UDC 664.7:631.24
DOI https://doi.org

O. Sokolovskaya, PhD of Technical Science, Associate Professor, *E-mail: sokolovskaya_alena@meta.ua*
https://orcid.org/0000-0003-4326-1932, ResearcherID: N-5304-2015
L. Valevskaya, PhD of Technical Science, Associate Professor, *E-mail: ludmila_valev@ukr.net*
https://orcid.org/0000-0003-0511-5643, ResearcherID: F-8756-2016
Odesa National University of Technology, 112, Kanatna Str., 65039, Odessa, Ukraine, Tel. +380676828516

STUDY OF GRAIN THERMOMETRY DURING STORAGE

Abstract

Grain thermometry is a process of measuring the temperature of grain masses during their storage. Key aspects that emphasize the importance of temperature control to ensure quality preservation: Prevention of self-ignition: prevention of fungal and bacterial growth, maintenance of moisture stability, reduction of nutrient loss, preservation of color and flavor, minimization of insect and pest growth. Overall, temperature control in grain storage is an important strategy for maintaining product quality, reducing losses, and ensuring storage safety. Modern monitoring and automation technologies allow for effective temperature control in storage facilities. The temperature of the grain in the storage can depend on a number of weather conditions and factors. Key factors that can affect grain temperature: air temperature, air humidity, solar heat, technical equipment of storage, natural conditions of grain, day and night temperature fluctuations. The temperature of the air around the storage has a significant effect on the temperature of the grain. In winter, cold weather can lead to a decrease in the temperature of grain masses, while in summer, high temperature can contribute to its increase. Air humidity is also important. High humidity can lead to condensation of moisture in storage, which in turn can increase the temperature of the grain through chemical processes such as decomposition. Solar heat can directly or indirectly affect the grain temperature, especially if the storage is located under direct sunlight. Storage efficiency and technical equipment, such as ventilation and air conditioning systems, can affect the distribution and retention of heat in the storage. The grain itself can affect its temperature through chemical and biological processes such as respiration and heat generation. Day and night temperature fluctuations can contribute to the distribution of heat in the storage. We conducted a study of grain temperature changes during storage at an enterprise in the Odesa region and established the influence of various factors on grain temperature changes.

Key words: grain temperature, thermometry, grain storage, thermal suspensions, thermosensors.

Introduction

The main task of grain preservation is to ensure reliable conditions for grain storage with the prevention of loss of its quality.

Today, the issue of the development of grain processing enterprises, which in turn are related to the storage of raw materials in elevators, is becoming relevant. Metal elevators have become widespread, which, unlike reinforced concrete ones, are much cheaper and require less time to erect them. But there are questions about how to store grain in metal silos, how often to control the temperature in it, under which environmental conditions it is better to store it there, and how the grain mass behaves in different layers of the embankment.

The temperature of the grain mass is an important indicator that characterizes the state of the grain mass during storage. An increase in the temperature of the grain mass, which does not correspond to the change in the ambient temperature, indicates the activation of physiological processes and the beginning of the self-heating process.

The most important reason for spoilage of grain during storage is lack of temperature control. This causes moisture to move from one part of the grain mass to another, where it can accumulate and cause grain spoilage. Although moisture movement can occur at any time when temperatures are different in different parts of storage, the most critical point occurs when warm grain is stored in cold winter temperatures.

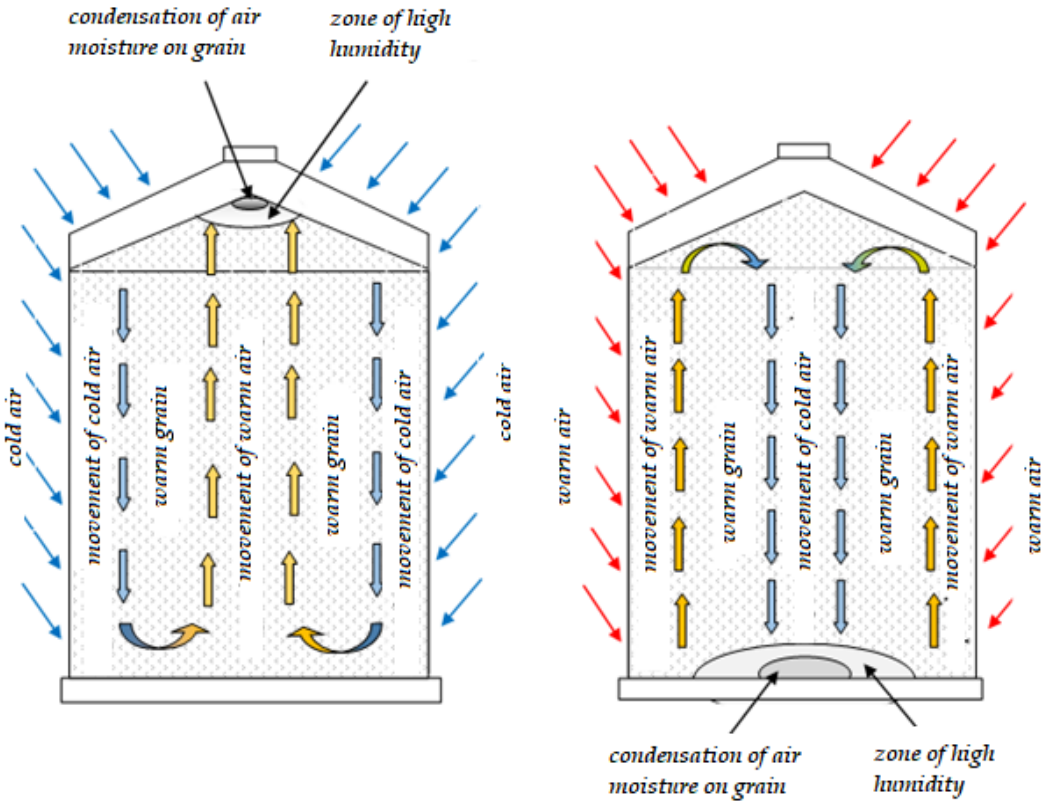
Grain is usually stored at a temperature of 10-25°C, and sometimes even higher.

By late autumn or early winter, the average temperature drops to -5°C and below. This drop in temperature causes cooling of the air and storage of grain next to the walls of the warehouse becomes difficult. Since the grain has quite good insulating properties, most of the grain and the air in the center of the storage remain at approximately the same temperature as when it was put into storage [1-3].

These differences in temperature cause slow movement of moisture and air. Such natural air circulation is called convection currents. They develop as a result of the fact that air and grain are close to the walls of the storage. Cooling makes the air heavier and it settles closer to the floor of the storage. As the air moves lower and then toward the center of the storage, it becomes warmer, less dense, and lighter. This causes air currents to rise over the warm grain, and its temperature rises. As the air temperature increases, the ability to hold moisture increases, and it begins to absorb a small amount of moisture.

Slowly, the air rises to the cooler grain at the top of the storage, where the temperature is lower. Part of the moisture precipitates into the grain by condensation of moisture on the surface of the grain and penetration of moisture into the cold storage of the grain. The problem of moving moisture is the first indication that a crust is forming on the surface of the grain. It is a thin superficial granular layer that is slightly moist, slimy and sticky. Sometimes during storage, grains freeze or stick together [4-7].

Covering grains with a crust predicts a rather serious spoilage process. This is almost a sure sign of the presence of unwanted temperature differences in the



а б

a – in cold weather conditions; b - in warm weather

Fig. 1 – Convection flows and moisture migration in metal silos

grain. If crusting occurs, the surface should be cleaned or, in extreme cases, removed, and ventilation should be started immediately.

Moisture can also move when cold grain is stored during the warm or hot months of the year. The inside of the roof should be checked on cold mornings for condensation or ice before the sun warms the roof. Such moisture condensation is almost always a sign of moisture movement and often reflects poor grain storage conditions. Regardless of the grain storage time, the main rule is to maintain the temperature at +15-20 °C.

Sharp changes in the temperature of the outside air during the day are especially harmful for grain masses stored in silos. As a result of sharp temperature fluctuations, moisture condenses on the internal surfaces of the silo, the appearance of which leads to the intensification of physiological processes in the grain mass, and as a result, grain deterioration (germination, self-heating, mold growth, etc.). In addition, due to differences in day and night temperatures in the metal silo, cyclic stresses of compression and expansion can occur, which can lead to compaction of the grain mass and its caking [8]. Convection flows and moisture migration in metal silos under different weather conditions are shown in Fig. 1.

The temperature of grain during storage during the harvesting period is plus (+10 ... 22) °C, i.e. it is equal to the temperature of the outside air. In winter, the external temperatures drop to minus (+1...20) °C, and the grain close to the walls of the granary cools down to temperatures close to the temperature of the winter air, while the grain close to the center of the bunker is still warm, which is explained by the low thermal conductivity of grain.

The larger the capacity of the bunkers, the longer it takes for the heat to move from the center to the periphery. With warm grain in the center of the storage and cold grain on the periphery, convection air flows occur, moving down, in the area of cold grain, and up, in the area of warm grain in the center of the storage (Fig. 1.1 a).

Convection currents are caused by the difference in the density of cold and warm air. When moving warm air from the center of the grain mass of the storage, it moves small amounts of moisture from the grain. Then, when the warm air comes into contact with the cold grain in the upper part of the grain and with the cold roof of the hopper, moisture condenses on the cold surfaces. Some moisture also moves between warm and cold grains due to diffusion. The combination of factors of convection currents and diffusion leads to gradual moistening of the grain in the upper layers of the central part of the hopper. With sufficient moisture and an increase in the temperature of the outside air, the grain is covered with mold and the number of insects in it increases.

The optimal grain storage temperature depends on geographical factors and weather conditions. In general, when choosing the recommended grain storage temperatures, you can be guided by the following principle: the grain temperature should be slightly above the average temperatures of the coldest winter months and below the average temperatures of the warmest summer months. To implement these recommendations, it is necessary to monitor the grain temperature frequently, and at the beginning of the new season, it is desirable to apply measures to change the grain temperature [1-4].

Grain thermometry is a process of monitoring the temperature of the grain mass during its storage or processing. The process of grain thermometry is extremely important, since it is the only way to detect foci of self-heating of grain - harbingers of serious losses of grain during its storage, and sometimes of catastrophic destructive consequences that threaten the lives of people and the company's property.

Grain temperature control is an important condition for effective preservation of quality indicators. The increase in temperature during the storage of grain mass-

es is due to the processes of so-called "self-heating of grain" - an involuntary increase in the temperature of grain masses due to weak thermal conductivity. Self-heating occurs unevenly, in those areas of the grain mass, where the return of heat to the environment becomes lower than the generation of heat at the point of the mass. The generated heat is usually retained in the grain and the temperature continues to rise continuously [6-8, 10].

Grain thermometry is of great importance in the agro-industrial sector and grain management. The main values of grain thermometry include:

Temperature control to preserve quality: Thermometry allows you to determine temperature regimes in grain storage. Maintaining the optimal temperature is a key factor in maintaining the quality and value of grain. High temperatures can lead to self-ignition or product spoilage, so it is important to monitor and control the temperature during storage.

Prevention of self-ignition and spoilage: Grain can generate heat due to chemical and biological processes that occur in it during storage. Thermometry allows you to detect an increase in temperature, which may indicate the beginning of spontaneous combustion. Timely detection of this phenomenon allows you to avoid large losses of grain.

Effective storage management: Temperature monitoring is part of effective storage management. This includes optimizing storage conditions, reacting to any changes in temperature and taking measures to ensure the best conditions for grain storage.

Safety and risk warning: Temperature monitoring is part of safety systems in the agro-industrial sector. This allows you to warn about possible risks and take timely measures to eliminate them.

Reduce costs and losses: Effective temperature control helps reduce costs and losses of grain as it helps prevent spoilage or losses due to spontaneous combustion.

The general purpose of grain thermometry is to ensure the safety, quality and effective management of the storage of grain crops, which is an important element in modern agro-industrial activity.

Materials and methods

The purpose of the work is to study the temperature changes of the formed layers of grain during its storage in metal silos of different diameters.

The object of the study is grain thermometry during storage at an enterprise in the Odesa region.

The subject of the study was the characteristics and statistical data of grain temperature during storage in various silos.

Research methods were chosen from generally accepted and special mathematical-statistical and grapho-analytical methods. Processing of tabular data received by the enterprise was carried out using a combined grapho-analytical method, for which, on the basis of tabular values, corresponding histograms and graphs were built, which gave a visual representation of the temperature of grain during storage. When constructing histograms and charts, standard Microsoft Excel 2007 spreadsheet tools were used.

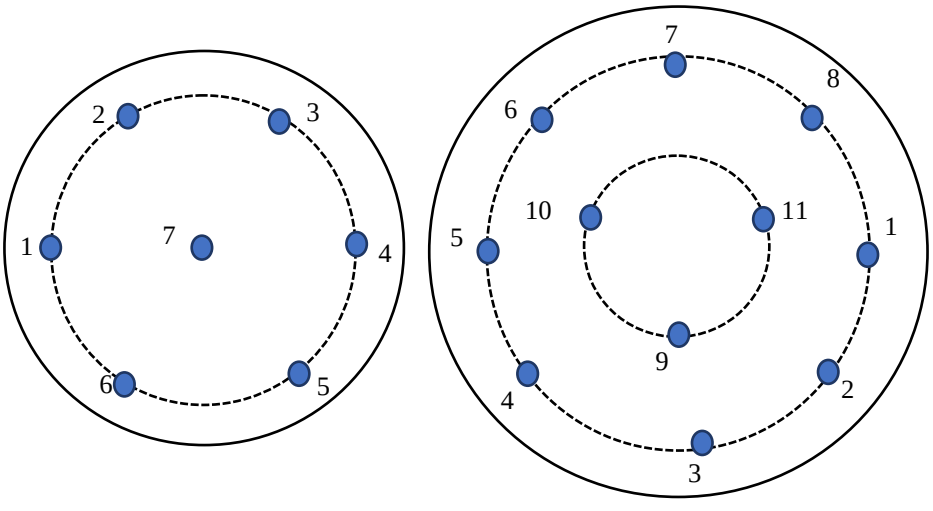
Characteristics of granaries

To control the temperature of the grain mass, the silos are equipped with a thermometry system. The grain temperature control device with a digital display allows you to display digital data on the temperature of the grain mass stored in the silos. The thermometry system (Fig. 2) in a silo with a diameter of 19.86 m consists of 7 thermal suspensions on which 7 sensors are installed and 8 on the central thermal suspension, and in a silo with a diameter of 22.15 m there are 11 thermal suspensions with 8 sensors each.

Results of the study and their discussion

We analyzed the wheat grain storage process in metal silos with a capacity of 6.0 thousand tons (silo diameter 19.86 m) and 9.0 thousand tons (silo diameter 22.15 m).

Wheat grain of the third class with indicators: moisture content 12.2%, content of garbage admixture 1.24%, content of grain admixture 5.4% is placed for storage in a silo with a diameter of 19.86 m. In a silo with a diameter of 22.15 m, wheat grain of the second class was placed with the following indicators: moisture content 12.7%, content of garbage admixture 1.5%, content of grain admixture 5.7%.



a b

a – silo with a diameter of 19.86 m; b – a silo with a diameter of 22.15 m

Fig. 2 – Location of the thermometry system in the silos

To determine the dependence of the temperature of the grain heap on external factors (the influence of heated walls, the roof of the silo, the temperature of the air layer inside the silo), graphs of changes in the temperature of the wheat grain heap on November 6, 2023 were constructed. The daytime air temperature at the location of the elevator is +10ºC, the night temperature is 4 ºC.

In fig. 3 and 4 show graphs of changes in the temperature of wheat grain in silos.

Grain temperature indicators in the zone of thermo-

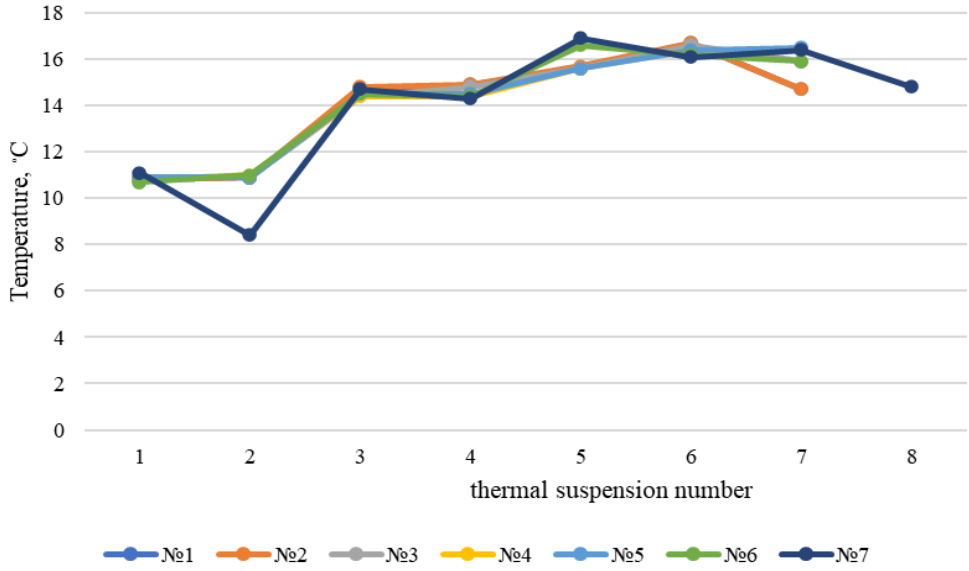


Fig. 3 – Thermometry data of wheat grain stored in a metal silo with a diameter of 19.86 m (November 10, 2022)

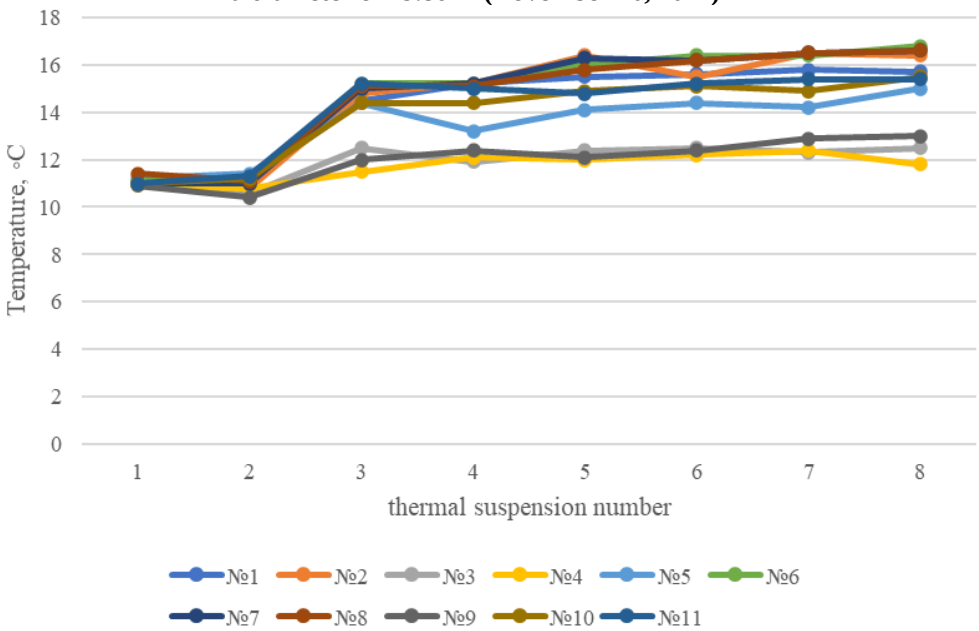


Fig. 4 – Wheat grain thermometry data, in wheat stored in a metal silo with a diameter of 22.15 m (November 10, 2022)

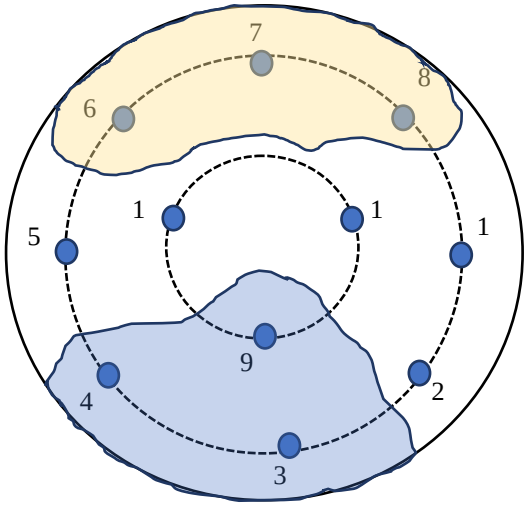


Fig. 5 – Zones of temperature increase and decrease in a silo with a diameter of 22.15 m

sensors 1-2 differed from others, this depends on the fact that the silos were filled to 80%.

Therefore, the upper layer of the grain embankment, namely the "cone" at its top, is the most affected by air temperature, as the most contacting surface, since the daytime temperature contributes to the cooling (or heating) of the metal structure of the silo and, as a result, somewhat lowers (increases) the air temperature in silos These areas require special attention, because with a large temperature difference, condensate may boil.

From the thermometry data of wheat grain stored in a metal silo with a diameter of 22.15 m, it is also clear that the temperature sensors on thermal suspensions No. 3, 4, 9 record a lower temperature of the grain (+11.5 ... 13.0 ºC) than others. Thermal sensors on thermal suspensions No. 6, 7, 8 record a higher grain temperature (+15.0...16.8 ºC) than others.

This may be related to the location of the silo. Taking into account the obtained results of temperature changes for all thermal suspensions, we can conclude that the placement of the silo according to the cardinal points affects the temperature of the grain. Much lower temperatures are concentrated in the north and northeast than in the southwest, which is typical for these parts.

We conducted a study of grain temperature in silos in winter. In fig. 6 – 7 shows grain thermometry data on February 12, 2023. Daytime air temperature at the location of the elevator is -3 ºC, night -7 ºC.

Storing grain in winter requires constant monitoring of its condition. The drop in temperature causes cooling of grain and air near the storage walls. Since the grain has sufficiently high insulating properties, most of the grain and the air in the center of the storage remain at approximately the same temperature as when it was put into storage. These differences in temperature cause the gradual movement of moisture and air.

In a silo with a diameter of 22.15 m, we can observe that the temperature of the grain in the upper layers is higher than the temperature in the lower layers of the grain.

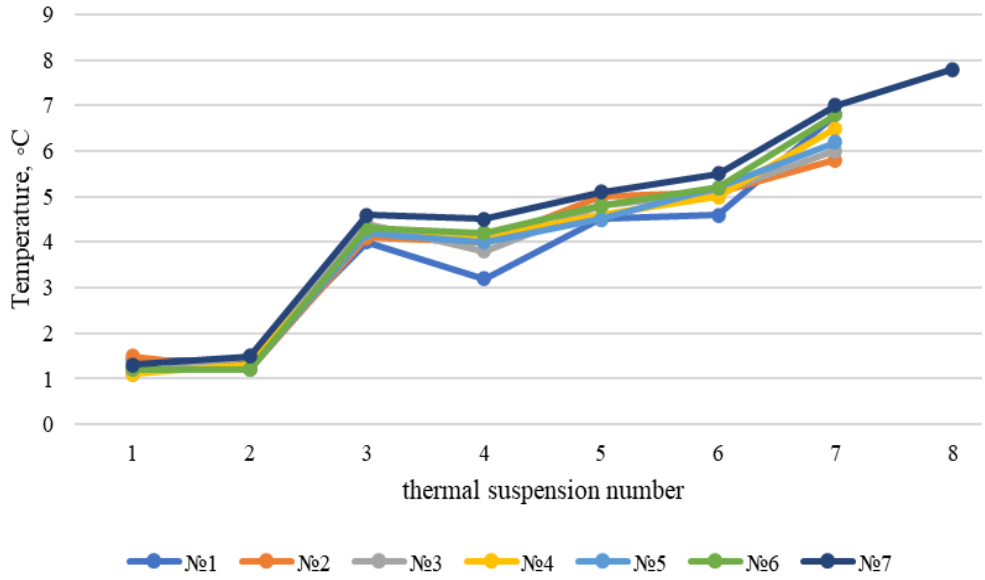


Fig. 6 – Thermometry data of wheat grain stored in a metal silo with a diameter of 19.86 m (February 12, 2023)

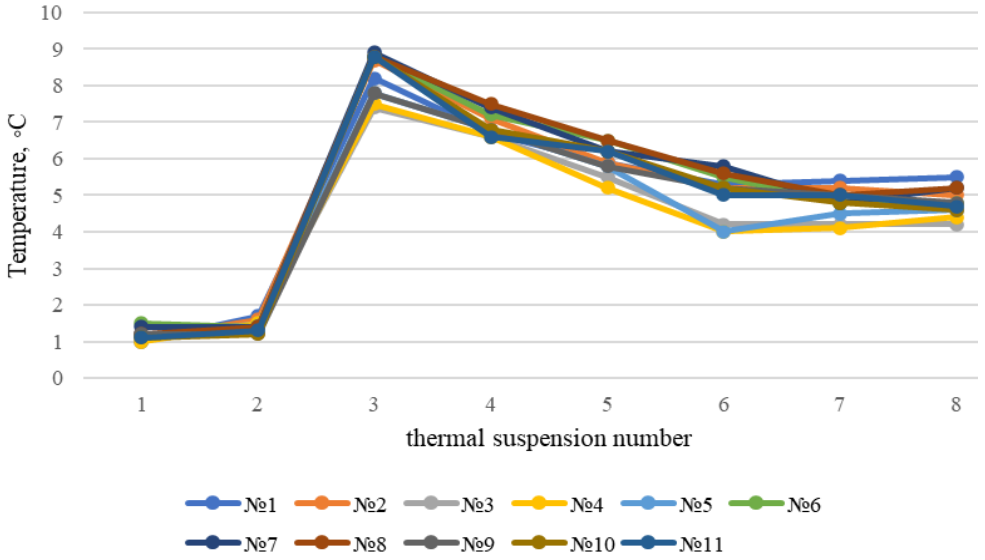


Fig. 7 – Wheat grain thermometry data, in wheat stored in a metal silo with a diameter of 22.15 m (February 12, 2023)

processes occurring in the grain heap during grain storage in granaries. The need to install a thermometry system is an integral part of the control of stored grain.

Special attention should be paid to the contact zones with the surface of the grain embankment and the zones adjacent to the walls of the slurry, they are the most sensitive to temperature changes. The air temperature in the silo affects the temperature of the upper layers of the grain mass, which are in direct contact with it.

When the ambient temperature rises, the air temperature in the silo rises, because the metal surfaces of the silo have high thermal conductivity.

As a result of convection currents and migration of moisture in metal silos, moisture condenses on the internal surfaces of the silo, the appearance of which leads to the intensification of physiological processes in the grain mass, and as a result, grain spoilage.

The temperature of grain during silo storage depends on geographical factors and their location. The silos inside the elevator are less exposed to the external environment than the external silos.

The placement of thermal suspensions in accordance with the cardinal points showed that the north and northeast have significantly lower temperatures than the southwest, which is typical for these cardinal points.

Conclusions

The temperature of grain in storage is a complex process determined by the interaction of various factors.

It is important to establish effective monitoring and management systems to ensure optimal storage conditions and avoid negative consequences such as spontaneous combustion or product spoilage.

Grain temperature control is the most effective and affordable way to track the results of biochemical

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О. Соколовська, канд. техн. наук, доцент, *E-mail: sokolovskaya_alena@meta.ua*
Л. Валевська, канд. техн. наук, доцент, *E-mail: ludmila_valev@ukr.net*
Одеський національний технологічний університет, м.Одеса, вул. Канатна, 112, 65039, Україна

ДОСЛІДЖЕННЯ ТЕРМОМЕТРІЇ ЗЕРНА ПІД ЧАС ЗБЕРІГАННЯ

Анотація

Термометрія зерна – це процес вимірювання температури зернових мас під час їх зберігання. Ключові аспекти, які підкреслюють важливість контролю температури для забезпечення якісного збереження: Запобігання самозайманню: запобігання росту грибків і бактерій, підтримання стабільності вологи, зменшення втрати поживних речовин, збереження кольору та смаку, мінімізація росту комах і шкідників. Загалом, контроль температури при зберіганні зерна є важливою стратегією для підтримки якості продукції, зменшення втрат і забезпечення безпеки зберігання. Сучасні технології моніторингу та автоматизації дозволяють ефективно контролювати температуру в сховищах. Температура зерна в сховищі може залежати від ряду погодних умов і факторів. Основні фактори, які можуть впливати на температуру зерна: температура повітря, вологість повітря, сонячне тепло, технічне оснащення сховищ, природні умови зерна, денні та нічні коливання температури. Значний вплив на температуру зерна має температура повітря навколо сховища. Взимку холодна погода може призвести до зниження температури зернових мас, а влітку висока температура може сприяти її підвищенню. Важлива також вологість повітря. Висока вологість може призвести до конденсації вологи в сховищі, що, у свою чергу, може підвищити температуру зерна через хімічні процеси, такі як розкладання. Сонячне тепло може прямо чи опосередковано впливати на температуру зерна, особливо якщо сховище знаходиться під прямими сонячними променями. Ефективність зберігання та технічне обладнання, таке як системи вентиляції та кондиціонування повітря, можуть впливати на розподіл та збереження тепла в сховищі. Саме зерно може впливати на свою температуру через хімічні та біологічні процеси, такі як дихання та виділення тепла. Денні та нічні коливання температури можуть сприяти розподілу тепла в сховищі. Нами було проведено дослідження зміни температури зерна під час зберігання на підприємстві в Одеській області та встановлено вплив різних факторів на зміну температури зерна.

Ключові слова: температура зерна, термометрія, зберігання зерна, термосуспензії, термосенсори.

Received 11.01.2023 **Revised 15.02.2023**
Reviewed 27.01.2023 **Approved 20.03.2023**

Cite as Vancouver Citation Style
Sokolovskaya O., Valevskaya L. Study of grain thermometry during storage, Grain Products and Mixed Fodder's, 2023; 23 (1, 89): 36-41.
***DOI** https://doi.org/10.15673/*

Cite as State Standard of Ukraine 8302:2015
Study of grain thermometry during storage / Sokolovskaya O.. et al. // Grain Products and Mixed Fodder's. 2023. Vol. 23, Issue 1 (89). P. 36-41. DOI https://doi.org/10.15673/

UDC 668.788
DOI https://doi.org

[1]V. Petrov, PhD of Technical Science, Associate Professor, *E-mail: 0673972002@ukr.net*
ORCID: 0000-0003-3262-9463
[2]S. Pozner, Head designer, *E-mail: agro@simo.com.ua,*
[1]Department of Technological Equipment of Grain Productions, Tel. 0673972002,
Odesa National University of Technology, 112, Kanatna Str., Odesa, 65039, Ukraine
[2]SIC AGRO-SIMO-MASHBUD, Tel. 0638287110, St. Bugaivska 46, Odesa 65005, Ukraine

DEVELOPMENT OF HIGHLY EFFICIENT TECHNOLOGICAL EQUIPMENT

Annotation

The article discusses the problems associated with processing buckwheat on roller deck machines and reducing the amount of crushed kernel. Recently, there has been a tendency to increase the number of processed fractions of buckwheat grain, which significantly improves the quality of the output product. At the same time, this requires more precise adjustment to the working gaps and obtaining the correct shape of the working area (crescent-shaped when processing buckwheat) between the abrasive roller and the deck. The designs of roller deck machines used in the cereal industry and their installation mechanisms are analyzed. The mechanisms used for installing the deck on rolling deck machines do not allow one to accurately set the shape of the working gap and its dimensions. A more advanced mechanism for removing the deck from the abrasive roller and a mechanism for installing the deck on a wedge shape between the deck and the abrasive roller (usually used