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Ensuring quality and safety in the production and storage of grain crops

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ABSTRACT

Grains are one of the countries' strategic products and the primary protein supply source in society. This study describes the qualitative and safety aspects of grains. Grain storage and preservation is a complex and active process, because after harvesting, grains can also perform all apparent vital functions, such as respiration, metabolism, and growth, as a living organism, and are subject to chemical and biological changes such as reduced strength, increased acidity, gluten weakening, enzymatic decomposition, loss of nutrients and apparent changes such as breakage and perforation and germination. On the other hand, losses due to grain handling, losses due to natural drying and moisture loss of grains, and losses related to the activity of microorganisms or the activity of storage pests are among the factors that will lead to a quantitative and qualitative loss of grains during storage. This study evaluated the standard for harvesting and preserving grains in Kazakhstan, and its qualitative classification has been carried out. The results show that moisture content, harvesting, packaging, and aeration are among the main factors in grain safety. In general, the main goal during storage and warehousing is to maintain the quantity and quality of grains so that the main properties of the grain are preserved during storage, and its change is prevented. Therefore, it is necessary to control moisture, temperature, contamination by storage pests, and the internal activity of grains, which are living structures.

Keywords: Grains, Food safety, Quality, Storage.
Article type: Short Communication.

INTRODUCTION

Grain crops are plants of the family of grains that are cultivated in different parts of the world for grain production. Grains are rich in starch and are used for human, livestock, and poultry nutrition. This research aims to provide a standard for grain testing to determine characteristics, grading, sampling, and test methods. Since ancient times, the people of Iran, Greece, and Egypt have used earthenware jars to store their grains, and they usually planted these jars in the ground or stacked them together in brick and mud rooms (Kumar & Kalita 2017). Over time, by the increase in population and production and consumption, grain rooms (granaries) became common. Since the beginning of the last century, due to the advances that humanity had in the fields of roads, construction, and engineering, advanced construction techniques have been used to build tall silos. Grains are the most important crop on earth. It is known that every day, it is planted in one place on the planet and harvested in another place on the same day. This indicates the plant's great ability to adapt to various climates. Globally, nearly 52% of the world's arable land is dedicated to growing grains (Mandal *et al.* 2024). Food production has played a key role in maintaining the country's independence in recent years, and global research is directed towards finding new food sources, increasing yield per unit area, and maximizing the use of existing agricultural potential (Tushar *et al.* 2023). By population growth, food shortages and the need for them are becoming more apparent worldwide. On

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the other hand, in most regions of the world, water limitations are much greater than soil limitations for agricultural production. Therefore, maximum use of water per unit volume should be made, and research should be conducted to produce as many crops as possible. In addition, the necessary planning was made. In central Asia, about 7.5 million hectares of arable and garden lands are cultivated in irrigated and semi-irrigated ways. In the last few decades, about 50% of irrigated agricultural lands have been allocated to irrigated grain cultivation. Unfortunately, water use efficiency in this sector is still unsatisfactory. Some estimates report irrigation efficiency of 15 to 25%, and given the amount of rainfall and the limitations of the country's water resources, it is necessary to address this issue (Zhao *et al.* 2023; Yousefi-Behzadi *et al.* 2023). Planting grains on wide ridges with less water consumption, considered an irrigation deficiency, is a solution to achieve this goal. Much research has been conducted on this subject, and various results have been obtained. Manandhar *et al.* (2018) observed in soils with a clayey loam texture that in the aeration method and ridges, soil specific gravity, permeability, and ultimately soil structure improved, and grain yield increased by 18% compared to flat cultivation. Tefera *et al.* (2011) observed in an experiment in saline soils with low water consumption and low quality with fertilizer treatments (nitrogen, zinc, copper) and various soil amendment methods that the highest grain yield was achieved with the creation of ridges and that the increase in yield was more affected by the cultivation method than by using fertilizers. Their results also showed that the amount of moisture and aeration should be among the main factors for grain storage. Hamel *et al.* (2020) examined the effects of irrigation depth and frequency in three managements: full irrigation, deficit irrigation in all growth stages, and a combination of the two in the vegetative and reproductive growth stages, on the yield as well as the water use efficiency of grains and barley. The results showed that shortening the irrigation frequency caused an increase in grain straw. Okparavero *et al.* (2024) concluded by examining the effect of irrigation on durum grains that short-frequency irrigation, especially in the final stages of growth, reduces the percentage of grain protein. In their study of grain production, Zhexenbay *et al.* (2020) concluded that grain protein content decreases at high yields. This study is a step towards determining the optimal water efficiency in grain production by comparing different planting methods and also determining the appropriate time for re-irrigation based on the percentage of usable water depletion in the soil. Grains and their products provide an important part of the household food needs. Due to the importance and stability of the share of consumption of this commodity in the household consumption basket, this commodity has had a positive impact on the indicators and variables of the economies of countries. The chart below shows the global production and consumption of grains in the last decade. In 2018, 2020, and 2024, the production rate was slightly lower than the utilization rate. The production rate was higher than the utilization rate between 2021 and 2023. The grain reserves were higher than the utilization and production rate between 2014 and 2018. Under the same conditions, the responsibility of governments to provide food to the people of the society was more difficult in 2016 than in 2020. Therefore, the packaging of grains has also gained special importance, and, as shown in Figs. 1-2. it is a growing trend worldwide.

Factors affecting grain quality during storage and handling

• **Humidity:** Excessive humidity can promote the growth of fungi, bacteria, and insects, reducing the quality and nutritional value of grains.
• **Temperature:** High temperatures can increase enzyme activity and accelerate spoilage.
• **Pests:** Insects and rodents can damage and contaminate grains.
• **Microbial contamination:** Bacteria, fungi, and yeasts can cause spoilage and produce toxins in grains.
• **Physical contamination:** Impurities such as rocks, soil, and foreign objects can damage equipment and reduce product quality.

Proper grain storage and handling techniques

Cleaning and disinfecting the warehouse: The warehouse should be thoroughly cleaned and disinfected before storing the grain to prevent contamination.
Drying the grain: The moisture content of the grain should be minimized to prevent the growth of microorganisms. Natural or artificial methods can be used for drying.
Proper ventilation: The warehouse should have a proper ventilation system to remove excess moisture and harmful gases.
Temperature control: The temperature of the warehouse should be continuously controlled to prevent temperature rise and grain spoilage.

Preventing pest penetration: The warehouse should be designed to prevent insects and rodents from entering it. Fine mesh and insect repellents can also be effective.
Regular inspection: Stored grains should be inspected regularly to detect any contamination or changes in their quality.
Proper handling: When handling grains, proper equipment should be used to prevent grain breakage and dust generation.
Proper packaging: Grains should be stored in proper and hygienic packaging to prevent contamination.

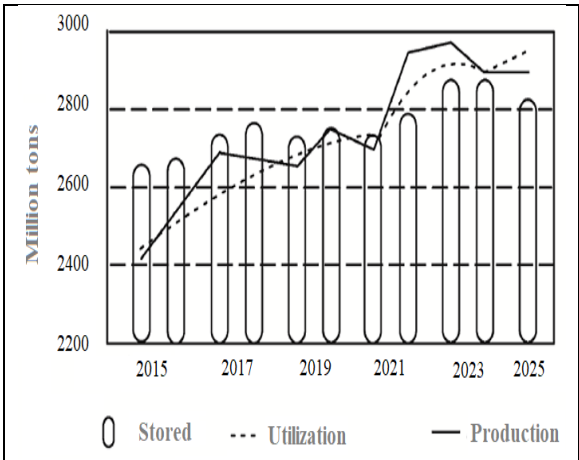

Fig. 1. Trends in grain storage levels worldwide.

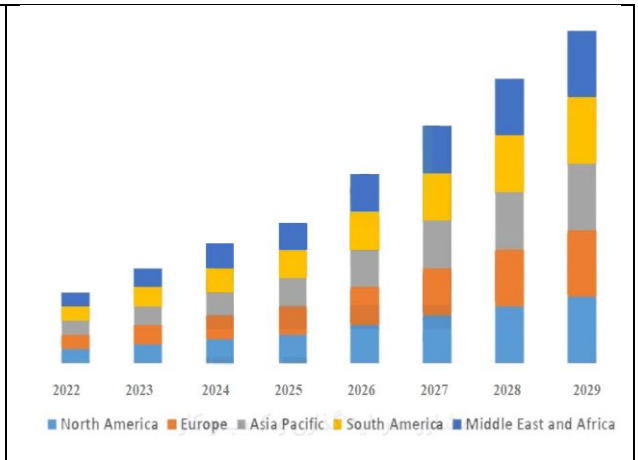

Fig. 2. Grain production, utilization and storage levels.

Equipment used in grain storage and handling
• **Silos**: For storing large volumes of grain under controlled conditions
• **Conveyors**: For transporting grain from one point to another
• **Mills**: For crushing and preparing grain for processing
• **Screens**: For separating impurities and broken grains
• **Dryers**: For reducing grain moisture

Safety considerations in storing and handling grains
• **Fire hazards**: Grains are flammable, especially in hot and dry conditions. Therefore, safety precautions must be taken to prevent fires.
• **Health hazards**: Contact with contaminated grains can cause various diseases. Therefore, workers must use appropriate protective equipment.
• **Physical hazards**: Handling grains can pose hazards such as falling objects, getting caught in equipment, and musculoskeletal injuries.

MATERIALS AND METHODS

This experiment was conducted during the 2022-2023 crop year at Research Farm No. 1 of the Kazakhstan Agriculture and Plant Breeding Group. This farm is located in northeastern Uzbekistan at 50 degrees and 41 minutes east longitude and 31 degrees and 19 minutes north latitude, at an altitude of 45 meters above sea level. Before planting and adding fertilizer to the soil of the test plot, sampling was carried out from 6 points of this plot at a depth of 0-30 cm. After mixing the samples, the resulting composite sample was analyzed. The soil of the test farm had a sandy loam texture, the chemical and physical characteristics given in Table 2. Various grains, including barley, corn, rice, millet, oats, rye (black grain), and flour, can be kept healthy for a long time if appropriately stored in various silos, warehouses, and halls equipped with temperature and humidity regulating devices, which are called air conditioning devices or heating and cooling facilities. The better and more accurately these parameters are applied, the longer the freshness and aroma of the product will last. For instance, suppose there is a proper ventilation system in a warehouse or rice silo, and the temperature and humidity of the grain can be kept constant within the defined limits. In that case, rice can be kept healthy for years with the same aroma as the first days. By installing a proper ventilation system, chemical preservatives can be eliminated. Today, with

stricter laws, produce should not be stored exposed to chemicals and pesticides. Today, these strict laws and the high cost of chemicals are the main factors that make storing produce with chemicals unattractive.

Table 1. Chemical and physical characteristics of the grain growing area.

Potassium (mg kg^{-1})	Phosphorus (mg kg^{-1})	Nitrogen (%)	Organic matter	Acidity	Electrical conductivity
181	10.52	0.057	0.52	7.5	3.2

When the temperature and humidity of the air circulating in the silo or storage hall are high, the properties and viability of the grain are lost, and suitable conditions are provided for the growth of various types of fungi, molds, and insects, and the product quickly spoils. The product must be stored in a calm environment immediately after harvest. At temperatures below 15 ℃, insects can no longer be active, and the grain can be stored for a long time without damage. Also, toxic contaminants (mycotoxins) caused by mold activity can be combated at such temperatures. In addition, cooling slows down cellular respiration, reduces the grain's internal temperature, and prevents the spread of insects, microbes, and molds. As the air temperature decreases, the heat produced by the grain (due to cellular respiration, which produces heat) also drops. Thus, it will not be suitable for growing insects, molds, etc.

If the grain is dried correctly and prepared for storage in warehouses and silos, one of the following factors usually causes problems during the storage period of the product:

1. Failure to keep the grain cool in the warehouse or silo
2. Poor initial grain quality
3. Inadequate inspection of stored grain and improper insect control

Safe storage of grains such as grains, rice, barley, corn, and flour in terms of temperature and humidity

The purpose of drying grains properly is to ensure that the moisture content of the grains does not exceed a specific limit in order to maximize the shelf life of the product in the warehouse or silo. The maximum amount of moisture (in percent) that must be present in different grains depends on the type of grain and its storage period, the most important of which are:

1. Storing shelled corn for 6 to 12 months: The maximum moisture content in shelled corn should be 14%.
2. Storing shelled corn for more than 1 year: The maximum moisture content in shelled corn should be 13%.
3. Storing grains, barley, and oats for up to 6 months: The maximum moisture content in these should be 14%.
4. Storing grains, barley, and oats for more than 6 months: The maximum moisture content in these should be 13%.

Note that if the harvested crop is of poor quality due to drought, frost, burns, or damage during harvesting, the moisture content should be reduced by 1%. For instance, grain of poor quality that will be stored for more than 6 months should have a maximum moisture content of 12%.

RESULTS

Types of grain storage centers

Currently, concrete silos, metal silos, and mechanized warehouses are used in the world for the optimal storage of grains.

A- **Concrete silos**: One of the best methods of storing grains is to use concrete silos. Concrete silos consist of one or many cylindrical or polygonal tanks, which are called hives. The hives can be placed in different shapes, separately or in groups next to each other. Concrete silos have different types. One type of concrete silo is prefabricated silos. If the grain moisture content is more than 13% and the storage time is only a few days, silos or hives should not be used to store grains because in such conditions, self-heating occurs, and the grain quickly spoils.

B- **Metal silos**: In recent years, using metal silos for grain storage and preservation has become common. In our country, these types of silos are used to preserve grains and other grains such as barley, corn, and livestock and poultry feed. The body of metal silos is made of galvanized steel or aluminum alloys. To prevent corrosion of the inner and outer walls of metal silos, anti-rust should be used regularly and regularly. In metal silos, heat exchange occurs rapidly, and there is a possibility of brain damage, especially in hot regions where the temperature reaches more than 11 ℃, and mainly the grains that are in contact with the body will be damaged to a depth of about 1-7 cm.

C- **Mechanized warehouses**: In semi-mechanized warehouses, loaders, special jacks, or similar devices unload. In other words, unloading is not done in such warehouses based on gravity. In fully mechanized warehouses, unloading is done according to the unique slope of the warehouse floor using air pressure or special conveyors that transport the cargo across the warehouse. Such warehouses have a ventilation and temperature control system and can be easily disinfected. Silos and mechanized warehouses generally consist of two parts: The working tower, where the machinery and tools are located; The hives, where the grains or seeds are stored. Equipment required in silos or mechanized warehouses are as follows:

- Equipment required to unload incoming grains (this equipment and devices can include pneumatic suction, mechanical shovels or hydraulic jacks, and input bunkers);
- Conveyors or carriers and bucket elevators and special pipes for unloading grains;
- Screening equipment, including primary and secondary screens or screening such as dust collection systems (aspirators), separators, magnets, and linear scales;
- Tableting and disinfection devices as well as a special disinfection room;
- Ventilation and aeration system;
- Temperature control system and warning devices;
- Tanks or bunkers for extracted materials.

Warehousing features

Grains are plants of the grain family cultivated in different parts of the world for grain production. They are rich in starch and are used for human, livestock, and poultry nutrition. This article presents, based on experimental research, grading, sampling, and testing methods for grains. This standard applies to common grains, including domestic and imported production.

1. Moisture: Grain moisture should not exceed 14%.
2. Live pests: Grains should not contain any live pests.
3. Pesticide residues: The level of pesticide residues in grains should be by the Standard of Pesticides - Maximum pesticide residue limit - Grains. Pesticide residues are any specific substances in food, agricultural products, and animal feed that result from pesticide use. This substance also includes any derivatives of a pesticide, such as any transformed products, substances resulting from the decomposition of pesticides, and impurities that have toxic properties.
4. Fungicides: The standard "Food for humans—Livestock—Maximum tolerance of mycotoxins" should set the maximum limit of fungal toxins.
5. Staleness: The staleness of grains should not exceed 2% by weight. Stale grains have been nourished by the bite of a stale insect, and their visible effects are a black spot on the grain with a light halo that can also be accompanied by grain shrinkage. The staleness of imported grains should be zero.
6. Alpha-amylase activity: The minimum Falling number (alpha-amylase activity) should be at least 200 seconds. The Falling number is a criterion for determining the activity of the alpha-amylase enzyme, which is measured by a Falling number device and shown in seconds.
7. Heavy metals: The maximum heavy metals should be within the National Standard, “Human and Animal Food—Maximum Tolerance of Heavy Metals.”

The microbiological characteristics of various grains and legumes supplied in bulk or packaged form must comply with Table 3.

CONCLUSION

Although the type of grain variety and its inherent characteristics are fundamental components in the quality of grains since the grain is alive and respires during storage, the set of enzymatic reactions during the respiration process that lead to the decomposition of starch, glucose, and protein and fat of the grain affects its quality, on the other hand, many factors, especially insects, molds and moisture, threaten the durability and quality of grains during storage. Therefore, adequate and standard storage is considered a serious and important component in maintaining the quality of grains. Storing grains from the harvest season for other seasons began in the Neolithic era with grains donated by people to temples. This practice was first practiced in Mesopotamia with simple and primitive methods and evolved over time. Storage has been done in the past to use grains in inappropriate seasons or famine and war. The amount of damage during storage throughout the year indicates the importance of identifying suitable storage locations, optimal storage conditions, and ways to combat storage threats. Proper storage and handling of grains is one of the most important steps in the food supply chain. By observing the correct

principles and techniques, the quality and safety of grains can be ensured, and the waste of resources can be prevented.

Table 2. Grain characteristics in terms of quality.

Grade Characteristics	Minimum Volumetric Weight	Other Grains	Broken	Sprouted	Discolored	Insect-Infested	Permitted History	Pest
Grade 1	81	2	3	0.9	1	0.1	5	
Grade 2	79	4	5	2	2	0.2	10	
Grade 3	74	6	7	3	3	0.4	14	
Grade 4	62	10	12	6	7	1	20	

Table 3. Microbial tests of grains in three stages of production, storage and packaging.

Feature	Harvested grains (CFU g^{-1})	Stored grains (CFU g^{-1})	Packaged grains (CFU g^{-1})
Total microorganism count	10^6	10^5	10^4
Regenerative Clostridium spores	100	80	60
Bacillus cereus	100	60	50
Mold	10^4	10^3	10^2

The limited food supply resources by humans have made it necessary to use these resources optimally by improving the quality and safety of manufactured products. Therefore, all producers and distributors must comply with the necessary standards before implementing any process. This article presents the necessary standards for producing, storing, and transporting grains, from production to environmental conditions.

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