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ANALYSIS OF THE EFFECT OF BIOLOGICALLY ACTIVE COMPOUNDS OF OATS AND ALFALFA IN THE DIET OF GEESE ON THE NUTRITIONAL VALUE OF GOOSE MEAT

The feasibility of introducing a mixture of oats (Avena Sativa) and alfalfa (Medicago sativa) into the diet of Legart geese was studied in order to improve the quality of the obtained meat of this bird both after slaughter and after long-term low-temperature storage by increasing its antioxidant activity. The paper analyzes and substantiates the use of oat and alfalfa admixtures in the diet of geese. As a result of the study, it was established that the addition of oats (experimental group I) and a mixture of oats and alfalfa (experimental group II) to the diet of geese contributed to a decrease in the content of the end products of lipid peroxidation (LPO) in breast meat after slaughter and during its long-term low-temperature storage (90 days). In the goose meat of both research groups, the prooxidant-antioxidant balance period was prolonged up to the 23rd day. The biggest difference in the LPO content products in the meat of the control and both experimental groups was recorded on the 45th day of meat storage. For the meat of the I research group, this difference was 29.2 %, for the II research group – 41.2 %. The LPO maximum intensity processes in the meat of geese of both experimental groups was established from the 45th to the 67th day of storage. During this time, the content of LPO products increased by 62.5 % in the meat of the geese of the I research group, and by 88.7 % in the II. By the 67th day, the content of LPO products in the meat of the control group significantly exceeded the corresponding indicators of the experimental groups. At the end of the experiment, the content of LPO products in the meat of geese of the control and experimental groups did not reliably differ. Analysis of the fatty acid composition of goose breast meat showed that the most positive changes occurred in the goose meat of the II research group. At the beginning of the storage period, the meat of this group showed an increased content of essential fatty acids: linoleic (18:2) by 11.4 %, linolenic (18:3) by 25.8 %, and arachidonic (20:4) by 12.4 %. The total content of ω6-fatty acids in the meat of this group was 10.9 % higher than that of the control group. However, on the 90th day of storage, there was no significant difference in the content of essential fatty acids in the meat of geese of II experimental and control groups of geese.

Keywords: *goose meat, biologically active compounds, seed oats, alfalfa, low-temperature storage, antioxidants, lipid peroxidation products.*

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1. Introduction

Poultry meat has a high nutritional and dietary value due to its low-fat content, as well as a significant amount of protein, vitamins and minerals, including iron, zinc, magnesium, sodium, potassium, phosphorus, and calcium [1].

Over the past twenty years, poultry meat has become the largest used livestock product on a global scale. It is assumed that in the next decade, poultry meat will remain the world's largest imported livestock product by volume, as its production cannot catch up with the growth rate of consumption in many countries [2].

The COVID-19 pandemic has caused a sharp decline in poultry production and supply, resulting in severe economic losses in local and international markets. The poultry sector in many countries, including China, the United States, Canada, the United Kingdom, Germany, Spain, Italy, France, and India, has suffered significant losses due to COVID-19, leading to changes in food availability [3]. In the context of this pandemic, it was proposed to take the necessary measures to ensure stable production of poultry meat, which could compensate for losses in the poultry sector [4].

The war in Ukraine led to significant material and economic losses in the country's agricultural sector, including such a specific industry as poultry farming. In this regard, the question of production of high-quality poultry meat and the preservation of nutrients in it during low-temperature storage becomes especially relevant. This is necessary not only to satisfy domestic consumption and maintain the health of the nation, but also to increase the export potential in the poultry industry and access to international markets.

Goose breeding is a special type of poultry farming. Geese are an economically profitable bird, the breeding of which requires less care and simplified management. The Legart Danish goose breed is promising for meeting the needs of consumers in poultry meat. Geese of this breed are characterized by precocity and high feed conversion [5].

However, the meat of waterfowl is characterized by a significant content of lipids in its structure, which is the reason for the intensive development of oxidative processes. During low-temperature storage, oxidative reactions can cause the accumulation of lipid peroxidation products (LPO), such as hydroperoxides, aldehydes (especially malondialdehyde), and ketones in meat. Oxidative processes lead to a decrease in the content of unsaturated fatty acids and loss of fat-soluble vitamins in meat [6], and therefore to a decrease in its biological value. One of the ways to combat oxidative spoilage of poultry meat during storage is the use of natural antioxidants that can neutralize a wide range of active forms of oxygen [7, 8].

The aim of research is to improve the quality of obtained goose meat after slaughter and during its subsequent low-temperature storage due to the addition of seed oats and alfalfa in the poultry diet.

2. Materials and Methods

Oats (*Avena sativa*) are a cereal crop that is an important source of natural antioxidants and is noted for its numerous nutritional, medical and pharmaceutical benefits. Oats contain a rich set of nutrients, including proteins, fiber, calcium, vitamins (B, C, E, and K), as well as amino acids [9]. Oats are a source of various phytochemicals with pronounced antioxidant, anti-inflammatory and anti-proliferative properties, including flavonoids, phenols, saponins, tocopherols, avenanthramides. The latter are recognized as unique for oats [10, 11].

Alfalfa is a highly productive perennial leguminous crop, widely used to create fodder for domestic animals. This culture is rich in useful fatty acids, especially α-linolenic and linoleic [12]. The inclusion of alfalfa in the diet of geese helps to improve the fatty acid and amino acid composition of meat [13].

To conduct the research, three groups of geese of the Legart Danish breed were created, 5 heads each – control and two experimental. The birds of the control group were fed a standard diet, which included compound feed and grass mass, the main component of which was bird mustard (*Polygonum aviculare L.*). The geese of the experimental groups also received a standard diet, but in the composition of the grass mass of the geese of the first experimental group, 25 % was replaced with seed oats, and for the geese of the second experimental group, 50 % of the grass mass was replaced with a mixture of oats and alfalfa in equal quantities. The process of adding oats and alfalfa to the poultry diet of the experimental groups lasted from the 7th to the 62nd day.

Geese were slaughtered by the external method at an early slaughter age – on the 63rd day. After that, the goose carcasses underwent technological processing: exsanguination, scalding (70–75 °C), removal of feathers, butchering, washing and cooling (0–1 °C, 24 hours). Next, the carcasses were packaged and packed in polymer film. The meat was stored at -18 °C for 90 days in accordance with the requirements of DSTU 3143-2013. During meat storage, the intensity of lipid peroxidation (LPO) processes and changes in the fatty acid composition were determined. Geese breast meat was used for biochemical research.

The LPO intensity was assessed by the content of end products of lipoperoxidation, which interact with 2-thiobarbituric acid (TBCAP) [14].

Fatty acid composition (FA) of meat lipids was determined by gas-liquid chromatography on a Carlo Erba chromatograph (made in Italy). Chromosorb W/DP with a Silar 5CP phase (Serva, Germany) was used as a carrier, the concentration of which was 10 %, at a temperature from 140 to 250 °C and a ramp rate of 2 °C/min (injector temperature – 210 °C; temperature detector – 240 °C) [15, 16].

The SPSS v. 17 software and MS Office Excel-2013 were used for statistical processing of the data obtained, using Student's t-test [17].

3. Results and Discussion

The analysis of goose meat TBCAP dynamics of the control group indicates a constant increase in the content of these LPO products throughout the entire storage period (Fig. 1). During the first 23 days of low-temperature storage, the content of lipid products increased by 31.2 %. From the 23rd to the 45th day, oxidation processes took place most actively – during this period, the content of lipid products increased by 57.4 %. Starting from the 45th day, the intensity of LPO processes began to decrease, and over the next 22 days, the content of LPO products increased by 27.7 %. From the 67th to the 90th day, the TBCAP content did not change reliably. In general, during the entire period of low-temperature storage, the content of LPO products in meat increased by 2.7 times.

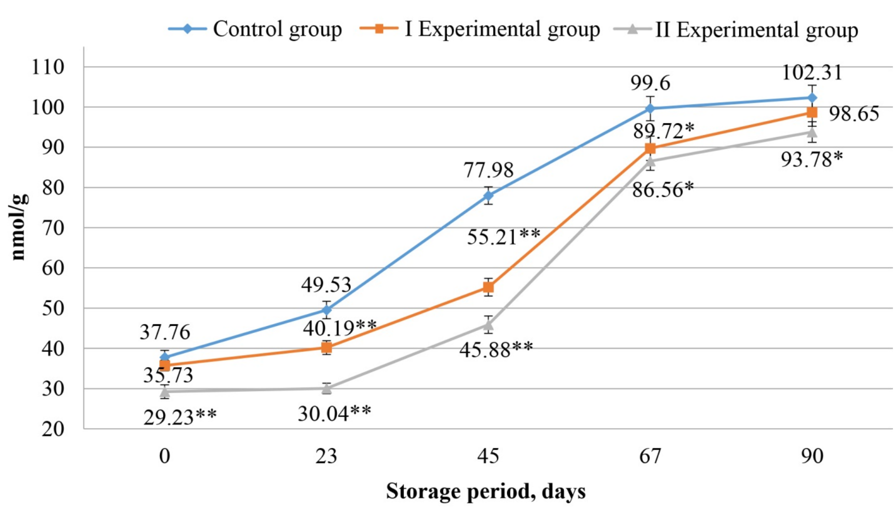

Fig. 1. Dynamics of TBCAP content in goose breast meat during storage ($M \pm m$, $n=5$) (here and below the difference is likely relative to the control group: * – $p \leq 0.05$; ** – $p \leq 0.01$)

A comparative analysis of the content of LPO products in the meat samples of the control and 1st experimental groups proves that at the beginning of the storage period, these indicators probably did not differ. However, the dynamics of the accumulation of lipid products against the background of the use of oats in the diet of geese has undergone significant changes. During the first 23 days of storage, there was no significant accumulation of TBCAP in the meat samples of the first experimental group. This indicates a prolongation of the state of pro-oxidant-antioxidant balance in the meat of this group of geese. From the 23rd to the 45th day, the content of LPO products increased by 37.4 %. As of the 45th day of storage, the content of lipid products in the meat of the geese of the first experimental group was 29.2 % lower than that of the control group. During the next 22 days of storage, the content of LPO products increased by 62.5 %, and from the 67th to the 90th day – by 10 % ($p \leq 0.05$).

The difference in the intensity of LPO processes in the meat of geese of the control and I experimental groups is probably caused by the presence of biologically active substances in the composition of oats, which exhibit antioxidant properties and slow down the processes of lipid peroxidation in the meat [18]. After all, oat BAS as an admixture was added to the diet of the geese of the first experimental group.

The meat of the II experimental group, compared to the control meat at the beginning of storage, was characterized by a significantly lower content of LPO products (by 22.6 %). Until the 23rd day, the content of lipid products remained at a constant level. The difference in the indicator between the control group and the II experimental group at that time was 39.4 %. This may indicate the antioxidant effect of biologically active substances of oats and alfalfa in inhibiting the oxidative deterioration of meat during its long-term low-temperature storage. By the 45th day, the content of LPO products in the meat of the II experimental group increased by 52.7 %. However, on this day as well, the TBCAP content in the geese meat of the II experimental group was lower by 41.2 % compared to the control group. From the 45th to the 67th day, the intensity of oxidative processes was maximum, which led to an increase in the content of lipid products in the geese meat of this group by 88.7 %. From the 67th day until the end of the storage period, the content of LPO products in the meat of geese of the II experimental group remained at a constant level.

The reason for this inhibition of lipid metabolism processes in the meat of geese of the II experimental group is probably that, like oats, alfalfa contains a significant amount of polyphenolic compounds, vitamin E, carotenoids, which, thanks to their antioxidant properties, are able to inhibit lipid peroxidation [19, 20]. And the combination of oats and alfalfa BAS in the geese diet contributes to an even greater increase in antioxidant activity in the meat of geese of experimental group II compared to I. However, a significantly higher antioxidant activity in the meat of geese of experimental group II compared to the corresponding indicator of the control was observed from the beginning to on the 67th day of storage, and compared to the goose meat of the I experimental group – only up to the 45th day.

Against the background of a change in the diet of geese, there were also changes in the fatty acid composition of their meat (Table 1). In the meat of the first experimental group at the beginning of the experiment, the content of the main saturated fatty acids, palmitic (16:0) and stearic (18:0), as well as the most abundant unsaturated oleic acid (18:1) did not differ significantly from the control group. However, the content of essential arachidonic acid (20:4) increased by 11.4 % ($p \leq 0.05$). The total content of ω3-fatty acids in the 1st experimental group compared to the control group was lower by 22.1 % ($p \leq 0.05$).

More positive changes occurred in the meat of the II research group. At the beginning of storage, an increase in the content of stearic acid (18:0) by 13.9 % ($p \leq 0.05$) and a decrease in oleic acid (18:1) by 12.4 % ($p \leq 0.05$) were recorded. However, the content of essential fatty acids, namely linoleic (18:2), linolenic (18:3) and arachidonic (20:4), was higher by 11.4 % ($p \leq 0.05$), 25.8 % and 12.4 % ($p \leq 0.05$). According to the content of polyunsaturated fatty acids and ω6-fatty acids, the samples of the II experimental group exceeded the control by 10.3 % ($p \leq 0.05$) and 10.9 % ($p \leq 0.05$), respectively.

Table 1

Dynamics of the content (ω, %) of fatty acids in goose breast meat during storage ($M \pm m$, $n=5$)

FA	1 day			90 days		
	Control	Experiment 1	Experiment 2	Control	Experiment 1	Experiment 2
(16:0)	24.6±0.69	24.4±0.73	24.8±0.7	24.2±0.7	24.7±0.87	24.4±1.05
(18:0)	12.3±0.39	13.0±0.43	14.0±0.52*	14.7±0.57	13.9±0.43**	14.3±0.56
(18:1)	35.8±1.04	36.0±1.26	31.4±0.94*	29.4±1.21	36.4±1.31**	32.0±1.28*
(18:2) ω6	14.5±0.58	13.1±0.49	16.1±0.42*	17.0±0.76	14.0±0.39	16.0±0.48
(18:3) ω3	0.5±0.02	0.4±0.02*	0.6±0.02**	0.5±0.01	0.5±0.02	0.5±0.02*
(20:4) ω6	5.6±0.23	6.3±0.25*	6.3±0.27*	6.3±0.28	4.5±0.19**	6.1±0.19
(22:4) ω6	0.4±0.01	0.3±0.01*	0.3±0.01**	0.3±0.01	0.3±0.01	0.3±0.01
(22:6) ω3	0.8±0.03	0.5±0.02**	0.7±0.03*	0.7±0.02	0.4±0.01**	0.7±0.02
SFA, %	39.1±1.16	39.7±1.23	41.2±1.29	41.8±1.39	40.7±1.37	41.0±1.69
UFA, %	60.7±2.02	60.0±2.17	58.5±1.81	58.0±2.41	59.2±2.04	58.8±2.12
MUFA, %	38.6±1.14	38.9±1.37	34.2±1.06*	32.1±1.29	39.2±1.41**	34.8±1.38*
PUFA, %	22.0±0.88	21.0±0.8	24.3±0.75*	25.8±1.12	20.0±0.63**	23.9±0.74
ω3PUFA, %	1.2±0.05	0.9±0.03**	1.2±0.05	1.2±0.04	0.9±0.03**	1.2±0.04
ω6PUFA, %	20.5±0.82	19.7±0.75	22.7±0.69*	23.5±1.05	18.7±0.59**	22.4±0.68

Notes: FA – fatty acids; the difference is probable relative to the control group: * – $p \leq 0.05$; ** – $p \leq 0.01$

The specified changes can be explained by the influence of oats, since its inclusion in the diet of geese helps to increase the antioxidant activity of muscle tissues. This is due to the high content of antioxidants in oats, which can effectively inhibit the oxidation of lipids in meat, thereby preserving unsaturated fatty acids [21].

The increase in the content of linoleic (18:2) and linolenic (18:3) acids in goose meat samples of the II research group may be associated with the presence of a large amount of these acids in alfalfa and their further absorption by the bird's body. After all, the results of the study of the composition of alfalfa organic acids established that the content of linoleic (18:2) and linolenic (18:3) acids is 15.8 % and 23.6 %, respectively, of the FA total amount [22].

On the 90th day of storage, an increase in the content of stearic acid (18:0) by 19.3 % and a decrease in the content of oleic (18:1) and docosatetraenoic (22:4) acids by 17.8 % were recorded in the meat samples of the control group and 30.9 %, respectively. An increase in the content of linoleic (18:2) acid by 17.6 % was also established. The reason for the increase in NFA content may be the increase in the bioavailability of these acids, including linoleic acid. In addition, there is information about the preservation of the activity of ω3- and ω6-desaturases after stopping blood circulation [23].

At the end of the storage period, the meat samples of the first experimental group had a 23.5 % higher content of oleic acid (18:1) than in the meat of the control group. However, the content of most unsaturated fatty acids decreased: linoleic acid (18:2) by 17.9 %, arachidonic acid (20:4) by 27.8 %, docosahexaenoic acid (22:6) by 39 %. The content of monounsaturated fatty acids in the experimental group exceeded the control indicator by 22.1 %. The total content of ω3- and ω6-fatty acids decreased by 23.8 % and 20.3 %, respectively. Therefore, the intensification of LPO processes in the meat of geese of experimental group I, which began on the 45th day of its storage, is accompanied by the loss of ω3- and ω6-fatty acids in the meat of geese of this group.

As a result of a comparative analysis of the gastrointestinal tract of the meat of the control and II experimental groups on the 90th day of storage, it was established that against the background of the use of oats and alfalfa in the diet of geese, the content of oleic acid (18:1) increased by 8.8 % ($p \leq 0.05$) and linolenic (18:3) by 12.4 % ($p \leq 0.05$). The content of other essential fatty acids remained at the level of the control sample. The total content of monounsaturated fatty acids in the meat of the II experimental group is higher by 8.6 % ($p \leq 0.05$). The total content of ω3- and ω6-fatty acids did not reliably change against the background of changes in the diet of geese.

Since the goose meat from the experimental groups showed a slower process of lipid peroxidation during the first 23 days, this may ensure longer meat storage compared to the control group. Thus, meat producers can increase the shelf life of products. Improving the fatty acid composition can make meat more useful for consumption from the point of view of human health and can be used in the development of diets and in health nutrition. Based on the results of the experiment, poultry producers may consider making changes to the geese's diet by adding oats and alfalfa to improve meat quality and shelf life.

Final conclusions regarding the feasibility of adding oats and alfalfa to the diet of geese can be made based on the results of biochemical studies, which will also include an analysis of the amino acid and vitamin composition of the obtained meat.

The war in Ukraine certainly led to a reduction in the possibilities of experimental research. However, the support of leading scientists of Ukraine, as well as other countries, made it possible to optimize work in the direction of using innovative research methods while reducing their scope.

4. Conclusions

The results of the research established that in the geese meat of the control group, the activation of LPO processes began immediately after slaughter. In the meat of geese of both experimental groups, under the influence of oats and alfalfa BAS, a state of pro-oxidant-antioxidant balance was maintained until the 23rd day, and only later was a LPO gradual activation. However, until the 67th day, the content of TBC-active products in the meat of geese of both experimental groups remained significantly lower than the corresponding reference indicator.

The most positive changes in dietary fiber occurred in the geese meat of the II experimental group. At the beginning of the experiment, this meat was characterized by an increased content of essential linoleic, linolenic and arachidonic acids. On the 90th day of storage, a higher content of only linolenic acid was found in the meat of the experimental groups. Therefore, the positive effect of oats and alfalfa on the antioxidant activity and fatty acid composition of goose meat has a gradually fading character over time.

However, within the established period of time to obtain better quality meat with increased antioxidant activity and a higher content of essential fatty acids, the use of a mixture of oats and alfalfa in the diet of geese is a promising technology that requires further research.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this study, including financial, personal, authorship, or any other, that could affect the study and its results presented in this article.

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Data availability

The manuscript has no associated data.

Use of artificial intelligence

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

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