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# ENHANCING THE QUALITY AND TECHNOLOGICAL PROPERTIES OF GOOSE MEAT DURING LOW-TEMPERATURE STORAGE THROUGH THE ACTION OF BIOLOGICALLY ACTIVE SUBSTANCES FROM OATS AND ALFALFA

**Daniil Maiboroda**
*Corresponding author*
Postgraduate Student*
E-mail: group.dan@gmail.com

**Olena Danchenko**
Doctor of Agricultural Sciences*

**Viktoriya Gryshchenko**
Doctor of Veterinary Sciences
Department of Animal Biochemistry and Physilogy named after Academician M. F. Gulyi
National University of Life and Environmental Sciences of Ukraine
Heroiv Oborony str., 15, Kyiv, Ukraine, 03041

**Mykola Danchenko**
PhD
Department of Higher Mathematics and Physics**
*Department of Food Technologies and Hotel and Restaurant Management**
**Dmytro Motornyi Tavria State Agrotechnological University
Zhukovskogo str., 66, Zaporizhzhia, Ukraine, 69600

***Poultry meat plays a key role as a source of high-quality protein, vitamins, minerals, and unsaturated fatty acids. However, unsaturated fatty acids, especially essential ones, are prone to oxidative reactions during meat storage, which can negatively affect its quality. The object of the study is the technology of obtaining and storing poultry meat. Legart Danish geese were used as the experimental material. Oats (Avena Sativa) and alfalfa (Medicago sativa) contain a large number of biologically active substances (minerals, unsaturated fatty acids, amino acids, antioxidants). Adding vegetative parts of oats and alfalfa to the diet of geese contributes to improving the quality of the obtained meat, especially after prolonged low-temperature storage. The geese were slaughtered on the 63rd day. The meat was stored at a temperature of –18 °C for 90 days.***

***It was found that there was an 11.5 % increase in the live weight of the geese at an early slaughter age, an increase in protein content (by 5 %), better moisture-binding capacity (by 6–7.3 %), and a decrease in the content of lipid peroxidation products, especially on the 67th day of storage (28.3 %). There was a significant increase in the content of ω3 and ω6 polyunsaturated fatty acids (by 24.2 % and 10.8 %, respectively). There was an increase in the content of vitamin E and β-carotene, both before freezing (38.5 % and 19.6 %) and at the end of the storage period (50.9 % and 20 %). A tendency to increase the content of essential amino acids (threonine and methionine) was found. The results can be used in the production of goose meat to improve its nutritional characteristics, which is important for the health of consumers, meat producers, and also in scientific research on the development of technologies in the field of meat production and storage***

***Keywords: goose meat, bioactive compounds, oats, alfalfa, low-temperature storage, antioxidants***

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## 1. Introduction

Poultry meat is an important source of high-quality protein and vitamin-mineral complex, including iron, zinc, magnesium, sodium, potassium, phosphorus, and calcium, while having a relatively low level of fat. This makes it an important component of a balanced diet [1].

Over the past two decades, poultry meat has grown to the status of a leader in global consumption of livestock products. Analysis of market trends predicts that poultry meat consumption will continue to increase as global production, which is projected to reach 145 million tons by 2029, lags behind increased demand in many countries [2].

The COVID-19 pandemic has caused significant disruptions in the production and distribution of poultry meat, which has had serious economic consequences, both locally and internationally. Key countries that have suffered losses due to the pandemic include China, the US, Canada, the UK, Germany, Spain, Italy, France, and India, which has affected overall food availability [3]. In developing countries, the consequences of COVID-19 for poultry production have been more negative than in developed countries since poultry plays an important role in the fight against poverty and food shortages [4]. The war in Ukraine led to significant losses in the agricultural sector as a whole, including poultry farming, especially in the southeastern regions. Effective restoration of agriculture in these areas is possible taking into account the natural and human potential [5].

Goose breeding is a special type of poultry farming. Geese are an economically profitable bird, the breeding of which requires less care and simplified management. Taking into account the highlighted problems, it is advisable to introduce, expand, and develop goose farming. The development of goose farming at the national level and the increase in the export of relevant products can help solve the problem of the budget deficit in the countries of Eastern Europe [6, 7].

Thus, the improvement of goose meat production technologies, aimed at increasing its quality, especially under low-temperature storage conditions, is a relevant and promising area of research. The results of such studies have the potential to improve consumer health through higher quality food products. In addition, such innovations can significantly enhance the competitiveness of producers in the market of meat products.

## 2. Literature review and problem statement

In study [8] it is noted that the consumption of poultry meat has a multifaceted effect on human health. Poultry meat has been shown to be moderate in energy content, high-quality digestible proteins with low collagen content, unsaturated lipids, B vitamins, and minerals such as iron, zinc, and copper. Epidemiological studies in various populations have shown that the consumption of poultry meat as part of a balanced diet is associated with a reduction in the risk of overweight, obesity, cardiovascular diseases, and type 2 diabetes. This makes it a valuable food product. However, issues related to detailed analysis of waterfowl meat, particularly geese, remained unresolved.

Paper [9] reports the results of studying the fatty acid composition of goose meat depending on the age and sex of the bird. It has been shown that goose fat is characterized by a high content of unsaturated fatty acids, including oleic (C18:1 n-9), linoleic (C18:2 n-6), linolenic (C18:3 n-3), and arachidonic (C20:4 n-6) acids. These data are important from the point of view of the role of the balance of consumption of ω3- and ω6-polyunsaturated fatty acids in maintaining health, reducing the risk of developing cardiovascular diseases and diabetes. However, the cited study does not resolve issues related to changes in the fatty acid composition and oxidative deterioration of goose meat during storage.

The high content of unsaturated fatty acids in meat can cause activation of oxidative processes. In [10], it is stated that the main non-microbial cause of the deterioration of the quality of meat and meat products is lipid oxidation. It is shown that oxidation reactions not only reduce the nutritional value of meat due to the loss of essential fatty acids and vitamins but also lead to a gradual decrease in organoleptic indicators. These changes include changes in color, texture, as well as the appearance of a rancid smell and taste, which affects the perception of consumers. In addition, in the process of lipid oxidation, numerous toxic compounds are formed. The content of antioxidant compounds (vitamins, polyphenols, peptides) in meat can inhibit the development of oxidative processes to some extent.

Study [11] confirms the above patterns. It was established that the storage of goose meat in a modified atmosphere with increased oxygen content at temperatures of 1 °C and 4 °C contributes to significant changes in the composition of fatty acids. In particular, an increase in the degree of lipid oxidation and loss of nutrients was recorded. It is worth noting that the impact of the use of antioxidants on the processes of oxidative spoilage of meat was not studied within the framework of the cited study. Questions regarding changes in the fatty acid profile of goose meat during frozen storage also remain open.

The main strategy used by the meat industry to prevent lipid oxidation is the use of antioxidants. Adding these substances to meat and meat products is an effective method for inhibiting the oxidative process. Studies [12, 13] consider the use of various plants and their extracts as sources of natural antioxidants. The studies are focused on the analysis of the effectiveness of the use of these plants in the form of additives and spices to prevent oxidative spoilage of meat. According to the results, it was found that the inclusion of clove, black cumin, and allspice extracts contributed to the reduction of lipid and protein oxidation, as well as provided an increase in the microbiological stability of raw ground chicken stored at 4 °C. Horseradish contains isothiocyanates, which can also inhibit lipid peroxidation.

Another way to obtain poultry meat that is more resistant to oxidative deterioration is to modify the diet of poultry. According to study [14], the inclusion of vitamin E in the diet had a positive effect on growth performance and immune response in geese. This approach significantly increased the protein and fat content of goose meat while reducing moisture and ash content. In addition, a decrease in the content of lipid peroxide oxidation products was observed. An improvement in the ratio of polyunsaturated fatty acids (PUFAs) to saturated fatty acids (SFAs) was also noted. However, the application of vitamin E can be relatively expensive, especially for large-scale production processes.

According to research data [15, 16], oats (*Avena sativa*) are a grain crop that is an important source of natural antioxidants and is noted for its numerous nutritional, medical, and pharmaceutical benefits. Oats contain a rich set of nutrients, including proteins, fiber, calcium, vitamins (B, C, E, and K). In addition, oats contain numerous phytochemical compounds, such as flavonoids, phenolic acids, saponins, tocopherols, and avenanthramides, which are known for their pronounced antioxidant and anti-inflammatory properties. Special mention should be made of avenanthramides, unique phytochemical components that are characteristic only of oats. However, its influence on meat quality has not been sufficiently studied.

In study [17] it is noted that adding alfalfa to the diet of piglets can increase their growth productivity and improve the quality of meat. The effect of alfalfa on the amino acid profile of meat is particularly important, as it contains a significant amount of lysine and methionine [18]. However, studying the effect of alfalfa on growth performance and poultry meat quality requires additional research.

Our review of the literature reveals the need to find effective, natural, and economically beneficial methods for improving the quality and resistance of goose meat to oxidative deterioration during storage. A potential solution to this problem could be the inclusion of crops such as oats (*Avena Sativa*) and alfalfa (*Medicago sativa*) in the diet of geese, which are sources of a large number of bioactive substances, in particular antioxidants.

## 3. The aim and objectives of the study

The aim of our work is to improve the technology of goose meat storage by using oats and alfalfa in their diet. This would make it possible to provide people with high-quality meat, which could contribute to health and the fight against hidden hunger.

To achieve the goal, the following tasks are solved:

– to determine goose slaughter indicators;

– to analyze the quality indicators of meat during low-temperature storage (acidity, moisture content, protein, fat, moisture-binding capacity, loss of mass during defrosting);

– to measure biochemical parameters during low-temperature storage (content of lipid peroxidation products (LPO), vitamins E, A, and β-carotene, analysis of fatty acid and amino acid composition of meat).

## 4. The study materials and methods

The object of our research is the technology of production and storage of goose meat.

The subject of the study is the effect of adding oats and alfalfa to the diet of geese on the quality of meat and its resistance to oxidative deterioration during low-temperature storage.

The research hypothesis is as follows. The inclusion of oats and alfalfa, rich in natural antioxidants, in the diet of Legart geese will lead to the inhibition of lipid peroxidation processes in the meat. This, in turn, will reduce the content of lipid peroxidation (LPO) products and improve the fatty acid profile of the meat. It is also expected that due to the nutrition and rich content of phytonutrients in oats and alfalfa, the content of fat-soluble vitamins, essential fatty acids and amino acids in goose meat will increase.

Two groups of 5 geese each were formed for the experiment. Geese of the control group (C) received a standard diet, which included compound feed and grass mass, the basis of which was bird's bitter gourd (*Polygonum aviculare L.*). The geese of the experimental group (E) received a similar diet, but 50 % of the grass mass was replaced by oats and alfalfa in the same proportions. The addition of oats and alfalfa to the feed of the geese of the experimental group lasted from the 7th to the 62nd day. Geese were slaughtered on the 63rd day. At this stage, goose slaughter indicators were determined. After slaughtering, goose carcasses underwent a number of technological procedures: exsanguination, scalding (70–75 °C), removal of feathers, removal of internal organs, washing, portioning, and cooling (0–1 °C).

Allotments of goose meat from both groups were stored at a temperature of –18 °C for 90 days. During this period, analytical measurements were carried out to determine meat quality indicators. Among them are acidity, moisture content, protein, fat, moisture-binding capacity, loss of mass during defrosting, content of lipid products, vitamins E, A, and β-carotene, fatty acid composition, and amino acid composition. These measurements were carried out in drumstick meat.

Determination of moisture content in meat samples was carried out according to the standard method, which includes the process of drying weighed batches in cups [19].

Determination of protein content in meat was carried out by photocolorimetry [20].

Intramuscular fat content was determined by extraction with chloroform using a Soxhlet apparatus. The method of determining the moisture-binding capacity is based on the release of water from a 300 mg sample during a 10-minute pressing with a weight of 1 kg [19].

The intensity of lipid oxidation in goose meat was assessed by the amount of lipoperoxidation products reacting with 2-thiobarbituric acid (TBA) [21].

Fatty acid composition (FAC) of meat lipids was determined by gas-liquid chromatography [22, 23].

The analysis of vitamin E was carried out by the spectrophotometric method. It consists in the ability of vitamin E to reduce $Fe^{3+}$ ions to $Fe^{2+}$. The resulting $Fe^{2+}$ upon interaction with 2,2-dipyridyl forms colored compounds that can be identified and quantified [24].

Vitamin A was determined on the basis of its ability to form blue complex compounds upon interaction with boron trifluoride ester ($C_4H_{10}OBF_3$) [24].

The content of β-carotene was determined by the intensity of their color in the extract by photocolorimetry. The color intensity was measured at a wavelength of 450 nm [24].

The study of amino acids was carried out on an automatic analyzer T 339 manufactured in the Czech Republic by the method of ion exchange liquid column chromatography [25].

Statistical data processing was performed using specialized software SPSS v.17 (United States of America) and MS Office Excel-2013 (United States of America); Student's *t*-test was applied [26].

## 5. Results of research into the possibility of obtaining high-quality goose meat and preserving its properties during low-temperature storage

### 5. 1. Determining goose slaughter indicators

Our study showed that the addition of oats and alfalfa to the diet of geese contributes to an increase in live weight by 11.5 % ($p \leq 0.05$) (Table 1). In the experimental group, there was also an increase in the weight of the gutted carcass by 17.1 % compared to the control group. It was recorded that the mass of muscle tissue in the geese of the experimental group exceeded the control indicators by 18.3 %. The inclusion of oats and alfalfa in the diet led to an increase in the total mass of edible parts by 12 % ($p \leq 0.05$). In addition, a significant increase in breast and drumstick mass was noted in the geese of the study group – by 26.4 % and 24.5 %, respectively.

Table 1

Indicators of slaughter of geese ($M \pm m$, $n$=5)

| Indicator | Control group | Experimental group |
|---|---|---|
| Live weight before slaughter, g | 3697.8±81.1 | 4124.4±115.6* |
| Weight of gutted carcass, g | 2100.0±82.4 | 2458.2±97.3* |
| Yield of eviscerated carcass, % | 56.7±1.0 | 59.5±0.7 |
| Muscle mass, g | 1151.6±37.6 | 1362.2±32.7** |
| Meatiness index, % | 31.1±0.3 | 33.0±0.4* |
| Mass of edible parts, g | 1705.4±48.9 | 1910.4±58.2* |
| Index of edible parts, % | 46.1±0.4 | 46.3±0.4 |
| Breast mass | 248.6±12.3 | 314.2±7.8** |
| The weight of drumsticks | 214.0±9.3 | 266.4±9.2* |

*Note: hereafter, the difference is probable relative to the control group: * – $p \leq 0.05$; ** – $p \leq 0.01$*

These results indicate a positive effect of diet modification on goose productivity. Our data are of practical importance and may be important for improving the goose meat production technology.

**5. 2. Analysis of meat quality during low-temperature storage**

In the course of our study, a gradual decrease in the moisture content in the meat of both groups of geese was noted (Fig. 1). After a 90-day storage period, the moisture content in the meat of the control group decreased by 7.8 % ($p\leq0.01$). Similar changes were observed in the experimental group – the moisture content decreased by 7.3 % ($p\leq0.01$).

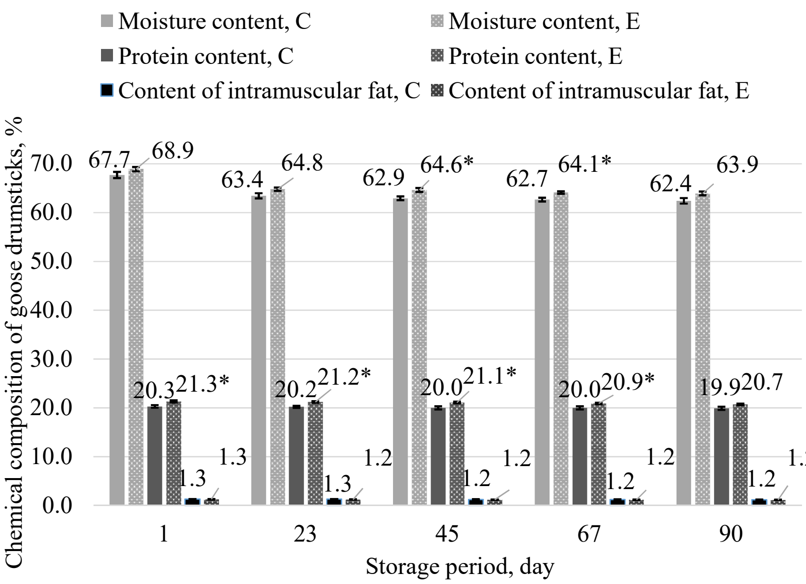


Fig. 1. Chemical composition of goose drumsticks ($M\pm m$, $n$=5)

A higher protein content by 5.0 % ($p\leq0.05$) was recorded in the meat of the experimental group compared to the control group, with the exception of the 90th day, where the difference is unreliable. The content of intramuscular fat remained stable in both groups until the end of the experiment.

During the entire period of 90-day storage, a decrease in the level of acidity of the meat was observed (Table 2). However, acidity indicators in the experimental group were almost identical to those of the control group. It was found that the moisture-binding capacity (MBC) of the meat in the control group decreased by 17.7 % after 90 days of storage at low temperatures, while a decrease of 14.4 % was observed in the experimental group. An increase in MBC in the experimental group compared to the control group was detected on the 45th and 67th day of storage (by 6.1 % and 7.3 %, respectively, $p\leq0.05$).

The study also showed that with an increase in the storage period, there is an increase in the loss of meat mass during defrosting. However, in the experimental group, these losses were lower throughout the entire storage period compared to the control group. The biggest difference was recorded on the 45th day of storage, where the weight loss in the experimental group was 8.3 % lower ($p\leq0.05$).

**5. 3. Measurement of biochemical indicators during low-temperature storage**

Analysis of the dynamics of secondary lipid products shows that in the goose meat of the control group, this indicator remained at a constant level during the first 23 days of meat storage (Fig. 2). From the 23rd day, the activation of peroxide oxidation processes in this sample began, and by the 45th day, the content of LPO products by 18.3 %. From the 45th day to the 67th day, there is also an increase in the content of LPO products by 38.7 %. Then, until the end of the storage period, the content of LPO products in the meat of the control group remains at a constant level.

The meat of the experimental group was characterized by a lower content of lipid products at the beginning of the storage period (8.9 %, $p\leq0.05$). In addition, a prolongation of the state of pro-oxidant-antioxidant balance is observed in it since the accumulation of lipid products occurred more slowly than in the samples of the control group. On the 45th day of low-temperature storage, the difference in the content of LPO products in the meat of the control and experimental groups was 13.9 % ($p\leq0.01$). On the 67th day of storage, the difference in this indicator was already 28.3 % ($p\leq0.01$). However, at the end of the experiment, the rate of LPO processes in experimental meat samples increases, and from the 67th day to the end of the experiment, the content of LPO products increases by 35.8 % ($p\leq0.01$).

The fatty acid composition of the meat (FAC) of the geese in the research group also changed (Table 3). The analysis of FAC of lipids of goose meat after poultry slaughter shows that the addition of oats and alfalfa to the diet contributed to a decrease in the content of oleic acid by 9.7 % ($p\leq0.05$). At the same time, the content of essential polyunsaturated acids, namely linoleic and linolenic acids, increased by 19.1 % and 32.0 %, respectively ($p\leq0.01$). The content of ω3-docosahexaenoic acid also increased significantly (by 20.6 %). The total content of ω3- and ω6-polyunsaturated fatty acids in the meat of the experimental sample increased by 24.2 % ($p\leq0.01$) and 10.8 % ($p\leq0.05$), respectively.

Table 2

Indicators of the studied geese drumsticks ($M\pm m$, $n$=5)

| Storage period, day | pH | | Weight loss during defrosting, % | | MBC, % | |
|---|---|---|---|---|---|---|
| | Control | Experiment | Control | Experiment | Control | Experiment |
| 1 | 6.15±0.01 | 6.14±0.01 | – | – | 91.4±1.01 | 93.2±1.10 |
| 23 | 6.14±0.01 | 6.14±0.01 | 2.74±0.08 | 2.54±0.07 | 81.0±1.43 | 85.8±0.59* |
| 45 | 6.12±0.01 | 6.13±0.01 | 3.09±0.05 | 2.83±0.07* | 77.5±1.05 | 82.2±0.63* |
| 67 | 6.12±0.01 | 6.13±0.01 | 3.14±0.05 | 2.92±0.05* | 75.0±1.40 | 80.5±0.84* |
| 90 | 6.11±0.01 | 6.12±0.01 | 3.28±0.05 | 3.05±0.07* | 75.2±1.61 | 79.8±1.34 |

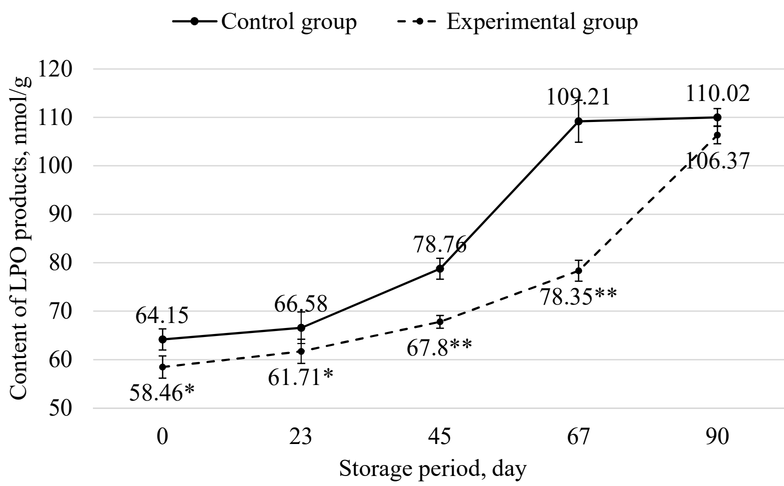


Fig. 2. Dynamics of the content of end products of lipid oxidation in goose meat during storage (*M*±*m*, *n*=5)

Table 3

Dynamics of the content (ω, %) of fatty acids in goose meat of the control and experimental groups during storage (*M*±*m*, *n*=3)

| Fatty acid | Storage period, day | | | |
|---|---|---|---|---|
| | 1 | | 90 | |
| | Control | Experiment | Control | Experiment |
| (16:0) | 21.78±0.72 | 21.91±0.9 | 20.66±0.81 | 20.86±0.73 |
| (18:0) | 14.3±0.4 | 14.97±0.66 | 15.73±0.77 | 13.43±0.48** |
| (18:1) | 35.39±1.34 | 31.96±1.05* | 32.87±1.02 | 33.68±0.98 |
| (18:2) ω6 | 13.95±0.5 | 16.61±0.6** | 17.1±0.75 | 17.94±0.77 |
| (18:3) ω3 | 0.26±0.01 | 0.34±0.01** | 0.35±0.01 | 0.47±0.02** |
| (20:4) ω6 | 8.1±0.32 | 7.81±0.22 | 6.9±0.28 | 6.49±0.19 |
| (22:6) ω3 | 0.55±0.02 | 0.66±0.03** | 0.62±0.02 | 0.96±0.04** |
| SFA | 38.57±1.21 | 39.65±1.66 | 39.11±1.38 | 36.64±1.29 |
| UFA | 61.05±2.31 | 59.78±1.99 | 60.52±2.18 | 62.77±2.12 |
| MUFA | 37.9±1.45 | 33.95±1.12 | 35.02±1.1 | 36.05±1.05 |
| PUFA | 23.15±0.87 | 25.84±0.87* | 25.49±1.08 | 26.72±1.07 |
| ω3PUFA | 0.81±0.03 | 1.01±0.04** | 0.97±0.03 | 1.42±0.06** |
| ω6ПУФА | 22.05±0.83 | 24.42±0.82* | 24±1.03 | 24.73±0.98 |

After 90 days of low-temperature storage, in the meat of the control sample the content of linoleic and linolenic acids increased by 22.6 % ($p \leq 0.01$) and 34.6 %, respectively. A decrease in the content of arachidonic acid by 14.8 % was established ($p \leq 0.01$). In the test sample of meat, the content of ω3-PUFA (linolenic and docosahexaenoic) is higher than the corresponding reference indicators by 32.3 % and 53.8 %, respectively. Tendencies toward a decrease in the content of saturated fatty acids and an increase in the content of polyunsaturated fatty acids were established. The total number of ω3-PUFAs in the experimental group is 46.4 % higher than in the control group.

A comparative analysis of the content of fat-soluble vitamins (Fig. 3) in the meat of geese of the control and experimental groups proves the positive effect of the admixture of oats with alfalfa on the content of vitamin E and β-carotene. There was an increase in the content of vitamin E in the goose meat in the experimental group by 38.5 % and β-carotene by 19.6 % ($p \leq 0.01$).

After 90 days of low-temperature storage, the amount of vitamin A and β-carotene in the meat of geese in the control group decreased by 33.6% and 64.2 %, respectively. The loss of vitamin E in the control sample during storage was 12.3 % ($p \leq 0.05$).

In the meat of the experimental sample on the 90th day of storage, the content of vitamin E is 50.9 % higher than the corresponding indicator of the control group of geese. A 20 % higher content of β-carotene in the experimental sample was also recorded ($p \leq 0.01$).

The addition of oats and alfalfa to the diet of geese had no significant effect on the content of vitamin A in meat.

Changes in the amino acid profile of goose meat under the influence of the established diet and low-temperature storage were studied (Table 4). In the meat of the experimental group, there is a tendency to increase the content of essential amino acids compared to the control group, both after slaughtering the poultry and on the 90th day of meat storage. The most noticeable changes occurred in the content of threonine and methionine, these indicators in the meat of the experimental group increased by 26 % and 22.8 % ($p \leq 0.01$) relative to the control sample, respectively.

During the 90-day period of low-temperature storage, a decrease in threonine and methionine content was observed in both meat samples. In addition, a decrease in the content of phenylalanine was found in the experimental sample. Nevertheless, an increase in valine content was noted in both groups, and isoleucine in the experimental group as well. On the 90th day of storage, a higher content of several essential amino acids was registered in the meat of the experimental group compared to the control group. Among them, lysine (by 13.4 %, $p \leq 0.05$), valiu (by 23.7 %), isoleucine (by 26.3 %), leucine (by 17.7 %, $p \leq 0.05$). At the same time, a decrease in the content of threonine by 21 % and phenylalanine by 49 % was established.

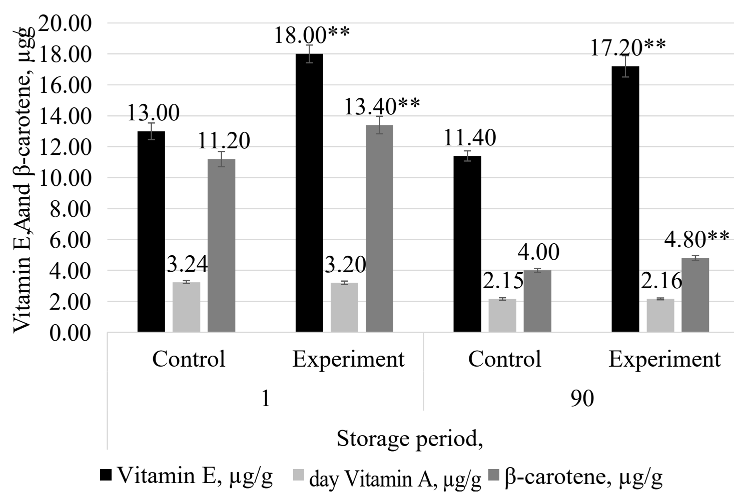


Fig 3. Dynamics of the content of vitamin E, vitamin A, and β-carotene (μg/g) in the meat of geese in the control and experimental groups during storage (M±m, n=3)

Table 4

Dynamics of the content of amino acids (mg/100 g) in goose meat of the control and experimental groups during storage ($M\pm m$, $n$=3)

| Amino acid | Storage period, day | | | |
|---|---|---|---|---|
| | 1 | | 90 | |
| | Control | Experiment | Control | Experiment |
| Lysine | 2.00±0.1 | 2.09±0.1 | 2.11±0.11 | 2.39±0.12** |
| Histidine | 0.56±0.03 | 0.62±0.03* | 0.31±0.02 | 0.25±0.01** |
| Arginine | 1.59±0.08 | 1.61±0.08 | 1.26±0.06 | 1.22±0.06 |
| O-proline | 1.31±0.07 | 0.99±0.05** | 0.88±0.04 | 0.58±0.03** |
| Asp. acid. | 1.11±0.06 | 1.21±0.06* | 1.63±0.08 | 1.41±0.07* |
| Threonine | 0.72±0.04 | 0.91±0.05** | 0.26±0.01 | 0.21±0.01** |
| Serin | 0.64±0.03 | 0.79±0.04** | 0.39±0.02 | 0.32±0.02** |
| Glut acid. | 2.94±0.15 | 3.17±0.16 | 3.56±0.18 | 3.54±0.18 |
| Proline | 0.94±0.05 | 0.81±0.04* | 0.84±0.04 | 1.00±0.05** |
| Glycine | 0.90±0.04 | 0.98±0.05* | 1.03±0.05 | 1.16±0.06* |
| Alanine | 1.19±0.06 | 1.29±0.06 | 1.67±0.08 | 1.76±0.09 |
| Cystin | 0.46±0.02 | 0.51±0.03* | 0.33±0.02 | 0.32±0.02 |
| Valin | 0.83±0.04 | 0.91±0.05* | 0.98±0.05 | 1.22±0.06** |
| Methionine | 0.29±0.01 | 0.35±0.02** | 0.16±0.01 | 0.15±0.01 |
| Isoleucine | 1.08±0.05 | 1.10±0.06 | 1.11±0.06 | 1.40 ±0.07** |
| Leucine | 1.89±0.09 | 1.94±0.1 | 2.14±0.11 | 2.52±0.13** |
| Tyrosine | 0.48±0.02 | 0.61±0.03** | 0.35±0.02 | 0.27±0.01** |
| Phenylalanine | 0.90±0.05 | 0.91±0.05 | 0.91±0.05 | 0.46±0.02** |

## 6. Discussion of results of investigating the possibility of improving the quality of goose meat during its low-temperature storage

The increase in live weight by 11.5 % ($p\leq0.05$) and the weight of gutted carcass by 17.1 % (Table 1) can be explained by the fact that phenolic compounds, which are contained in such plants as oats and alfalfa, can increase the efficiency animal growth. This is possible by increasing the secretion of digestive enzymes, reducing the number of pathogenic bacteria in the gastrointestinal tract, and modulating the morphology of the intestines. This contributes to a better assimilation of nutrients and, as a result, an increase in the body weight of animals [27].

The gradual decrease in moisture content by 7.3 % ($p\leq0.01$) in the meat of the experimental group during low-temperature storage (Fig. 1) may be associated with the processes of ice crystal formation in the extracellular spaces and changes in the concentration of dissolved substances in the unfrozen water. These processes can cause degradation and oxidation of proteins, which negatively affects the ability of meat to retain water. Freezing also causes denaturation of myofibrillar proteins (MFPs), including changes in their secondary and tertiary structure through cold denaturation. Cellular enzymes are also released, which accelerates the processes of degradation and oxidation of proteins [28].

Alfalfa, which is rich in protein and amino acids, increases the protein content in the muscles of geese by 5.0 % ($p\leq0.05$). A study on geese showed that the use of alfalfa silage enriches the diet with amino acids and biologically active substances. It can improve metabolic processes, promote digestion and assimilation of nutrients, reduce fat deposition, and increase the content of muscle tissue [29].

Increased MBC on the 45th and 67th days of storage (by 6.1 % and 7.3 %, respectively, $p\leq0.05$) (Table 2) may be associated with a higher content of hydrophilic proteins in the meat, which play a key role in water retention. These proteins, in particular myosin and other sarcoplasmic components, are critically important for water retention in meat tissues. The increased moisture-binding capacity of meat contributes to the reduction of water loss during cryopreservation and subsequent thawing. During freezing, the water in the meat turns into ice crystals, which can induce mechanical damage to the meat fibers, contributing to dehydration during thawing. However, with a higher moisture-binding capacity, structural damage to meat fibers is minimized, which in turn leads to a reduction in water loss and meat mass during defrosting.

At the beginning of storage, the content of lipid products in the meat of the experimental group (Fig. 2) was 8.9 % lower ($p\leq0.05$), which indicates increased antioxidant activity. By the 45th day of storage, the difference in the content of LPO products between the control and experimental groups increased to 13.9 % ($p\leq0.01$), and by the 67$^{th}$ day – to 28.3 % ($p\leq0.01$). The admixture of grass mass of oats and alfalfa to the ration of geese contributes to the extension of the terms of stabilization of peroxide oxidation processes during meat storage [30]. It is known that the antioxidant potential and quality of nutrients that enter the animal's body is determined by the composition of the diet and the bioavailability of BAR [31]. Changes in the dynamics of the final products of peroxide oxidation in the meat of the experimental sample certainly occurred with the participation of avenanthramides, polyphenols, flavonoids, and BAR of oats and alfalfa in the geese's diet. This, in turn, affects the biochemical composition and biological value of meat [31]. Established changes in the dynamics of lipid products indicate that the admixture of oats and alfalfa to the diet of geese has a positive effect on the stability of the lipid component of meat throughout its storage period [32].

Changes in the fatty acid composition of the meat in the experimental sample (Table 3) are probably related to the action of compounds that have antioxidant properties [10] because oats contain a large number of antioxidants, including β-glucan, avenanthramides, polyphenols, flavonoids, and β-carotene. These antioxidants can effectively inhibit the oxidation of meat lipids, which contributes to the preservation of unsaturated fatty acids [15].

Also, the significant content of linoleic and linolenic acids in oats and alfalfa can be the cause of changes in dietary fiber [15]. These acids can be directly assimilated by the body of geese, which caused changes in the fatty acid composition of lipids in their meat [33]. The increase in the content of ω3-PUFA in goose meat during low-temperature storage indicates the preservation of a certain activity of the corresponding desaturases [34].

Changing the fatty acid composition in the direction of increasing the content of polyunsaturated fatty acids is a desirable phenomenon since these fatty acids are known for their positive effect on human health. Such changes are particularly important in view of the need to maintain a balanced intake of ω3- and ω6-fatty acids for a healthy diet [35].

An increase in the content of vitamin E in the meat of geese in the experimental group by 38.5 % and β-carotene by 19.6 % ($p\leq0.01$) (Fig. 3) may be due to the high content of these substances in oats, which could be incorporated into the bird's body [15]. The higher content of vitamin E and β-carotene on the 90th day of storage (by 50.9 % and 20 %, respectively) may be associated with the inhibition of oxidative processes in meat due to the action of bioactive oat compounds with antioxidant properties, in particular avenanthramides [36]. The main reason for the loss of β-carotene during storage is enzymatic and non-enzymatic oxidation [37]. The decrease of vitamin E during the storage period may be due to its antioxidant properties, the ability to inhibit the oxidation of lipids in meat [15]. However, its insignificant losses are evidence of the implementation of other mechanisms of antioxidant protection in the meat of the control sample.

The reason for the increase in threonine and methionine content by 26 % and 22.8 % ($p\leq0.01$) (Table 4), respectively, may be the admixture of oats and alfalfa in the geese's diet. The addition of alfalfa was found to increase protein content, reduce cholesterol and fat content, and improve the antioxidant status of chicken meat [38]. Oats contain high levels of threonine, methionine, and other essential amino acids, which may also contribute to their increase in goose meat [39].

Among the limitations of this study, it should be highlighted that it is relevant mainly to the Danish Legart goose breed, as the obtained results may not be fully transferable to other breeds. Also, it is necessary to take into account that the influence of the diet on the quality of meat during low-temperature storage may be limited and requires additional study. The main drawback is the limited sample size, which complicates the statistical significance of the results. In addition, the gender characteristics of the bird were not taken into account. Future development of this study may include expanding the measured parameters for a more complete understanding of the effect of diet on meat quality. It is also important to analyze changes in meat quality during longer storage to understand the long-term effects. Taking into account gender characteristics will make it possible to interpret the results more accurately. In addition, expanding the research to other breeds of geese will allow us to draw conclusions about the possibility of using the proposed technology for the production of a wider range of poultry meat.

## 7. Conclusions

1. It was established that the inclusion of oats and alfalfa in the diet of geese ensured a significant increase in live weight by 11.5 % ($p\leq0.05$) and the weight of gutted carcass by 17.1 %. There is also an increase in the mass of muscle tissue (by 18.3 %), the total mass of edible parts (by 12 %, $p\leq0.05$), an increase in the mass of the breast and drumsticks (by 26.4 % and 24.5 %, respectively. Such results indicate the potential of using oats and alfalfa as functional ingredients in the diet of poultry, which can contribute to the improvement of meat quality and its biochemical properties.

2. Meat analysis showed an increase in protein content by 5.0 % ($p\leq0.05$) in the experimental group during the storage period. However, on the 90th day of storage, the difference in protein content did not reach statistical significance. The moisture-binding capacity (MBC) of meat in the control group decreased by 17.7 % after 90 days of low-temperature storage, while in the experimental group this decrease was 14.4 %. A statistically significant difference of MBC in the experimental group was recorded on the $45^{th}$ and $67^{th}$ day of storage – the indicator was higher by 6.1 % and 7.3 %, respectively ($p\leq0.05$). Losses of meat mass during the defrosting process increased in proportion to the duration of storage in both studied groups. However, these losses in the meat of the experimental group were lower. The maximum difference with the control group was recorded on the $45^{th}$ day of storage (8.3 %, $p\leq0.05$).

3. In the goose meat of the experimental group at the beginning of storage, the content of LPO products was 8.9 % lower ($p\leq0.05$), which indicates increased antioxidant activity. By the $45^{th}$ day of storage, the difference in the content of LPO products between the control and experimental groups increased to 13.9 % ($p\leq0.01$), and by the $67^{th}$ day – to 28.3 % ($p\leq0.01$). This indicates the possibility of including oats and alfalfa in the diet of geese in order to prolong the state of the pro-oxidant-antioxidant balance of goose meat during long-term low-temperature storage.

The use of oats and alfalfa increased the content of polyunsaturated acids: linoleic by 19.1 %, linolenic by 32.0 %, docosahexaenoic acid by 20.6 %. The total content of ω3- and ω6-PUFA increased by 24.2 % and 10.8 %, respectively. After 90 days of low-temperature storage, samples in the experimental group showed a higher content of linolenic and docosahexaenoic acids by 32.3 % and 53.8 % compared to the control. The total amount of ω3-PUFA in the experimental group exceeded the control group by 46.4 %.

The meat of the study group is characterized by a higher content of vitamin E and β-carotene (by 38.5 % and 19.6 %, respectively). After 90 days of low-temperature storage, the content of vitamin E in the meat of the experimental group was higher by 50.9 %, and β-carotene by 20 % ($p\leq0.01$), compared to the control group.

A higher content of threonine and methionine was recorded in the meat of the experimental group at the beginning of storage (by 26 % and 22.8 %, respectively). At the end of the storage period, the meat of the experimental group was characterized by a higher content of lysine (by 13.4 %), valine (by 23.7 %), isoleucine (by 26.3 %), and leucine (by 17.7 %). However, the content of threonine and phenylalanine was lower by 21 % and 49 %, respectively.

## Conflicts of interest

The authors declare that they have no conflicts of interest in relation to the current study, including financial, personal, authorship, or any other, that could affect the study and the results reported in this paper.

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## Data availability

The manuscript has associated data in the data warehouse.

## Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the current work.

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