VYTAUTAS MAGNUS UNIVERSITY M C M X X I I
ISSN 1392-1134/ eISSN 2345-0371
AGRICULTURAL ENGINEERING
2026, Vol.1, No. 58, 1-7 p.
https://doi.org/10.15544/ageng.2026.58.1

INFLUENCE OF ABIOTIC FACTORS ON THE BIOLOGICAL ACTIVITY OF WHEAT GRAINS

Jocas D., Zvicevičius E., Žiūra K., Mickevičius M.
Faculty of Engineering, Vytautas Magnus University, Kaunas, Lithuania

The article examines the effect of the main abiotic factors: temperature, wheat grain moisture content and carbon dioxide (CO_2) concentration on the biological activity of grains. Biological activity, which is assessed by the intensity of respiration and the amount of CO_2 released during it, is one of the most important indicators that allows assessing the condition of grains and the storage process. During grain respiration, organic matter is decomposed, accompanied by mass loss, emissions of metabolic products and, most importantly, the resulting heat flows, which directly affect the storage process and its success.

Experimental studies were carried out using wheat grains of different moisture content (15.4 ± 0.07%, 18.0 ± 0.1% and 20.0 ± 0.06%), which were stored at temperatures of 4 °C and 12 °C in tightly closed containers. It was found that the biological activity of wheat stored at a temperature of 4 °C with the lowest humidity (15.4 ± 0.07%) was minimal – the emitted comparative carbon dioxide flux did not exceed 0.0783 ± 0.0099 mg/(kg·h), and the generated heat flux was very low (0.233 ± 0.0296 W/t). The highest biological activity was found in grains that were 20 ± 0.06% humid and stored at a temperature of 12 °C. Their emitted comparative carbon dioxide flux reached 3.07 ± 0.128 mg/(kgh), and the generated heat flux was 9.13 ± 0.382 W/t. An increase in temperature from 4 °C to 12 °C in all cases intensified grain respiration and metabolic processes. Meanwhile, CO_2 gas, reaching a certain concentration in the environment, reduced the viability of wheat and acted as a factor inhibiting its biological activity. However, the greatest influence was exerted by the grain moisture content, which determined the intensity of respiration, while temperature and carbon dioxide were factors that enhanced or inhibited this effect.

Keywords: wheat, biological activity, moisture content, temperature, carbon dioxide, heat flow.

Received 2026-04-09, accepted 2026-05-11

1. Introduction

Wheat grains are one of the most important agricultural products, used both in food production and in animal husbandry. Since grains are consumed throughout the year, preserving their quality during storage is extremely important. It has been established that grain losses during storage can reach 1-2% and more, depending on storage conditions, applied technologies and their management [1, 2].

Grains placed in a warehouse form an ecosystem that is alive and breathing. During respiration, oxygen is used, carbon dioxide (CO_2) and heat are released. This is directly related to changes in the condition of the grains. The intensity of respiration is one of the main indicators that allows assessing the biological activity of grains, their condition and the storage process, and predicting possible quality changes during storage [3, 4].

The biological activity of grains is determined by both abiotic and biotic factors. Grains are a very favorable environment for the development of microorganisms, especially mold fungi. Under favorable conditions of humidity and temperature, they can colonize the surface and internal tissues of grains [5]. Their activity promotes the degradation of organic matter, increases the intensity of respiration and causes qualitative changes in grains, including the loss of nutrients and the formation of mycotoxins. The activity of pests (arthropods and vertebrates) can cause significant mechanical, biological and sanitary damage: damaged grains are a more favorable environment for the spread of microorganisms. They are also characterized by a higher intensity of respiration and faster spoilage [5, 6].

The risk and impact of biotic factors are closely related to abiotic factors, the most important of which are temperature, humidity and gas composition. Temperature is one of the most important abiotic factors regulating the speed of biochemical and microbiological processes. As the temperature increases, respiration intensifies and CO_2 release increases [1, 7]. In addition, temperature irregularities in the grain layer can cause condensation phenomena, which further increase the humidity and activate degradation processes [6]. Grain humidity is a critical factor determining their biological activity. Water is necessary for biochemical reactions to occur and for the development of microorganisms. Therefore, as humidity increases, respiration becomes more active, CO_2 release and heat generation increase. At high humidity, these processes can cause spontaneous heating and spoilage of grains [2, 8]. The gas composition in the intergrain space is no less important. During storage, due to respiration, the oxygen concentration naturally decreases and the CO_2 content increases. In certain cases, a higher carbon dioxide content can act as a natural preservative [1, 9]. However, at the same time, a more intense increase in CO_2 concentration indicates a greater biological activity of grains and warns of a greater risk of changes in their quality.

Biotic and abiotic factors in the grain storage space form an artificial ecosystem and act in a complex way. They interact with each other, determining each other's viability, as well as the overall biological activity of grains and their storage stability. Given the importance of temperature, grain moisture and gas composition, it is necessary to study their interaction and impact on the biological activity of wheat [4, 10].

The aim of the research is to assess the impact of temperature, humidity and carbon dioxide on the respiration intensity of wheat grains, CO_2 release and heat generation under different storage conditions.

Objectives:

1. To investigate the biological activity of wheat grains of different humidity, determining the flux of carbon dioxide and heat released by them.
2. To assess the impact of temperature on the biological activity of wheat grains.
3. To assess the impact of carbon dioxide concentration on the biological activity of wheat grains.

2. Object and methods

The research was conducted at the VMU Academy of Agriculture, Department of Mechanical, Energy and Biotechnology Engineering. The aim was to determine the effect of storage temperature, humidity and carbon dioxide (CO_2) concentration on the biological activity of wheat grains. The experiments were carried out in accordance with the recommendations for the study of grain storage processes and ensuring the accuracy of environmental conditions management [1, 4].

The object of the research was wheat grains with three different moisture contents: 15.4 ± 0.07%, 18.0 ± 0.1% and 20.0 ± 0.06%. These moisture contents were chosen in order to assess the biological activity of both relatively dry and sufficiently moist grains, the storage of which is potentially risky. Grain moisture was determined by the reference method according to the standard LST EN ISO 712 “Grains and their products. Determination of moisture content. Reference method.”: grain samples were dried at 105 °C in a drying oven “Memmert UFP 700” to constant weight.

Grain biological activity studies were performed using glass desiccators and periodically recording the carbon dioxide concentration in them with a gas analyzer (Fig. 1). Depending on the volume of the desiccator, 1.2 kg or 2.4 kg of wheat were poured into them, forming a layer of test grains about 7 cm high. By applying different desiccator opening strategies, aerobic or anaerobic conditions were created for the grains in the desiccators. When storing grains under aerobic conditions, the desiccators were periodically opened in order to ventilate the grains there, avoid oxygen deficiency and maintain aerobic conditions. During these experiments, the carbon dioxide flux released by the grains and the heat flux generated were determined. Another group of desiccators was kept unopened. The aim was to create anaerobic conditions and study the effect of increasing carbon dioxide concentration on the biological activity of grains.

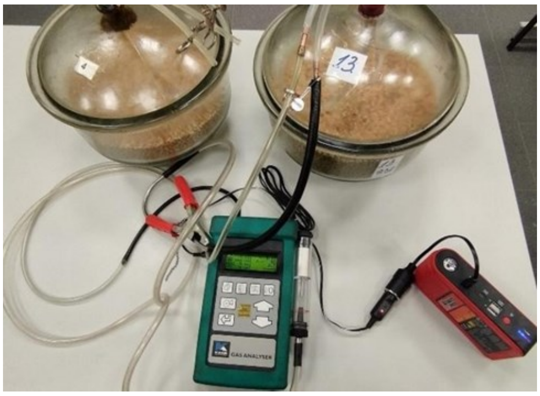


Fig. 1. Measurement of carbon dioxide (CO_2) concentration in desiccators with grains

Fig. 2. Desiccators with wheat samples in a climatic chamber

Desiccators with grain samples were stored in an incubator "Memmert ICP 450" and a climatic chamber "Feutron KPK 600" (Fig. 2), where temperatures of 12 °C and 4 °C were maintained, respectively. These conditions reflected the storage conditions of cooled grains and uncontrolled or insufficiently controlled storage. The carbon dioxide concentration in the desiccators was measured using a gas analyzer "Kane Auto 2–2", connected to the desiccator by hoses. Measurements were performed periodically, taking into account the intensity of the biological activity of the grains. Then, using the measurement results, the comparative carbon dioxide (CO2) flows released by the grains and the generated heat flows were calculated according to the methodology presented below:

$$m_1^* = \frac{m_{\mathrm{CO_2}}}{m_2^* \cdot t}, \quad (1)$$

$$m_{\mathrm{CO_2}} = V_{\mathrm{CO_2}} \cdot \rho_{\mathrm{CO_2}} \cdot 10^6, \quad (2)$$

$$V_{\mathrm{CO_2}} = V_{oro} \cdot \frac{\mathrm{CO_2}\,\%}{100}, \quad (3)$$

where m_1^* – amount of carbon dioxide formed during respiration of products, mg/(kg·h); m_2^* – mass of products in the desiccator, kg; t – time, h; $m_{\mathrm{CO_2}}$ – mass of CO_2 released, mg; $\rho_{\mathrm{CO_2}}$ – density of carbon dioxide, kg/m^3; $V_{\mathrm{CO_2}}$– volume of carbon dioxide in the desiccator, m^3.

Heat flux released during grain respiration:

$$\mathrm{q}_k = m_1^* \cdot 0.00298, \quad (4)$$

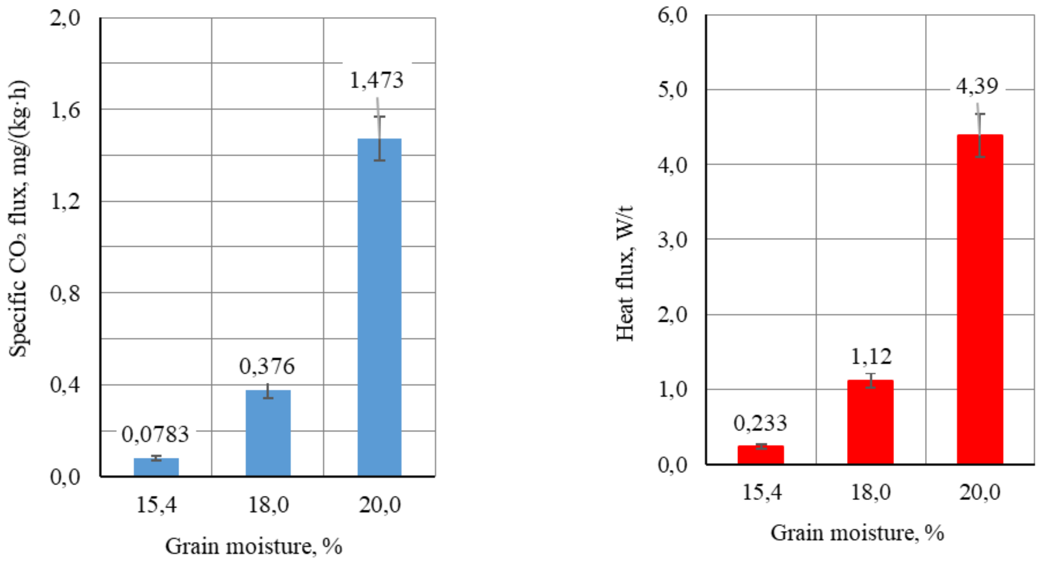
where q_k – heat flow, W/kg.

Data analysis was performed using MS Excel, calculating mean measurements and confidence intervals.

3. Results and discussion

The biological activity of wheat grains was assessed based on the metabolic process – respiration intensity during storage. The amount of carbon dioxide released was determined (CO_2) quantities, the intensity of its concentration increase in the storage space (desiccators) and the heat flows generated by the grains were calculated. The obtained results confirmed clear dependencies between the respiration intensity of wheat grains and the main abiotic factors - humidity, temperature and carbon dioxide concentration in the environment. At a temperature of 4 °C, the biological activity of wheat grains was relatively low. Nevertheless, the research results (Fig. 3) confirmed that as moisture content increased, the intensity of grain respiration and the generated heat flux also increased. For grains with a moisture content of 15.4 ± 0.07%, the specific carbon dioxide emission rate reached only 0.0783 ± 0.0099 mg/(kg·h), while the generated heat flux was 0.233 ± 0.0296 W/t. However, at a moisture content of

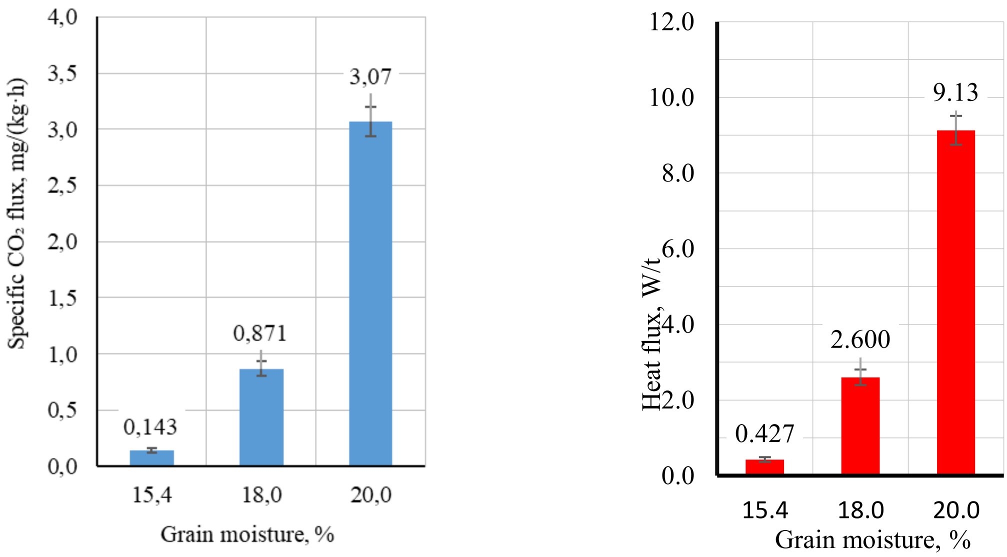
18.0 ± 0.1%, the biological activity of the grains was 4.81 times higher, and at 20.0 ± 0.06% moisture content, it was as much as 18.8 times higher. The corresponding specific carbon dioxide emission rates and heat fluxes for wheat reached 0.376 ± 0.0344 mg/(kg·h) and 1.12 ± 0.103 W/t, and 1.473 ± 0.0963 mg/(kg·h) and 4.39 ± 0.287 W/t, respectively.



a) **b)**

Fig. 3. Biological activity of wheat at 4 °C temperature: a – specific carbon dioxide (CO_2) flux; b – heat generation flux

The biological activity of wheat grains stored at a temperature of 12 °C was on average 2.08 times higher than when stored at 4 °C. The greatest change in respiration intensity (2.32-fold) was recorded in grains with a moisture content of 18.0 ± 0.1% (Fig. 4). Their specific carbon dioxide emission rate increased to 0.871 ± 0.0690 mg/(kg·h), and the generated heat flux rose to 2.6 ± 0.206 W/t. For grains with a moisture content of 20.0 ± 0.06%, biological activity increased even further: the values of specific carbon dioxide emission and heat flux reached 3.07 ± 0.128 mg/(kg·h) and 9.13 ± 0.382 W/t, respectively.



a) **b)**

Fig. 4. Biological activity of wheat at 12 °C temperature: a – specific carbon dioxide (CO_2) flux; b – heat generation flux

It was determined that moisture content had a greater influence on the respiration intensity of wheat grains than temperature. At 12 °C, the difference between the specific carbon dioxide emission rates—and also between the generated heat fluxes—of grains with moisture contents of 20.0 ± 0.06% and 18.0 ± 0.1% reached 3.51 times. An even more pronounced difference was observed when comparing grains with moisture contents of 18.0 ± 0.1% and 15.4 ± 0.07%. The latter produced a specific carbon dioxide emission rate of only 0.143 ± 0.0208 mg/(kg·h), while the generated heat flux was 0.427 ± 0.0621 W/t. The biological activity of wheat at 15.4 ± 0.07% moisture content was 6.09 times lower than that of grains at 18.0 ± 0.1% moisture and as much as 21.3 times lower than that of grains at 20.0 ± 0.06% moisture.

The biological activity of wheat increased very rapidly as moisture content rose from 15.4 ± 0.07% to 18.0 ± 0.1%. In contrast, the effect of temperature was weaker: when the temperature of grains with 15.4 ± 0.07% moisture content increased from 4 °C to 12 °C, their carbon dioxide emission and heat flux increased only 1.83 times—from 0.0783 ± 0.00993 mg/(kg·h) to 0.143 ± 0.0208 mg/(kg·h), and from 0.233 ± 0.0296 W/t to 0.427 ± 0.0621 W/t, respectively.

Another important factor is the gaseous composition of the environment. During biochemical processes, the gas composition in a non-ventilated grain bulk naturally changes—the concentration of oxygen decreases, while the concentration of carbon dioxide (CO_2) increases in the intergranular spaces. Experiments conducted using sealed desiccators made it possible to evaluate the effect of increasing carbon dioxide concentration on the dynamics of wheat respiration intensity during storage.

At a temperature of 4 °C, in desiccators containing grains with 15.4 ± 0.07% moisture content, the CO_2 concentration remained low throughout the observation period (Fig. 5). The values did not exceed 0.05%. This indicates that respiration processes in wheat grains proceeded slowly, biological activity was minimal, and the conditions formed were favorable for long-term grain storage.

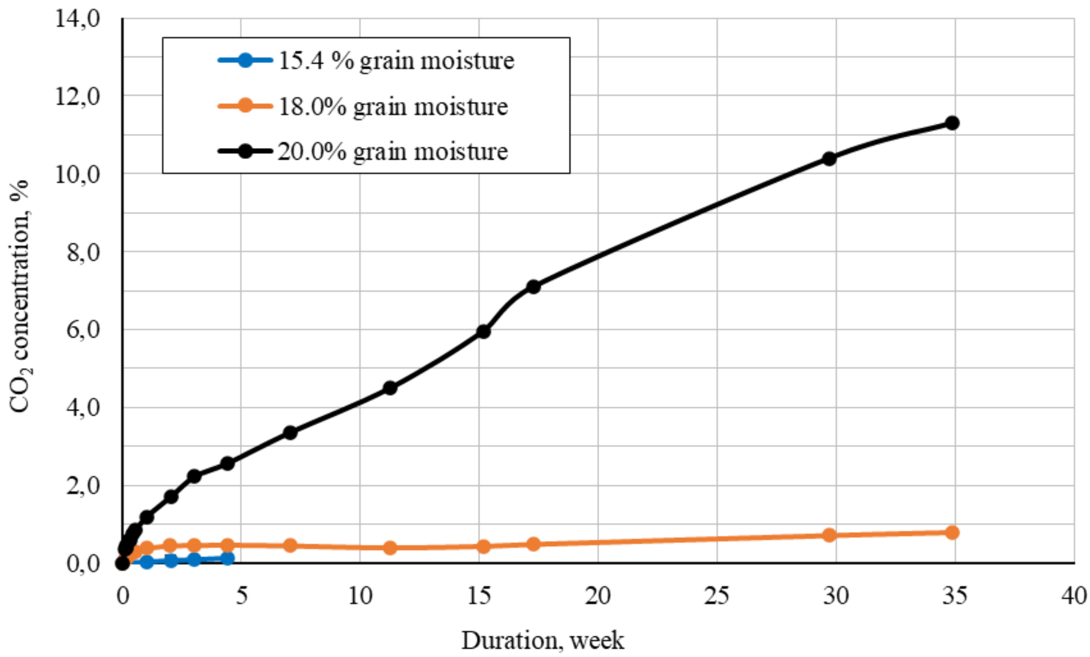


Fig. 5. Variation of carbon dioxide (CO_2) concentration during wheat storage at 4 °C temperature

A similar, although less stable, environment also formed in the bulk of wheat with a moisture content of 18.0 ± 0.1% stored at 4 °C. The carbon dioxide concentration in the desiccators was higher than in the case of grains with 15.4 ± 0.07% moisture content, indicating more intensive biological activity. However, after the CO_2 concentration increased to 0.38% within one week, the conditions stabilized. Higher moisture content resulted in a higher CO_2 concentration required to temporarily stabilize the state, as well as a higher overall concentration in the storage environment. A further increase in CO_2 concentration was observed only after 15 weeks from the beginning of the experiment. By week 35, the CO_2 concentration in the desiccators with grains reached 0.80%. The highest CO_2 concentration was observed in wheat with a moisture content of 20.0 ± 0.06%. Over 35 weeks, the CO_2 concentration in the desiccators increased logarithmically to 11.30%. Grain respiration was most intense during the first 17 weeks, when the CO_2 concentration increased on average by 0.42% per day, reaching 7.10% by the end of this period. Subsequently, the rate of increase slowed: from week 17 to week 30, the CO_2 concentration rose by only 3.3 percentage points, from 7.10% to 10.40%. During the final five weeks, the increase was minimal, from 10.40% (week 30) to 11.30% (week 35). This indicates the onset of a transition to a period of relative dormancy. However, a stable state during this period was not achieved. The wheat grains remained biologically active until the end of the experiment. A temperature of 4 °C was insufficient to stabilize the condition of high-moisture (20.0 ± 0.06%) wheat grains and to create a stable storage environment. Even a CO_2 concentration of 11.30% was not sufficient to slow the biological activity of wheat, which was driven by high grain moisture.

Storage at a higher temperature (12 °C) resulted in a more intensive increase in CO_2 concentration. The highest CO_2 values and the fastest growth were recorded in desiccators containing grains with a moisture content of 20.0 ± 0.06% (Fig. 6). The most intensive respiration occurred during the first 7 weeks, when the CO_2 concentration increased on average by 1.97% per day, reaching 13.80% by the end of this period. This was followed by a sharp decrease in biological activity. From week 7 to week 30, the CO_2 concentration increased by only 5.15 percentage points (to 18.95%), which is 2.68 times less than during the initial period. During the final five weeks, the CO_2 concentration slightly decreased, from 18.95% (week 30) to 18.80% (week 35). This indicates the onset of a dormancy, or stable state, period in the grain bulk.

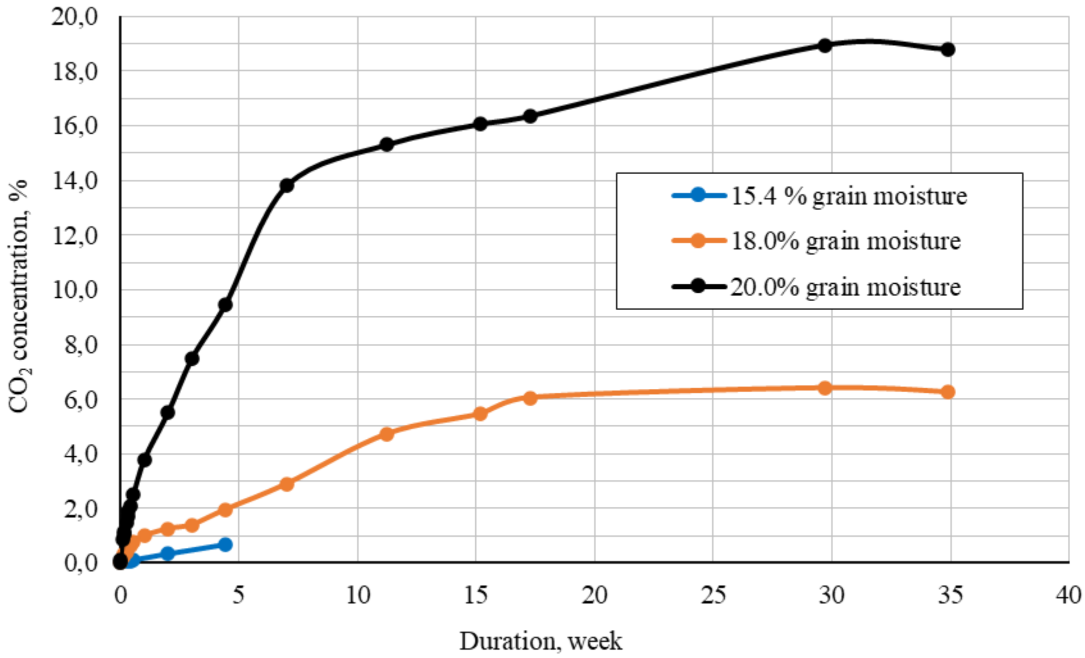


Fig. 6. Variation of carbon dioxide (CO_2) concentration during wheat storage at 12 °C temperature

The biological activity of grains with a moisture content of 18.0 ± 0.1% was lower; however, the period of intensive respiration at the beginning of storage lasted longer, up to week 15. During this period, the CO_2 concentration increased at an average rate of 0.36% per day, which is 5.47 times slower than in desiccators containing grains with 20.0 ± 0.06% moisture content. Subsequently, the increase in carbon dioxide concentration slowed significantly: CO_2 levels rose from 4.45% (week 15) to 6.4% (week 30), i.e., by 1.95 percentage points. During the final five weeks, a slight decrease in concentration to 6.25% was recorded. Thus, to stabilize the biological activity of wheat grains with 18.0 ± 0.1% moisture content, approximately three times lower CO_2 concentration was sufficient compared to grains with 20.0 ± 0.06% moisture content. A reduction in temperature to 12 °C alone was not sufficient to slow the respiration intensity of wheat grains with either 20.0 ± 0.06% or 18.0 ± 0.1% moisture content, nor to create a stable grain bulk.

Meanwhile, a temperature of 12 °C had no significant effect on the biological activity of grains with 15.4 ± 0.07% moisture content. The CO_2 concentration remained low throughout the entire experimental period and did not exceed 0.1%, indicating weak respiration intensity and low biological activity. This differed little from wheat grains stored at 4 °C. Therefore, a temperature of 12 °C was sufficient to create favorable conditions for the long-term storage of grains with 15.4 ± 0.07% moisture content under non-ventilated conditions.

4. Conclusions

1. The biological activity of wheat grains ranged from the lowest, observed in grains with a moisture content of 15.4 ± 0.07% at 4 °C (specific CO_2 emission rate – 0.0783 ± 0.00993 mg/(kg·h), generated heat flux – 0.233 ± 0.0296 W/t), to the highest, recorded in grains with a moisture content of 20.0 ± 0.06% at 12 °C (specific CO_2 emission rate – 3.07 ± 0.128 mg/(kg·h), generated heat flux – 9.13 ± 0.382 W/t).
2. It was determined that moisture content is the most important factor influencing the biological activity of wheat grains: when it increased from 15.4 ± 0.07% to 20.0 ± 0.06%, the respiration intensity of wheat increased up to 18.8 times at 4 °C and more than 21 times at 12 °C. However, the greatest change in biological activity was observed in the moisture range from 15.4% to 18.0%.
3. Increasing the temperature from 4 °C to 12 °C raised the biological activity of wheat grains by an average of 2.08 times, with the greatest effect (2.32 times) recorded for grains with a moisture content of 18.0 ± 0.1%.
4. Unlike 12 °C, a temperature of 4 °C suppressed the biological activity not only of relatively low-moiure (15.4 ± 0.07%) but also medium-moisture (18.0 ± 0.1%) wheat grains; however, it was insufficient to stabilize the condition of high-moisture (20.0 ± 0.06%) wheat.
5. In a closed storage environment, increasing carbon dioxide (CO_2) concentration suppressed the biological activity of wheat; however, the effectiveness of this effect depended on the storage temperature and, in particular, the grain moisture content.

References

[1]. Ramachandran, R. P. (2022). *Integrated approach on stored grain quality management with CO_2 monitoring*.
[2]. Kumar, D., et al (2017). Reducing postharvest losses during storage of grain crops to strengthen food security in developing countries.
[3]. Kibar, H. (2021). *CO_2 respiration rates of wheat at different temperature and moisture contents*.
[4]. Raila, A., et al. (2019). *Grūdų sandėlių ventiliacija*.
[5]. Magan, N., et al. (2011). Possible climate-change effects on mycotoxin contamination of food crops pre-and postharvest.
[6]. Walker, S., et al. (2018). Comparative effects of hermetic and traditional storage devices on maize grain: Mycotoxin development, insect infestation and grain quality.
[7]. Kiaya, V. (2014). Post-harvest losses and strategies to reduce them.
[8]. Novošinskas, H., Raila, A. (1999). *Augalininkystės produktų laikymo technologijos*.
[9]. Likhayo, P., et al. (2018). Maize grain stored in hermetic bags: Effect of moisture and pest infestation on grain quality.
[10].Mateen, M., et al. (2025). Enhancing wheat storage efficiency.