CHAPTER 7

Optimization of goose meat quality through oat and alfalfa-based feed additives

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Abstract

This article presents the results of a study dedicated to examining the effects of incorporating vegetative parts of oats (*Avena sativa L.*) and alfalfa (*Medicago sativa L.*) into the diet of Legard Danish breed geese on the physico-chemical, biochemical, and nutritional properties of the meat, particularly its oxidative stability, fatty acid, and amino acid composition. Two groups of geese were formed for the experiment. The control group received a standard diet consisting of compound feed and green mass dominated by knotweed (*Polygonum aviculare L.*). In the experimental group, 50% of the green mass was replaced with a mixture of vegetative parts of oats and alfalfa in equal proportions. Goose meat was stored for 90 days at a temperature of −18°C.

The research findings indicate that feeding oats and alfalfa had a positive impact on the technological properties of the meat. In particular, the experimental group showed improved water-holding capacity and reduced weight loss during thawing, directly related to better water retention in muscle fibers. These indicators are important for both consumer attributes and industrial meat processing. Special attention was given to evaluating the intensity of lipid peroxidation. It was found that the meat of the experimental group had a lower level of primary lipid peroxidation products on the 45th day of storage. This trend indicates the inhibition of oxidative processes under the influence of phytonutrients, particularly avenanthramides, oxylipins, and polyphenols present in oats and alfalfa. An increase in vitamin E and β-carotene content was observed throughout the storage period, suggesting the ability of bioactive feed components to be deposited in poultry tissues and preserved even during long-term low-temperature storage. The fatty acid composition of the goose meat from the experimental group was enriched with mono- and

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polyunsaturated fatty acids. An increase in oleic acid content was noted in the experimental group on the 90th day. Optimization of the ω-6/ω-3 polyunsaturated fatty acid ratio was also established, which is a positive trait in terms of food safety and product functionality. The amino acid profile of the meat from the experimental group showed an increase in essential amino acids such as leucine, isoleucine, and phenylalanine. These changes indicate an increase in the biological value of muscle protein, which is significant for rational human nutrition.

Keywords

Geese, meat, alfalfa, oats, antioxidants, fatty acids, amino acids, vitamins, lipid peroxidation, meat quality.

7.1 Modern approaches to improving goose meat quality using natural-origin strategies

Poultry meat, particularly that of waterfowl, is considered one of the most valuable components of human nutrition due to its high nutrient density, biologically complete proteins, optimal content of vitamins and minerals, and relatively low-fat content. Among the key micronutrients found in meat are iron, zinc, phosphorus, potassium, magnesium, calcium, sodium, and others, which makes this product an essential element of the diet in the context of growing nutritional imbalance [1].

Over the past decades, there has been a steady increase in global demand for poultry meat. According to analytical reports, global production of this commodity is projected to exceed 145 million tons by 2029, driven not only by its nutritional value but also by its economic affordability [2]. At the same time, external challenges – such as the COVID-19 pandemic, disruptions in supply chains, and armed conflicts, particularly the war in Ukraine – have adversely affected the stability of agri-food production in general and the poultry sector in particular [3]. These developments have underscored the need for effective recovery of the industry based on locally available resources adapted to current realities.

Goose farming, as a segment of the poultry industry, possesses considerable potential in the context of expanding meat production and diversifying meat products. Geese demonstrate a high efficiency in utilizing pasture-based feed, exhibit strong resilience, and require relatively low rearing costs, making them particularly attractive for small and medium-sized farming enterprises. The development of goose farming may also serve as a component of food security strategies in regions with limited capacity for intensive agricultural production.

Despite the high nutritional value of goose meat, the issue of its stability during storage remains unresolved. It is well established that goose meat contains elevated levels of unsaturated fatty acids – particularly linoleic (C18:2 n-6), linolenic (C18:3 n-3), oleic (C18:1 n-9), and arachidonic (C20:4 n-6) acids – which are susceptible to oxidative degradation during prolonged storage [4]. This deterioration negatively affects both the organoleptic properties of the product (color, odor, taste, texture) and its biological value and safety for consumers [5]. Lipid oxidation, as a non-microbial form of spoilage, is considered the primary factor contributing to the decline in meat quality under low-temperature storage conditions [6].

Currently, two primary strategies are employed to enhance the antioxidant stability of meat: the use of exogenous antioxidants (as additives to raw meat) and the modification of poultry diets through the inclusion of natural sources of bioactive compounds. While the incorporation of plant and spice extracts – such as clove, cumin, and ginger – has proven effective [7], the use of natural feed-based ingredients is considered more economically viable and technologically feasible under commercial production conditions.

According to the literature, promising natural dietary components include oat (*Avena sativa*) and alfalfa (*Medicago sativa*). These plants are rich in antioxidant phytochemicals such as avenanthramides, tocopherols, and phenolic acids, and are notable for their high content of dietary fiber, proteins, and essential amino acids [8, 9]. However, their use as feed ingredients for waterfowl, particularly geese, remains insufficiently studied in terms of their impact on meat quality during storage.

In the context of current challenges related to food security, the search for biologically sound methods to extend the shelf life of meat products and improve their nutritional quality, studies aimed at evaluating the effects of oat and alfalfa on goose meat parameters are of considerable scientific and practical significance.

The aim of this study is to enhance the quality characteristics of goose meat and ensure their stability during long-term frozen storage by enriching the birds' diet with vegetative parts of oat (*Avena sativa*) and alfalfa (*Medicago sativa*).

To achieve the stated objective, the following tasks were defined:

– to determine the main slaughter parameters of geese in the control and experimental groups;

– to analyze the physicochemical properties of meat during 90-day low-temperature storage;

– to assess biochemical indicators that characterize the stability of meat raw material during storage.

7.2 Materials and methods of the study

The research hypothesis was as follows: the inclusion of feed components enriched with natural antioxidants – specifically, oat and alfalfa – into the diet of Legart Danish geese would inhibit lipid peroxidation processes in meat. This intervention is expected to lead to a reduction in the concentration of lipid peroxidation products (LPO) and an improvement in the fatty acid profile. Furthermore, due to the high nutritional value and phytochemical composition of these feed additives, an increase in the content of fat-soluble vitamins, as well as essential fatty acids and amino acids, in goose meat is anticipated.

Within the framework of the experiment, two groups of geese, each consisting of five birds, were formed. The control group (C) received a standard diet based on compound feed and green forage, primarily composed of knotgrass (*Polygonum aviculare L.*). In the experimental group (E), 50% of the green forage was replaced with a mixture of oat and alfalfa in equal proportions. This dietary modification was applied from day 7 to day 62 of rearing. Slaughter was performed on day 63, after which the slaughter performance indicators were evaluated.

After slaughter, the goose carcasses underwent a standard technological process, which included exsanguination, thermal treatment (scalding at 70–75°C), feather and viscera removal, washing, portioning, and chilling at a temperature of 0–1°C.

Subsequently, the meat from both groups was stored for 90 days at a temperature of –18°C. During this storage period, analytical assessments were conducted to evaluate key quality parameters, including: pH (acidity), moisture content, protein and fat levels, water-holding capacity, thawing loss, levels of lipid peroxidation products (LPO), concentrations of vitamins E, A, and β-carotene, as well as the amino acid and fatty acid profiles. All measurements were carried out on samples of breast meat.

Moisture content in the meat was determined by drying weighed samples in drying dishes.

Protein content was analyzed using a photocolorimetric method [10].

The amount of intramuscular fat was assessed by extraction using a Soxhlet apparatus with chloroform as the solvent. Water-holding capacity (WHC) was evaluated based on the amount of water released from a 300 mg sample during 10 minutes of pressing under a 1 kg load [11].

Lipid oxidation processes in the meat were evaluated by determining substances reactive with 2-thiobarbituric acid (thiobarbituric acid reactive substances, TBARS) [11].

The fatty acid composition was analyzed using gas-liquid chromatography [12].

Vitamin E was determined spectrophotometrically based on its ability to reduce Fe^{3+} to Fe^{2+}, which forms colored complexes with 2.2′-dipyridyl [13].

Vitamin A content was measured based on the formation of a blue complex with boron trifluoride ($C_4H_{10}OBF_3$) [13].

β-carotene was quantified using a photocolorimetric method by measuring its intrinsic absorbance at 450 nm [13].

Amino acid composition was determined using ion-exchange liquid-column chromatography with an automatic amino acid analyzer T 339 (Czech Republic) [14].

Data analysis was performed using SPSS software version 17 (USA) and Microsoft Excel 2013 (USA), applying Student's t-test for statistical evaluation [15].

7.3 Results and discussion

The study revealed a gradual decrease in moisture content in the breast meat of both the control and experimental groups over the 90-day storage period (**Fig. 7.1**). The total reduction in moisture content amounted to 8% ($p \leq 0.01$) in the control group and 7.3% ($p \leq 0.01$) in the experimental group. Beginning from day 45 of storage, the breast meat of the geese in the experimental group exhibited a statistically significantly higher moisture level compared to the control group ($p \leq 0.05$), indicating an improved ability of the muscle tissue to retain moisture under freezing conditions.

During the first 45 days of storage, the breast meat of geese in the experimental group exhibited a higher protein content compared to the control group: specifically, by 5.3% on day 1 ($p \leq 0.05$), 5.2% on day 23 ($p \leq 0.05$), and 5.7% on day 45 ($p \leq 0.05$). This effect may be attributed to the high content of readily digestible proteins in alfalfa and oat, which promotes the accumulation of structural proteins in muscle tissue. Studies on geese have demonstrated that the inclusion of alfalfa silage in the diet enriches the feed with amino acids and biologically active compounds. This contributes to improved metabolic activity, enhanced digestion and nutrient absorption, reduced fat deposition, and increased muscle mass gain [16].

The intramuscular fat content remained relatively stable throughout the entire storage period in both groups, indicating that the inclusion of oat and alfalfa in the diet did not negatively affect the intramuscular fat levels in goose meat. Hwang et al. reported similar findings, where intensive feeding with alfalfa did not result in significant changes in fat content in goat meat [17].

Throughout the 90-day storage period, the pH level of goose breast meat remained stable in both groups (**Table 7.1**). The differences between the control and experimental groups were not statistically significant, indicating that dietary

modifications had no notable effect on the acid-base status of muscle tissue. The recorded pH values were within the physiological range typical for waterfowl meat. Maintaining a normal pH level is critical for meat quality, as excessively low pH may lead to the development of PSE (pale, soft, exudative) defects, which are associated with increased moisture loss and diminished product quality [18].

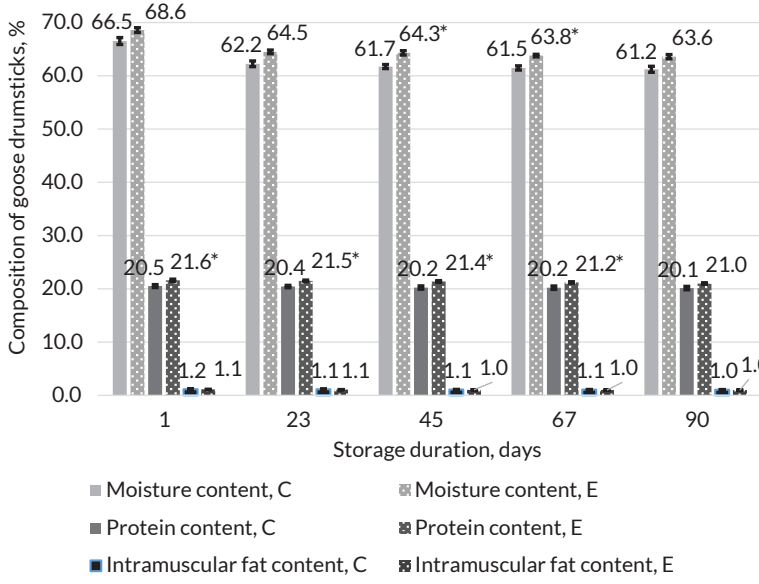

Fig. 7.1 Chemical composition of goose breast meat ($M \pm m$, $n = 5$)
*Note: here and below, differences are statistically significant relative to the control group: * $p \leq 0.05$; ** $p \leq 0.01$*

Table 7.1 Physicochemical parameters of the studied goose breast samples ($M \pm m$, $n = 5$)

Storage duration, days	pH		Thawing loss, %		WHC, %	
	C	E	C	E	C	E
1	6.3 ± 0.01	6.32 ± 0.01	–	–	87.6 ± 1.07	92.2 ± 1.11
23	6.29 ± 0.01	6.32 ± 0.01	2.41 ± 0.08	2.13 ± 0.07*	76.8 ± 1.49	84.7 ± 0.6
45	6.27 ± 0.01	6.31 ± 0.01	2.76 ± 0.05	2.42 ± 0.07*	73.1 ± 1.09	81.1 ± 0.64*
67	6.27 ± 0.01	6.31 ± 0.01	2.81 ± 0.05	2.51 ± 0.05*	70.6 ± 1.46	79.3 ± 0.85*
90	6.26 ± 0.01	6.3 ± 0.01	2.95 ± 0.05	2.64 ± 0.07	70.8 ± 1.68	78.6 ± 1.36*

Throughout the entire storage period, thawing losses increased progressively; however, the values of this parameter consistently remained statistically lower in the experimental group. The most pronounced difference was recorded on day 45 of storage, when moisture loss in the experimental group was 12.3% lower ($p \leq 0.05$), indicating superior structural integrity of the muscle tissue. This effect may be attributed to the influence of phytonutrients present in oat and alfalfa, which positively affect muscle structure and contribute to improved moisture retention.

The water-holding capacity was consistently higher in the experimental group throughout the entire study period. From day 23 onward, a gradual decline in WHC was observed in both groups; however, the values remained higher in the experimental group. The greatest difference was recorded on day 67 of storage, reaching 12.4% ($p \leq 0.05$). This indicates superior hydration capacity in the meat of geese fed a diet supplemented with oat and alfalfa. Improved water-holding capacity contributes to reduced water loss during cryopreservation and subsequent thawing. During freezing, water within the meat crystallizes, which can cause mechanical damage to muscle structures and promote dehydration upon thawing. However, when WHC is maintained at a high level, the structural integrity of muscle fibers is better preserved, minimizing moisture and mass losses in the final product after defrosting.

The study established that, throughout the entire storage period, a gradual accumulation of end products of lipid peroxidation was observed in the meat of both goose groups (**Fig. 7.2**). However, the intensity of this process differed significantly between the control and experimental samples.

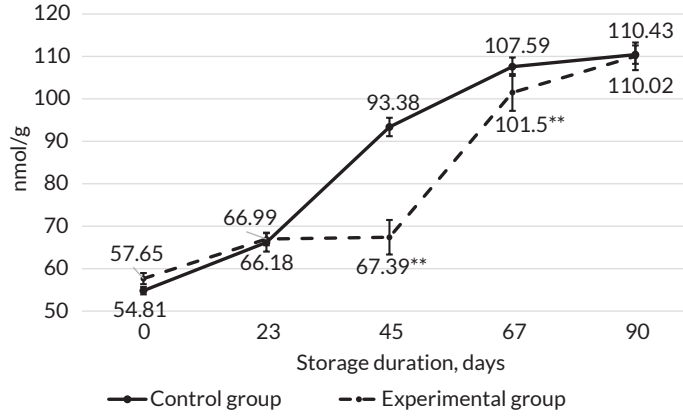

Fig. 7.2 Dynamics of end-products accumulation from lipid peroxidation in goose breast meat during storage ($M \pm m$, $n = 5$)

In the meat of the control group, the concentration of lipid peroxidation end products increased rather intensively. The most pronounced rise was observed between days 23 and 45, with an increase of 41.1%, followed by a further 15.2% increase between days 45 and 67 ($p \leq 0.01$). During the remainder of the storage period, the level of lipid peroxidation products in the control group remained relatively stable.

At the beginning of storage and up to day 23, the level of lipid peroxidation products in the meat of the experimental group did not differ significantly from that of the control group. However, the subsequent dynamics showed a noticeable slowdown in the accumulation of secondary oxidation products, which may indicate activation of antioxidant defense mechanisms within the tissues. The most pronounced difference between groups was observed on day 45 of storage, when the concentration of lipid peroxidation products in the experimental group was 27.8% lower than in the control samples ($p \leq 0.01$). This suggests stabilization of oxidative processes and prolonged maintenance of the prooxidant–antioxidant balance. From day 45 to day 67, an increase in peroxidative activity was noted in the meat of the experimental group, with LPO product levels rising by 50.6% ($p \leq 0.01$). By the end of the storage period, LPO levels in both groups had nearly equalized, indicating a gradual depletion of the antioxidant capacity in the tissues of the experimental group.

The results obtained indicate that the inclusion of oat and alfalfa in the diet of geese contributes to the prolongation of the stabilization phase of the prooxidant-antioxidant balance during meat storage [19]. This effect may be attributed to the high content of natural antioxidants in oat and alfalfa, such as phenolic compounds, tocopherols, and carotenoids, which are capable of neutralizing free radicals and slowing down lipid oxidation processes [20]. It has been established that the antioxidant activity and the qualitative composition of nutrients entering the animal's body largely depend on the formulation of the feed ration and the bioavailability of biologically active substances (BAS) [21]. The observed changes in the dynamics of lipid peroxidation end products in the meat of experimental animals are likely associated with the presence of avenanthramides, polyphenolic compounds, flavonoids, and other BAS, which were introduced into the organism through oat- and alfalfa-based feeds. These compounds have a direct influence on the biochemical properties of the tissue and enhance the biological value of the meat product [22].

The fatty acid composition (FAC) of goose meat underwent significant changes following the inclusion of vegetative parts of oat and alfalfa in the diet (**Table 7.2**). At the time of slaughter, the breast meat of the experimental group showed a higher content of linoleic acid (18:2 $\omega 6$) by 21.1% ($p \leq 0.01$), linolenic acid (18:3 $\omega 3$) by 15.6% ($p \leq 0.01$), and docosahexaenoic acid (22:6 $\omega 3$) by 12.7% ($p \leq 0.01$). The total content of $\omega 3$ polyunsaturated fatty acids (PUFAs) in the breast meat of the

experimental group was 13.9% higher ($p \leq 0.01$). At the same time, the level of arachidonic acid (20:4 $\omega 6$) in the experimental group was 26.9% lower compared to the control ($p \leq 0.01$).

After 90 days of low-temperature storage, a decrease in the content of oleic acid (18:1) by 13.1% ($p \leq 0.01$), linolenic acid (18:3 $\omega 3$) by 21.3% ($p \leq 0.01$), and docosahexaenoic acid (22:6 $\omega 3$) by 10.4% ($p \leq 0.01$) was observed in the meat of the control group. In contrast, these values were higher in the experimental samples by 15.8% ($p \leq 0.01$), 25.3% ($p \leq 0.01$), and 10% ($p \leq 0.01$), respectively. However, the content of arachidonic acid (20:4 $\omega 6$) in the experimental group remained 19.1% lower than in the control ($p \leq 0.01$). By the end of the storage period, the total $\omega 3$-PUFA content in the meat of the experimental group did not significantly differ from that of the control. Nonetheless, the $\omega 6$-PUFA content was 9.9% lower than the corresponding value in the control group ($p \leq 0.05$), which highlights a more optimal $\omega 6/\omega 3$ ratio from a nutritional standpoint [23].

Table 7.2 Dynamics of fatty acid content (ω, %) in goose breast meat from the control (C) and experimental (E) groups during storage ($M \pm m$, $n = 3$)

Fatty acid	Storage duration, days			
	1		90	
	C	E	C	E
(16:0)	23.3 ± 0.82	24.3 ± 0.85	22.8 ± 0.98	23.0 ± 0.83
(18:0)	13.6 ± 0.53	13.0 ± 0.34	13.9 ± 0.54	13.2 ± 0.38
(18:1)	34.0 ± 1.36	32.4 ± 1.23	29.6 ± 1.30	34.2 ± 1.51**
(18:2) $\omega 6$	13.5 ± 0.55	16.4 ± 0.69	18.1 ± 0.54	17.1 ± 0.77
(18:3) $\omega 3$	0.49 ± 0.02	0.56 ± 0.03	0.38 ± 0.02	0.48 ± 0.01
(20:4) $\omega 6$	9.0 ± 0.31	6.6 ± 0.26**	7.7 ± 0.29	6.2 ± 0.25**
(22:6) $\omega 3$	0.67 ± 0.02	0.76 ± 0.03**	0.60 ± 0.04	0.66 ± 0.03*
SFA	39.5 ± 1.43	39.8 ± 1.28	39.2 ± 1.61	38.1 ± 1.28
UFA	60.4 ± 2.35	60.0 ± 2.35	59.8 ± 2.32	61.8 ± 2.69
MUFA	36.3 ± 1.44	35.3 ± 1.33	31.9 ± 1.38	36.5 ± 1.60**
PUFA	24.1 ± 0.91	24.7 ± 1.02	27.8 ± 0.94	25.3 ± 1.09*
$\omega 3$PUFA	1.16 ± 0.04	1.32 ± 0.06	1.54 ± 0.07**	1.58 ± 0.04
$\omega 6$PUFA	22.5 ± 0.86	22.9 ± 0.95	26.2 ± 0.85	23.6 ± 1.03*

The changes observed in the fatty acid composition of breast meat in the experimental group are likely attributable to the influence of compounds with antioxidant

activity [5]. Oat is known to be a rich source of various antioxidants, including β-glucan, avenanthramides, polyphenolic compounds, flavonoids, and β-carotene. Due to their properties, these compounds can effectively inhibit lipid oxidation processes in meat, thereby contributing to the stabilization of unsaturated fatty acids. In addition, the modification of the fatty acid profile may be explained by the high content of linoleic and linolenic acids present in both oat and alfalfa [8]. These essential fatty acids are readily absorbed by the goose organism, which likely played a role in the altered lipid profile of muscle tissue [24]. The increased concentration of ω-3 polyunsaturated fatty acids in goose meat after storage at low temperatures may also indicate the preserved activity of relevant enzymes, particularly desaturases [25].

An analysis of fat-soluble vitamin content in goose breast meat (**Fig. 7.3**) revealed a positive effect of including oat and alfalfa in the geese's diet on the levels of vitamin E and β-carotene. On day 1 of the experiment, the vitamin E content in the meat of the experimental group exceeded that of the control group by 17.1% ($p \leq 0.01$). After 90 days of storage, the vitamin E level in the control group's meat had decreased by 10.6% ($p \leq 0.01$), whereas the meat from the experimental group retained a 13.6% higher concentration of vitamin E ($p \leq 0.01$).

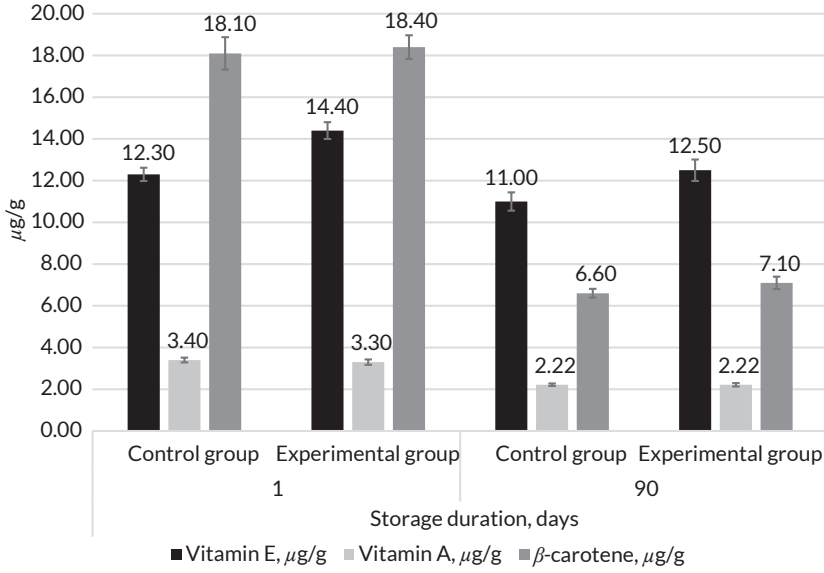

Fig. 7.3 Dynamics of vitamin E, A, and β-carotene content (μg/g) in goose breast meat from the control (C) and experimental (E) groups during storage ($M \pm m$, $n = 3$)

At the beginning of the experiment, β-carotene content was high in both groups. However, after 90 days of storage, a significant decline was observed – by 63.5% ($p \leq 0.01$) in the control group's meat and by 61.4% ($p \leq 0.01$) in the experimental group. Nevertheless, by the end of the study, the β-carotene level in the experimental meat sample remained 7.6% higher than in the control ($p \leq 0.05$).

The increased concentrations of vitamin E and β-carotene in the muscle tissue of geese in the experimental group are likely attributable to the elevated levels of these nutrients in oat, which served as a dietary source for the birds [8]. The higher content of vitamin E and β-carotene in the breast meat of the experimental group on day 90 of storage may also be explained by the antioxidant activity of bioactive compounds found in oat, particularly avenanthramides, which inhibit the intensity of oxidative processes in tissue [26]. The primary cause of β-carotene loss during storage is both enzymatic and non-enzymatic oxidation [27]. The inclusion of oat and alfalfa in the geese's diet did not affect the dynamics of vitamin A content in muscle tissue [19].

The inclusion of oat and alfalfa in the geese's diet resulted in alterations in the amino acid composition of breast meat (**Table 7.3**). On day 1 of the experiment, the meat of the experimental group showed a statistically significant increase in arginine content by 27.5% ($p \leq 0.01$), hydroxyproline by 77.4% ($p \leq 0.01$), leucine by 13.3% ($p \leq 0.05$), and isoleucine by 9.4% ($p \leq 0.05$), compared to the control group. However, the content of methionine and tyrosine was lower – by 66.7% and 45.1%, respectively ($p \leq 0.01$).

Table 7.3 Dynamics of amino acid content (mg/100 g) in goose breast meat from the control (C) and experimental (E) groups during storage ($M \pm m$, $n = 3$)

Amino acid	Storage duration, days			
	1		90	
	C	E	C	D
1	2	3	4	5
Lysine	1.40 ± 0.05	1.46 ± 0.04	1.61 ± 0.05	1.57 ± 0.07
Histidine	0.41 ± 0.02	0.40 ± 0.02	0.27 ± 0.01	0.27 ± 0.01
Arginine	0.90 ± 0.03	1.15 ± 0.04**	0.99 ± 0.04	1.10 ± 0.04*
Hydroxyproline	0.62 ± 0.02	1.10 ± 0.03**	0.69 ± 0.03	0.67 ± 0.02
Aspartic acid	1.18 ± 0.04	1.17 ± 0.04	0.92 ± 0.02	1.06 ± 0.04**
Threonine	0.65 ± 0.03	0.57 ± 0.02*	0.25 ± 0.01	0.23 ± 0.01
Serine	0.58 ± 0.02	0.52 ± 0.02	0.40 ± 0.01	0.34 ± 0.01*
Glutamic acid	2.66 ± 0.08	2.60 ± 0.09	2.25 ± 0.10	2.57 ± 0.10*
Proline	0.55 ± 0.02	0.52 ± 0.02	0.79 ± 0.02	0.72 ± 0.03

Continuation of Table 7.3

1	2	3	4	5
Glycine	0.70 ± 0.03	0.74 ± 0.02	0.93 ± 0.04	0.82 ± 0.02*
Alanine	0.90 ± 0.03	0.95 ± 0.04	1.36 ± 0.06	1.21 ± 0.03*
Cystine	0.29 ± 0.01	0.25 ± 0.01*	0.17 ± 0.01	0.16 ± 0.00
Valine	0.60 ± 0.02	0.62 ± 0.02	0.68 ± 0.02	0.64 ± 0.02
Methionine	0.24 ± 0.01	0.08 ± 0.01**	0.12 ± 0.01	0.08 ± 0.01**
Isoleucine	0.71 ± 0.03	0.78 ± 0.02*	0.70 ± 0.03	0.67 ± 0.02
Leucine	1.25 ± 0.03	1.42 ± 0.04*	1.50 ± 0.04	1.90 ± 0.06**
Tyrosine	0.41 ± 0.01	0.22 ± 0.01**	0.30 ± 0.01	0.32 ± 0.01
Phenylalanine	0.64 ± 0.02	0.66 ± 0.03	0.34 ± 0.01	0.52 ± 0.02**

After 90 days of storage, significant changes in the amino acid composition were observed in both meat samples. In the breast meat of the experimental group, higher levels of several essential amino acids were recorded – specifically, leucine and phenylalanine increased by 25.5% ($p \leq 0.01$) and 51.3% ($p \leq 0.01$), respectively. Additionally, arginine content was 11% higher ($p \leq 0.01$) compared to the control group. At the same time, methionine content remained 33.4% lower ($p \leq 0.01$) in the breast meat of the experimental group.

The observed changes in amino acid composition are likely attributable to differences in the birds' diets, as it is well established that the inclusion of alfalfa in poultry feed enhances protein quality, reduces fat and cholesterol content, and improves the antioxidant potential of chicken meat [28]. Additionally, oat is known for its high content of essential amino acids, which may further contribute to the increased concentrations of these compounds in goose meat [29].

7.4 Conclusions

The inclusion of vegetative parts of oat (*Avena sativa*) and alfalfa (*Medicago sativa*) in equal proportions in the diet of geese exerts a multifactorial positive effect on meat quality under conditions of prolonged low-temperature freezing. This feeding strategy contributes to the preservation of the functional and technological properties of muscle tissue and the optimization of its chemical composition.

The physicochemical properties of meat from the experimental group demonstrated enhanced resistance to alterations induced by freezing and thawing processes. Over the 90-day storage period, the meat exhibited higher water-holding capacity and lower

thawing loss compared to the control group. These findings indicate superior structural stability of the muscle tissue and better preservation of its moisture-retention ability.

At the early stages of storage, the meat of geese from the experimental group exhibited a higher protein content, which can be attributed to the increased bioavailability of amino acids and proteins present in oat and alfalfa. These nutrients likely contributed to the formation and accumulation of protein structures within the muscle tissue.

An analysis of lipid peroxidation processes revealed an antioxidant effect of the dietary modification. In the meat of geese from the experimental group, a statistically significant suppression of oxidative processes was observed, particularly on day 45 of storage, when the content of lipid peroxidation products was 27.8% lower ($p \leq 0.01$). This effect is likely attributable to the influx of biologically active compounds into the tissues, including tocopherols, avenanthramides, polyphenols, and carotenoids.

The inclusion of oat and alfalfa in the geese's diet led to a modification of the fatty acid profile of the meat. An increase in ω-3 polyunsaturated fatty acids (linolenic and docosahexaenoic acids) was observed, along with a reduction in ω-6 PUFA levels, particularly arachidonic acid. This shift contributes to the optimization of the $\omega 6/\omega 3$ ratio, which is important for preventing metabolic disorders in humans.

The content of vitamin E and β-carotene in the meat of the experimental group was significantly higher both at the beginning of the experiment and at the end of the storage period. This indicates effective accumulation and retention of antioxidant compounds within the tissue, enhancing the meat's resistance to oxidative spoilage.

The amino acid profile of goose meat from the experimental group was characterized by elevated levels of several essential amino acids, particularly arginine, leucine, and phenylalanine. This contributes to an increase in the biological value of the meat and enhances its functional potential as a nutritious food product.

Thus, the use of oat and alfalfa in the diet of geese represents a rational biotechnological approach that enables the prolongation of the prooxidant–antioxidant equilibrium and the deceleration of oxidative processes during meat storage. This strategy enhances the preservation of key nutrients (proteins, vitamins, and PUFAs), facilitates the formation of meat with superior sensory and dietary properties, and broadens the application of natural phytocomponents as alternatives to synthetic antioxidants in the production and preservation of waterfowl meat.

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