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# CHEMICAL COMPOSITION AND BROILER MEAT QUALITY WHEN USING MELANIN

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**Keywords:** *broilers, chemical composition of meat, quality, fatty acid*

***Abstract***
*The research was carried out to study an effect of the antioxidant melanin in the broiler nutrition on the chemical composition, antioxidant and technological properties of meat, and the fatty acid composition of abdominal fat. The experiment was conducted in the conditions of the physiological courtyard of the L. K. Ernst Federal Research Center for Animal Husbandry in 2023. Broilers (n = 27, N = 54) of the domestic broiler cross "Smena-9" were divided into two groups (control and experimental). Broilers of the control group were fed the basic diet, birds of the experimental group received the basic diet with the addition of water-soluble melanin at a dose of 1.42 mg /kg of bird weight from the $7^{th}$ to $45^{th}$ day of age. At the age of 45 days, the birds were slaughtered and the meat chemical composition, fatty acid content, and quality characteristics were determined. The addition of melanin to the diet led to an increase in the meat antioxidants in the breast by 18.75% ($p < 0.0001$) and in the thigh by 5.6%, and also resulted in an increase in reduced glutathione by 20.25%, glutathione peroxidase by 10.43%, catalase 17.35% in the breast compared with the control. The use of melanin in broiler diets contributed to an increase in the content of erucic and 8,11,14-eicosatrienoic acids in abdominal fat compared with the control (at $p = 0.02$ and $p = 0.07$, respectively), as well as to an increase in the moisture content in muscles and the enrichment of meat with the antioxidant.*

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## Introduction

The poultry industry has received many benefits from achievements in the field of genetics, nutrition, and poultry keeping [1]. However, genetic selection based on productivity can lead to an increase in the number of metabolic disorders in the poultry body of modern genotypes [2], and a rapid growth rate is associated with the occurrence of meat quality defects [3]. Chicken meat is a source of protein, lipids, and minerals, which play an important role in basic human nutrition [4]. The quality and safety of food products is currently a very significant factor due to the enormous impact of products on human health and life expectancy [5,6].

The product quality and efficiency of poultry farming directly depend on the health of poultry [7]. The poultry meat quality is also influenced by the rearing systems [5,8].

Recently, the demand for organic food products has been growing due to their ability to reduce the risks of many diseases and improve the physical and mental well-being of consumers.

Since poultry of modern genotypes reacts acutely to stresses of various etiologies, metabolic disorders prevention and elimination is necessary to obtain high-quality poultry products [9,10].

One of the approaches to improving poultry health and meat quality is the use of various feed antioxidants [11–13].

Melanin is an irregularly shaped pigment, a product of the natural polymerization of dioxyphenol derivatives (tyrosine type) into a high-molecular compound under the action of tyrosinase in the presence of $O_2$. It is widely present in various organisms and has a wide range of biological effects, including the antioxidant activity [14,15]. Melanins are extensively used in medicine, pharmacology, cosmetology and other fields, but there is little information about the effect of this antioxidant on the composition and quality of meat and internal fat of broilers.

The purpose of the research was to study an effect of the adaptogen-antioxidant melanin in the broiler diet on the chemical composition, antioxidant and technological properties of muscle tissue, as well as the abdominal fat (FA) composition.

## Objects and methods

Two groups of broilers (n = 27, N = 54) (control and experimental) of the domestic broiler cross "Smena-9" were formed in the physiological yard of the L. K. Ernst Federal Research Center for Animal Husbandry and an experiment was conducted. As the main ration for chickens of

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all groups, full–fledged compound feeds were used, corresponding to the growing periods: up to 11 days — starting compound feed (up to 11 days), growth (12–26th day), finishing (27–45th day). From the 7th to the 45th day of life, water-soluble melanin was added to the main diet of poultry in the experimental group at a dose of 1.42 mg/kg of poultry weight. A highly concentrated water solution of melanin was prepared, which was sprayed onto the feed before feeding. On the 45th day, broilers (n = 27, N = 54) were slaughtered and parameters of the meat chemical composition were evaluated.

*Moisture content*

Moisture content of meat was determined according to GOST 33319–2015[1]. Purified sand and a glass rod were placed a weighing cup, dried at a temperature of 103 °C for at least 30 minutes, cooled at room temperature and weighed. A prepared crushed meat sample of about 5 g was placed in the weighing cup, weighed, and mixed with a glass stick. It was dried at a temperature of 103 °C for 2 hours, after which it was cooled to room temperature and weighed. The weighing cups were re-placed in a drying cabinet and kept at a temperature of 103 °C for 1 hour, after which they were cooled to room temperature and weighed. The weighing cups were dried to a constant weight (the discrepancy between two consecutive weighings did not exceed 0.1% of the sample weight). The moisture content in the samples was calculated using the equation:

$$X\,(\%) = \frac{(m_1 - m_2)}{m_1 - m} \times 100$$

Where:

$X$ — mass fraction of moisture;
$m_1$ — the weight of the weighing cup with the analyzed sample, stick and sand before drying, g;
$m_2$ — the weight of the weighing cup with the analyzed sample, stick and sand after drying, g;
100 — conversion to a percentage;
$m$ — the weight of the weighing cup with a stick and sand, g.

*Fat content*

The fat content of meat was determined according to GOST 23042–2015[2]. The method is based on the extraction of fat with a mixture of chloroform and ethyl alcohol using a filter separation funnel followed by separation of the extract, removal of the solvent and drying of the isolated fat. Chloroform and ethyl alcohol were mixed in a ratio of 2:1. About 2 g of the prepared sample was weighed in a glass. The analyzed sample was quantitatively transferred to a filter separation funnel, 20 cm$^3$ of the extraction mixture was poured, kept for 5 minutes, and extraction was carried out shaking the funnel for 2 minutes. The resulting extract from the dividing funnel was filtered using a water jet pump into the receiver. The extract was transferred from the receiver to a measuring flask. Extraction was performed two more times. After the end of the third extraction, the filter separation funnel and receiver were washed with an extraction mixture, which was collected into a measuring flask. The contents of the flask were brought to the mark with an extraction mixture and mixed. Then, 20 cm$^3$ of the extract was transferred to a weighing cup that had been dried at a temperature of 103 °C for at least 30 minutes and weighed beforehand. To remove the solvent, the weighing cup with the extract was placed in a water bath with a temperature of 40 °C and kept for 20 minutes until the smell of the solvent completely disappeared. The weighing cup with fat was placed in a drying cabinet, kept at a temperature of 103 °C for 15 minutes, cooled and weighed. The fat content in the samples was calculated using the equation:

$$X\,(\%) = \frac{(m_1 - m_2) \times 100}{m \times 20} \times 100 \tag{1}$$

Where:

$X$ — mass fraction of fat;
$m_1$ — the weight of the weighing cup with fat, g;
$m_2$ — the weight of the weighing cup, g;
100 — total volume of the extract, cm$^3$;
100 — percentage conversion factor;
$m$ — mass of the analyzed sample, g;
20 — volume of the extract selected for evaporation, cm$^3$.

*Ash content*

The total ash content of processed broiler meat was determined according to ISO 936:1998[3]. Test portions (1 g) from samples of each group were weighted into preheated crucibles and incinerated overnight in a Muffle furnace at 550 °C until white ash free of carbon was obtained. The crucibles were removed from the Muffle furnace, cooled in a desiccator at a room temperature of 27 °C and reweighed. The ash content of the samples was calculated using the equation:

$$Ash\,(\%) = \frac{W_a}{W_s} \times 100 \tag{2}$$

Where:

$W_a$ — weight of ash;
$W_s$ — weight of the sample.

*Fatty acid composition*

The fatty acid composition of abdominal fat was determined according to GOST R55483–2013[4]. A 15% solution of acetyl chloride in methanol, a saturated solution of potassium hydroxide in methanol, a saturated aqueous solution of sodium chloride, and a standard solution of a mixture of methyl esters of fatty acids were previously prepared. The

[1] GOST 33319–2015 Meat and meat products. Method for determination of moisture content. Retrieved from https://docs.cntd.ru/document/1200123927. Accessed February 06, 2024

[2] GOST 23042–2015 Meat and meat products. Methods of fat determination. Retrieved from https://docs.cntd.ru/document/1200133107. Accessed February 06, 2024

[3] ISO 936:1998 Meat and meat products. Determination of total ash Retrieved from https://docs.cntd.ru/document/1200098742. Accessed February 06, 2024

[4] GOST R55483–2013. Meat and meat products. Determination of fatty acids composition by gas chromatography Retrieved from https://docs.cntd.ru/document/1200103852/ Accessed February 06, 2024

analyzed sample (10 g) was placed in a flask with a ground stopper, filled with a mixture of 10 $cm^3$ methanol and 10 $cm^3$ chloroform and kept at room temperature for 24 hours for complete dissolution of lipids. Then, 3 $cm^3$ of a 15% acetyl chloride solution in methanol was added to the fat obtained after evaporation and the mixture was kept in a water bath at a temperature of 100 °C for 2 hours. After that, 1.25 $cm^3$ of a potassium hydroxide solution saturated in methanol was added to the mixture cooled to room temperature to a pH value of 5.0–6.0 and also 3 $cm^3$ of a saturated aqueous solution of sodium chloride and 3 $cm^3$ of hexane. The mixture was shaken and centrifuged until a transparent top layer of liquid was obtained. Finally, 1 $cm^3$ of a transparent upper hexane solution of methyl esters of fatty acids was placed in vials for use in a gas chromatograph.

*Meat pH*

The pH of meat was recorded using a Testo 205 pH meter (China).

*Calcium content*

The calcium content of meat was determined according to Methodological recommendations for chemical and biochemical studies of livestock products and feed[5]. The ash sample was boiled for 15 minutes with 5 ml of concentrated hydrochloric acid and 50 ml of water. The solution was transferred to a 100 ml flask. After cooling, it was brought to 100 ml with water and mixed. The next day, 0.1 ml of the tested ash solution was added to a test tube with 1 ml of caustic potassium, an indicator and a trilon. The solution was titrated with trilon B until the green color disappeared. The calcium content in the ash was determined by the formula:

$$Ca\ (\%) = \frac{a \times 0.04 \times 100 \times 100}{0.1 / c \times 1000} \quad (3)$$

Where:

$a$ — the amount (ml) of 0.001 M of the trilon B solution used for titration of the test solution;
0.04 — the amount of calcium bound by 1 ml of 0.001 M trilon B solution, mg;
100 — dilution;
0.1 = volume of ash solution taken for titration, ml;
$c$ — ash weight, g;
100 — conversion to %;
1000 — conversion of mg to g.

*Phosphorus content*

The *phosphorus* content of meat was determined according to Methodological recommendations for chemical and biochemical studies of livestock products and feed[5]. A sample of the analyzed substance was placed in a 100 ml Kjeldahl flask, 2.5 ml of concentrated sulfuric acid, 10 drops of a solution of hydrochloric acid were poured and burned until discoloration. After cooling, the contents of the flask were diluted with a small amount of water and transferred to a 100 ml volumetric flask, the solution was brought to the mark. The test solution (5 ml) was taken into a dry test tube, 1 ml of ammonium molybdenum solution was added and the test tube was shaken. After that, 0.25 ml of amidol solution was added and the test tube was put in a water bath at 37 degrees for 5 minutes. Then, the tube was placed in ice water and colorimetrated on a photometer with a wavelength of 635 nm. The phosphorus content was determined by the formula:

$$P\ (\%) = \frac{a \times 20 \times 100}{W_s \times 1000000} \quad (4)$$

Where:

$a$ — the amount of phosphorus found on the calibration curve contained in 5 ml of the ash solution, mcg;
20 — recalculation to determine the phosphorus content in the mg of the sample;
100 — conversion to%;
$W_s$ — weight of the sample;
1000000 — conversion of mcg to g.

*Magnesium content*

The magnesium content of meat was determined according to Methodological recommendations for chemical and biochemical studies of livestock products and feed[5].

The ash solution (5 ml) was placed in a 150 ml flask. Then, 20 ml of water, 2 ml of triethanolamine solution, 5 ml of trilon B solution, 2 drops of methylroth were added and neutralized with 255 M ammonia solution until yellow color appeared. After that, 10 ml of the ammonia buffer solution, 12 drops of 0.02% alcohol solution of methyl red and 5 drops of chromogen black were added. The color became green. The solution was titrated with magnesium sulfate until the color changed. The calculation of the magnesium content was carried out according to the formula:

$$Mg\ (\%) = \frac{(a - b) \times k \times 0.00012 \times 100 \times 100}{5 \times c} \quad (5)$$

Where:

$a$ — amount of 0.01 M trilon B solution bound by the sum of calcium and magnesium ml;
$b$ — amount of 0.01 N solution of trilon B (ml) bound with calcium, ml
0,00012 — the amount of magnesium corresponding to 1 ml of 0.01 N of trilon B solution, g;
$k$ — correction to trilon B;
100 — the volume, in which the ash was dissolved, ml;
$c$ — ash weight, g;
100 — conversion to %.

*Water holding capacity*

Water holding capacity was measured by pressing according to Grau and Hamm in the modification of Volovinskaya [16]; the amount of water-soluble antioxidants (AWSA) was determined on the device Tsvet-Yauza-01-AA (Khimavtomatika, Russia) by the amperometric method. The activity of glutathione peroxidase, catalase, the concentration of reduced glutathione were determined using

[5] Drozenko, N.P., Kalinin, V.V., Raetskaya, Yu. I. (1981). Methodological recommendations for chemical and biochemical studies of livestock products and feed. Dubrovitsy, 1981.

commercial Elabscience kits (Elabscience, China) on a Photometer Immunochem-2100 device (High Technology Inc., USA).

*Ethics statement*

Studies were carried out with approval by the bioethical commission of the L. K. Ernst Federal Research Center for Animal Husbandry (No. 3, May 27, 2022). The experiments were carried out in accordance with the requirements of the Federal Law of the Russian Federation[6], the Declaration of Helsinki[7], the European Convention for the Protection of Vertebrate Animals Used for Experimental and Other Scientific Purposes (ETS No. 123, Strasbourg, 1986)[8].

*Statistical analysis*

Mathematical and statistical processing of the results was performed with the use of Microsoft Office Excel 2003, STATISTICA 10 (Statistica 13RU, StatSoft, USA) by the methods of variance and factor analysis, using the Dunnett's test and Tukey's test (t-test). The differences were considered statistically significant at $p < 0.05$, highly significant at $p < 0.01$; $p < 0.001$.

**Results and discussion**

In thigh and breast meat of poultry treated with melanin, an increase in the moisture content was noted compared with the control (at $p<0.001$ and $p<0.0001$). In the experimental group, the protein content (at $p<0.001$), ash (at $p<0.001$) and the content of minerals calcium, phosphorus (at $p<0.01$), fat (at $p>0.05$) in the studied tissues decreased (Table 1).

The pH-45 in the breast of broilers slaughtered at 45 days of age was the same in all groups, and a day later it decreased by 0.13 units (the control), and by 0.14 units (the experimental group). The pH of the femoral muscle decreased from 6.04 to 5.54 units (by 0.5) in the control, and from 6.04 to 5.56 (by 0.48 units) in the experimental group. The water holding capacity (WHC) of thigh muscles in poultry of the control and experimental groups was at the same level and amounted to 58.79 and 58.36%, respectively. The addition of melanin to the broiler ration had a positive effect on the meat antioxidant content and, accordingly, the antioxidant capacity of muscle tissue. Thus, the AWSA in the breast of chickens treated with melanin was 18.75% higher ($p<0.0001$) compared with the control, in the femoral muscle this difference was 5.6%. The content of reduced glutathione in the breast of the experimental group was 151.87 μM/g, which is 20.25% higher than in the control. There was a trend towards an increase in the concentration of glutathione peroxidase by 10.43% and catalase by 17.35% in the breast of chickens treated with melanin compared with the control (Table 2).

**Table 1. Chemical composition of broiler meat at the age of 45 days,% (M ± SEM, n = 27)**

| Indicator | Group | |
|---|---|---|
| | Control | Experimental |
| | Thigh meat | |
| Moisture | 68.22 ± 0.43 | 70.23 ± 0.70** |
| Protein | 22.18 ± 0.24 | 20.42 ± 0.41*** |
| Moisture/protein | 3.08 | 3.44 |
| Fat | 8.49 ± 0.44 | 8.29 ± 0.63 |
| Ash | 1.11 ± 0.02 | 1.06 ± 0.03 |
| Calcium | 0.05 ± 0.001 | 0.05 ± 0.0001 |
| Phosphorus | 0.17 ± 0.002 | 0.16 ± 0.0001 |
| Magnesium | 0.02 ± 0.0006 | 0.02 ± 0.0001 |
| | Breast meat | |
| Moisture | 71.30 ± 0.29 | 73.15 ± 0.19*** |
| Protein | 26.05 ± 0.23 | 24.34 ± 0.04*** |
| Moisture/protein | 2.73 | 3.00 |
| Fat | 1.35 ± 0.09 | 1.30 ± 0.08 |
| Ash | 1.30 ± 0.02 | 1.21 ± 0.01*** |
| Calcium | 0.06 ± 0.001 | 0.05 ± 0.0001** |
| Phosphorus | 0.19 ± 0.003 | 0.18 ± 0.0001** |
| Magnesium | 0.03 ± 0.0007 | 0.03 ± 0.0001 |

**Note: the differences are significant at: ** $p<0.01$ *** $p<0.001$ with the indicators of animals in the control group/**

**Table 2. Qualitative characteristics of broiler meat aged 45 days (M ± SEM, n = 27)**

| Indicator | Group | |
|---|---|---|
| | Control | Experimental |
| Breast pH-45 | 5.91 ± 0.05 | 5.86 ± 0.04 |
| Breast pH-24 | 5.78 ± 0.03 | 5.72 ± 0.04 |
| Thigh pH-45 | 6.04 ± 0.03 | 6.04 ± 0.05 |
| Thigh pH- 24 | 5.54 ± 0.30 | 5.56 ± 0.43 |
| Thigh WHC, % | 58.79 ± 1.0 | 58.36 ± 1.46 |
| AWSA in the breast, mg/g | 0.16 ± 0.002 | 0.19 ± 0.01*** |
| AWSA in the thigh, mg/g | 0.18 ± 0.008 | 0.19 ± 0.01 |
| Glutathione reduced in the breast, μM/g | 126.30 ± 15.15 | 151.87 ± 7.31 |
| Glutathione peroxidase in the breast, U/g | 125.43 ± 8.60 | 138.52 ± 7.90 |
| Catalase in the breast, U/g | 6.11 ± 0.45 | 7.17 ± 0.72 |

**Note: the differences are significant at: * $p<0.05$, *** $p<0.001$ — compared with the control group**

The results of single factor analysis of variance show that the moisture ($p=0.004$), protein ($p=0.002$), fat ($p=0.001$), calcium ($p=0.006$), magnesium ($p=0.05$) content in breast muscle and the protein ($p=0.003$), ash ($p=0.03$), phosphorus ($p=0.02$), magnesium ($p=0.01$) content in thigh muscle, pH-45 in the breast ($p=0.00001$), and pH-24 in the breast ($p=0.00001$) were associated with BW of poultry (Table 3).

[6] Federal Law of the Russian Federation dated December 27, 2018 No. 498-FZ "On the responsible treatment of animals and on amendments to certain legislative acts of the Russian Federation."Retrieved from https://docs.cntd.ru/document/552045936 Accessed February 06, 2024

[7] WMA Declaration of Helsinki — ethical principles for medical research involving human subjects Retrieved from https://www.wma.net/policies-post/wma-declaration-of-helsinki-ethical-principles-for-medical-research-involving-human-subjects/ Accessed February 06, 2024

[8] European Convention for the Protection of Vertebrate Animals used for Experimental and Other Scientific Purposes. Retrieved from https://rm.coe.int/168007a67b. Accessed February 06, 2024

**Table 3. Relationship of the body weight (BW) with the chemical composition and quality of broiler muscle tissue (n = 54) (results of one-way analysis)**

| Indicator | BW | p-value |
|---|---|---|
| Thigh meat | | |
| Moisture | *** | 0.004 |
| Protein | *** | 0.002 |
| Fat | *** | 0.001 |
| Ash | n.r. | 0.02 |
| Calcium | *** | 0.006 |
| Magnesium | * | 0.05 |
| Phosphorus | n.r. | 0.20 |
| Thigh pH-45 | n.r. | 0.10 |
| Thigh pH- 24 | n.r. | 0.10 |
| Thigh WHC | n.r. | 0.95 |
| Breast meat | | |
| Moisture | n.r. | 0.08 |
| Protein | *** | 0.003 |
| Fat | n.r. | 0.35 |
| Ash | * | 0.03 |
| Calcium | n.r. | 0.70 |
| Magnesium | * | 0.01 |
| Phosphorus | * | 0.02 |
| Breast pH-45 | *** | 0.00001 |
| Breast pH-24 | *** | 0.00001 |
| Glutathione reduced in the breast | n.r. | 0.05 |
| Glutathione peroxidase in the breast | n.r. | 0.42 |

Note: the differences are significant at: * $p < 0.05$, ** $p \leq 0.01$; *** $p \leq 0.001$; n. r. — no relationship

The saturated fatty acid content (SFAs) in the studied abdominal fat samples was 21.21–21.50%, while monounsaturated fatty acids (MUFAs) were at a level of 33.03–33.65%, polyunsaturated fatty acids (PUFAs) at a level of 44.89–45.76%. The sum of n-6 fatty acids ranged from 40.93 to 41.73%, and n-3 from 3.87 to 3.93%.

The feeding factor had a positive effect on the content of erucic and 8,11,14-eicosatrienoic acids. The differences between the animal groups were significant, at $p = 0.02$ and $p = 0.07$, respectively (Table 4).

Poultry meat is a rich source of protein, which according to various sources comprises 23–25% in the breast and 18% in the thigh [17]. The main amino acids (AA) in poultry meat (asparagine, lysine, leucine, arginine, glutamine) determine the taste and technological properties of meat. The AA content is usually maintained, but may vary depending on a diet and its amino acid composition. Some experiments show that increasing the quantity of certain AAs in birds diets before slaughter leads to an increase in the AA content in tissues [17,18]. In our studies, the protein level in the breast was 24.34–26.05%, and in the thigh — 20.42–22.18%, and in the group of poultry that received melanin, the indicators were slightly lower than in the control. At the same time, the moisture content in both the pectoral and femoral muscles in the poultry of the experimental group was significantly higher (at $p < 0.001$ and $p < 0.0001$) than in the control, which may be more attractive in terms of consumer and culinary properties of chicken. An increase in the dietary properties of meat from poultry treated with melanin is indicated by a decrease in the fat content in the breast and thigh compared to poultry of the control group. Similar results were observed by other authors who established a direct relationship between the use of additional vitamins with the antioxidant properties in poultry diets and a decrease in fat deposition in tissues [19]. A possible mechanism of this action is the fact that an increase in the level of antioxidants in the diet is directly related to an increased level of the hormone T3 and the enzyme iodothyronine deiodinase in the blood. Thyroid hormones regulate the metabolic activity in animals and can stimulate the mobilization of fat reserves and reduce their deposition on the carcass [20].

The mineral content in the muscles of the broilers used in the experiment was 1.06–1.30%. In our studies, there was no difference between the groups in the content of individual mineral elements, both in the femoral and pectoral muscles of broiler chickens. As is known from the literature, feeding and other growing factors have little effect on these values if the feed intake meets the needs of animals [19].

pH is an important indicator that shows the mobilization of glycogen reserves, resulting in the formation of lactic acid in meat, which affects the isoelectric point of the main muscle proteins and determines their ability to retain or release water. The pH level of meat can affect its susceptibility to oxidation. The more acid in meat, the higher the risk of oxidation [21]. In our studies, we did not observe significant differences between the groups in this indicator. The pH 45 minutes after slaughter in both groups was at a level of 5.86–5.91 in the breast and 6.04 in the thigh. A day after slaughter, this indicator in the breast muscle decreased by 0.13 units in the control group, by 0.14 units in the experimental group, and by 0.5 and 0.48 units in the thigh muscle, respectively.

There was no difference between the groups in the WHC. Other authors have pointed out that the inclusion of antioxidants in the diet has a direct effect on the water holding capacity (WHC) of meat. By increasing the content of selenium yeast in feed cooking loss was reduced by 5% [22]. The same picture was obtained when zinc was added to the diet. The WHC can be affected by age, genotype, and other conditions. In broiler chickens slaughtered at the age of 35 to 63 days, juice losses after storage and cooking decreased by 1% and 0.6%, respectively [17].

An important characteristic in evaluation of broiler chicken growth and meat quality is a degree of correlation between the main parameters and live weight. High ($p < 0.05$) correlation of some important nutritional characteristics (protein, fat, calcium, phosphorus, magnesium content in thigh and breast muscles), as well as qualitative parameters (pH) with live weight has been experimentally established, which should be taken into account when raising poultry of modern crosses.

Table 4. Fatty acid composition of abdominal fat of broilers, % (M ± SEM, n = 27)

| Indicator | | Group | | p-value |
|---|---|---|---|---|
| | | Control | Experimental | |
| Caproic acid | $C_{6:0}$ | 0.0047 ± 0.0019 | 0.0042 ± 0.00199 | 0.70 |
| Caprylic acid | $C_{8:0}$ | 0.0046 ± 0.0009 | 0.0037 ± 0.0004 | 0.59 |
| Capric acid | $C_{10:0}$ | 0.0075 ± 0.0015 | 0.0061 ± 0.0009 | 0.81 |
| Caproleic acid | $C_{10:1}$ | 0.0062 ± 0.0013 | 0.0052 ± 0.0004 | 0.54 |
| Lauric acid | $C_{12:0}$ | 0.0118 ± 0.0012 | 0.0114 ± 0.0007 | 0.48 |
| Tridecanoic acid | $C_{13:0}$ | 0.0025 ± 0.0005 | 0.0023 ± 0.0004 | 0.58 |
| Myristic acid | $C_{14:0}$ | 0.2616 ± 0.0084 | 0.2498 ± 0.0065 | 0.41 |
| Pentadecanoic acid | $C_{15:0}$ | 0.0630 ± 0.0032 | 0.0569 ± 0.0014 | 0.20 |
| Cis-10-Pentadecenoic acid | $C_{15:1}$ | 0.0173 ± 0.0038 | 0.0120 ± 0.0008 | 0.28 |
| Palmitic acid | $C_{16:0}$ | 15.7141 ± 0.3062 | 15.8129 ± 0.0297 | 0.74 |
| Margaric acid | $C_{17:0}$ | 0.1338 ± 0.0039 | 0.1380 ± 0.0069 | 0.37 |
| Stearic acid | $C_{18:0}$ | 4.7617 ± 0.0916 | 4.9493 ± 0.1268 | 0.41 |
| Nonadecanoic acid | $C_{19:0}$ | 0.0209 ± 0.0015 | 0.0206 ± 0.0016 | 0.89 |
| Heneicosanoic acid | $C_{21:0}$ | 0.0591 ± 0.0079 | 0.0549 ± 0.0026 | 0.96 |
| Behenic acid | $C_{22:0}$ | 0.0298 ± 00025 | 0.0269 ± 0.0017 | 0.58 |
| Lignoceric acid | $C_{24:0}$ | 0.0317 ± 0.0030 | 0.0309 ± 0.0024 | 0.99 |
| Myristoleic acid | $C_{14:1}$ | 0.0442 ± 0.0050 | 0.0379 ± 0.0026 | 0.39 |
| Palmitoleic acid | $C_{16:1}$ | 2.4910 ± 0.0098 | 2.4714 ± 0.1385 | 0.86 |
| Cis-10-Heptadecenoic acid | $C_{17:1}$ | 0.0782 ± 0.0037 | 0.0743 ± 0.0027 | 0.48 |
| Oleic acid | $C_{18:1}$ | 30.1205 ± 0.3989 | 30.7619 ± 0.4741 | 0.81 |
| Gondoic acid | $C_{20:1}$ | 0.2038 ± 0.0110 | 0.2098 ± 0.0061 | 0.88 |
| Cis-11,14-Eicosadienoic acid | $C_{20:2}$ | 0.1505 ± 0.0079 | 0.1564 ± 0.0072 | 0.51 |
| Erucic acid | $C_{22:1}$ | 0.0063 ± 0.0010 | 0.0068 ± 0.0010* | 0.02 |
| Nervonic acid | $C_{24:1}$ | 0.0122 ± 0.0030 | 0.0105 ± 0.0026 | 0.45 |
| Linoleic acid | $C_{18:2}$ | 41.5611 ± 0.7080 | 40.7790 ± 0.7647 | 0.84 |
| Linolenic acid | $C_{18:3(n6)}$ | 0.1236 ± 0.0070 | 0.1135 ± 0.0067 | 0.46 |
| Arachic acid | | 0.0988 ± 0.0058 | 0.0913 ± 0.0044 | 0.24 |
| α-linolenic acid | $C_{18:3(n3)}$ | 3.8004 ± 0.0609 | 3.7362 ± 0.0779 | 0.77 |
| Cis-8,11,14-Eicosatrienoic acid | $C_{20:3}$ | 0.0222 ± 0.0081 | 0.0124 ± 0.0020 | 0.34 |
| Cis-11,14,17-Eicosatrienoic acid | $C_{20:3}$ | 0.1024 ± 0.0064 | 0.1065 ± 0.0070 | 0.07 |
| Arachidonic acid | $C_{20:4}$ | 0.0239 ± 0.0019 | 0.0243 ± 0.0019 | 0.36 |
| Cis-5,8,11,14,17-eicosapentaenoic acid | $C_{20:5}$ | 0.0152 ± 0.0029 | 0.0142 ± 0.0013 | 0.57 |
| Cis-4,7,10,12,15,19-docosahexaenoic acid | $C_{22:6}$ | 0.0156 ± 0.0076 | 0.0088 ± 0.0031 | 0.63 |
| The sum of acids | | | | |
| The sum of SFA | 21.2082 ± 0.3221 | | 21.4592 ± 0.3276 | |
| The sum of MUFA | 33.0285 ± 0.4896 | | 33.6546 ± 0.5954 | |
| The sum of PUFA | 45.7633 ± 0.7624 | | 44.8863 ± 0.8274 | |
| The sum of UFA | 78.7918 ± 0.3221 | | 78.5409 ± 0.3276 | |
| n-6 | 41.7308 ± 0.7086 | | 40.9292 ± 0.7643 | |
| n-3 | 3.9336 ± 0.0677 | | 3.8657 ± 0.0820 | |
| MUFA/SFA | 1.5592 ± 0.0170 | | 1.5711 ± 0.0241 | |
| n-6/n-3 | 10.6257 ± 0.1306 | | 10.6318 ± 0.1763 | |

Note: the differences are significant at: * $p < 0.05$ — compared with the control group.

In our studies, chickens treated with melanin had a higher content of the amount of water-soluble antioxidants (AWSA) in the breast by 18.75% ($p < 0.0001$) and in the thigh by 5.6% compared to the control. The reduced glutathione content of the breast in the experimental group was 151.87 μM/g, which was 20.25% higher than that in the control. There was a tendency towards an increase in glutathione peroxidase by 10.43% and catalase by 17.35% in the breast of chickens treated with melanin compared with the control. Due to these facts, meat from poultry that received melanin was less exposed to oxidative effects during ageing. Other researchers have also observed improvements in meat quality and oxidative stability of broiler muscles when using various antioxidants in diets [23,24].

Chicken meat is rich in unsaturated fatty acids (FAs), which makes it more susceptible to lipid oxidation and the formation of volatile organic compounds. FAs of chicken meat consist of about one-third of SFAs, one-third of MUFAs and one-third of PUFAs [25].

The results of the study by Kanakri et.al [25] show that the content and ratio of fatty acids in diets largely determine their profile in meat and other tissue, which makes it possible to predict the poultry FA composition. The same opinion was reached by other researchers who showed that feeding the fat of insect larvae contributed to an increase in the proportion of SFA to the detriment of PUFA in breast and thigh with an increase in the ratio of n-6 FA/n-3 [26,27].

The use of melanin in broiler diets contributed to an increase in the content of erucic and 8,11,14-eicosatrienoic acids in abdominal fat compared with the control (at $p = 0.02$ and $p = 0.07$, respectively). Cis-11,14,17-eicosatrienoic acid belongs to omega-3 PUFAs, which are part of cell membranes and blood vessels, are not synthesize in the right amounts in the human body and are one of the necessary components of a full-fledged healthy diet.

The FA content in broilers can also be influenced by gender, genotype and the growing system. For example, it was found that a higher percentage of n-3 PUFAs was produced in slow-growing chickens compared to fast-growing ones [28]. Castellini et al. [29] showed that this content could increase in slow-growing birds raised in free range and in organic systems due to high grass consumption. At the same time, the consumption of herbs improved the antioxidant content of poultry meat and prevented the oxidation of PUFAs [30]. The energy source of the feed can also affect the FA composition of poultry meat. Diets with the high carbohydrate content will promote lipogenesis in the liver and, consequently, the synthesis of SFAs and MUFAs, whereas diets with a high fat content will rather contribute to the direct deposition of dietary fats in peripheral tissues [31].

**Conclusion**

The use of antioxidants in broiler diets not only has a positive effect on the health of fast-growing poultry, but also contributes to improving product quality. In our studies, it has been found that the inclusion of melanin in the diets of broilers of the Smena-9 cross contributes to an increase in the moisture content in the pectoral and femoral muscles, the enrichment of meat with antioxidants, and an increase in the content of erucic and eicosatrienoic acids in abdominal fat. The absence of the effect of melanin feeding on the WHC and pH of broiler muscle tissue requires further study.

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