and street food is increasing due to various factors, such as population growth, quick access, affordability, and portability. For example, the results of a study titled "Factors Affecting the Choice of Street Food in China" show that the number of street food vendors, particularly in Beijing, is rapidly increasing, raising serious concerns for the government and the Ministry of Health of China. These concerns arise because street food vendors are not registered and lack the necessary licenses, posing a threat to food security and safety. Furthermore, these foods have been linked to an increase in customer obesity, which amplifies the need for stricter control over this sector (Atinkot et al., 2018).

Since many street food vendors are not registered with local municipalities and are less accountable to relevant authorities, vendors focus more on lowering food costs rather than ensuring the quality of ingredients. As a result, the food produced by these vendors is less safe, leading to the transmission of diseases to customers and the broader community. In this regard, the results of a study conducted in Bangladesh titled "Review of Health Measures and Health Hazards Related to Street Food and Drinking Water in Roadside Restaurants of Khulna City" show that the consumption of street food in this country is rapidly increasing. These foods and drinking water in Khulna are often contaminated and are major contributors to various diseases, as these roadside restaurants lack complete food safety and security (Roy et al., 2019). In this regard, the results of a study conducted by Gorodassani et al. (2019) titled "Food Safety Knowledge and Consumer Attitudes in Various Food Service Centers" indicate that, in many cases, the negligence of street food vendors in ensuring food safety and security has led to the transmission of various diseases, including cholera. The main causes of this issue were found to be the low level of vendors' awareness about food safety and the associated risks. Moreover, a study conducted in Durban, South Africa, using tests and observations of food sold on the streets, revealed that many of the foods from these vendors were microbiologically contaminated. A significant contributing factor was the lack of proper training provided by relevant authorities to restaurant owners (Ronel, 2020).

A study in Ghana, titled "Street Foods in Accra, Ghana: How Safe Are They?" found that street food vendors require health training on how to ensure food safety. The unhealthy foods sold in these shops are often responsible for the spread of diseases, particularly diarrhea, among the population (Mensah et al., 2002). Another study conducted in Pakistan showed that approximately 80% of respondents believed that street foods sold in Rawalpindi, Pakistan's fourth-largest city, were not hygienically safe and posed a risk of disease transmission. Additionally, the training provided to street food vendors in Rawalpindi was found to be insufficient (Zebiro et al., 2017). A study conducted in Nigeria revealed that only 12% of street food vendors in Abeokuta, Nigeria, had received the necessary training in food hygiene (Omimo et al., 2008). Similarly, researchers in another study in Assam, India, found that only about 30% of street food vendors had formal knowledge about food hygiene and safety practices, and the food hygiene situation in the city was deemed concerning. The researchers called for urgent government action in this regard (Chaudhury et al., 2011). Additionally, a study conducted in the city of Jashore, Bangladesh, showed that 72.5% of street food vendors had received training on food hygiene and safety, and there was a direct correlation between education level and adherence to food safety practices (Hussain et al., 2020).

In this regard, the results of studies conducted in several European countries indicate that in many cases, consumers of street food do not follow proper hygiene practices when consuming food (Sida et al., 2021). Additionally, the findings of a study conducted in Yangon, Myanmar, show that most food vendors in this city do not adhere to food safety and security standards due to incomplete access to clean water and a lack of knowledge regarding how to follow food hygiene standards (Lin et al., 2014). Therefore, it is essential to examine the status of street food vendors in Pul-e-Alam city to identify the existing problems in this area and prevent the potential spread of diseases among the citizens. The study was done for achieving the following objectives:

1. To assess the status of street food shops in Pul-e-Alam city.
2. To examine food safety and security in ready-to-eat food shops in Pul-e-Alam city.
3. To evaluate how the management and control of ready-to-eat food shops are carried out in Pul-e-Alam city.

Materials and Methods

This study is applied in terms of its objective and qualitative analytical in terms of data collection method. The statistical population consists of all street food vendors in the city of Pul-e-Alam, Afghanistan, with a total of 55 registered food vendors in the municipality of Logar province. The sample was purposefully selected using a snowball sampling method, consisting of 9 food vendors and food-related officials and market control authorities from the Logar provincial municipality. The interview questions were semi-structured, and each interview lasted approximately one hour. The interviews were conducted in person, and the researchers reached theoretical saturation after the seventh interview. However, to enhance the validity of the results, the interviews continued until the ninth participant. The responses were initially recorded in audio format and later transcribed. To ensure validity, the interview questions were reviewed by colleagues, and the responses were analyzed using the three-stage coding method of Strauss and Corbin (open, axial, and selective coding). As a result, the theoretical codes, or components, were reviewed by the interviewees using the feedback method. Finally, after obtaining their secondary feedback, the final components were identified.

Results and discussion

In this section, the demographic details of the interviewees are presented, followed by an analysis and interpretation of the results derived from the interviews using the three-stage coding table.

Table 1: Demographic Characteristics of the Interviewees

No.	Interviewee Name	Father's Name	Position	Duration of Service	Place of Service
1	Mohammad Ghani	Mohammad Alam	Market Regulation Manager	More than 5 years	Logar Province Municipality
2	Syed Farooq Shah	Sayed Saifur Shareh	Greenery Manager	More than 5 years	Pul-e-Alam City Market
3	Wazir Gul	Motiullah	Cook	More than 5 years	Pul-e-Alam City Market
4	Fazal Ahmad	Ahmad Zia	Cook	More than 5 years	Pul-e-Alam City Market
5	Ahmad Jan	Aref	Cook	More than 5 years	Pul-e-Alam City Market
6	Iqbal Jan	Motiullah	Cook	More than 5 years	Pul-e-Alam City Market
7	Haji Rahim	Habib Rahman	Cook	More than 5 years	Pul-e-Alam City Market
8	Khwaja Gul	Hayatullah	Cook	More than 5 years	Pul-e-Alam City Market
9	Noor Ahmad	Hashmatullah	Cook	More than 5 years	Pul-e-Alam City Market

According to the above table, 9 individuals were interviewed in this study. The majority of the interviewees were food vendors and cooks in Pul-e-Alam city.

Additionally, several managers of the market regulation department and the head of the municipality's greenery division in the province were also involved in the study.

Table 2: Analysis of Qualitative Findings

No.	Dimensions	Respondents' Codes	Open Codes	Selected Codes	Codes or Components
1	Adherence to health conditions during food preparation and sale	1-9	Presence of mask and non- use	Neglect in wearing cooking clothes	Weak Personal Hygiene
		1-9	Presence of hat and non-use		
		1-9	Presence of gloves and non-use		
2	Adherence to cleanliness and environmental hygiene	3.7	Daily washing	Lack of water and sanitation facilities	Lack of Water and Facilities
		5.6	Daily public washing		
		1-4	Weekly public washing		
		5.	Lack of sufficient water for dish and utensil washing		
		5.	Distance of trash bins from the location		
		5.7	Lack of suitable hygienic location		
3	Food storage	5.	Mostly use refrigerators to protect food	Lack of Food Storage Equipment	
		6-9	Throwing away leftover food		
		6-9	Lack of equipment		
4	Educational support	1-9	Not receiving any educational program	Weak awareness	Weak Awareness
5	Customer complaints	1-9	No complaints received		
6	Use of technical tools in food quality assessment	1-9	Lack of tools to assess food quality	Supervision without technical tools	Weak Supervision
7	Supervision	5.6	Monthly supervision by the municipality		
		6-8	Monthly supervision by the Ministry of Public Health		
		7-8	Supervision by provincial authorities and other related agencies such as Food Industries, Ministry of Economy, Public Health, Municipality, etc.		

Analysis of the results from the interviews revealed four main components or theoretical codes, which include: poor personal hygiene practices, lack of water and facilities, vendors' lack of knowledge about food safety, and weak oversight by relevant authorities.

Poor Personal Hygiene Practices: Based on the analysis of the above table, it is clear that food cooks and vendors in Pul-e-Alam city do not adhere to personal hygiene standards. For instance, they do not use necessary tools and attire such as cooking uniforms, hats, masks, and gloves while preparing and selling food, even though these items are available in their stores. As interviewees 1 to 9 have expressed, they have cooking uniforms in their shops, but the staff does not use them due to carelessness and a lack of seriousness regarding hygiene. Observations also showed that none of the interviewees were wearing cooking uniforms.

Lack of Water and Facilities: The research results indicate that the majority of street food vendors in Pul-e-Alam face a shortage of drinking water and washing facilities. There is no system for water piping or plumbing, and the vendors have to bring water from distant sources or buy it. In

such cases, they try to use as little water as possible and delay washing their utensils and equipment.

As interviewees 1 to 4 mentioned, they can only clean their shops once a month. Regarding other facilities, unstable electricity has caused the food to face higher risks of contamination. The lack of facilities, alongside the absence of electricity and water, directly affects food safety in these stores. Additionally, almost all interviewees complained about the absence of suitable spaces for washing food, the lack of proper restrooms for both vendors and customers, and even the absence of waste disposal tools. These issues further increase the risk of food contamination in these stores.

Vendors' Lack of Knowledge about Food Safety: The results of this study clearly show that the lack of awareness among street food vendors and cooks is one of the main problems and a significant factor contributing to weak food safety and security globally, especially in developing countries. Afghanistan is no exception, and it is not immune to the risks of diseases transmitted through the consumption of street food that lacks proper safety and hygiene measures. As this study has shown, food vendors and cooks in street food shops in Pul-e-Alam city, Logar province, Afghanistan, have not received any professional or relevant training on how to maintain food safety and security. Most of them are unaware of proper food hygiene and safety measures. Consequently, the lack of awareness among the public and customers has led to the absence of complaints regarding food safety, as no necessary information is provided in this regard.

Weak Oversight: The results of this research indicate that the process of monitoring and evaluating the quality of food in street food shops in Pul-e-Alam faces many challenges. These include the lack of technical tools to differentiate between contaminated and non-contaminated food, and long delays in the evaluation process. This situation has led to a lack of serious attention from vendors regarding the health and safety of citizens. Additionally, the municipality and other relevant institutions in Logar province do not have a clear program for addressing these deficiencies. As mentioned by interviewee 1, monitoring and evaluation of street food shops in Pul-e-Alam is carried out by teams from the municipality, public health, and in some cases, joint teams from provincial authorities, public health directorate, agriculture, economy, and industries and food departments. This monitoring is based on a specific schedule, conducted once a month. However, the process mainly relies on observation, without the use of technical equipment, and simple observation cannot easily detect food contamination by microbes.

Conclusion

The results of this study indicate that the tendency of people in Pul-e-Alam city to consume street food is rapidly increasing due to reasons such as population growth, the lower cost of these foods compared to those in hotels, their quick availability, and ease of transportability. These findings are fully consistent with previous research.

For instance, studies conducted in China confirm this trend, highlighting that street food contributes to the spread of diseases and weight gain, particularly among consumers of such food. Moreover, the majority of these street food vendors are not registered with municipal authorities and are not held accountable for the aforementioned issues (Aninkot et al., 2018).

Similarly, the results of this research regarding the problems related to safe drinking water, washing utensils used for food in these stores, and the lack of proper sanitary facilities are considered very serious.

These findings align with the research conducted by Rai et al. (2018) in Khulna, Bangladesh, where street food vendors in the city complained about the lack of sufficient clean water.

Regarding the level of awareness among street food vendors and cooks in Pul-e-Alam city, the results of this study show that they have not received any educational programs from any authority and are mostly reliant on their personal knowledge about food safety and hygiene. This finding is consistent with the results of the study by Gorodassani et al. (2019) conducted in India, which revealed the lack of awareness among street food vendors in India regarding food safety practices. Similarly, this study's results are in agreement with research conducted by Ronel (2020) in Durban, South Africa, which highlighted the lack of knowledge among street food vendors in the city of Durban. Furthermore, the findings of this study align with the results of Mansah et al. (2002), which indicated the lack of knowledge among street food vendors in Accra, the capital of Ghana, regarding food preservation and safety. Additionally, similar results were found in studies conducted by Zubair et al. (2017) on the health status of food vendors in Rawalpindi, Pakistan, Chaudhary et al. (2011) in Assam, India, and Omimo et al. (2008) in Nigeria. All these studies found similar results related to the lack of awareness of food safety practices among street food vendors.

The results of this study indicate that a similar situation exists in Pul-e-Alam city, Logar province. Street food shops in Pul-e-Alam face various problems that threaten the safety and security of food in these establishments, which in turn exposes consumers to serious health risks. Issues such as a severe shortage of drinking and washing water, lack of equipment for food storage, inadequate sanitary facilities for vendors and customers, the distant placement of trash bins installed by the municipality, the absence of a water supply system for street food shops, and, in some cases, the lack of registration of street food vendors in the city, all contribute to increasing the risks of disease transmission to customers and other citizens.

Based on this, it can be concluded that such problems exist in many countries in the region and globally. However, it is crucial to take necessary measures to address these issues, as they are of great importance for ensuring food safety and public health.

Recommendations

1. It is recommended that the esteemed municipal authorities and relevant departments responsible for controlling street food vendors use appropriate technical equipment for food quality assessments.
2. We urge the relevant municipal authorities and other concerned agencies to pay more attention to providing clean and hygienic water in the city, especially for street food vendors.
3. Since street food vendors and customers require access to sanitation facilities, and this directly affects food contamination with microbes, we request the responsible authorities, especially the municipality, to make greater efforts in providing adequate sanitation facilities throughout the city.
4. We kindly request the Ministry of Public Health and other relevant departments to organize regular and specific training programs for vendors and employees of street food shops and ensure continuous education for them.

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Analysis of Wheat value chain in Daman district Kandahar, Afghanistan

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Abstract

This study focused on the analysis of wheat value chain in Daman district of Kandahar province with specific objectives of analyzing the market structure-conduct-performance of wheat markets; identifying the determinants of wheat supply to the market and market outlet choice of wheat producers, and wheat value addition at different stages of the marketing chain, this study used a quantitative method using a set of structured questionnaires that developed and adopted based on previous research tools, results show that the main wheat value chain actors are assemblers, wholesalers, processors and consumers respectively, they take 43%, 37%, 12% and 8% of the total sales conducted by farmers respectively, the research result indicated that size of landholding, family size and quantity of wheat produced influences amount of wheat supplied to market significantly, the multinomial logit model result indicated that the likelihood to choose wholesalers market outlet was significantly influenced by frequency of extension contact, distance from market place and own price of the commodity compared to accessing assemblers wheat market outlet, the likelihood of accessing processors market outlet was significantly influenced by price of commodity, ownership of transportation facilities and distance of processors from production place, result of probity model indicated that access to market information, quantity of wheat produced, distance from market place, access to extension and credit services significantly affected farmer's decision to be engaged in value addition, therefore, policies aiming at increasing farmer's awareness of producing value added wheat produce to enhance value creations are recommended to strengthen chain development.

Keywords: Value chain, structure-conduct-performance, value addition, multinomial logit, market outlet.

Introduction

Wheat is one of the most important and valuable agricultural crops in Afghanistan, accounting for 70% of the country's grain, and is grown in all parts of the country, mainly as a rain fed crop. Afghans get an average of 60% of their energy from wheat, which is the main source of food for households in Afghanistan. The main wheat growing areas are concentrated in the northern, northeastern, southern, western and southwestern regions. Winter wheat makes 90%, spring wheat 10%. However, when growing wheat, traditional technology is used, innovations are practically not introduced.

Kandahar is one of the largest and most popular trading provinces in Afghanistan with an area of 47,676 km², 17 districts and a population of 2 million. 117,920 hectares of land are cultivated, of which 64,020 hectares are wheat alone, the annual wheat production is 180,000 tons.

However, several problems hinder the performance of wheat production and productivity in Daman district. Shortage of improved seed variety, low price of wheat products, high price of fertilizer, pesticides and seed, price instability problems for agricultural products, high costs of combine harvesting, reduced soil fertility, lack of sustainable market outlet, poor infrastructure, grass weed and disease are the major constraints of wheat production.

Daman is one of the largest wheat producing district in Kandahar province that shares largest area coverage of the province and where problems reflected above are prevalent. It is also known for high production of cereal crops in the province.

To reverse this situation and improve wheat production and productivity in the area among calls for development of well-performing marketing system which satisfies consumer demands with the minimum margin between producers and consumer prices. Well-functioning marketing system is not limited to stimulation but it also increases production by seeking additional output. However, wheat value chain and their characteristics have not yet been studied and analyzed for different parts of the country, especially in Kandahar province which are known in the production of wheat.

This study will focus on sequencing the value of wheat in Daman district of Kandahar province with the specific objectives of analyzing the market structure; determining the determinants of the supply of wheat grain to the market and the choice of the market point of view of wheat producers. This study focused on investigating the wheat value chain and important constraints using value chain analysis approach in Daman district of Kandahar province. The finding of the study can assist in developing improved market development strategies to benefit all stakeholders that are participating in wheat value chain in the study area.

Materials and Methods

Data collection methods: the data was collected from primary and secondary sources. Primary data were collected from producers, wholesalers, assemblers, retailers and agricultural input suppliers including processors. Secondary information were gathered from published and unpublished materials, district agriculture and rural development offices, organizations, input suppliers, marketing agencies and from different development organizations of the study area.

Sampling procedures: In order to collect a representative sample from wheat farmers and traders, Systematic Random Sampling Method was used for farmers and Snowball Sampling method was used for traders. The size of the sample was selected according to Yamane's (1967) formula. It has been done, and as a result, information has been collected among 100 farmers and 40 wheat traders from registered farmers and traders in the district based on a questionnaire.

Data analysis: The collected data of this research has been firstly checked for clear and accurate data, then the correct data has been analysed by SPSS Version 26 software.

Results and discussion

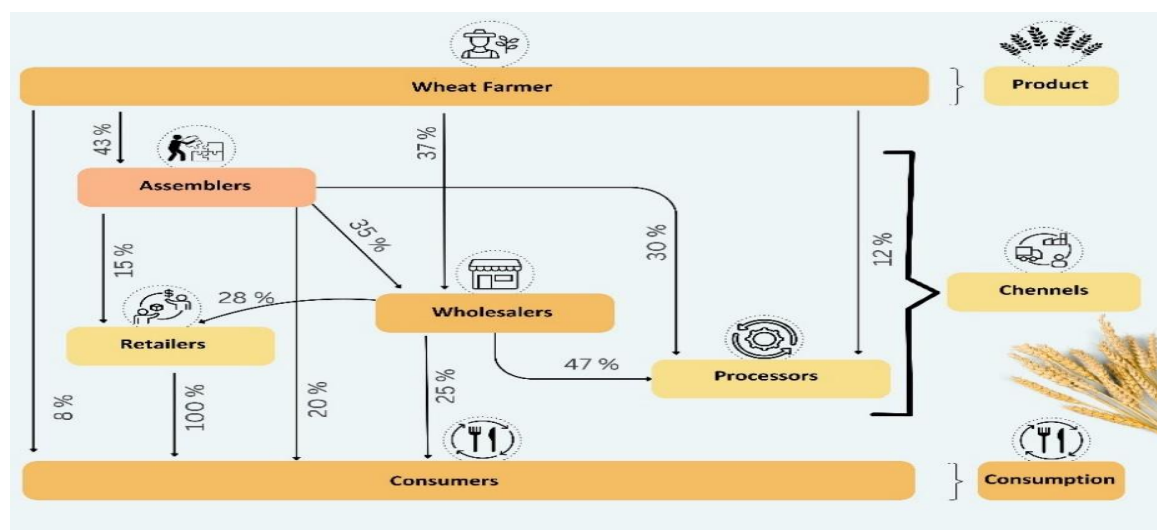
1. Descriptive Statistics

Table 1: Demographic and socioeconomic characteristics of respondents

Variables		Frequency	Percent
		N=100	N=100
Sex	Male	100	100%
	Female	0	0%
Education level	Illiterate	67	67%
	Read and write	18	18%
	Primary (1-4)	3	3%
	Junior (5-8)	3	3%
	Secondary (9-10)	1	1%
	Preparatory (11-12)	6	6%
	above	2	2%
Marital status	Married	90	90%
	Single	5	5%
	Widowed	5	5%
Age	Mean	43.76	
Family size	Mean	15.06	

Source: Survey 2020

2. Wheat market channels



3. Analysis of Wheat Market Structure-Conduct and Performance

3.1. Market concentration

Table 2: Concentration ratio of top five traders

Trader	Total volume of product Handled per week (ton,1000kg)	Market share (%)
1	15820.1	6.52%
2	15820.1	6.52%
3	17955.3	7.4%
4	11573.9	4.77%
5	11573.9	4.77%
total	72743.3	30%

Source: Survey 2020

For these study major actors which participate in wheat buying and selling activity was taken for considering market structure.

Calculation of the concentration ratio by considering an average volume of wheat handled by largest wholesaler per week in peak production season basing the five firm criteria indicated the existence of oligopoly market power. Five firms control 30% of the total amount of wheat sold in market during peak production season at district which is provincial market at the same time. Hence, it is concluded that wheat market is inefficient and non-competitive.

3.2. Barriers to entry (Skill/ experience): The survey result indicated that traders experience ranges from 4 up to 20 years with an average experience of 10.5 years. The existence of wider gap between traders indicated that experience was not a barrier to enter in to wheat trading in the study area.

3.3. Capital: Capital requirements serve as an entry barrier because only those who can afford such a monetary can enter the market. In order to handle reasonable quantity of the commodity, traders need sufficient amount of money that assists their business to operate in healthy way.

3.4. Conduct of wheat market (Price setting strategy)

The survey result indicated that 40% of the respondents reported that wheat price decision was set by traders. About 59% of the respondents reported that market price was through negotiation of farmers and traders. The remaining 1% reported that they decide on the price of their product taken to market themselves.

3.5. Buying and selling strategy

Out of the interviewed farmers, majority of them 30% decide to sell their product by assessing market price. The remaining 70% of respondents supply to market when they need money for different purposes. All of the respondents confirmed that price was the determining factor which influences them for whom to sell among the buyer outlet choices. Most respondents indicated that the selling system was based on cash payment, but some who are familiar with the buyer also selling on a short-term loan.

4. Major Constraints and Opportunities in Production and Marketing of Wheat

4.1. Production constraints and opportunities

Major wheat production constraints reported in the study area include: Shortage of rain, High price of inputs, Low soil fertility, Weeds, Low yield of wheat, Disease, Shortage of improving variety seeds and Pests, all of these obstacles combined lead to a decrease in wheat yields.

4.2. Marketing constraints and opportunities

The major marketing constraints raised by farmers and traders of the study area were: Lack of capital, Low bargaining power, Price instability, Lower price of wheat, Less/No market information and No buyer/Lack of market, There are also regular market fluctuations and shortage of storage facilities in addition to poor transportation. Processors main challenges were lack of uniformity in quality of flour for bread and cakes all which do not have standards established for them. There are also unfair competition from illegal traders and finally frequent electric power and water interruptions were also mentioned as constraint.

5. Econometrics Model Results

In this section factors affecting volume of wheat supplied to market and market outlet choices of producers are presented and discussed.

5.1. Factors affecting wheat market outlet choices

Table 3: Results of Multinomial Logit and marginal effects for choice of wheat market outlets

	Robust			Robust		
	Coefficient	Std.err	z-value	Coefficient	Std.err	z-value
Wholesalers						
EXTCON	0.85*	0.452	1.88	0.211	0.112	1.89
COPMEMB	1.223*	0.725	1.69	0.307	0.180	1.7
LAGPRC	0.068***	0.016	4.26	0.017	0.004	4.36
OWNTR	-0.771	0.712	1.08	-0.182	0.178	-1.02
ACCRE	0.464	1.684	0.28	0.102	0.423	0.24
OFFINC	0.657	0.644	1.02	0.156	0.159	0.98
DSTMRK	-0.168	0.099	-1.71	-0.040	0.025	-1.64
FAMILSZ	-0.065	0.086	-0.76	-0.015	0.022	-0.72
Constant	-55.02***	11.523	-4.78	—	—	—
Processors						
EXTCON	-1.418	0.896	-1.58	-0.000	0.00008	-0.25
COPMEMB	-0.609	1.794	-0.34	-0.000	0.00006	-0.25
LAGPRC	0.0107***	0.021	4.99	8.170	0.00000	0.25
OWNTR	-2.957**	1.478	-2.00	-0.0003	0.00012	-0.24
ACCRE	1.671	1.586	1.05	0.0002	0.00007	0.22
OFFINC	-0.469	1.224	-0.38	-9.070	0.00004	-0.21
DSTMRK	1.404*	0.787	1.78	0.0002	0.00006	0.28
FAMILSZ	0.069	0.210	0.23	1.160	0.00001	0.18
Constant	-95.29*	20.587	-4.63	—	—	—

Number of observation = 100, Log pseudo likelihood = -68.51***, Pseudo R² = 0.49, Wald chi - square (24) = 74.27, ***, ** and * are statistically significant at 1%, 5% and 10% respectively

Source: Survey 2020

5.2. Frequency of extension contact: Frequency of extension contact positively and significantly affected accessing wholesalers market outlet choices as compared with assembler market outlet choices at 10% probability level. The marginal effect result shows that the likelihood of accessing wholesale market outlet choice increases by 21.1% as compared to assembler market outlet choices for a unit contact of extension services.

5.3. Own price of the commodity: It is continuous variable, which was, price given for the commodity with different market outlets per hundred kilograms. Hence, it was hypothesized that price given by market outlets can negatively affect cooperative market outlet choice. Price offered by wheat market outlet per kilogram significantly and negatively affected accessing cooperative wheat market outlet as compared with accessing assembler's wheat market outlet. It also affected wholesaler and processor wheat market outlets positively and significantly at 1% probability level respectively. The marginal effect result shows that the likelihood of accessing cooperative wheat market outlet decreases by 0.1% for an Afghani increase per kg, the likelihood of accessing wholesaler outlet increases by 1.07% for an Afghani increase per kg and the likelihood of accessing processor outlet increases by 81.7% for an Afghani increase per kg of wheat as compared with accessing assembler wheat market outlet. The study by Birhanu (2013) also found out that price offered by milk market outlet per liter of milk significantly and negatively affected accessing cooperative milk market outlet as compared with accessing individual consumer milk market outlet.

5.4. Ownership of market transport facilities: This variable affects negatively and significantly accessing processors wheat market outlet. Ownership of market transport facilities decreased the likelihood of choosing processors market outlet by 0.03% compared to accessing assemblers' market outlet.

6. Analysis of Value Chains (Characteristics and roles of wheat value chain actors)

6.1. Farmers/producers: Producers are smallholder wheat producer farmers. They are major actor involved in production and marketing of surpluses they produce. Mainly they start from input preparation, produce, and store provide surplus to market. Wheat producers in Daman district supply their product either to nearest market or zonal market using Zarange, Tractor, Toyota and Mazda or traders come to farm gate and buy from them. According to the study, 47% and 7% sold within village and outside village respectively. The remaining 12% and 34% sold at both within and outside district. Producers have several options to sell their product: sell to wholesalers, retailers, assemblers and processors (flour factory).

6.2. Assemblers (Collectors): Assemblers play an important role in collecting produce from smallholder producers at farm gate and delivering to wholesalers at different levels. They are the first actor that links producers to other participating traders, the result of the study showed that they sell 43% of their total sales from farmers, who then distribute it to others.

6.3. Wholesalers: These were those participants of the marketing system who used to buy wheat on the farm field with a larger volume than other actors. Wholesalers buy wheat grain mainly from individual farmers, some collectors/small traders and a few other wholesalers within the district and districts around the business. Wheat wholesalers sell grain to consumers, processors, Retailers and other small wholesalers from within the district and beyond province, the result of the study showed that they sell 37% of their total sales.

6.4. Millers/processors: The surveyed flour processors purchase wheat grain from individual farmers, wholesalers and Assemblers within the district and the surrounding districts. On average 235500 kg is purchased in high supply session and 6525 kg is purchased in low supply sessions per week per flour processor. The main sources of wheat for flour factories are Momand, Khushab, Nasaji, Azam Qala, Mohammad shah, Najoi, Malang kariz, Mandisar, Behban dara and Landy villages suppliers who use hired vehicles. Some processors pick wheat grain from suppliers using own vehicles. Flour processors process grains into flour as well as wheat bran before selling to end consumers, retailers and wholesalers. All processors have stores with capacities of 571,500 kg for flour processors. The highest grain supplies to flour processors are made in May to August while the lowest supplies are experienced from January to April. Processors engage in grading, labelling and packaging before selling the products. The value added is reflected by the differences in prices charged per kilogram of processed products.

6.5. Retailers: Retailers are market actors operating at the last stage of the marketing channels selling to consumers. They buy from wholesalers, assemblers and farmers in their surroundings and directly sell wheat to consumers. They perform several value addition activities such as buying, transporting, storing and selling to end users. The problem raised by retailers during the survey was limited financial capacity that hinders them from being involved in larger trade, the result of the study showed that they sell 3,6% of their total sales.

6.6. Commission agents: Agent middlemen who physically handle products for buyers and sellers and paid for the service they delivered per 100 kg bases. Mostly they work between producers and processors.

7. Wheat marketing routes of the study area

Wheat marketing routes sketched below is drawn based up on primary data taken from traders and farmers of the study area. Traders in Daman district buy wheat grain from different supplier markets within district and districts around Daman. The wheat distribution system which starts from Nasaji village flow principally to different market places within province.

7.1. Factors affecting wheat market outlet choices

Multinomial logistic regression was used to analyze factors affecting choice of wheat marketing outlets with four alternative categories. If there are a finite number of choices (greater than two), multinomial logit estimation is appropriate to analyze the effect of exogenous variables on choices.

Producers choose their marketing plans and assess outside options that are available before participating in any marketing outlet. The producer's choice of a marketing outlet is based on utility maximization among the existing alternatives. After identifying choices of outlets, they choose where and for who to sell based on comparative advantage in bargaining and accessibility of outlets for farm products. The alternative "assembler" was used as a base category. This implies that the discussion of the results focuses on the impact of the explanatory variables on a use of retailer, wholesaler and processors category relative to use of assemblers (the base category).

7.2. Distance from market place: the study area located 22 kilometers east from the provincial market, Distance from the closest market place positively and significantly affected accessing millers/processors market outlet as compared with accessing assembler market outlet. It also affected wholesaler market outlet negatively and significantly. The marginal effect indicates that probability of choosing millers/processors increases by 0.02% as compared with accessing assembler market outlet for a unit decrease in kilometer. The likelihood of accessing wholesaler market outlet decreases by 0.4% for a unit increase in kilometer from market place. Distance to the nearest urban center is statistically significant and negatively associated with farmer's likelihood to add values to wheat produce. This indicates that as farmer's distance from the nearest urban center increases by a kilometer, farmer's likelihood to add values to wheat produce decreased by 0.3%. The reason behind this is that farmers nearest to market sale most their wheat grain to processors. This could be attributed to the reality that wheat processors need quality product compared to other actors involved in wheat marketing system in the study area.

7.3. Own price of the commodity: It is continuous variable, which was, price given for the commodity with different market outlets per 100 kilograms. Hence, it was hypothesized that price given by market outlets can negatively affect processor market outlet choice. Price offered by wheat market outlet per kilogram significantly and negatively affected accessing processor wheat market outlet as compared with accessing assembler wheat market outlet. It also affected wholesaler and retailer wheat market outlets positively. The marginal effect result shows that the likelihood of accessing wholesaler outlet increases by 5% increase per kg and the likelihood of accessing processor outlet increases by 40% increase per kg of wheat as compared with accessing assembler wheat market outlet. The study by Birhanu (2013) also found out that price offered by milk market outlet per liter of milk significantly and negatively affected accessing cooperative milk market outlet as compared with accessing individual consumer milk market outlet.

7.4. Ownership of market transport facilities: This variable affects negatively and significantly accessing processors wheat market outlet. Ownership of market transport facilities decreased the likelihood of choosing processors market outlet by 0.3% compared to accessing assemblers' market outlet.

Conclusion

This study was conducted in Daman district of Kandahar province in South zone region. The main focus of this study was analyzing wheat market value chain. The specific objectives of the study include analyzing the market structure of wheat markets in the study area, identifying the determinants of wheat supply to the market in the study area.

The study indicated that 100% of the respondents was male household heads. The minimum and maximum age of the respondents were 22 and 80 years respectively with mean age of 43.7 years. The average family size in the study area was 15.06. The minimum and maximum sizes of landholding of the respondent farmers were 0.6 and 290.00 hectare respectively with mean landholding of 16.79 hectares. Respondents allocated most of their plots for wheat plantation which was 9.52 hectares on average out of total holding.

Provision of adequate services for the communities enhances the communities' socioeconomic development in general and the well-being of individuals, in particular. It has important contribution in improving production and productivity and thereby increasing marketable surplus and ultimately for increasing the income of smallholder farmers. The most important services that are expected to promote production and marketing of wheat in the study area include access to short term loan, access to extension service, and access to market information. Wheat producer farmer's market major sources of information was friends/neighbor farmers, traders and agent which is 60%, 10% and 7% respectively. The result also showed that 65% of the respondents have access to short term loan. Extension service in agriculture is indispensable and it provides assistance for farmers in improvement of production and productivity, it also enables flow of information and transfer of knowledge and scientific findings to practice. There are currently no effective and sustainable cooperative programs in the study area. In this regard, only in collaboration with the department of agriculture and some charitable organizations and NGOs, a small number of farmers in some areas have been provided with information on some agricultural programs for a very short period of time, which is too little to deliver technical advice to farmers sufficiently. The interviewed farmers indicated that 47% of respondent farmers get information about some agricultural programs for a very short period of time.

The main wheat value chain actors in the area are input suppliers, farmers/producers, assemblers (collectors), wholesalers, millers/processors and retailers. Assemblers play an important role in collecting produce from smallholder producers at farm gate and delivering to wholesalers and retailers at different levels. Wholesalers buy wheat grain mainly from individual farmers, assemblers and retailers. Flour processors purchase wheat grain from individual farmers, wholesalers, within the district and the surrounding districts. Retailers are market actors operating at the last stage of the marketing channels selling to consumers. They buy from wholesalers and farmers in their surroundings and directly sell wheat to consumers.

Out of the 57231.9 tons of total wheat production in Daman district total surplus of wheat which would follow to market through all channels were estimated to be 19458.8 tons. The result of multiple regression indicated that size of landholding and quantity produced of wheat influences amount of wheat supplied to market positively and significantly.

This indicated that the two variables should get attention if we are going to increase marketable supply of wheat in the study area.

Factors affecting wheat production and volume supplied to market were also analyzed using econometric model. Farmers experience in wheat production, total farmland owned by farmers positively and significantly affect wheat production. Amount of fertilizer applied to wheat per jirib of wheat farm positively and significantly affected wheat production. Quantity produced of wheat, size of landholding, livestock ownership positively and significantly affected volume of wheat supplied to market.

Family size affected volume of wheat supplied to market negatively and significantly.

Wheat producers of the study area supply their product to different market outlets. Farmers supply their products to wholesalers, assemblers, retailers and processors market outlets. The survey results indicated that the likelihood to choose wholesalers market outlet was significantly influenced by frequency of extension contact, distance from market place, own price of the commodity as compared to accessing assemblers wheat market outlet. The likelihood of accessing processors market outlet was significantly influenced by price of commodity given at different market outlets, ownership of transportation facilities and distance of processors from production place.

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Effects of Agricultural Development on Poverty Reduction in Afghanistan

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Abstract

Agricultural development is very important tool for poverty reduction. This study investigates the positive effects of rehabilitating an irrigation canal in Nangarhar Province, Afghanistan, on agricultural productivity, poverty reduction, and rural livelihoods. Poverty alleviation is a key focus for both the Afghan national government and the Nangarhar regional government, with agricultural intensification identified as a primary strategy to achieve this goal. The research uses a descriptive design, gathering primary data through surveys conducted with 80 households benefiting from the canal and secondary data from credible sources such as journal articles, books, and reports. The findings reveal that rebuilding the canal has led to significant improvements, including higher crop yields, increased farmer incomes, and a noticeable reduction in unemployment across most villages served by the canal. This study emphasizes the critical role of irrigation in enhancing agricultural revenue and reducing poverty so small irrigation canal infrastructure as a vital tool for sustainable development and improving the quality of life in rural areas.

Keywords: [Afghanistan, Agriculture development, Rebuild Irrigation canal, Poverty reduction]

Introduction

Agricultural Development refers to the process of improving the productivity, sustainability, and overall performance of the agricultural sector. It involves the implementation of innovations, technologies, policies, and practices aimed at increasing food production, enhancing the quality of life for farmers, and promoting the long-term viability of agricultural systems (Hazell, 1991). Thus, Infrastructure Development like Building roads, irrigation systems, storage facilities, and market access to improve agricultural productivity are important parts of agricultural development (Zhang, 2004).

Reducing poverty is a central policy goal for both the Afghan government and the regional government of Nangarhar. It is widely agreed that boosting agricultural production and alleviating poverty should largely be achieved through agricultural intensification. To support this effort, both governments have identified the rehabilitation of irrigation canals as a key strategy for improving agricultural productivity and enhancing the livelihoods of rural communities. Irrigation is one of the most essential resources for farming and a significant tool for reducing poverty in the 21st century (Lipton et al., 2003). A common methodological issue in studying the impacts of irrigation is the tendency to assume that all income and poverty differences between households with and without access to irrigation are solely caused by irrigation (Dhawan, 1988). Bhattarai et al. (2002) found that irrigation increases cropping intensity and crop revenue per hectare in countries like Vietnam, India, and Sri Lanka, a result also supported by Pender et al. (2004).

Providing a consistent, year-round water source for irrigation can greatly improve agricultural yields and productivity. Numerous studies have shown the positive effects of irrigation on both agricultural output and the livelihoods of farmers, especially in Africa (Awulachew and Merrey, 2007). Research has consistently indicated that irrigation boosts crop production, increases household income, and helps reduce poverty (Bhattarai and Moorthy, 2003). For instance, Pender et al. (2000) observed significant increases in agricultural output from irrigation projects in Tigray, Northern Ethiopia. Similarly, Owusu et al. (2011) found that adequate irrigation water improved agricultural incomes and contributed to poverty alleviation in Ghana's Savannah region. Hussain et al. (2006) demonstrated that irrigation development in Punjab's peri-urban districts helped reduce poverty, whereas rain-fed areas had higher poverty rates than irrigated.

Materials and Methods

This study aimed to investigate the impact of irrigation system development and agricultural projects on food security and poverty alleviation in Nangarhar Province, Afghanistan. Descriptive research design was employed to achieve the study's objectives. Both primary and secondary data were utilized in the research process. The primary data were gathered through a questionnaire distributed to 80 households, all of whom were farmers benefiting from the irrigation canal project. Secondary data were obtained from various sources, including journal articles, books, and reports, to support and complement the primary findings. The data were analysed using Excel to facilitate a comprehensive understanding of the effects on food security and poverty alleviation in the region.

Results and discussion

The findings of this research reveal that the rehabilitation of the irrigation canal has brought about substantial positive changes in the lives of people in the region. These improvements include increased agricultural productivity, better access to water for both farming and daily needs, higher household incomes, and an overall enhancement in living standards. This demonstrates the significant impact that infrastructure development can have on rural livelihoods.

As illustrated in Figure 1, agricultural crop production has notably increased during both the summer and winter seasons in the research area. This data underscores the effectiveness of the irrigation project in boosting crop yields throughout the year, contributing to food security and economic growth in the region.

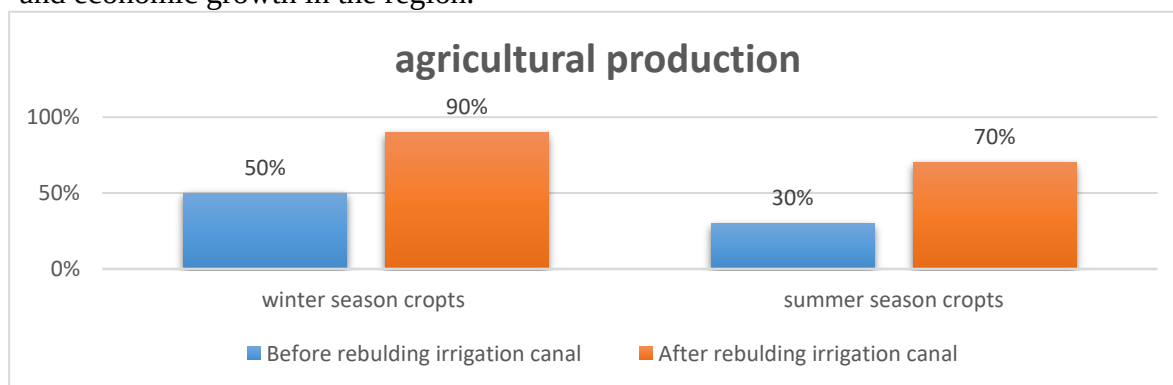


Fig. 1. Amount of agriculture production before and after the rebuild irrigation canal in research area

Figure 2 shows the employed and unemployed rate before and after the project in the areas where agricultural development has been implemented, clearly showing that unemployment has decreased in research place.

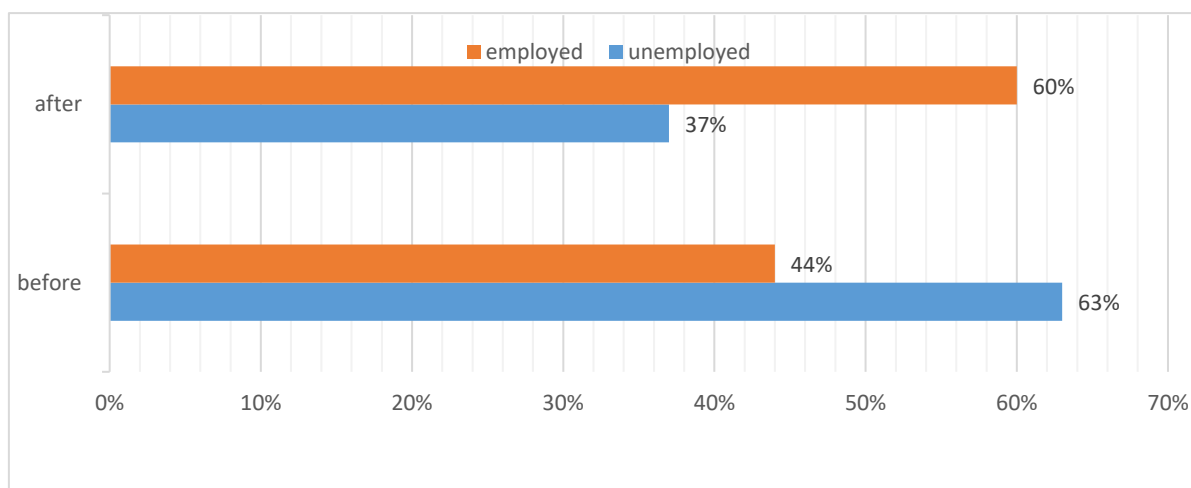


Fig. 2. Employment and unemployment rate before and after the rebuild irrigation canal

Poverty is frequently quantified using income or consumption levels. A person is deemed impoverished if their income or consumption is less than what is required to meet their fundamental necessities (Bhutto, 2007). The government's numerous initiatives to combat poverty have had varying effects on the issue. The area is where irrigation canal rebuild clearly shows that the effects of this irrigation canal had effected on poverty reduction as seen in Figure 3.

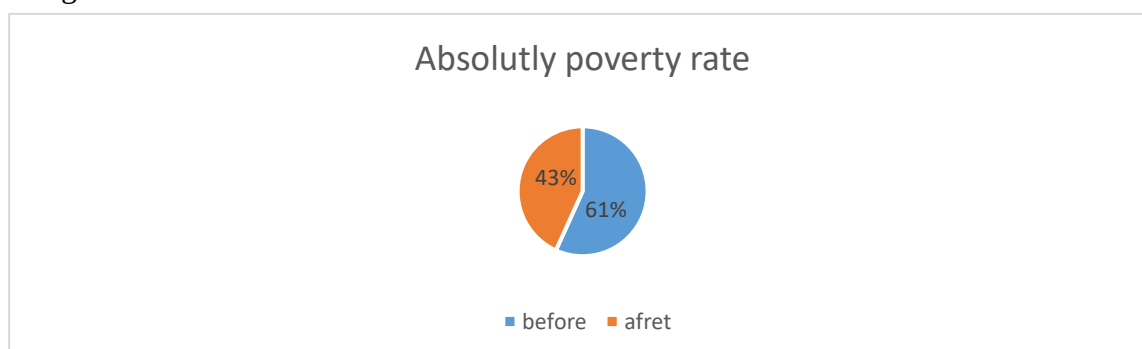


Fig. 3. Show absolute poverty rate before and after

Conclusion

As the primary source of income and subsistence for 80 percent of the rural population, agriculture is an essential sector for both economic growth and national food security. However, Afghanistan's agricultural sector has many challenges but the big challenge is water scarcity. In this research analysis clearly shows that rebuilding irrigation canal have good effects on farmer livelihood. Also, analysis shows that due to rebuilding irrigation canal the amount of the agricultural production increased and the level of absolute poverty decreased. In generally the finding of this research show that the rebuilding of this canal had good effects on livelihood of the rural people.

Recommendation

After finding of this research is so necessary a few recommendation:

- For good livelihood and poverty reduction more irrigation canal have to build
- The wastage of water must be prevented.
- Investment should be made in agricultural irrigation.

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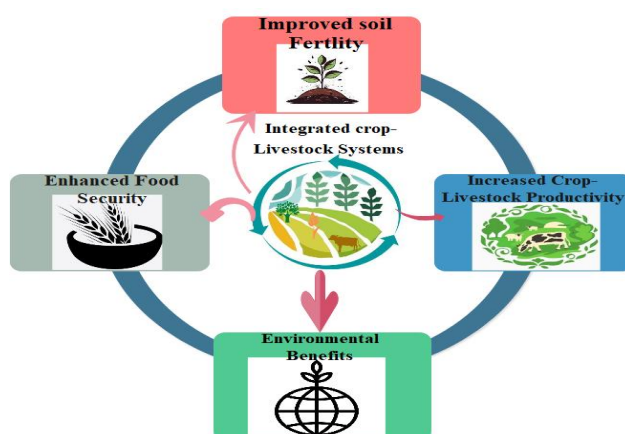


The Contribution of Integrated Crop-Livestock Systems to Enhancing Agricultural Production and Tackling Food Security

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Graphical Abstract

ABSTRACT

Crop–livestock integration represents a productive, sustainable, and climate-smart alternative to conventional agricultural practices. As highlighted in this present study, these integrated systems offer multiple advantages, including enhanced food security, improved social and economic outcomes, and strengthened resilience to environmental stressors. Food insecurity remains a global challenge, with nearly one billion people experiencing protein-energy malnutrition, a burden disproportionately affecting smallholder farmers and landless households in low- and middle-income countries (LMICs). In contrast, intensive monocropping practices often degrade soil structure, reduce fertility, and contribute to long-term environmental harm. Integrated crop–livestock systems (ICLS) provide a viable solution by improving crop yields while enhancing nutritional indicators such as food consumption scores and dietary diversity. These systems thus contribute simultaneously to food security and ecological sustainability. Despite their potential, the widespread adoption of ICLS is hindered by several constraints, including limited capital investment, low consumer awareness, and market competition. Therefore, effective implementation particularly in LMICs requires strong institutional support. Policies that improve access to finance, markets, education, and training are essential. Such support can facilitate the development of necessary skills and foster positive attitudes among producers, ultimately promoting broader adoption of integrated systems.

Keywords— Integrated Crop–Livestock Systems (ICLS); Food Security; Crops; Livestock.

INTRODUCTION

Food security, as defined by the World Health Organization (WHO, 2010), refers to the sustained and adequate access to safe,

nutritious, and sufficient food required for normal physiological functioning. It encompasses four key dimensions: food availability, food accessibility, food utilization, and food stability. However, food availability alone does not guarantee equitable access to essential calories and nutrients, particularly among low-income populations who often struggle to afford high-quality food (Godfray et al., 2010). The global population is projected to reach 9.7 billion by 2050 and 10.9 billion by 2100 (WPP, 2019), raising concerns about meeting future food demand under conditions of climate change and declining natural resources (Lemaire et al., 2015). Nearly 40% of the world's undernourished population comprises smallholder farming communities, while another 10% consists of landless households, many of whom engage in agricultural labor in low- and middle-income countries (LMICs) (Narula, 2022). Smallholders particularly in China and India manage approximately one-third of global agricultural land and produce up to 70% of food calories needed in developing nations (Altieri et al., 2011; Samberg et al., 2016). Yet their productivity remains limited by reliance on traditional practices, restricted use of off-farm inputs, and cultivation of fragmented, low-quality soils (Altieri et al., 2011). In parallel, a global dietary shift over the past five decades from grain-based diets to higher consumption of animal protein has increased livestock production but reduced overall energy efficiency (WHO, 2003; McLeod, 2011). This transition has been accompanied by unsustainable farming practices, soil degradation, pollution, and a severe decline in biodiversity (Jack, 2011; Tilman, 1999). Integrated crop–livestock systems (ICLS) have emerged as a promising strategy for addressing these challenges by combining crop and livestock production within the same agricultural landscape (Hilimire, 2011). These systems enhance overall productivity and strengthen resilience against climate-induced shocks. Hertel et al. (2021) demonstrated that ICLS farms exhibit lower sensitivity to climatic variability compared with specialized monoculture systems, a finding consistent with earlier estimates of up to 75% revenue loss in specialized farms under climate stress (Seo, 2010). ICLS improve resource-use efficiency by recycling outputs across components—for example, using crop residues as livestock feed and applying livestock manure to improve soil fertility (Soussana & Lemaire, 2014; Petersen et al., 2007). Empirical evidence supports their productivity benefits; for instance, corn grain yields under ICLS have reached 11.5 Mg/ha compared with 10.8 Mg/ha in monoculture systems (Maughan et al., 2009). Furthermore, studies by Russelle et al. (2007) and Kumar et al. (2014) indicate that ICLS enhance soil quality by increasing organic matter content, reducing dependence on synthetic fertilizers, and promoting biodiversity conservation. Livestock manure contributes to nutrient cycling and mitigates soil erosion (Bansal et al., 2022), while crop diversification and mixed crop–livestock systems improve pest regulation and support pollinator populations (Bale et al., 2008; Soussana & Lemaire, 2014).

Economic assessments have also shown promising outcomes, with potential gross returns from grazing leases ranging between USD 144 and 481.80 ha⁻¹. Despite these benefits, the adoption of ICLS particularly in LMICs remains limited due to barriers such as inadequate financial investment, limited farmer awareness, and market competition (Petersen et al., 2007; Peyraud et al., 2014). Effective policy interventions should enhance access to credit, strengthen market opportunities, and expand training and extension services to facilitate widespread adoption (Lemaire et al., 2014). At the local level, exchange systems involving crop residues and animal manure can further improve regional productivity and sustainability (Xie et al., 2007). In conclusion, integrated crop–livestock systems are receiving growing scholarly attention for their potential to address food security challenges in developing countries, where stable and sufficient food supplies remain critically needed. However, further research is required to better understand how ICLS can be scaled globally to promote sustainable food production and enhance resilience. By synthesizing previous findings, this review underscores the potential of ICLS in advancing long-term food and nutritional security.

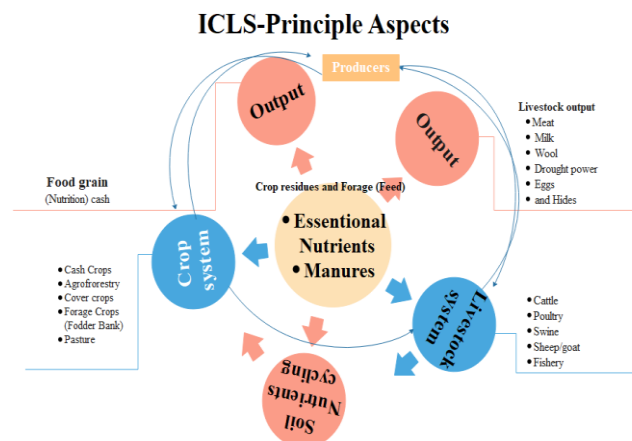


Fig. 1. Principle aspects of the integrated crop-livestock system.

2. METHODOLOGY

This selected study adopts a qualitative research approach to examine the potential and performance of mixed crop–livestock farming systems. A comprehensive literature search was conducted using three major academic databases: Web of Science, Google Scholar, and ScienceDirect. The search strategy was guided by four primary keyword combinations: (1) Advantages and disadvantages of integrated crop–livestock systems and their development, (2) Integrated crop–livestock systems and food security: An analysis, (3) Integrated crop–livestock systems and climate resilience, (4) Strategies for the adoption of integrated crop–livestock systems. The literature search covered publications from 1988 to 2023, with an emphasis on peer-reviewed articles, particularly review papers relevant to integrated crop–livestock research. A rigorous screening process was applied to ensure the relevance and quality of the selected materials. Titles, keywords, and abstracts were carefully assessed to verify alignment with the thematic focus of the review, while studies deemed irrelevant or lacking substantive contribution were excluded. From an initial pool of 130 articles, 112 publications met the inclusion criteria and were retained for thematic categorization.

The distribution of references across major sections of the review is summarized in Table 1 below.

Table 1. Number of references corresponding to each thematic section of the literature.

Screen the literature	Number of references
Integrated crop-livestock system advantages, disadvantages, and development and introduction	40
contributions of I Integrated crop-livestock system towards food security	47
Integrated crop-livestock system and climate resilience	11
Integrated crop-livestock system adoption strategies	14

3. RESULTS AND DISCUSSION

The findings of this review highlight that Integrated Crop Livestock Systems (ICLS) provide substantial agronomic, economic, nutritional, and environmental benefits across diverse farming contexts. By synthesizing results from 112 high-quality studies, the review shows that ICLS significantly enhances soil fertility, crop productivity, livestock nutrition, and household dietary diversity while also strengthening resilience to climate variability. The discussion further reveals that although ICLS offer transformative potential for food security especially in low- and middle-income countries the full adoption of these systems is constrained by structural barriers such as limited market access, financial shortages, and knowledge gaps among smallholder farmers. Overall, the compiled evidence emphasizes that strategically implemented Integrated Crop Livestock Systems can markedly improve food

production efficiency, raise farmers' incomes, and promote long-term ecological sustainability.

3.1.2. Development of Integrated Crop–Livestock Systems: Integrated Crop–Livestock Systems have a long historical trajectory, with evidence of their practice spanning eight to ten millennia (Halstead, 1996). Early agricultural communities incorporated draft animals for plowing and transportation between 6000 and 4000 BC, which significantly enhanced production capacity in regions such as the Middle East and South Asia (Gupta, 2004). In ancient China, integrated farming practices involving crops, trees, livestock, and aquaculture were already well established during the Shang–Western Zhou dynasties (1600–800 BC). Similarly, in Europe, two-year crop rotations incorporating livestock grazing during fallow periods played a pivotal role in agricultural development during the Middle Ages (Lemaire et al., 2014). During the 20th century, rapid technological advancement and the scaling-up of agricultural enterprises led to increased specialization and a decline in ICLS, particularly in high-income countries (De Moraes et al., 2014; Ryschawy et al., 2017). However, in recent decades, renewed interest in ICLS has emerged, driven by growing concerns over climate change, environmental degradation, and the need for sustainable and resilient food production systems. For example, although ICLS occupied less than 10% of agricultural land in the United States during the 1990s (Krall & Schuman, 1996), by 2010, grazing on maize residue was practiced on 12% of total maize land across 19 states, particularly in the western Corn Belt (Schmer et al., 2017). ICLS have also become increasingly important in low- and middle-income countries (LMICs), where they constitute a key component of sustainable farming strategies. In Sub-Saharan Africa, ICLS underpin dryland farming systems and support household food security (Udayakumar et al., 2021; Powell et al., 2004). In Southeast Asia, 75–90% of ruminant livestock production is integrated within crop-based systems (Devendra & Thomas, 2002). Brazil presents another notable example, having doubled its ICLS area over the past decade as part of national efforts to restore degraded pasturelands and increase agricultural efficiency (Hou et al., 2021).

3.2. Contributions of Integrated Crop–Livestock Systems (ICLS) to Food Security

3.2.1. Role of Crop–Livestock Interactions in Sustainable Food Production and Food Security: In marginal and resource-constrained environments, crop–livestock interactions facilitate stable increases in both crop and livestock productivity (Udayakumar et al., 2021; Devendra & Thomas, 2002). At the global level, animal-derived foods currently contribute approximately 13% of caloric intake and 28% of protein consumption, highlighting the crucial role of livestock in human nutrition. Integrated crop–livestock systems account for nearly 50% of global cereal production, and crop residues remain a major feed source for livestock, thereby reducing competition between animal feed and human food resources (De Ron et al., 2017). In agricultural regions across Africa and Asia, smallholder farmers commonly reserve portions of cereal residues for livestock while retaining the remainder as mulch to improve soil health (Andrieu et al., 2015). Livestock also represent a key economic asset for rural households, particularly among impoverished communities. Ownership of livestock enables households to accumulate savings, invest in small businesses, diversify income sources, and thus improve both food availability and dietary quality (Ellis & Freeman, 2004). Consequently, ICLS contribute significantly to food security through enhanced productivity, diversified output, and reduced vulnerability to environmental and economic shocks.

3.1. Integrated Crop–Livestock System: Advantages, Disadvantages, and Development

3.1.1. Advantages and Disadvantages of Integrated Crop–Livestock Systems: In recent years, the agricultural sector has increasingly adopted Integrated Crop Livestock Systems (ICLS) in response to rising food demand, escalating production costs, and intensifying market competition. ICLS synchronize crop and livestock enterprises through temporal and spatial integration, a process described by Franzluebbers (2007), Lemaire et al. (2014), and Russelle et al. (2007) as a functional interface that enhances productivity,

economic efficiency, and environmental sustainability while mitigating agriculture's negative ecological impacts. A range of economic advantages has been identified in the implementation of ICLS. These systems promote enterprise diversification at the farm level, thereby increasing net farm income and reducing economic risks associated with market volatility. For example, a study conducted in India reported that ICLS improved annual net farm profit by USD 660 compared to monoculture systems (Ponnusamy & Devi, 2017). Furthermore, ICLS reduce the dependence on chemical inputs such as inorganic fertilizers and pesticides; incorporating sheep into vineyards, for example, reduced chemical control costs by USD 64 per hectare (Niles et al., 2017). Beyond economic gains, ICLS significantly contribute to food and nutrition security by enhancing the availability of grains, animal protein, and diverse agricultural products, particularly among smallholder farmers in low- and middle-income nations. Environmental benefits represent another major strength of ICLS. These systems enhance soil health by improving soil organic carbon, soil microbial biomass, and overall ecosystem function. For instance, microbial biomass increased from 124 mg kg⁻¹ in continuous cotton systems to 237 mg kg⁻¹ in ICLS, while soil organic carbon increased from 9.0 g kg⁻¹ to 13.5 g kg⁻¹ (Acosta-Martínez & Zobeck, 2004). Well-managed ICLS also reduce greenhouse gas emissions and support biodiversity conservation (Soussana & Lemaire, 2014; Russelle et al., 2007; Hilimire, 2011). In addition, these systems create rural employment, stimulate local economies, and offer supplementary income opportunities for smallholders (Udayakumar et al., 2021). Despite these advantages, ICLS are associated with several challenges. These systems are inherently complex, requiring substantial technical knowledge of both crop and livestock management as well as continuous monitoring of animal health and pasture conditions (Peterson et al., 2020). Grazing on wet soils can result in severe soil compaction, which negatively affects crop performance; prolonged or intensive grazing exacerbates this issue (Niu & Zhu, 2019). Resource-use trade-offs also present constraints, particularly when crop residues must serve multiple purposes such as livestock feed, soil mulch, or household fuel making it difficult to optimize all functions simultaneously (Erenstein, 2002; Erenstein et al., 2011; Andrieu et al., 2015). In rangeland systems, continuous grazing may encourage the proliferation of unproductive plant species, reducing nutrient availability for subsequent cropping (Rufino et al., 2006). Additional constraints include limited fodder availability due to land and water scarcity (Notenbaert et al., 2013), uneven nutrient distribution caused by localized manure deposition, and high initial investment requirements for infrastructure, equipment, and skilled labor. Inefficient nutrient recycling may also lead to nutrient losses, further reducing system performance. Overall, ICLS offer a promising pathway for enhancing agricultural productivity, environmental health, and livelihood outcomes. However, their success depends heavily on context-specific management strategies, regional agroecological conditions, and the ability of farmers to address the system's inherent challenges.

3.2.2. Diversity of Crops in ICLS and Its Contribution to Food Security and Human Health: Crop diversification is a fundamental feature of Integrated Crop–Livestock Systems, contributing to agricultural development, improved food production, and enhanced nutritional quality. The inclusion of cover crops and nitrogen-fixing legumes increases plant protein availability, benefiting both livestock and human nutrition (Adewole et al., 2020; Romeo et al., 2016; Wilkins, 2008). In Brazil, for example, ICLS involving overlapping soybean/maize cultivation during summer followed by winter grazing have demonstrated substantial improvements in productivity and food security outcomes (De Moraes et al., 2014). Similarly, integrating grasses and legumes within dairy and poultry systems has been shown to double yields compared with single-crop systems (Gill & Singh, 2009). Given the widespread adoption of diversified ICLS in low- and middle-income countries (LMICs), these systems substantially enhance food security while reducing production risks for smallholder farmers.

A cross-sectional study in Malawi, for instance, found that children in households practicing legume intercropping showed improved anthropometric status, with significantly better weight-for-age Z-scores compared to control groups (Kerr et al., 2010). Inter-species diversity within ICLS tends to generate greater nutritional benefits than diversity within a single species (Romeo et al., 2016). Dietary diversity is also substantially improved in households practicing ICLS. Romeo (2016) reported that such households exhibited high consumption rates of nutrient-rich food groups—100% consumed cereals and vegetables, 91% consumed fish, 78% pulses, 62% fruits, 65% milk, 41% meat, and 32% eggs. These systems not only promote healthier diets but also increase resilience to climate variability and market instability. Jones and Shrinivas (2014) further demonstrated that including livestock within cropping systems is positively associated with dietary diversity. However, Wright and Tarawali (2012) emphasized that market access and off-farm income often exert even greater influences on dietary quality than on-farm production diversity. Supporting this, Sibhatu et al. (2015) found that each additional crop or livestock species increased household dietary diversity by 0.9%, although households in remote areas continued to experience lower dietary diversity due to limited market access. Off-farm earnings therefore provide a critical mechanism for smallholders to purchase diversified foods and improve nutritional intake.

3.2.3. Role of Livestock in Food and Nutrition Security within ICLS: Livestock form a vital component of Integrated Crop Livestock Systems, principally through the provision of animal-sourced foods (ASFs), including milk, meat, and eggs (Gupta et al., 2012; Udo, 2002). ASFs are indispensable for meeting human protein needs (Fischer, 2009; Mann et al., 2023) and supply high-quality proteins as well as essential amino acids such as lysine, methionine, and threonine which are often limited in plant-based diets (Mariotti & Gardner, 2019; Allen, 2005). Moreover, ASFs provide highly bioavailable micronutrients, including iron, vitamin A, vitamin B12, and calcium, all of which support healthy immune function and physiological development (Allen, 2005). Even modest amounts of ASF in the diet significantly improve nutritional adequacy and reduce the risk of undernutrition (Sekaran et al., 2021; Neumann et al., 2002). Regular consumption of ASF is associated with enhanced child growth and cognitive development, improved pregnancy outcomes, and reduced morbidity (Neumann et al., 2002).

Investment in livestock within Integrated Crop Livestock Systems particularly small ruminants such as goats and sheep has been shown to substantially enhance household food and nutrition security (Romeo & Meerman, 2016).

In Asia, Integrated Crop Livestock Systems contribute most of the region's food grain, milk, and meat supply, while accounting for 40–60% of cattle, sheep, goat, and poultry meat production in sub-Saharan Africa (Herrero et al., 2012). Evidence from Udo and Aklilu (2011) showed that integrating dairy cattle into smallholder Integrated Crop Livestock Systems generated the highest economic returns (USD 400–1030 per year), surpassing returns from poultry (USD 70) and small ruminants (USD 120–165). The substantial market demand for milk was identified as a driving factor behind the profitability of dairy-based Integrated Crop Livestock Systems.

3.2.4. Social and Economic Benefits of ICLS and Their Role in Food Security: Integrated Crop Livestock Systems generate multiple social and economic benefits that collectively contribute to enhanced food security. Empirical evidence consistently demonstrates that Integrated Crop Livestock Systems are more profitable than specialized or monoculture farming systems. For example, in North Dakota, labor income increased by 46.8% in integrated crop–cattle systems compared with monoculture cropping (Anderson & Schatz, 2003). Likewise, cattle cotton ICLS in Texas yielded USD 362.17 ha⁻¹, significantly higher than the USD 190.91 ha⁻¹ generated under monoculture cotton farming, largely due to reduced water and fertilizer requirements (Allen et al., 2005). ICLS also support income stability in LMICs by enabling production of small ruminants that cater to both domestic and export markets. In Sudan, for instance, sheep integrated within cropping systems provide critical

financial resources for crop production and household needs (Amankwah et al., 2012).

Additionally, ICLS contribute to gender empowerment. Evidence suggests that women are more likely to receive income from integrated farming enterprises and allocate it toward improving household diets and food security (Smith, 2013; Njuki & Miller, 2013). Compared with specialized farming households, ICLS households obtain a greater share of their food from home production. Approximately 68% of food consumed in ICLS households is home-produced, compared with 33% in specialized farming households (Tipraqsa & Craswell, 2007). This high level of self-provisioning ensures access to safe, nutritious food and reduces vulnerability to market fluctuations. The diversification inherent in ICLS also enhances resource efficiency, boosts productivity, and provides a buffer against crop failure and unstable market conditions (Thornton & Herrero, 2015). Furthermore, income generated through ICLS enables farmers to purchase diverse and high-quality foods, thereby improving dietary diversity (Jones et al., 2013). In this way, the socio-economic benefits of ICLS translate directly into improved food and nutrition security at the household level.

3.3. Integrated Crop–Livestock Systems and Climate Resilience

Food security under climate stress refers to the capacity of agricultural systems to produce sufficient and high-quality food despite exposure to both short- and long-term environmental hazards (Bullock & Dhanjal-Adams, 2017). Climate projections indicate that arid and semi-arid regions will experience rising temperatures, more frequent and severe droughts, and increasing water deficits conditions that critically reduce crop yields, alter crop development cycles, and diminish the extent of cultivable land (Allen et al., 2007; Durrell, 2018; Stocker et al., 2014). For example, an increase of 4°C in temperature is projected to shorten growing seasons in dry regions by up to 20%, exacerbating poverty, food insecurity, and dependence on imported food supplies (Durrell, 2018). In this context, sustainable Integrated Crop–Livestock Systems, particularly in low- and middle-income countries, offer viable adaptive strategies to mitigate the adverse impacts of progressive climate variability on both crops and livestock. These systems aim to optimize natural resource use such as soil nutrients, water, and biomass to enhance food stability and overall resilience (Durrell, 2018; Smith & Olesen, 2010). Climate change also threatens livestock productivity through declining rangeland quality, increased disease prevalence, and intensifying competition for land and water resources. Nevertheless, Integrated Crop Livestock Systems can help buffer these challenges by improving crop productivity, enhancing nutrient recycling, reducing economic vulnerability, and broadening livelihood opportunities (Duru & Therond, 2014; Godber & Wall, 2014).

Projections suggest that the adoption of integrated systems will increase significantly by 2060, especially across Africa, highlighting the urgent need for investment in ICLS technologies to safeguard future food security (Seo, 2010). Moreover, diversification across multiple crop species and livestock types enhances system stability compared with specialized crop- or livestock-only production models (Rao et al., 2015; Bullock et al., 2017). This diversification offers greater versatility and builds resilience against climate extremes. Strengthening the effectiveness of Integrated Crop Livestock Systems also requires enhancing knowledge exchange, fostering farmer-to-farmer learning, and strengthening social capital. Building strong farmer organizations and promoting collaborative innovation are essential for increasing climate resilience at farm, community, and global levels (Bullock et al., 2017; Carlisle, 2014).

3.4. Integrated Crop–Livestock System Adoption Strategies

Integrated Crop–Livestock Systems offer substantial benefits for enhancing global food security by promoting diversified, resource-efficient, and climate-resilient agricultural production (Carlisle, 2014; Sulc & Franzluebbers, 2014). Despite these advantages, the widespread adoption of Integrated Crop Livestock Systems is constrained by several factors,

including limited resources, poor market access, inadequate infrastructure, and knowledge gaps among producers. Therefore, effective strategies are required to facilitate adoption and ensure that smallholder and commercial farmers alike can fully realize the potential of integrated agricultural systems.

3.4.1. Adoption Strategies for Smallholders in Low- and Middle-Income Countries:

Smallholder farmers in low- and middle-income countries (LMICs) increasingly utilize ICLS to maximize productivity from limited land, livestock, and labor resources, thereby improving household livelihoods (Abegaz et al., 2007). However, several obstacles hinder widespread adoption:

Resource competition: Competition between crops and livestock particularly for land, crop residues, and biomass can limit grain production. Adopting pasture-cropping systems and improved fodder production can alleviate resource constraints and enhance system efficiency (Thornton et al., 2018).

System complexity: Effective Integrated Crop Livestock Systems require coordinated management of crops, livestock, and natural resources. Without appropriate management practices, farmers may struggle to achieve optimal yields or maintain ecological balance (Ewing & Flugge, 2004).

Market access and land-use constraints: Intensifying land-use pressure, declining grazing areas, and shrinking farm sizes pose major challenges for smallholders attempting to meet rising demand for livestock products (Godfray et al., 2010; Udo et al., 2011).

Technological limitations: Limited access to improved seeds, high-yielding forage varieties, and livestock breeds restricts the adoption of innovative Integrated Crop Livestock Systems practices (Azadi et al., 2016).

To overcome these barriers, coordinated policy support and targeted interventions are essential. Recommended strategies include:

Capital support: Provision of microfinance, low-interest loans, grants, and input subsidies to enable smallholders to invest in integrated systems.

Investment in research and extension: Strengthening agricultural research, innovation, and farmer-oriented extension services to build capacity in Integrated Crop Livestock Systems management.

Improved market access: Developing local and regional markets, value chains, and processing facilities to support smallholder production.

Public awareness and education: Enhancing farmer and consumer understanding of the sustainability and nutritional benefits of integrated systems.

Risk management tools: Expanding access to crop and livestock insurance to reduce vulnerability to climate, disease, and market shocks (Udo et al., 2011).

Overall, successful adoption of Integrated Crop Livestock Systems in LMICs requires improved agronomic practices, efficient manure management, and sustainable resource use to enhance productivity on limited land while minimizing environmental impacts.

3.4.2. Adoption Strategies in High-Income Countries:

In high-income countries, several structural and economic challenges inhibit the adoption of Integrated Crop Livestock Systems:

High initial investment costs: Integrated systems often require greater capital inputs than specialized crop or livestock operations, discouraging adoption among risk-averse producers (Krall & Schuman, 1996).

Infrastructure and management requirements: Integrated Crop Livestock Systems necessitate efficient supply chains, advanced management skills, and broader knowledge of crop-livestock interactions, which many producers lack (Russelle et al., 2007; Sulc & Franzluebbers, 2014).

Traditional and specialized practices: Long-standing specialization in either crop or livestock farming limits the willingness of producers to modify existing practices, particularly when familiarity with integrated models is low (Dunlap et al., 2000; Krall & Schuman, 1996).

Consumer preferences and market pressures: Demand for inexpensive, standardized food products encourages highly specialized and industrialized production systems, reducing incentives for adopting long-term sustainable practices such as Integrated Crop Livestock Systems (Ambikapathi et al., 2022; Dunlap et al., 2016).

To promote greater adoption in high-income regions, the following strategies are recommended:

Financial incentives: Government-backed loans, subsidies, and tax incentives can offset high start-up and transition costs associated with integrated systems.

Training and educational programs: Outreach, extension services, and demonstration farms can help producers acquire the skills and knowledge needed to manage complex integrated systems effectively.

Research and demonstration initiatives: Collaborative research, on-farm trials, and farmer-led demonstrations can validate the environmental and economic benefits of Integrated Crop Livestock Systems, thereby increasing farmer confidence and willingness to adopt.

4. Conclusion

The adoption of Integrated Crop–Livestock Systems holds substantial potential to enhance income generation and diversify food sources, particularly for farmers in low- and middle-income countries. By integrating crop and livestock enterprises, these systems can improve household dietary quality, increase smallholder incomes, and reduce economic vulnerability, while simultaneously delivering a range of socio-economic and environmental benefits. Effective implementation, however, requires a comprehensive understanding of both crop and livestock management components. Notably, women's participation in Integrated Crop Livestock Systems has been shown to increase household income and strengthen purchasing capacity for nutritious foods. Given the limited opportunities for agricultural land expansion among most smallholders, on-farm integration represents a practical and sustainable strategy for improving food security. Moreover, Integrated Crop Livestock Systems contribute to broader social and cultural benefits by fostering resilience, strengthening community resource use, and enhancing local self-sufficiency. To support wider adoption, government policies should prioritize capital investment, infrastructure development, and on-farm demonstration programs, particularly targeting small and marginal farmers. Additional efforts should emphasize the integration of small ruminants, protein-rich crops, fruits, and vegetables to maximize nutritional and economic gains within these systems.

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