Studying wheat grain conservation in different types of granaries

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Abstract. The main task of grain storage is to preserve it without loss in mass or with minimal losses, without deterioration in quality, reduce labor costs and expenses per unit of production with the best preservation of indicators. This research paper provides a comparative analysis of two methods of storing wheat grain for food purposes to identify the optimal and most rational method from both process and economic points of view. Two consignments of grain, of the same quality, were placed for storage in an elevator silo and an ordinary grain warehouse. During the storage period, the temperature measurements were carried out in accordance with the recommendations of the regulatory documents. The quality of the stored products was assessed according to the main technological indicators. The economic efficiency of grain masses storage was calculated in different ways. According to the results of the research, the advantages and disadvantages of each of the storage methods have been established.

1. Introduction

Nowadays, wheat is one of the most important agricultural crops not only in Russia, but also in Kazakhstan. Ensuring the food security of countries and one of the main items of export income, grain production constantly requires some research in the direction of the increase in process capacity. The essential components in this direction are post-harvest processing technologies aimed at bringing grain into a stable state for storage in the shortest possible time with minimal costs \cite{1, 2}.

Grain and its processed products serve as strategic raw materials and are used all over the world for food, fodder, food-processing and technical purposes in more than 15 industries. The results of the development of social production as a whole depend on the quality of grain products, the conditions for their production and storage.

Grain storage is the final stage in the process of its production and is of tremendous importance in obtaining high quality processed products. Enterprises that receive, store and process grain raw materials rightly occupy a special place in the structure of the agro-industrial complex, many of them store stocks of the state grain fund, which determines their strategic importance \cite{3}.

According to expert estimates, the annual loss of grain in industrially developed countries is about 5-10\%, in Russia it is 10-15\%. According to the data from the same author, 1\% of grain losses occurred during transportation, and 74\% in post-harvest processing and storage \cite{4}.
Post-harvest losses are direct physical and quality losses that reduce the economic efficiency of production or lead to the fact that grain products cannot be used for their intended purpose, which necessitates its disposal [5].

In this regard, the main task of storing grain is to preserve it without loss in mass or with minimal losses, without deterioration in quality, reducing labor costs and expenses per unit of production with the best preservation of indicators.

The complexity of organizing the storage of large volumes of grain masses is associated with the creation of the necessary conditions to ensure the safety of the physiological and physicochemical properties of raw materials. The conditions for the consumption of grain storage services are the availability of a storage place (granaries) and the creation of conditions for the preservation of the quantity and quality of grain placed in them (the provision of processing services).

Grain storage facilities in the agro-industrial complex are elevators, in which storage is usually accompanied by depersonalization of grain masses (batches of products from different manufacturers are combined into a common mass).

Grain storage is an important technological process, the quality of which determines the preservation of consumer properties of products for a sufficiently long period of time. If storage is the first link in the technological chain of processing the received grain, then flour-grinding and bakery enterprises are already the next links. Each subsequent link works on the raw materials that were produced at the previous stage, and, accordingly, the quality of the subsequent and final product as a whole depends, first of all, on the quality of the grain supplied for grinding and baking. This quality should be ensured precisely at the stage of storage of grain products (if we do not take into account the cultivation process, which the farmers are responsible for) [6, 7, 8, 9].

Many parameters have a significant effect on the safety of grain, for example, the temperature and humidity of the air surrounding the grain mass and inside it. The intensity of grain storage processes is influenced not only by its humidity and temperature, but also by the composition of the air in the intergranular space, the temperature and relative humidity of the ambient air, the thermal diffusivity and moisture permeability of the walls and roof of granaries (warehouses, elevator silos), which primarily lead to a change in grain quality. The high temperature and humidity are a favorable environment for the development of bacteria, fungi, molds, insects and other negative processes that reduce the storage resistance of grain and lead to loss of weight and quality [10].

A decrease in the quality characteristics of grain and a loss in product mass ultimately results in a decrease in the quality and price of finished products. It is possible to reduce these costs without resorting to significant financial investments by organizing and maintaining the proper level of storage of cereals and legumes using the methods of modern logistics [11].

2. Results and discussion

To identify the optimal and the most rational way of storing wheat grain for food purposes not only from the technological, but also from the economic point of view, we have carried out some research on the basis of "Elevator" LLP, located in the Zyryanovsk District of the East Kazakhstan Region. The studies were conducted from August 2017 to December 2019.

The objects of research were a batch of the 3rd commercial class soft wheat grain accepted for storage weighing 3,102 tons, which was subsequently divided and sent for storage in two different granaries: batch 1 weighing 1,600 tons to the floor warehouse № 8 and batch 2 weighing 1,502 tons to the elevator in silo № 102.

The storage temperature has a significant effect on the preservation of a number of important indicators of the quality and the weight of grain. The analysis of the obtained temperature measurement values in the warehouse and in the silo at the time when the grain arrived for storage in the third quarter of 2017 showed that in the silo of the elevator its maximum level reached + 20.9° C, while in the warehouse it reached + 21.8 ° C. The difference in the values of the maximum positive temperature in different types of granaries turned out to be insignificant and amounted to 0.9° C. After the expiration of the storage time, it was found that in the silo of the elevator the maximum
temperature in the warm season practically reached the initial value of + 20°C, while in the warehouse it increased to + 25°C. At the same time, the temperature difference has already reached 5°C (Figure 1).

![Figure 1. The change in temperature in granaries at different periods of storage.](image)

For long-term storage in the silo, the minimum temperature in the storage facility was noted at -16°C. In the warehouse, it dropped to -23°C. At the same time, the temperature difference in the studied storage facilities in the cold season turned out to be more significant and amounted to 7°C.

The minimum difference in the average temperatures for the entire storage period was 1.7°C and fell on the 3rd quarter of 2017. The maximum difference in the average temperatures in the warehouse and the silo of the elevator was obtained in the 3rd quarter of 2019 and amounted to 5.5°C.

To reduce the temperature in the grain mass and replace the air in the intergranular spaces, the grain batches were transferred for winter storage in the 4th quarter every year, i.e. were subjected to cooling. After this activity, the temperature reduced to -7... -10°C in the silo of the elevator and to -16... -18.5°C in the warehouse.

In order to establish how the temperature change over the storage periods affects the quality and safety of grain masses in different types of storage, the product quality was assessed in accordance with the requirements of STRK 1046-2008 "Wheat. Technical conditions ".

The analysis has shown that both in the silo of the elevator and in the grain storage, the wheat grain, immediately upon laying for storage and at the end of the storage period, had a fresh look, was in a healthy, non-heating state. The smell was characteristic of healthy grain of the specified culture, without moldy, malt, musty, wormwood, smut and other extraneous odors. The colour was normal, typical of healthy grain of this type. Pest infestation of grain stocks was not found.

Grain moisture is one of the important indicators of the quality of grain products. When its values deviate from the conditions established in the regulatory documentation, physiological processes are activated, leading to a change in other indicators: infestation, contamination, content and quality of raw gluten, falling number.
The measurements of the moisture content of grain masses were carried out when they were laid for storage and then once a month throughout the entire storage period. During the indicated observation period, fluctuations in humidity in both types of granaries from 13.9 to 14.5%, depending on the season, were noted, which is permitted by the corresponding normative documents regulating the organization of grain storage. The results obtained have allowed us to conclude that the change in the temperature regime in the granaries according to the storage seasons have not lead to an increase in the moisture content of wheat grain above the permissible norms, and, consequently, to the activation of the living components of the grain mass. In turn, this testifies to the stability of the grain state in terms of moisture and serves as a guarantee for long-term safe storage of the products.

In addition to the already considered indicators of the quality of the grain mass, when receiving and during the storage period, the content of impurities in the grain consignments was also determined. So the content of trash after the arrival of the products for storage was 1.8%, which did not exceed the norms established by the standard.

At the end of the entire storage period, the value of this indicator did not change for grain consignments in different types of storage facilities, which cannot be said about the content of grain impurities. Over the entire period of monitoring the grain mass, the maximum value of the grain impurity content was revealed at the level of 4.3%, which is 0.7% lower than the basic norms, but 0.5% higher than the arrival indicators. The increase in the value of this indicator was due to an increase in the proportion of broken grains that are formed when moving grain masses using transporting machinery, for example, when transferring grain for winter storage. At the same time, the content of grain impurities in the batch stored in the silo of the elevator is higher than in the warehouse, where it is damaged less.

In a comparative assessment of the storage methods for food wheat, in addition to the mandatory quality indicators, the mandatory special ones that characterize the technological advantages of raw materials were also analyzed. These indicators include hardness, bushel weight, content and quality of gluten, falling number.

The hardness of the evaluated batches of grain using different storage methods during the analyzed period varied from 42 to 46%, regardless of the location of the products. Such fluctuations in the indicator are insignificant, and may be due to the heterogeneity of the grain batch. The obtained values of hardness fit into the basic norms for the 3 commercial class soft food wheat (not less than 60-40%), which guarantees good milling properties.

The value of the "bushel weight" indicator when receiving and putting products for storage was 760 g/l. Further, during monitoring, an increase in this indicator was found to 765-780 g/l.

The content of crude gluten in the batches of wheat grain received for storage and after the end of storage did not undergo changes and amounted to 24.0-25.0% with values of 80-85 units according to the IDK (gluten deformation index) device, characterizing its quality. The falling number turned out to be the most stable of all the quality indicators. In all studied samples, its value was obtained for 200 s, regardless of the method of storage of grain masses.

3. Conclusion
Thus, when observing the consignments of food-grade wheat grain for more than two years, stored in different types of granaries at “Elevator” LLP, it was found that, although there were minor changes in the quality of products, but they were within the limits of conditions permitted by the regulatory documentation. According to the complex of quality indicators provided for this object, both batches stored in the warehouse and in the silo of the elevator corresponded to the 3rd commercial class at the beginning and at the end of the storage period. In this regard, it became necessary to compare not only the qualitative characteristics of products, but also to analyze them from the point of view of the efficiency of using a particular method of storing grain masses. In this regard, we have identified both positive and negative aspects of each method.

The positive aspects of silo-type storage include: the ability to accommodate large batches of grain, minimal manual labor (less manual labor is involved in servicing 1 ton of grain and a number of
technological processes are automated), grain is less susceptible to temperature differences in the outside air. The positive aspects of warehouse storage include: the possibility of visual inspection of products, sampling at any time without moving grain masses, less mechanical damage to grain, the possibility of placing small batches.

The disadvantages of the storage in the silo of the elevator in this case are as follows: the excessive damage of grain when the grain mass is moved, which leads to an increase in the proportion of grain impurities due to broken grain; lack of the possibility of visual inspection of the stored batch of grain. In addition, the temperature sensors are located in the silo every 6 m, so a significant amount of stored product remains without any temperature control.

Some negative moments have also been revealed when storing the grain in the warehouse. First of all, the temperature in this type of storage facility is more dependent on the ambient temperature. With sharp changes in outdoor air temperatures, the likelihood of condensation formation increases, and this causes an increase in the moisture content of the grain mass. In addition, the storage temperature is measured manually. The low level of mechanization of a number of technological processes leads to an increase in the cost of manual labor per unit of product.

Thus, each of the evaluated methods is acceptable for long-term storage of wheat grain. However, when placing grain masses for storage, one should be guided, first of all, by what demands for storage the owner of the grain makes. For example, if necessary, one should place a high-quality batch of grain or grain with a gluten content of more than 28% separately. As a rule, small batches (200-400 tons) are formed with such indicators. It is not economically feasible to place such a quantity of products in the silo of the elevator which has a capacity of about 800 tons. In this case, it is more profitable to put the grain mass for storage in a warehouse, where storage in small batches without mixing and with the same quality efficiency is possible.

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