CHAPTER 8

Biological activity of phenolic compounds of oats depending on the technology of its use in feeding geese

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Abstract

Avenanthramide phenolic compounds are present in the composition of the green mass and seed oat grain. These compounds have powerful biological activity, however, the content of these compounds fluctuates significantly. The purpose of the conducted research was to determine the content of avenanthramides in the composition of the green mass of oats of the Spurt variety of milk-wax maturity and further optimization of the technology of using oats in feeding geese. The results of the chromatographic analysis of oat samples proved the presence of avenanthramides, tricin and oxylipins both in the grain and in the green mass of oats. A comparative study of the influence of the aqueous extract of the green mass of sowing oats and the green mass of oats in the geese diet on their development in ontogenesis and the biological value of the obtained meat was conducted. It has been established that under the influence of biologically active compounds of oats, the antioxidant activity of the muscle tissues of geese increased significantly during ontogenesis, which contributed to the increase in the nutritional value of the obtained meat. It has been proven that oat extract contributes to a more powerful activation of the antioxidant system of geese muscle tissues during the physiological stress of feather formation. However, a higher content of ω3- and ω6-polyunsaturated fatty acids of lipids in skeletal muscles after slaughter was established for geese that received green mass of oats. Addition of oat extract to the geese diet prolonged the state of pro-oxidant-antioxidant balance and contributed to an increase in the content of essential fatty acids in meat during 120 days of storage of whole goose carcasses.

The addition of oats and alfalfa to the geese diet led to an improvement in poultry meat yield and an increase in its protein content. A positive effect of oats and alfalfa

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on the ability of meat to retain moisture and loss of mass during defrosting was established. An increase in the content of ω3-polyunsaturated fatty acids, vitamin E, β-carotene and essential amino acids threonine and methionine was also observed. At the same time, the level content of other essential amino acids remained at the level of the meat of the control group.

In the thigh goose meat of the experimental group, during low-temperature storage, the processes of peroxide oxidation were activated 12 days later than in the corresponding samples of the control group. At the end of storage, the meat of the research group had a significantly higher content of vitamin E, β-carotene and ω3-PUFA. The content of essential amino acids valine, leucine and isoleucine in the experimental sample also exceeded the corresponding indicators of the control group.

Keywords

Sowing oats, avenanthramides, goose meat, end products of lipoperoxidation, vitamin E, β-carotene, fatty acids, amino acids.

Goose breeding is a traditional and promising sub-sector of poultry production in Ukraine. It does not compete with other agricultural industries, as goose farming can use land that is unsuitable for plowing and grazing. Goose breeding has a number of advantages over other poultry industries, namely: high quality meat, efficient use of feed, high growth rate, multifunctionality of goose products, natural pest control, frost resistance, etc. [1].

The COVID-19 pandemic has caused a sharp decline in poultry production and supply, resulting in serious economic losses on local and international markets. The war in Ukraine has significantly deteriorated the situation in our domestic agricultural market, including the poultry industry. The goose industry is particularly affected, as it is the one that primarily needs free pastures.

8.1 The use of biologically active substances of oats in feeding geese as a way to improve the quality of geese farming products

Among modern goose breeds, one of the most promising is the Legart Danish. These geese are characterized by early maturity and high feed conversion [2]. The meat of this breed of geese is considered dietary because fat accumulates in the subcutaneous layer. This feature makes it useful for a variety of diets and healthy eating. In addition, this breed of geese is characterized by low maintenance and rapid growth.

However, goose meat, due to its high content of unsaturated fatty acids, is highly susceptible to oxidative damage during storage. These processes adversely affect the quality of meat products, reduce the nutritional value of meat and shorten its shelf life [3–5]. One of the ways to counteract oxidative spoilage of poultry meat during storage is to use antioxidants, compounds that can inhibit the oxidation of fatty acids, primarily unsaturated ones. Providing the general population with quality food products requires the use of safe antioxidants of natural origin.

In recent years, consumers have been increasingly preferring more natural and less processed foods. The food industry is responding to this demand with clean-label products that use natural antioxidants and preservatives derived from plants. These ingredients not only extend the shelf life, but also bring health benefits. The positive impact of biologically active plant compounds on meat quality has been proven by many recent studies [6–9].

Since 1995, scientists of the TADTU under the leadership of Doctor of Agricultural Sciences, Professor V. Kalytko have been conducting research to determine the effect of synthetic and natural antioxidants on the development of poultry and the quality of meat. A reliable positive effect on the quality of poultry meat of grape seed extracts, dioecious nettle and other wild plants has been proven. In 2018, we started researching the effect of biologically active compounds of oats on the development of poultry and the quality of meat.

Oats (*Avena sativa L.*) is a cereal crop that is an important source of natural antioxidants and is noted for its numerous nutritional, medical, and pharmaceutical benefits. These antioxidants include flavonoids, phenols, saponins, tocopherols, and unique oat compounds called avenanthramides (AVNs) [10, 11]. The structure of avenanthramide molecules determines their multifunctionality, which provides protection against many diseases.

Scientists at the University of Wageningen proved [12] that the composition of seed oats contains 28 unique avenanthramides, including the new avenanthramide 6f. It has been found that the content of avenanthramides increases 25 times from seed to seedling. Avenanthramides 2p, 2c, and 2f, which are usually identified as the main avenanthramides, accounted for less than 20 % of their total content in seedlings. Therefore, quantitative analysis should include a wider range of avenanthramides to prevent underestimation of the total amount of these compounds.

In view of this, oats have been recognized worldwide as a highly valuable food product for maintaining a healthy lifestyle and a rational diet. In Ukraine, oats as a crop do not have a significant market value for most farmers, which is

confirmed by the low level of interest of commodity producers in its cultivation over a long period of time. However, in fact, oats have significant and still invaluable opportunities that are directly related to global trends in changing humanity's views on a healthy lifestyle and the development of organic agriculture, including poultry farming.

The analysis of scientific literature shows that the use of biologically active phenolic compounds of oats in the production of geese for meat can provide a number of potential benefits to the meat obtained. First, it is an increase in antioxidant activity. Phenolic compounds found in oats, such as ferulic acid, caffeic acid, and avenanthramides, are powerful antioxidants. These compounds help neutralize free radicals in the body, reducing oxidative stress and inflammation. The inclusion of oats in the geese diet can provide antioxidant protection, which will help improve the overall health of the bird and reduce the risk of oxidative damage to tissues, including muscle. Secondly, oat phenolic compounds have been shown to have anti-inflammatory properties, have a positive effect on animal development and, consequently, on the quality of the meat produced. Avenanthramides have a beneficial effect on the cardiovascular system, including lowering blood pressure and improving blood lipid profile. The inclusion of oats in the geese diet can help improve the condition of the cardiovascular system, which indirectly affects the quality of poultry meat. Thirdly, oat phenolic compounds reduce stress in animals. The inclusion of oats in the geese diet will help to reduce the negative impact of stress on the condition of the bird, which will also potentially lead to improved meat quality. Fourth, phenolic compounds improve the flavor profile of oats. Geese raised on a diet rich in oat phenolic compounds produce meat with improved flavor characteristics, which is also desirable for consumers. Fifth, natural preservation. Some phenolic compounds have antimicrobial properties that can help inhibit bacterial growth and extend the shelf life of meat products. Although the direct impact of oat phenolic compounds on meat preservation may be limited, their antioxidant and anti-inflammatory effects will indirectly contribute to the quality and shelf life of meat.

However, depending on the technological modes of oat use, the effect of its biologically active substances can vary significantly.

The aim of the research was to determine:

1. The content of avenanthramides in the green mass of sowing oats at the stage of milky-wax ripeness.

2. Influence of the technology of using green oat mass in feeding geese on their development and nutritional value of the resulting meat and its further oxidative deterioration during low-temperature storage.

8.2 Schemes and methods of research

8.2.1 Phenolic compounds of oats of the Spurt variety

The oats of Spurt variety were used in the research, the seeds of which were obtained from Synelnikov SDG ZG of Ukraine. The oats were grown on the black soil of the agricultural company "Victoria" of the Priazovsky district of Zaporizhzhia region.

The chromatographic analysis of phenolic compounds in oat samples was carried out by scientists from the Netherlands University, Department of Food Chemistry. For the extraction of phenolic compounds, the aerial part of oat *Avena sativa* L. was used in the earing and flowering phase. The extraction of flavonoids from the starting material was carried out with by methanol. The preliminary preparation of these oat samples included drying, grinding, and subsequent extraction of fats with hexane (**Fig. 8.1**) [12].

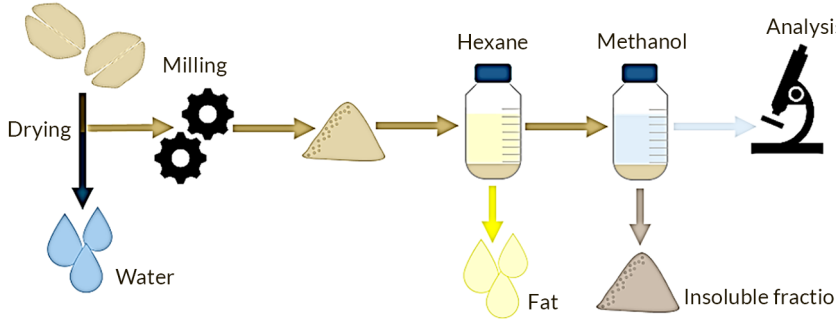

Fig. 8.1 Scheme of preparation of oat samples for chromatographic determination of phenolic compounds

8.2.2 Peculiarities of the influence of the technology of using oats in feeding geese on the poultry development and the quality of the meat obtained

The purpose of the first experiment was to determine the effect of the extract of *Avena sativa* L. on the antioxidant status and fatty acid composition of lipids in skeletal muscle of geese, dynamics of their live weight and pterilographic parameters during physiological stress formation of contour and juvenile feathers in this bird.

The study was conducted on Leghorn geese. At the age of 14 days, 2 groups of goslings (control and experimental) were formed on the principle of analogues, 26 birds each. Throughout the experiment, the birds of the control group were kept on a standard diet balanced in terms of metabolic energy, protein and vitamins according to recommendations [13]. Goslings of the experimental group were fed with oat extract from day 14 to day 49. For the extraction of biologically active compounds (BAS), the aerial part of oat *Avena sativa* L. was used in the earing and flowering phase. The extraction of phenolic compounds from the feedstock was carried out with water (ratio of feedstock to extractant – 1:10, extraction time in a boiling water bath – 60 min) followed by dilution of the extract 3 times. The object of study was the muscle tissue of geese limbs. Determination of the antioxidant activity and fatty acid composition of these tissues was carried out in physiologically reasonable terms: 14th day – completion of postnatal adaptation, 28th day – formation of contour feathers, 49th day – formation of juvenile feathers, 56th day – presence of formed plumage, stabilization of prooxidant-antioxidant balance [2]. The period of poultry keeping was determined by DSTU 3136-95 (8–9 weeks).

Geese were slaughtered and biological material for biochemical studies was collected weekly in compliance with the Council of Europe Convention for the Protection of Animals Used in Scientific Research (Strasbourg, 1986) and the First Scientific Congress of Ukraine on Bioethics (September, 2001).

The intensity of peroxidation processes was assessed by the content of its end products (TBARC) in tissue homogenates and by the initiation of lipid peroxidation (LPO) by Fe^{2+} (TBARCi) [14]. As an integral indicator of the state of the antioxidant defense system (AOS), the antioxidant activity coefficient (K_{AOA}) was used. It was calculated as the ratio of TBARC to TBARCi, since tissue homogenates contain not only the peroxidation substrate, but also components of the antioxidant defense system that can inhibit lipid peroxidation [15].

The fatty acid content was determined by gas-liquid chromatography, and lipid extracts for analysis were prepared according to the method of E. G. Bligh and W. J. Dyer with the recommendations of F. B. Palmer [16]. In addition to the total content of unsaturated fatty acids (SFA) (ΣC), the total equivalent concentration of SFA relative to multiple bonds (unsaturation, ΣN) was calculated [15]. In parallel, the dynamics of live weight of geese and their pterilographic parameters were monitored. Statistical processing of the results was performed using Microsoft Office Excel 2013 and SPSS v.13 with Student's t-test.

In the second experiment, a comparative analysis of the effect of oat extract and green oat mass on the antioxidant activity of geese muscle tissue in the

pre-slaughter period (from day 35 to day 63) and the nutritional value of the resulting meat was performed.

On the 35th day of postnatal goslings' development, 3 groups were formed (1 control and 2 experimental, 26 goslings in each). Geese in the control group were kept on a standard diet balanced in terms of metabolic energy, protein, and vitamins throughout the experiment according to recommendations [13]. The goslings of the I experimental group were supplemented with oat extract. Goslings of the II experimental group received an equivalent weight of the aerial part of milk-wax ripeness oats as part of the diet.

8.2.3 Analysis of the influence of oats on oxidative damage to meat

For the first experiment, we used goose meat from two samples. Meat of the control sample was obtained from geese of the control group, which were kept on a standard diet balanced in all nutrients. Meat of the experimental sample was obtained from geese of the experimental group, to the diet of which an aqueous extract of sowing oats was added from day 10 to day 50. Goslings were slaughtered at 60 days of age. After slaughtering, the goose carcasses were processed, frozen and then stored for 210 days at a temperature of –18 °C.

For the second experiment, two groups of 5 geese were formed. Geese of the control group received a standard diet, which included mixed fodder and grass mass, the basis of which was bird's foot (*Polygonum aviculare* L.). Geese in the experimental group received a similar diet, but 50 % of the grass mass was replaced with oats and alfalfa (25 % each). The addition of oats and alfalfa to the feed of geese in the experimental group lasted from day 7 to day 62. Geese were slaughtered on day 63. At this stage, the slaughter rates of geese were determined. After slaughtering, the geese carcasses underwent a number of technological procedures: exsanguination, scalding (70–75 °C), feather removal, removal of internal organs, washing, portioning and cooling (0–1 °C).

Goose meat from both groups were stored at –18 °C for 90 days. During this period, analytical measurements were made to determine meat quality indicators, including acidity, moisture content, protein, fat, moisture binding capacity, weight loss during defrosting, content of lipid peroxidation products, vitamins E, A, and β-carotene, fatty acid and amino acid composition. The above analyzes were performed on drumstick meat.

The moisture content of the meat samples was determined by the standard method, which includes the process of drying the samples in bunks [17].

The protein content was determined by the photocolorimetric method [18].

The content of intramuscular fat was determined by chloroform extraction using a Soxhlet apparatus. The method for determining moisture-binding capacity is based on the release of water from 300 mg of a sample during a 10-minute pressing with a 1 kg weight [17].

Vitamin E was analyzed by a spectrophotometric method based on the ability of vitamin E to reduce Fe^{3+} ions to Fe^{2+}. The resulting Fe^{2+} forms colored compounds upon interaction with 2.2-dipyridyl, which are identified and quantified [19].

For the analysis of vitamin A, we used its ability to form blue complex compounds when interacting with boron trifluoride ether ($C{\cdot}H{\cdot}OBF_{4103}$) [19].

The β-carotene content was determined by the color intensity of the extract by the photocolorimetric method. The color intensity was measured at a wavelength of 450 nm [19].

The study of amino acids was carried out on an automatic analyzer T 339 manufactured in the Czech Republic by ion-exchange liquid column chromatography [20].

8.3 Results and discussion

8.3.1 Phenolic compounds of oats

The results of chromatographic analysis of the methanolic extract of oat green mass and seeds confirmed the presence of avenanthramides in its composition (**Fig. 8.2**).

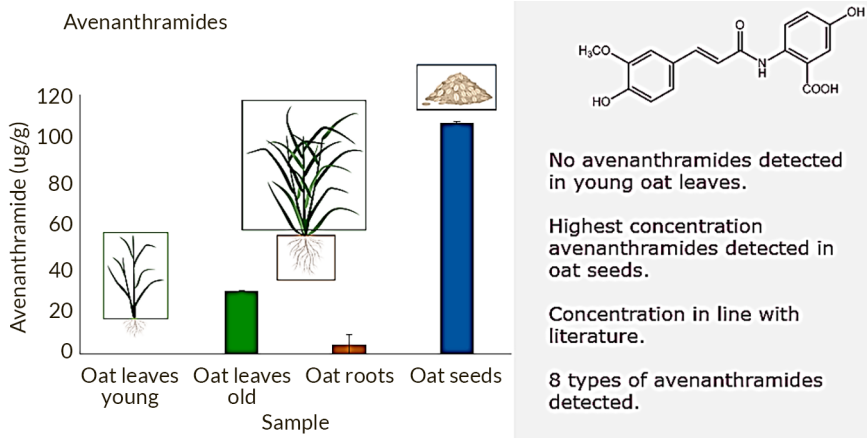

Fig. 8.2 Comparative analysis of avenanthramide content in oat plants and seeds

Comparative analysis of the green mass of oat and its seeds for the AVNs content shows that the content of these compounds in oat seeds is 3.72 times higher than in the aerial parts of plants. However, it should be borne in mind that the mass of oat greens in the geese diet is several times higher than the mass of oat seeds in the feed of this bird [11]. The presence of differin glycerol (DFG), an organic compound consisting of two molecules of ferulic acid esterified with a glycerol molecule, has been proven. This compound is a natural antioxidant and has antibacterial properties. In addition, it was found that oats also contain special phenolic compounds called oxylipins. The presence of 9 types of oxylipins in the studied oat samples was found, with the highest content in oat seeds (**Fig. 8.3**).

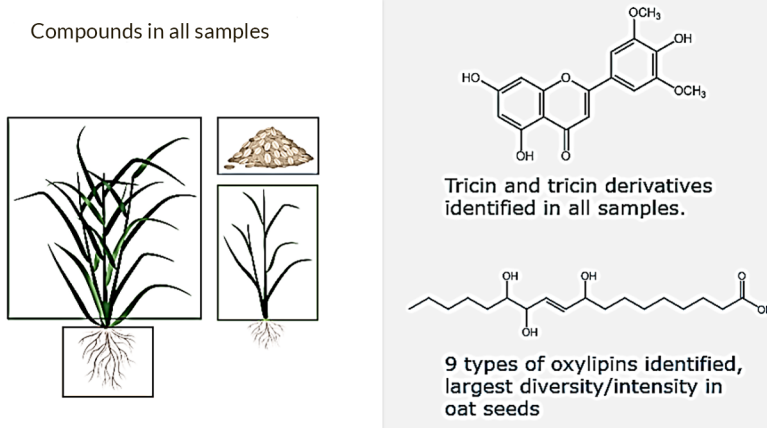

Fig. 8.3 The content of avenanthramides in oat plant parts and seeds

In humans, oxylipins play an important role in various processes, such as inflammatory and immune responses, apoptosis (programmed cell death), and regulation of hormone secretion. Some studies also point to possible beneficial properties of oxylipins for human health, including their antioxidant and anti-inflammatory effects [11]. The chromatogram of oat seeds shows the presence of tricine and its derivatives and oxylipins in addition to avenanthramides (**Fig. 8.4**).

In general, the results of the chromatographic analysis proved the presence of a number of compounds with powerful antioxidant properties not only in the grain, but also in the composition of the green mass of oats. Thus, the results of the chromatographic study confirmed the feasibility of using green oat mass in poultry feeding.

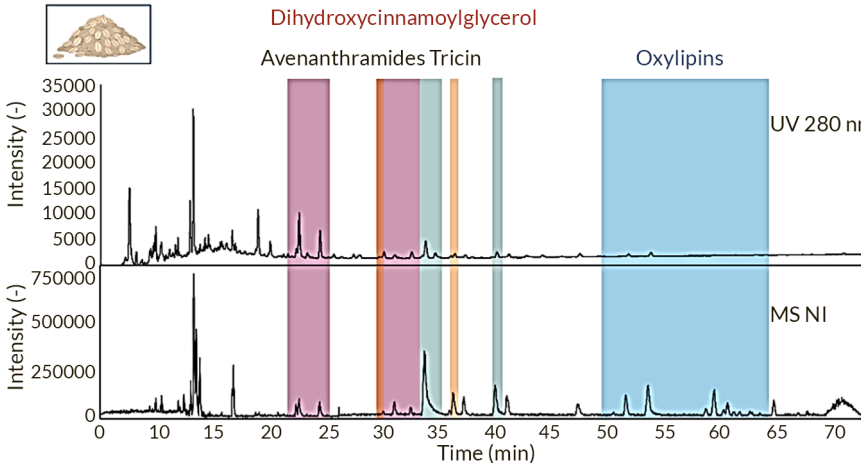

Fig. 8.4 Chromatogram of oat seeds

8.3.2 Peculiarities of the influence of oats in the geese diet on the development of the bird and the quality of the obtained meat

The formation of an adaptive response to the conditions of postnatal existence during the first two weeks of goslings' life is accompanied by an increase in the antioxidant status of their body [15]. The results of the experiment confirm a sufficiently high level of K_{AOA} in the studied tissues of 14-day-old goslings (**Table 8.1**).

From day 14 to day 28, contour feathers are formed, and a 29.4 % decrease in K_{AOA} is observed in the skeletal muscles of goslings of the control group. At the same time, under the influence of oat extract, the decrease in K_{AOA} in these tissues of goslings of the experimental group slows down (only by 25.0 %).

It is known that one of the mechanisms for improving the antioxidant status of tissues of a functioning organism during physiological stress may be a decrease in the content of the main substrate of lipid peroxidation, unsaturated fatty acids, and, accordingly, the ability of biomembrane lipids to oxidative damage [15–16]. The study of changes in fatty acid composition during the formation of contour and juvenile feathers helps to determine the mechanisms of increasing the adaptive status of geese at this period of ontogeny.

A comparative analysis of fatty acid composition (FAC) the muscle tissue of geese in the control group at 14 and 28 days of age shows some changes, but these

differences are insignificant compared to the difference in FAC of 28-day-old geese in the control and experimental groups (**Table 8.2**). First of all, a sharp drop in the total content of SFA under the influence of the extract is noteworthy. In the SM tissues of the experimental group, this indicator decreased by 3.6 times compared to the corresponding indicator of the control group.

The unsaturated fat content also decreases in SM by 2.3 times. Thus, the increase in antioxidant activity occurs both due to a reduction in the total content of PUFAs and metabolic processes aimed at reducing the content of polyunsaturated fatty acids (PUFAs), which is possibly realized by inhibiting fatty acid synthase [21] and blocking the expression of genes for other lipid metabolism enzyme.

Among all the differences in the unsaturated fatty acids in the SM tissues of 28-day-old geese, a sharp decrease (86.47 times) in the content of oleic acid under the influence of the extract is noteworthy. At the same time, a significant increase in saturated palmitic and stearic acids by 1.83–1.97 times was found in these tissues. Also, a significant decrease in the content of essential linoleic acid was found: under the influence of the extract in the SM tissues, its content decreased by 4.22 times. The content of the second essential linolenic acid decreased by 66.7 %. The content of essential arachidonic acid also significantly decreased (14.2 %), and the most unsaturated ω-3 docosahexaenoic acid disappeared under the influence of the extract.

Thus, the physiological stress in the body of geese associated with the formation of contour feathers under the influence of oat extract is significantly reduced due to the inclusion of regulatory mechanisms that selectively inhibit the synthesis of unsaturated fatty acids (UFA) [21]. This primarily concerns Δ-9 desaturase, which is involved in the synthesis of oleic acid. At the same time, elongases involved in the synthesis of palmitic and stearic acids are activated.

Further changes in FAC, accompanied by the formation of juvenile plumage in 49-day-old geese, are characterized by the FAC equalization of the control and experimental groups, first of all, an increase in the content of oleic acid in the SM of the experimental group to the level of the control group and, conversely, a decrease in the content of palmitic and stearic acids. The most significant differences in the tissues of 49-day-old goslings were found in ω-3 PUFA (linolenic by 41.2 % and docosahexaenoic by 2.33 times). Thus, the antioxidant effect of the extract is also manifested during the formation of juvenile plumage of a bird. However, the mechanism of realization of this effect at the stage of juvenile feather formation is different, which is confirmed by a decrease in the significant difference of the FAC of 49-day-old geese of the control and experimental groups.

Table 8.1 The coefficient of antioxidant activity of skeletal muscles of geese in ontogenesis and live weight of geese (*M*±*m*, *n*=6, experimental group – with oat extract in the geese diet)

	Fabric	Group	Age of geese, days			
			14	28	49	56
Antioxidant activity coefficient	Skeletal muscles	control	0.68	0.48	0.33	0.42
		experimental	0.68	0.51	0.45	0.53
Weight of geese, (M), kg		control	–	2.05±0.11	2.68±0.14	2.95±0.09
		experimental	–	2.12±0.08	2.91±0.10	3.36±0.13*

Table 8.2 Fatty acid content in skeletal muscles of geese in ontogenesis (*M*±*m*, *n*=6, experimental group – with oat extract in the geese diet)

Fatty acid	14	28		49		56	
	K	K	E	K	E	K	E
16:0	29.13±1.34	21.09±0.95	38.64±1.62**	24.71±1.63	22.93±0.96	20.94±0.87	21.70±1.03
18:0	18.13±0.93	21.94±1.03	43.28±1.94**	14.18±0.52	15.67±0.68	16.39±0.69	14.69±0.52
18:1	30.27±1.35	25.94±0.98	0.30±0.01**	38.24±1.67	37.27±1.43	33.71±1.05	39.53±1.73*
18:2	12.35±0.51	13.91±0.62	3.30±0.12**	11.11±0.36	12.78±0.47	11.94±0.42	11.30±0.38
18:3	0.15±0.01	0.09±0.00	0.15±0.00**	0.17±0.01	0.24±0.01**	0.19±0.00	0.26±0.01*
20:4	4.06±0.16	8.61±0.29	7.39±0.29*	5.56±0.21	4.70±0.19*	9.60±0.32	5.86±0.23**
22:3	0.09±0.00	0.19±0.05	0.21±0.01	0.14±0.00	0.17±0.00*	0.15±0.00	0.09±0.00**
22:4	–	0.20±0.01	–	0.29±0.01	0.29±0.01	0.32±0.01	0.11±0.00**
22:6	0.21±0.01	0.15±0.00	–	0.21±0.00	0.49±0.02**	0.43±0.02	0.29±0.01**
∑C NFA, %	50.61±1.93	52.83±2.07	14.61±0.63**	59.12±2.71	58.61±2.07	59.20±2.63	61.39±2.48
∑N	273.21	326.44	142.82	314.54	312.67	356.74	324.02

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

The stabilization of prooxidant-antioxidant balance in 56-day-old geese, which indicates the completion of feather formation processes, is characterized by a significantly higher content of ω-3 and ω-6 PUFAs in the SM of goslings of the experimental group.

Control of the dynamics of goslings' weight during the experiment shows a certain tendency to increase the weight of goslings of the experimental group compared to the control group (**Table 8.1**). However, the weight of geese of the experimental group compared to the control group (by 17.9 %) became significantly higher only at the end of the experiment at 56 days of age, which is an additional confirmation of the activation of the antioxidant defense system in geese under the influence of oat extract.

During the comparative analysis of the plumage condition in geese of the control and experimental groups at the end of the experiment (**Fig. 8.5**), it was found that in the control group the plumage of birds looks untidy, especially the forming wing feathers. The development of the feather cover is somewhat delayed, especially the primary and secondary feathers of the wing and rudder feathers compared to the contour feathers, in addition, the growth of feathers on the thighs and sides of the body is delayed.

Control group Experimental group

Fig. 8.5 Condition of wing feathers of geese of the experimental group at 56 days of age

In the experimental group, the plumage as a whole and on individual pteriles looks healthy and fresh. The flight and steering feathers on the back continue to grow. On other pterilia, the growth and development of feathers is complete, including down feathers and tassel feathers on the fifth point.

Thus, the addition of oat extract to the geese diet during feather formation increases the antioxidant activity of geese tissues. The increase in antioxidant activity in geese tissues not only contributes to a significant increase in the weight of geese at the end of the experiment, but also to the improvement of their pterilographic

indicators, which will also help reduce production costs, since geese feathers and down are a by-product that is in demand.

However, the technology with use of extract in poultry feeding involves additional costs for its production. In order to optimize the costs associated with the use of oat extracts, a comparative analysis of the effect of oat extract and its green mass in the geese diet in the pre-slaughter period (from 35 to 63 days) on the development of this bird and the quality of the meat obtained. This period of geese ontogeny is characterized by physiological stress in the bird's body (from day 42 to day 56) due to the formation of juvenile feathers. This process requires high energy and amino acids, including sulfur-containing ones. Therefore, even against the background of a diet balanced in terms of metabolic energy and protein, the process of juvenile feather formation is accompanied by tension in the antioxidant defense system [21].

A comparative analysis of the dynamics of TBAAP content in the muscle tissue of geese of the control and experimental groups shows (**Fig. 8.6**) that the addition of oat extract to the geese diet of the I experimental group, even for a week, contributes to a significant decrease in the TBAAP level in their muscle tissue (by 19.0 %, $p \leq 0.05$).

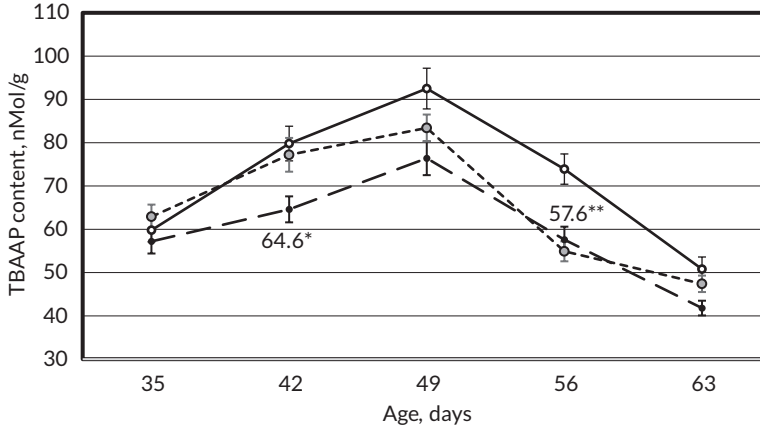

Fig. 8.6 Dynamics of TBAAP content in muscle tissue of geese of control (——), I experimental (— —) and II experimental (- - - -) groups, nMol/g ($M \pm m$, $n = 5$) (I experimental group – the oat extract, II experimental group – green mass of oat)

In 49-day-old goslings of the experimental group I, during the maximum stress of juvenile plumage formation and further until the end of the experiment, the content of these lipid peroxidation products remained significantly lower than the corresponding indicator of the control group of goslings (by 17.4–22.1 %, $p \leq 0.05$). Unlike oat extract,

the addition of its green mass to the diet of goslings of II experimental group at the beginning of the experiment did not cause significant changes in this indicator. However, in 49-day-old goslings of this group, against the background of the formation of juvenile plumage, a decrease in TBAAP content by 10.9 % ($p \leq 0.05$) was observed compared to the control. Later, in 56-day-old goslings, this difference increased to 25.7 %, but at the end of the experiment, the TBAAP content in the muscle tissue of geese of the control and II experimental groups probably did not differ (6.7 %).

The results of the correlation analysis of the TBAAP dynamics of the control and experimental groups of geese show that the addition of extract and green mass of oats to the geese diet does not significantly change the nature of the dynamics of this indicator in geese of both experimental groups compared to the control. This is confirmed by intergroup correlation coefficients of changes in TBAAP content (control and experimental groups): $r_1 = 0.950$ ($\gamma = 0.01$) and $r_2 = 0.863$ ($\gamma = 0.06$). Under the influence of oat extract, the average level of TBAAP in geese of the first experimental group decreased by 16.6 % compared to the control, and of the second experimental group – by 9.7 %, respectively.

The analysis of the results of this experiment shows that the positive effect of oats on the antioxidant activity of the geese SM is observed regardless of the technology of its use in poultry feeding [21]. During physiological stress, the formation of juvenile plumage in 49-day-old geese K_{AOA} muscle tissues of both experimental groups of geese significantly exceeded the corresponding indicator of the control group (by 62.5 and 34.4 %, respectively) (**Fig. 8.7**). The last two weeks of the experiment were characterized by a gradual restoration of prooxidant-antioxidant balance in the poultry body. However, even against the background of stabilization of the antioxidant defense system in 63-day-old geese, a significant increase in K_{AOA} of muscle tissues in the experimental groups compared to the control group was observed (by 32.7 and 25.0 %). The average level of K_{AOA} in the first experimental group exceeded the corresponding indicator of the control group by 27.9 %, and in the second experimental group – by 19.2 %.

The results of the correlation analysis of the dynamics of this indicator indicate that oat extract not only promotes more powerful activation of the antioxidant defense system of geese muscle tissue during the physiological stress of juvenile feather formation, but also significantly changes its nature: the correlation coefficient of the dynamics K_{AOA} of geese muscle tissue in the control and experimental groups $r = 0.570$. At the same time, the consistency of changes in this indicator of the control and II experimental groups was kept at a very close level ($r = 0.935$). Thus, the antioxidant effect of the oat aqueous extract is more significant, which is probably due to the better bioavailability of oat phenolic compounds in the extract.

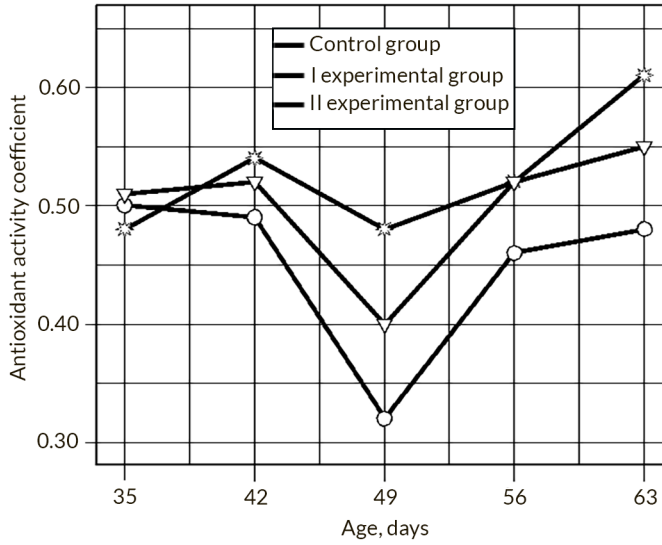

Fig. 8.7 Dynamics of the coefficient of antioxidant activity of skeletal muscles of geese (I experimental group – the oat extract, II experimental group – green mass of oat)

A comparative analysis of the fatty acid composition of lipids in the geese meat of the control and experimental groups after slaughter (63 days) shows that with the participation of oat BAC, there is a redistribution of fatty acids **(Fig. 8.8, 8.9**).

The general tendency to decrease the content of saturated fatty acids with a simultaneous increase in the level of unsaturated, including essential, fatty acids is noteworthy. Thus, the total content of saturated palmitic and stearic acids in the goose meat of the first experimental group decreased by 17.7 %, and the second experimental group – by 19.9 %, respectively, while the content of essential linoleic and linolenic acids significantly increased in the meat of the I group of geese, and essential arachidonic acid – in the meat of the II group. As a result, it was in the meat of the II experimental group that a greater increase in ω3- and ω6-polyunsaturated fatty acids (PUFAs) was found.

Thus, under both technological modes of application of oat BAC in feeding geese, an increase in the antioxidant activity of muscle tissue and, accordingly, the activity of endogenous antioxidants in meat obtained after slaughter was found. However, the differences in the FAC of lipids in the meat of the experimental groups of geese prove the existence of differences in the mechanisms of antioxidant effects. Further research should be aimed at optimizing the technological

modes of application of oat bioactive substances in order to obtain goose meat of higher quality.

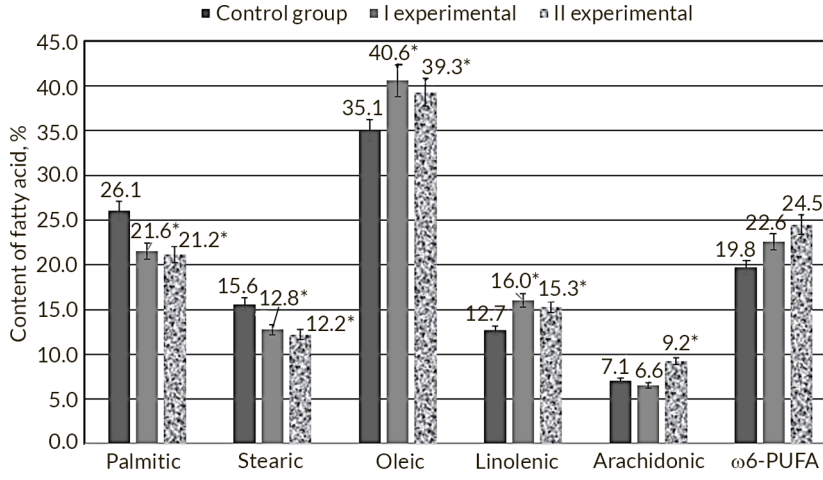

Fig. 8.8 The content of fatty acids in geese meat after slaughter ($M \pm m$, $n=6$) (I experimental group – the oat extract, II experimental group – green mass of oat)

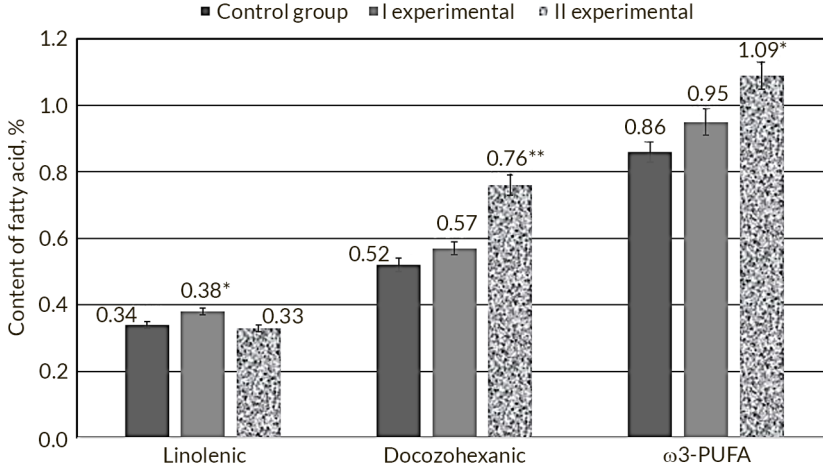

Fig. 8.9 The content of fatty acids in geese meat after slaughter ($M \pm m$, $n=6$) (I experimental group – the oat extract, II experimental group – green mass of oat)

8.3.3 Peculiarities of influence of oats and alfalfa in feeding geese on the quality of the obtained meat

This section presents the results of a study of the influence of aqueous extract of oats and a mixture of oats and alfalfa in the geese diet on the quality of meat during storage.

The live weight of geese before slaughter in the experimental group treated with oat extract was 11.3 % higher ($p<0.05$) compared to the control group (**Table 8.3**). The weight of the gutted carcass of the experimental group was also higher by 11.8 % ($p<0.05$) compared to the control group. The muscle weight of geese of the experimental group exceeded that of the control group by 12.4 % ($p<0.05$). An increase in breast and leg weight was also noted by 21.2 % and 11.7 %, respectively ($p<0.05$).

Table 8.3 Geese meat yield ($M\pm m$, $n=6$, experimental group – with oat extract in the geese diet)

Indicator	Control group	Experimental group
Live weight before slaughter, g	3215.0±86.8	3567.3±157.0*
Weight of gutted carcass, g	1802.0±75.7	2014.7±70.5*
Output of gutted carcass, %	56.1±1.7	56.5±1.7
Muscle mass, g	949.7±37.0	1067.4±42.7*
Meatiness index, %	29.5±0.8	29.9±1.0
Weight of edible parts, g	1643.8±70.7	1749.8±64.7
Edible parts index, %	51.1±1.8	49.1±1.4
Breast weight, g	202.4±5.3	245.3±8.3*
Weight of the lower legs, g	209.8±8.0	234.4±10.5*

The addition of a mixture of oats and alfalfa contributed to an increase in live weight of geese in the experimental group by 11.5 % ($p\leq0.05$). An increase in the weight of gutted carcasses of geese of the experimental group by 17.1 % was recorded compared to the corresponding indicator of the control group (**Table 8.4**).

The advantage in the weight of muscle tissue in geese of the experimental group was found to be 18.3 %. The introduction of oats and alfalfa into the diet caused an increase in the weight of edible parts by 12.1 % ($p\leq0.05$). There was also a significant increase in the weight of the thoracic muscle part and legs by 26.4 % and 24.5 %.

The positive impact on meat yield may be due to the presence of phenolic compounds in oats and alfalfa, which play a key role in improving the growth characteristics of animals. These substances can stimulate the secretion of digestive enzymes,

minimize the presence of pathogenic microflora in the gastrointestinal tract and improve intestinal morphology. A a result of this biochemical interaction, nutrient absorption is more efficient, which contributes to the increase in animal weight [22].

Table 8.4 Geese meat yield ($M \pm m$, $n = 6$, experimental group – with oat and alfalfa grass in the geese diet)

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*
Output of gutted 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*
Weight of edible parts, g	1705.4±48.9	1910.4±58.2*
Edible parts index, %	46.1±0.4	46.3±0.4
Breast weight	248.6±12.3	314.2±7.8**
Weight of the lower legs	214.0±9.3	266.4±9.2*

Analysis of the moisture content of the meat of the control group showed that during the specified shelf life, this indicator decreased by 9.2 %. In the meat of the experimental group, which was obtained with the use of oat extract, the decrease in moisture content was 8 % (**Fig. 8.10**).

The research results of the effect of oat and alfalfa grass on goose meat revealed a decrease in moisture levels in samples from both groups (**Fig. 8.11**).

After a shelf life of 90 days, a 7.8 % decrease in moisture content ($p \leq 0.01$) was found in the geese meat of the control group. Similar dynamics of moisture reduction was recorded for the goose meat of the experimental group. In the goose meat of the experimental group, a higher protein content was found by 5.0 % ($p \leq 0.05$). The level of intramuscular fat remained at the same level in the meat of both groups throughout the entire storage period.

A gradual decrease in moisture and protein content in meat during storage at low temperatures is possible due to the formation of ice crystals in the intercellular space and changes in the concentration of dissolved substances in water that does not become solid. These phenomena can lead to the destruction and oxidation of protein structures, which affects the ability of meat to retain water. The freezing process causes denaturation of myofibrillar proteins, including changes in their secondary and tertiary structure due to cold denaturation. Activation of cellular enzymes is also observed, which accelerates the processes of protein degradation and oxidation [23].

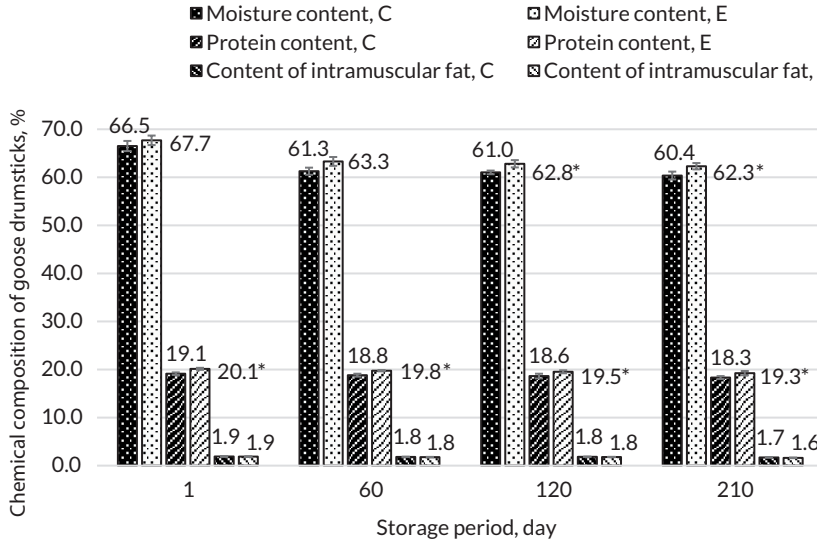

Fig. 8.10 Chemical composition of the goose meat thighs ($M \pm m$, $n = 3$, experimental group – with oat extract in the geese diet)

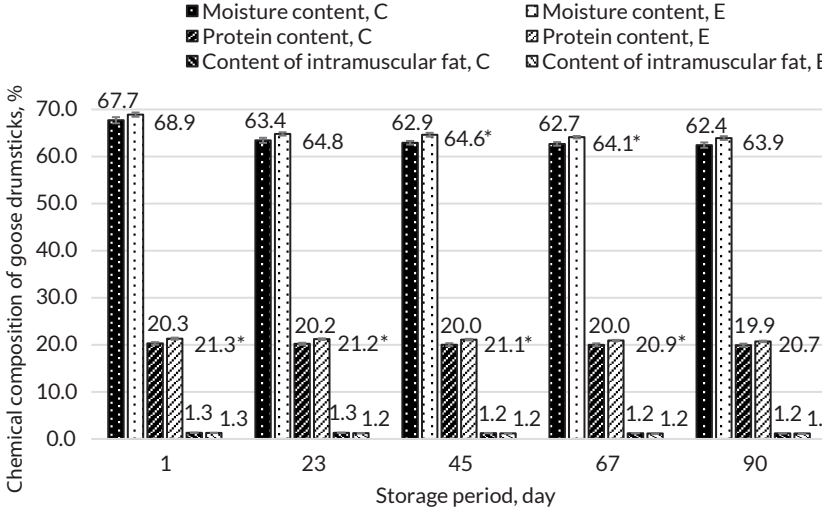

Fig. 8.11 Chemical composition of the goose meat thighs ($M \pm m$, $n = 5$, experimental group – with oat and alfalfa grass in the geese diet)

On the other hand, alfalfa as a source of protein and amino acids helps to increase the protein content in the muscle tissue of geese. The use of alfalfa silage in the diet enriches the diet with amino acids and biologically active components. This improves metabolic processes, increases the efficiency of digestion and absorption of nutrients, reduces the accumulation of fat deposits and increases the amount of muscle mass [24].

Insignificant fluctuations in pH were recorded in the meat of the control and experimental groups, to the diet of which oat extract was added (**Table 8.5**). The moisture binding capacity (MBC) of meat was higher in the experimental group during the entire storage period. The largest difference in this indicator for the control and experimental groups was found on the 60th and 210th day of storage and amounted to 10.2 % and 10.4 % ($p \leq 0.05$), respectively.

Table 8.5 Indicators of geese meat during storage ($M \pm m$, $n = 6$, experimental group – with oat extract in the geese diet)

Shelf life of days	pH		Weight loss during defrosting, %		GWP, %	
	K	E	K	E	K	E
1	6.04±0.01	6.03±0.01	–	–	87.1±3.27	87.6±2.99
60	6.01±0.01	6.01±0.01	3.57±0.05	3.55±0.05	72.2±2.16	79.5±1.55*
120	5.98±0.02	5.99±0.03	3.60±0.07	3.57±0.08	68.5±1.12	73.9±2.45
210	5.94±0.02	5.96±0.03	3.64±0.08	3.58±0.08*	66.4±1.13	73.3±1.57*

In the experiment, with the addition of oats and alfalfa to the geese diet, a decrease in the acidity of meat for both groups of geese was found during 90 days of low-temperature storage (**Table 8.6**). The moisture-binding capacity of meat in the control group decreased by 17.7 % after 90 days of storage, while in the experimental group a decrease of 14.4 % was observed. On the 45th and 67th day of storage in the experimental group, the moisture content of meat was higher by 6.1 % and 7.3 % ($p \leq 0.05$), respectively. An increase in meat weight loss during its defrosting was found with an increase in the shelf life. However, in the experimental samples, weight loss was lower at all stages of storage. The largest difference was recorded on the 45th day of storage, when the mass loss in the experimental group was 8.3 % lower ($p \leq 0.05$).

The increase in moisture-binding capacity in the meat of the experimental group is possible due to an increase in the amount of hydrophilic proteins that contribute to water retention in meat tissues. Among these proteins, myosin and other sarcoplasmic components play a crucial role in moisture retention. They ensure less water

loss during the cryopreservation process and subsequent thawing. The freezing process converts water in meat into ice crystals, which can cause mechanical damage to meat fibers and lead to dehydration during thawing. However, the increased moisture-binding capacity of meat can help minimize structural damage to meat fibers, significantly reducing water and weight loss during defrosting.

Table 8.6 Indicators of geese meat during storage ($M \pm m$, $n = 6$, experimental group – with oat and alfalfa grass in the geese diet)

Shelf life of days	pH		Weight loss during defrosting, %		GWP, %	
	K	E	K	E	K	E
0	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

During the first 60 days of storage in the meat of the control group, there was a gradual decrease in lipid peroxidation products (LPO), reaching a minimum level that was 2.6 times lower than the initial value. The further intensification of LPO processes in the control meat sample was due to the accumulation of endogenous oxygen during storage. A particularly pronounced increase in the activity of lipid peroxidation was recorded starting from the fourth month of storage, which led to a significant increase in the content of secondary lipoperoxidation products – 8.2 times after 210 days of storage compared to the initial value.

The goose meat from the experimental group was characterized by 83.8 % higher TBAAP levels than the meat of the control group (**Fig. 8.12**). The inclusion of oat extract in the geese diet contributed to the preservation of the stability of the prooxidant-antioxidant balance in the meat of the experimental sample. During the first 60 days of storage, the content of lipoperoxidation end products remained stable. With further storage from the 60th to the 120th day, a 3.7-fold decrease in this indicator was observed, and from the 120th to the 210th day, activation of lipid peroxidation began, which led to a 10.7-fold increase in TBAAP levels. In general, during the entire storage period, the content of secondary lipoperoxidation products in the meat of the experimental sample increased by 3.2 times, but at the end of storage it was 28.6 % lower than that of the control group.

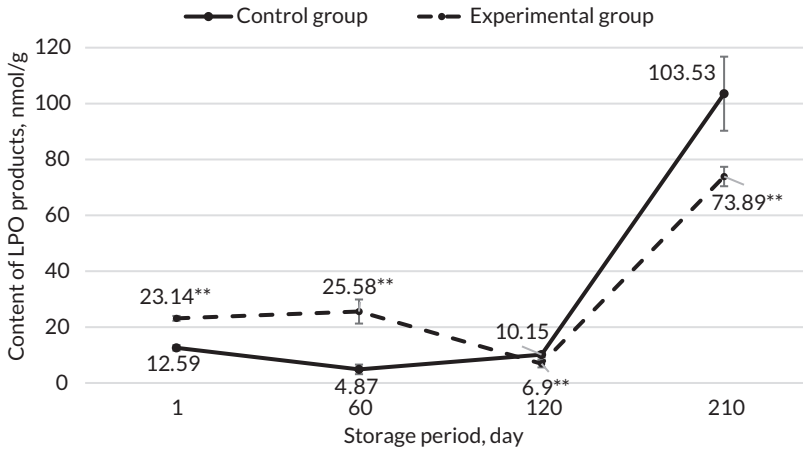

Fig. 8.12 Dynamics of the TBAAP content in the goose meat thighs ($M \pm m$, $n = 3$, experimental group – with oat extract in the geese diet)

In the second experiment, when studying the effect of oat and alfalfa grass on goose meat, the analysis of the content of LPO products in the goose meat of the control group showed that during the first 23 days of storage this indicator remained unchanged (**Fig. 8.13**). Starting from the 23rd day, an activation of oxidative processes was observed, which led to an increase in the TBAAP level by 18.3 % on the 45th day of storage. From the 45th to the 67th day, there was a further increase in the concentration of LPO products by 38.7 %. After that, by the end of the storage period, the level of lipid peroxidation products in the meat of the control group stabilized.

The meat of the experimental group was characterized by a lower content of lipid peroxidation products by 8.9 % ($p \leq 0.05$) compared to the control group. In addition, it showed a prolongation of the period of stability of prooxidant-antioxidant equilibrium, where the accumulation of LPO products was slower. By the 45th day of storage, the difference in TBAAP content between the control and experimental groups increased to 13.9 % ($p \leq 0.01$), and by the 67th day – to 28.3 % ($p \leq 0.01$). However, after the 67th day of storage, an acceleration of the LPO processes was observed in the experimental samples, and by the 90th day the content of LPO products increased by 35.8 % ($p \leq 0.01$).

The inclusion of oats and alfalfa in the geese diet helps to prolong the period of stabilization of prooxidant-antioxidant balance during meat storage [25]. It is known that the antioxidant potential and quality of nutrients entering the animal's body is determined by the diet composition and the BAS bioavailability [26]. The change

in the amount of ROS products in the goose meat of the experimental group is probably the result of the action of avenanthramides, polyphenols, flavonoids, and other bioactive substances contained in oats and alfalfa. Such changes contribute to optimizing the biochemical composition and increasing the biological value of meat [26].

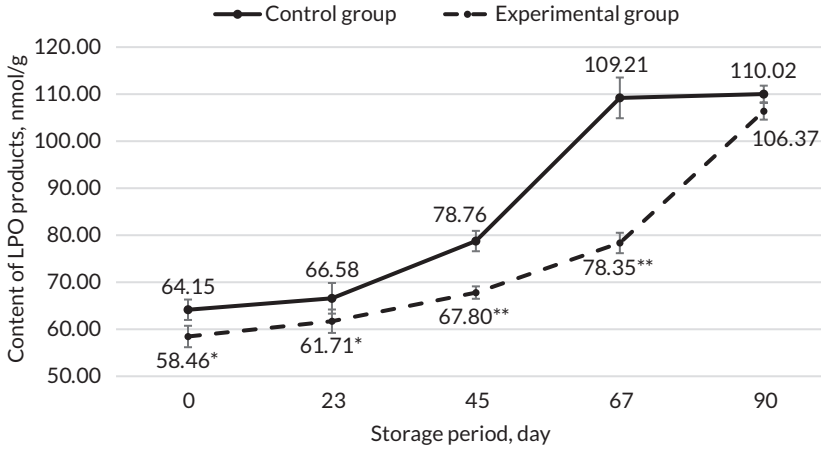

Fig. 8.13 Dynamics of the TBAAP content in the goose meat thighs ($M \pm m$, $n = 5$, experimental group – with oat and alfalfa grass in the geese diet)

This is confirmed by the detected changes in the dynamics of TBAAP indicators, which indicates an improvement in the stability of the fatty component of meat throughout the entire storage period. Thus, the established changes in the dynamics of TBAAP indicate that the addition of oats and alfalfa to the geese diet has a positive effect on the stability of the lipid component of meat throughout the entire shelf life [27].

Depending on the initial state of chickens and the technological conditions of their keeping, the fatty acid composition of poultry meat lipids can change significantly [28, 29]. The analysis of the fatty acid composition of the goose meat of the first experiment shows that among the unsaturated fatty acids in the meat of the control group, the highest content is oleic, linoleic, and arachidonic acids, and among the saturated ones, palmitic and stearic acids (**Table 8.7**). During the first 120 days of storage, the total share of PUFAs in the goose meat of the control group increased by 11.7 % due to oleic (23.9 %), linoleic (13.6 %) and linolenic (2.22 times) acids. A significant decrease in the content of the most unsaturated docosahexaenoic acid (by 2.57 times) compensated for a more significant increase in the level of unsaturated fatty acids during this period. The second part of the experiment was characterized

by significant losses of the most unsaturated fatty acids: arachidonic (by 42.9 %) and docosahexaenoic (by 34.8 %). At the same time, the content of essential linoleic and linolenic acids increased significantly (by 47.1 % and 2.65 times, respectively).

Table 8.7 Dynamics of the content (ω, %) of fatty acids in geese meat during storage ($M \pm m$, $n = 3$, experimental group – with oat extract in the geese diet)

Fatty acid	Shelf life, days					
	1		120		210	
	K	E	K	E	K	E
(16:0)	19.48±0.51	20.74±0.79	19.05±0.65	20.92±0.77*	20.09±0.7	20.99±0.92
(18:0)	22.31±0.89	18.61±0.8**	17.9±0.55	18.24±0.51	15.7±0.53	16.07±0.53
(18:1)	27.84±0.84	30.49±0.76	34.48±1.55	27.3±0.93*	32.12±0.84	35.56±1.42*
(18:2) ω6	14.7±0.66	16.25±0.73*	16.74±0.54	18.99±0.85*	24.56±1.11	17.41±0.5*
(18:3) ω3	0.09±0.01	0.13±0.01**	0.2±0.01	0.15±0.01*	0.53±0.02	0.29±0.01**
(20:4) ω6	6.04±0.25	6.64±0.23*	5.63±0.23	7.47±0.28**	3.19±0.13	5.12±0.18**
(22:6) ω3	0.59±0.02	0.55±0.02	0.23±0.01	0.62±0.02**	0.15±0.01	0.17±0.01
SFA	45.56±1.54	42.65±1.68	39.57±1.29	42.26±1.39	37.48±1.29	39.24±1.52
UFA	53.81±1.93	57.15±1.86	60.14±2.43	57.39±2.21	62.29±2.16	60.61±2.19
MUFA	31.27±0.95	32.59±0.84	36.42±1.62	29.17±1.01	33.79±0.9	37.25±1.48
PUFA	22.54±0.98	24.56±1.02	23.72±0.81	28.22±1.2**	28.5±1.26	23.36±0.71*
ω3-PUFA	0.68±0.02	0.68±0.02	0.43±0.02	0.77±0.03**	0.68±0.02	0.45±0.02**
ω6-PUFA	20.74±0.92	22.89±0.96*	22.38±0.77	26.46±1.14*	27.75±1.23	22.53±0.68*

These oppositely directed changes in the FAC of meat of the control group resulted in stabilization of both total unsaturation and total PUFA content during this experimental period. The results of the comparative analysis of the fatty acid composition of the meat of the control and experimental samples at the beginning of the experiment confirm the positive effect of oat extract on the fatty acid composition of goose meat. Before being stored, the experimental sample of meat exceeded the control sample in terms of oleic (by 9.5 %) and essential linoleic (by 10.5 %), linolenic (by 44.4 %) and arachidonic acids (by 9.9 %). In terms of the total content of NFAs and their unsaturation, the experimental sample exceeded the control sample less significantly (by 6.2 % and 6.9 %, respectively, $p \leq 0.05$). After 120 days of storage, the meat of the experimental sample contained 13.8 % more linoleic acid, 33.9 % more arachidonic acid, and 2.70 times more docosahexaenoic acid compared to the corresponding control meat sample. In terms of total unsaturation of FA, the experimental

sample significantly (by 6.3 %, $p \leq 0.05$) exceeded the control sample. Thus, the positive effect of oat extract on the fatty acid content of geese meat was observed during 120 days of storage. In the second part of the experiment, the changes in the quality of the meat of the experimental sample were less positive. After 210 days of storage, the experimental sample had a significantly higher content of the most abundant unsaturated oleic acid (by 10.7 %), arachidonic acid (by 59.4 %), and docosahexaenoic acid (by 13.3 %). However, the content of linoleic and linolenic acids was lower than that of the control sample (by 29.1 % and 45.3 %, respectively).

The analysis of the goose meat FAC after slaughtering the birds of the second experiment revealed that as a result of the use of oats and alfalfa (**Table 8.8**), the content of oleic acid in the meat of the experimental sample decreased by 9.7 % ($p \leq 0.05$). At the same time, an increase in the content of polyunsaturated fatty acids, namely linoleic and linolenic acids, was recorded by 19.1 % ($p \leq 0.01$) and 32.0 % ($p \leq 0.01$), respectively. In addition, a significant increase in the level of docosahexaenoic acid (by 20.6 %) was found. There was also an increase in the total content of ω3- and ω6-polyunsaturated fatty acids in the meat of the experimental samples by 24.2 % ($p \leq 0.01$) and 10.8 % ($p \leq 0.05$), respectively.

Table 8.8 Dynamics of fatty acid content in geese meat during storage (ω, %, $M \pm m$, $n = 3$, experimental group – with oat and alfalfa grass in the geese diet)

Fatty acid	Shelf life, days			
	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
ω3-PUFA	0.81±0.03	1.01±0.04**	0.97±0.03	1.42±0.06**
ω6-PUFA	22.05±0.83	24.42±0.82*	24.0±1.03	24.73±0.98

After 90 days of low-temperature storage, an increase in the content of linoleic and linolenic acids by 22.6 % and 34.6 % ($p \leq 0.01$), respectively, was observed in the goose meat of the control group. A decrease in the level of arachidonic acid by 14.8 % ($p \leq 0.01$) was detected. In the sample of meat of the experimental group, the content of linolenic and docosahexaenoic acids exceeded the value of the meat of the control group by 32.3 % and 53.8 %, respectively. There was also a tendency to a decrease in the content of saturated fatty acids and an increase in the content of polyunsaturated fatty acids. The content of ω3-polyunsaturated fatty acids in the experimental group was 46.4 % higher than that of the control group.

The recorded improvement in the fatty acid profile of meat in the experimental group can be explained by the influence of antioxidants, in particular those contained in oats. After all, oats have been shown to be rich in antioxidants such as β-glucan, avenanthramides, polyphenols, flavonoids, and β-carotene [5]. These substances play a key role in protecting lipids from oxidation, contributing to the preservation of unsaturated fatty acids in meat [10].

Such changes may also be due to the high levels of linoleic and linolenic acids present in oats and alfalfa [10]. These acids can be assimilated by the body of geese, which contributes to the optimization of the fatty acid content of the goose meat in the experimental group [30]. An increase in the proportion of ω3-PUFA may be caused too by the preservation of a certain activity of the corresponding desaturases [31].

The addition of oats and alfalfa to the geese diet had a positive effect on the vitamin composition of the meat obtained (**Fig. 8.14**). A significant increase in the content of vitamin E by 38.5 % and β-carotene by 19.6 % ($p \leq 0.01$) was found in the goose meat of the experimental group.

After 90 days of low-temperature storage, a decrease in the content of vitamin A and β-carotene in the meat from the control group was observed by 33.6 % and 64.2 %, respectively. A decrease in vitamin E content by 12.3 % ($p \leq 0.05$) was also recorded.

On the other hand, in the meat of the experimental group on the 90th day of storage, the vitamin E content exceeded that of the control group by 50.9 %. In addition, the experimental sample showed a 20 % higher content of β-carotene ($p \leq 0.01$). The study found no significant effect of oats and alfalfa on the vitamin A content of goose meat. The changes in the content of vitamin E and β-carotene may be based on their high content in oats, which could be incorporated into the poultry body [10]. Also, a decrease in the intensity of oxidative processes in meat may be caused by the action of bioactive elements present in oats that have antioxidant activity. Among these components, a special place is occupied by avenanthramides [32]. The reason for the decrease in the amount of β-carotene during storage is its oxidation, which can occur

by enzymatic and non-enzymatic means [33]. The decrease in the level of vitamin E can be explained by its antioxidant activity and, accordingly, the ability to protect meat lipids from oxidation [10]. However, its insignificant loss is evidence of the implementation of other mechanisms of antioxidant protection in the meat of the control sample.

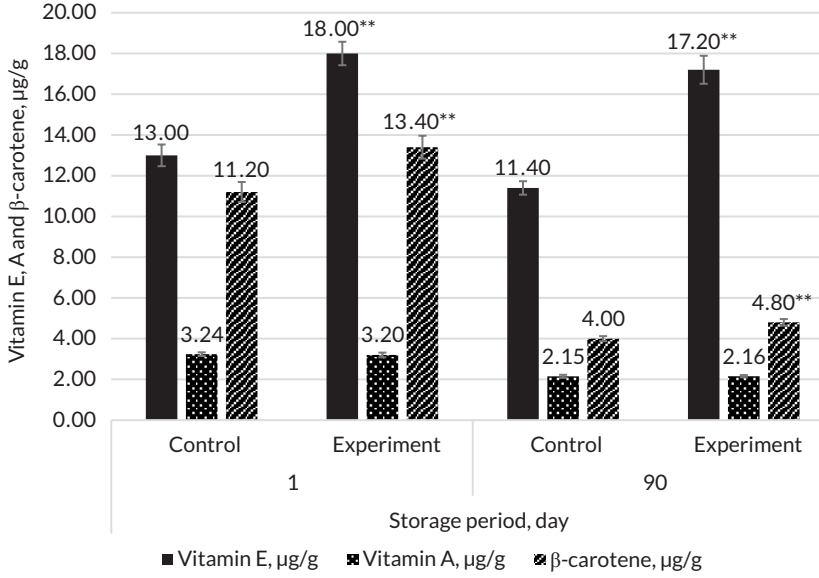

Fig. 8.14 Dynamics of the content of vitamins A, E and β-carotene (μg/g) in the goose meat ($M \pm m$, $n = 5$, experimental group – with oat and alfalfa grass in the geese diet)

The analysis of changes in the amino acid composition of goose meat (**Table 8.9**) indicates an increase in the content of essential amino acids in the goose meat of the experimental group.

This was observed not only immediately after slaughter, but also after 90 days of low-temperature storage. An increase in threonine and methionine by 26 % and 22.8 %, respectively ($p \leq 0.01$) was detected.

After 90 days of storage, a decrease in the content of threonine and methionine was observed in the meat of both groups. In addition, a decrease in the amount of phenylalanine was detected in the test sample. At the same time, an increase in the level of valine was noted in both study groups, and an increase in isoleucine was also recorded in the samples of the experimental group. Against the background of the use of oats and alfalfa in the geese diet, a statistically significant increase in the

content of lysine (by 13.4 %), valine (by 23.7 %), isoleucine (by 26.3 %), leucine (by 17.7 %) was recorded on the 90th day of storage of meat of the experimental group compared to the control group. At the same time, a 21 % decrease in threonine and a 49 % decrease in phenylalanine was found.

Table 8.9 Dynamics of amino acid content in goose meat during storage (mg/100 g, $M \pm m$, $n = 3$, experimental group – with oat and alfalfa grass in the geese diet)

Amino acid	Shelf life, days			
	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**
Aspartic 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**
Serine	0.64±0.03	0.79±0.04**	0.39±0.02	0.32±0.02**
Glutamic 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
Cystine	0.46±0.02	0.51±0.03*	0.33±0.02	0.32±0.02
Valine	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**

The reason for the changes in the amino acid composition of meat may be the presence of oats and alfalfa in the diet. The addition of alfalfa has been shown to increase protein content, reduce cholesterol and fat, and improve the antioxidant status of chicken meat [7]. Oats contain high levels of threonine, methionine and other essential amino acids, which may also contribute to their increase in geese meat [34].

Conclusions

The results of the chromatographic analysis proved the presence of compounds with powerful antioxidant properties of avenanthramides of 8 types not only in the grain, but also in the composition of green oat mass and, thus, confirmed the feasibility of using green oat in poultry feed.

With both technological regimes of using oats in feeding geese (green oat mass or its extract), an increase in the antioxidant activity of muscle tissue and, accordingly, the activity of endogenous antioxidants in meat obtained after slaughter was observed. However, the addition of green oat to the geese diet of experimental group II led to a significantly greater increase in the content of ω3- and ω6-polyunsaturated fatty acids compared to the control after slaughter.

Addition of oat extract to the geese diet led to an increase in the time of pro-oxidant-antioxidant balance in meat during storage. An increase in the content of essential fatty acids was found in the meat of this experimental group. After 120 days of storage, the content of linoleic, arachidonic, and docosahexaenoic acids was higher in the meat of the experimental group. After 210 days of storage, an increase in the content of oleic, arachidonic and docosahexaenoic acids was observed in the meat of the experimental group compared to the control group. However, in terms of the content of linoleic and linolenic acids, the experimental sample yielded to the control.

Incorporating a mixture of oats and alfalfa into the geese diet leads to an 11.5 % increase in live weight, indicating the high effectiveness of this dietary component in stimulating growth and development. This geese diet contributed not only to the improvement of poultry meat yield, but also to an increase in its protein content by 5.0 %, confirming the improvement in the quality characteristics of the product.

A positive influence of oats and alfalfa on the technological characteristics of meat during low-temperature storage was established, namely, an increase in the ability of meat to retain moisture and a smaller loss of mass during defrosting. There was also an increase in the content of ω3-polyunsaturated fatty acids, vitamin E, β-carotene, as well as the essential amino acids threonine and methionine, while the level of other essential amino acids remained at the level of the meat of the control group.

During low-temperature storage in the meat of this experimental group, the processes of peroxide oxidation were activated 12 days later than in the corresponding samples of the control group. At the end of storage, a significantly higher content of vitamin E, β-carotene and ω3-PUFA was found in the meat of the experimental group. The content of essential amino acids valine, leucine and isoleucine in the experimental sample also exceeded the corresponding indicators of the control group. However, the meat of the experimental group was characterized by a lower content

of phenylalanine. Thus, the admixture of oats and alfalfa in the geese diet contributes to the enrichment of meat with important food components. These positive changes are preserved even during long-term low-temperature storage, which ensures an increase in the nutritional value of meat products.

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Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

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