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INFLUENCE OF NATURAL PLANT SUBSTANCES ON QUALITY INDICATORS OF BROILER CHICKEN MEAT

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Keywords: *broiler chickens, chemical composition, essential elements, cinnamaldehyde*

Abstract

The research was conducted in the vivarium of the Federal Research Centre of Biological Systems and Agrotechnologies in 2023 to study the effect of biologically active substances isolated from medicinal plants on the productivity and meat quality indicators. Week-old broiler chickens were divided into 4 groups (N = 180, n = 45). Broilers in the control group received the basic diet; animals from experimental groups I, II and III, along with the basic diet, were fed cinnamaldehyde in the amount of 15, 30 and 55 mg/kg of feed, respectively. At the age of 42 days, the animals were slaughtered and the chemical, amino acid and mineral composition of the muscles was determined. Broilers that, in addition to the basic diet, received cinnamaldehyde in the amount of 30 and 55 mg/kg of feed, exceeded the control group in pre-slaughter live weight by 4.50% and 7.27%, respectively. Similarly, the mass of muscle tissue and edible part of carcass in group III increased by 8.67% and 8.40% relative to the control group values, respectively. It was found that the mass fraction of protein in the breast was higher in young animals from group II than in the poultry from groups C, CA-I and CA-III by 1.57%, 2.16% and 1.35%, respectively. In terms of calcium content in the thighs, broilers from groups CA-II and CA-III exceeded the control group by 2 times. Young animals from the experimental groups CA-I and CA-III exceeded the poultry from group C in the accumulation of the essential amino acid arginine in the thighs by 0.4% and 0.2%, respectively. Thus, the use of cinnamaldehyde as a feed additive for agricultural poultry has a positive effect on the chemical composition of meat, the content of essential elements and amino acids.

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Introduction

Poultry production is one of the fast-growing and most flexible sectors of the livestock industry. In particular, due to very high demand, it has expanded, consolidated and become global in countries with different income levels. Broiler meat production has increased significantly in recent decades, especially through intensive production systems, increasing its importance for the global animal protein production and economics. Since antibiotic growth promoters are still used in many countries to improve poultry productivity, their use has simultaneously increased. However, they contribute to the development and increase of antibiotic-resistant bacteria, such as extended-spectrum beta-lactamase-producing bacteria in poultry. As a result of these negative consequences of antibiotic use and the prohibition against the use of antibacterials as growth promoters in the European Union (2006), their use as a feed additive was banned [1,2]. Currently, feed additive manufacturers face two challenges: production of additives that have a bactericidal effect and stimulate the growth of high-quality muscle tissue [3,4]. There are more than a dozen solutions on the market that have the above-mentioned properties with varying degrees of effectiveness, such as probiotics [5], prebiotics [6], symbiotics [7], phytobiotics [8,9] and plant extracts [10,11]. They are widely used worldwide due to their unique properties and positive effects on productivity. Phytobiotics play a growing role as potential alternatives to antibiotic growth promoters, since they are natural, readily available, non-toxic and contain no residues [12]. Phytobiotic additives may stimulate appetite, increase the secretion of digestive enzymes, stimulate immunity and have bactericidal, antiviral and antioxidant effects, as well as improve growth performance and the quality of animal products [13,14].

An increasing number of studies have shown that new additives such as phytobiotics may be used as an alternative to in-feed antibiotics. However, the effectiveness of alternative additives depends on many factors such as the concentration of digestible substances, the diet, the method of additive administration or the rearing conditions. Lee et al. [15] demonstrated in their studies that feeding cinnamaldehyde (125 mg/kg) increased the levels of intestinal mRNA encoding IL-1β, IL-6, IL-15 and interferon-γ and reduced body weight loss induced by *Eimeria acervulina* and *Eimeria maxima*. The anticoccidial

and antiparasitic activities were probably related to the immunomodulatory capacity of cinnamaldehyde. A recent study showed that dietary supplementation with encapsulated cinnamaldehyde (100 mg/kg) improved growth performance, reduced intestinal lesions caused by *Eimeria* spp. and *C. perfringens*, and modulated the cecal microbiota of broiler chickens vaccinated against coccidiosis [16].

Among feed additives, another possibility is the use of pure bioactive compounds found in plants, such as chemically synthesized analogues of these bioactive substances, referred to as nature-identical compounds or pure plant (phytochemical) components. Natural feed products are increasingly preferred because they are believed to have fewer undesirable side effects than synthetic analogues. The difference in using nature-identical compounds rather than plant extracts is that the former are single, pure molecules. By using pure molecules or mixtures of molecules whose composition is known, the amount of inclusion in the feed is therefore precise. In addition, products may be formulated by selecting the most effective compounds and combining them to obtain potential synergies [17].

Cinnamaldehyde is the main component of cinnamon essential oil (up to 90%) and cassia essential oil (up to 75%), which determines their odor. Cinnamaldehyde has been used for many years to produce food flavors and medicines, without taking into account its properties as an alternative to antimicrobial drugs for broilers [18]. Despite the fact that studies have been conducted to replace growth promoters with plant components, including cinnamaldehyde, it remains unknown what levels of their inclusion give the best results in terms of broiler meat quality and how do they act.

The aim of our study was to evaluate the effect of organic substances isolated from medicinal plants on the productivity and quality indicators of broiler chicken meat.

Objects and methods

The study was conducted in the vivarium of the Center for Shared Use of Scientific Equipment of the Federal Research Centre of Biological Systems and Agrotechnologies of the Russian Academy of Sciences; the period of the study was February to August 2023. The objects of the study were broiler chickens of the Arbor Acres cross, cinnamaldehyde (chemical formula C9H8O, molar weight 132.16 g/mol, manufacturer: Acros Organics BVBA, Belgium). The objects of the study, 7-day-old broiler chickens, in the amount of 180 animals were divided into 4 groups (n = 45) using the analog method. The control group (C) received the basic diet (BD), experimental group I (CA-I) received BD + cinnamaldehyde 15 mg/kg feed/day, experimental group II (CA-II) received BD + cinnamaldehyde 30 mg/kg feed/day, experimental group III (CA-III) received BD + cinnamaldehyde 55 mg/kg feed/day. During the experiment, all animals were kept in the same conditions. The formulation of basic diet (BD) for the experimental poultry during the studies was carried out taking into account the recommendations by the All-Russian Scientific Research and Technological Institute of Poultry (VNITIP)[1]. The experiment used industrial compound feed from CJSC "Ptitsefabrika Orenburgskaya", consisting of sunflower meal, corn, wheat, soybean meal, vitamin and mineral premix. The experimental animal was fed 2 times a day; the consumption was recorded daily. Decapitation of poultry using pentobarbital ether was performed on the 42nd day (n = 5).

The analysis of meat chemical composition was carried out according to standardized methods in an independent certified Testing Center of the Federal Research Centre of Biological Systems and Agrotechnologies of the Russian Academy of Sciences.

Post-slaughter anatomical cutting of carcasses

The cutting was carried out according to the VNITIP method. Eviscerated broiler carcasses, weighed on Mercury 327 ACP LCD scales (MERCURYWP TECH GROUP CO., LTD., Republic of Korea) with an acceptable scale division error of ±2 g, were cut into the primal cuts: breast, legs + thighs, wings, anterior part and back. The obtained cuts were anatomically deboned, the constituent tissues (muscles, skin, veins, fat, bones with and without residual trim) were isolated, and their yield was determined by weighing on MW-II laboratory scales (CAS Corporation, Republic of Korea) with an acceptable weighing error of ±0.01 g.

Eviscerated carcasses had all internal organs, head (between the second and third cervical vertebrae), neck (without skin) at the level of the shoulder joints, feet up to the tarsal joint or below it, but not more than 20 mm, removed. Eviscerated carcasses with a set of giblets and a neck are eviscerated carcasses, in the cavity of which a set of processed giblets (liver, heart, muscular stomach) and a neck are placed, packed in a polymer film approved for contact with similar food products.

Determination of moisture mass fraction[2]

A sample of at least 200 g was selected from a representative sample. The sample was stored in such a way as to prevent spoilage and changes in chemical composition. Samples were freed from fasciae or skins, ground in a homogenizer or passed through a meat grinder twice and mixed thoroughly. In this case, the sample temperature should not exceed 25 °C. Then, 8 to 10 g of purified sand and a glass rod were placed in a weighing cup and dried for 30 minutes in a drying cabinet at a temperature of 150 ± 2 °C. Next, the weighing cup was covered with a lid, cooled in a desiccator to room temperature and weighed. Weighing results were recorded to the third decimal digit. Then, 2 to 3 g of the prepared sample were placed in

[1] Fisinin, V.I., Egorov, I.A., Lenkova, T.N., Okolelova, T.M., Ignatova, G.V., Shevyakov, A.N. et al. (2009). Guidelines for optimizing compound feed recipes for agricultural poultry. VNITIP, Moscow. 2009.

[2] GOST 9793–2016 Meat and meat products. Method for determination of moisture content. Retrieved from https://docs.cntd.ru/document/1200144231 Accessed March 06, 2024

a weighed weighing cup, re-weighed, thoroughly mixed with sand using a glass rod and dried in a drying cabinet in an open weighing cup at a temperature of 150 ± 2 °C for 1 hour. Then the weighing cup was covered with a lid, cooled in a desiccator to room temperature and weighed. The mass fraction of moisture X (%) was calculated using the equation:

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

where:
X is the moisture mass fraction, %;
m_1 is the weight of a weighing cup with sample, glass rod and sand, g;
m_2 is the weight of a weighing cup with sample, glass rod and sand after drying, g;
m is the weight of a weighing cup with glass rod and sand, g; 100 is the percentage conversion factor.

Determination of fat mass fraction[3]

The method is based on multiple extraction of fat with a solvent from a dried sample in a Soxhlet extraction apparatus, followed by removal of the solvent and drying of the separated fat to a constant weight. About 5 g of the prepared sample was weighed and the result was recorded to the fourth decimal digit. The analyzed sample was dried on a watch glass in a drying cabinet at a temperature of 103 ± 2 °C for 1 hour. The dried sample was quantitatively transferred to a sleeve made of filter paper, on the bottom of which a piece of cotton wool was placed. The watch glass was wiped with cotton wool soaked in a solvent (diethyl ether), which was also placed in the sleeve. The sleeve was carefully closed and placed in the extractor of the Soxhlet apparatus. The extraction flask was placed in a heating mantle or a water bath. The extraction duration was 5 to 7 hours with the extract draining rate being 5 to 8 times per hour. The completeness of degreasing was checked by applying a drop of the extract flowing from the extractor to filter paper. No greasy stain should remain on the paper. After the extraction was complete, the solvent was distilled off from the extraction flask. The extraction flask with the fat remaining after extraction was dried in a drying cabinet at a temperature of 103 ± 2 °C until constant weight.

The mass fraction of fat X (%) was calculated using the equation:

$$X(\%) = \frac{(m_2 - m_1) \times 100}{m} \quad (2)$$

where:
X is the fat mass fraction, %;
m_2 is the weight of extraction flask with fat, g;
m_1 is the weight of extraction flask, g;
100 is the percentage conversion factor;
m is the weight of analyzed sample, g.

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

Determination of protein mass fraction[4]

The method is based on mineralization of organic substances in the sample with subsequent determination of nitrogen by the amount of formed ammonia. About 15 g of anhydrous potassium sulfate and 0.5 g of sulfate were placed in a Kjeldahl flask. About 2 g of the prepared sample was weighed on a piece of ash-free filter paper to an accuracy of 0.001 g and carefully placed in the Kjeldahl flask. Then, 25 cm^3 of sulfuric acid were added to the Kjeldahl flask. The contents of the flask were carefully mixed by slightly rotating the flask with the liquid. The flask was placed in an inclined position at an angle of about 40° relative to the vertical position on a heating device. First, the flask was carefully heated until foaming appeared and until the sample was completely dissolved. Then, mineralization was continued with vigorous boiling, turning the flask from time to time until the liquid became absolutely transparent and acquired a light green-blue color. After the contents of the flask had completely cleared, boiling was continued for another 90 minutes. The total duration of mineralization should be at least 2 hours. The Kjeldahl flask with the contents was cooled to a temperature of 40 °C; 50 cm^3 of distilled water were carefully added, mixed and cooled to room temperature. The mass fraction of protein X (%) was calculated using the equation:

$$X(\%) = \frac{0{,}0014 \times (V_1 - V_2) \times K \times 100}{m} \times 6.25 \quad (3)$$

where:
X is the protein mass fraction, %;
0.0014 is the amount of nitrogen equivalent to 1 cm^3 of 0.1 mole/dm^3 hydrochloric acid solution, g;
V_1 is the volume of 0.1 mole/dm^3 hydrochloric acid solution spent on titration of the test sample, cm^3;
V_2 is the volume of 0.1 mole/ dm^3 hydrochloric acid solution spent on titration of the control sample, cm^3;
K is the correction factor to the nominal concentration of hydrochloric acid solution;
100 is the percentage conversion factor;
m is the weight of the sample, g;
6.25 is the protein conversion factor.

Determination of meat amino acid composition

The analysis was carried out by capillary electrophoresis on Kapel-105 equipment, manufactured by Lumex (Russia) (GOST R 55569–2013[5]). The method is based on the decomposition of the sample by acid hydrolysis with the conversion of amino acids into free forms, obtaining FTC derivatives of amino acids, their further separation and quantitative determination by capillary electrophoresis. To determine the amino acids, the analyzed sample of 0.100 ± 0.001 g was placed in a hydrolysis vial; 10.0 cm^3

[4] GOST 25011–2017 Meat and meat products. Protein determination methods. Retrieved from https://docs.cntd.ru/document/1200146783 Accessed March 06, 2024

[5] GOST R 55569–2013. Feedstuffs, compound feeds, feed raw materials. Determination of proteinogenic amino acids using capillary electrophoresis. Retrieved from https://docs.cntd.ru/document/1200105562 Accessed March 06, 2024

of hydrochloric acid was added. The hydrolysis vial was hermetically sealed with a screw cap and mixed. The hydrolysis vials were placed in a drying cabinet. Hydrolysis was carried out at a temperature of 110 °C for 14 to 16 h. After hydrolysis, the hydrolysis vials were removed from the cabinet and cooled to room temperature. After cooling, the contents of the hydrolysis vials were filtered through blue ribbon filters, discarding the first portions and collecting the filtrates in vessels with lids to prevent evaporation. Then the obtaining of FTC derivatives was carried out. The prepared solutions were transferred to Eppendorf tubes and centrifuged for 5 minutes at a rotation speed of 5000 rpm. The capillary was prepared for work. The mass fraction of each amino acid in the sample X (%) was calculated using the equation:

$$X(\%) = \frac{V_{hydr} \times V_{fin} \times C_{mes} \times 100}{m \times V_{al} \times 1000} \quad (4)$$

where:
X is the mass fraction of amino acids, %;
V_{hydr} is the total volume of hydrolysate, cm³ (10 cm³);
V_{fin} is the volume of the final (analyzed) solution, cm³ (0.5 cm³);
C_{mes} is the measured value of the amino acid concentration in the solution prepared as 7.4, mg/dm³;
100 is the percentage conversion factor;
m is the weight of the analyzed sample, mg (100 mg);
V_{al} is the volume of an aliquot portion of the hydrolysate taken to obtain FTC derivatives, cm³ (0.05 cm³);
1000 is the coefficient for converting volume units.

Determination of meat chemical element composition

The analysis was carried out by atomic emission spectrometry and mass spectrometry (ICP-AES and ICP-MS) on Elan 9000 (Perkin Elmer, USA) and Optima 2000 V (Perkin Elmer, USA) equipment. The prepared sample introduction into the spectrometer, as well as the measured of atomic radiation of the elements and the concentration of the elements being determined were carried out under environmental conditions, taking into account the requirements of the spectrometer operating manual. The optimal mode for recording spectra and measurements was set. The intensity of the characteristic radiation was recorded by a photosensitive detector after this radiation passed through a monochromator. The intensity and position of the spectral lines were measured and processed by the spectrometer computer system.

Ethics statement

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

Statistical processing was performed using "SPSS Statistics Version 20" software by calculating the mean value (M), standard deviation (σ), and standard deviation error (m). The significance level was considered reliable at $p \le 0.05$.

Results and discussion

Broilers from the experimental groups CA-II and CA-III were characterized by high pre-slaughter live weight; according to this indicator, they exceeded group C by 4.50% and 7.27%, respectively (Table 1).

Al-Kassie [19] found that broilers receiving dietary supplements of thyme and cinnamon mixture had a significantly higher body weight gain than the control.

The young animals from group CA-III had the highest eviscerated carcass weight. Poultry from group C were 6.53% lower in this indicator than animals from group CA-III. Similarly, the weight of muscle tissue and edible part in the experimental group III significantly differed from the control values by 8.67% and 8.40%, respectively ($p \le 0.05$). Similar data were obtained by foreign colleagues, so the weight of the carcass (by 10.4 and 7.4%), weight of the breast and the relative percentage of breast increased ($p \le 0.05$) when Tecnaroma PL herbal mixture containing essential oils was added to the diet compared to the diet of poultry fed the control diet [11]. This may be due to the effect of cinnamaldehyde on the increase in villi width and surface area, which contributed to the improvement of nutrient absorption. Lower productivity of animals receiving a larger amount of microencapsulated carvacrol and cinnamaldehyde mixture may be explained by possible irritability of the intestinal mucosa with a decrease in the intestinal surface and, as a result, a smaller absorption area. Addition of phytobiotics did not have a significant effect on the slaughter yield of carcasses [20,21]. In this experiment, the slaughter yield of young poultry from the control group exceeded the similar indicator of broilers from groups CA-I and CA-III by 0.7 and 0.5%, respectively. Poultry, which received cinnamaldehyde with the basic diet in the amount of 30 mg/kg of feed per day, had an advantage over the control group by 0.9% in terms of slaughter yield of carcasses.

According to laboratory data, the mass fraction of dry matter in the keel bone was maximum in poultry from group CA-II; according to this parameter they reliably exceeded the control group (C) by 2.22% ($p \le 0.05$) (Table 2).

Similar results were obtained by İpçak et al. [22], who noted that the addition of secondary metabolites to the

[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 March 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 March 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 March 06, 2024

Table 1. Slaughter indicators of broiler chickens at the end of the experiment ($n = 5$)

Indicator	Treatment			
	C	CA-I	CA-II	CA-III
Pre-slaughter live weight, g	2974.8 ± 222.82	2928.0 ± 170.10	3108.8 ± 154.06	3191.3 ± 53.12*
Eviscerated carcass, g	2185.0 ± 161.24	2131.0 ± 138.72	2312.4 ± 123.05	2327.7 ± 16.76
Muscle tissue, g	1074.9 ± 82.64	1047.5 ± 62.19	1137.0 ± 60.59	1168.2 ± 3.92
Bone tissue, g	619.5 ± 42.35	622.1 ± 36.27	664.4 ± 32.46	647.8 ± 13.30
Edible part, g	1922.2 ± 106.03	1884.9 ± 98.44	2033.4 ± 104.70	2083.7 ± 15.04*
Inedible part, g	880.2 ± 70.02	876.4 ± 50.55	933.5 ± 46.09	916.8 ± 27.11
Edible part/inedible part ratio	2.18 ± 0.017	2.15 ± 0.016	2.18 ± 0.042	2.27 ± 0.051
Slaughter yield,%	73.5 ± 0.43	72.8 ± 1.00	74.4 ± 0.63	73.0 ± 0.77

Note: C is the control group, CA-I is the experimental group I, CA-II is the experimental group II, CA-III is the experimental group III (here and below) * P-value ≤ 0.05; ** P-value ≤ 0.01 relative to the control group.

Table 2. Chemical composition of muscles from broiler chickens, % ($n = 5$)

Indicator	Treatment			
	C	CA-I	CA-II	CA-III
Breast				
Moisture mass fraction	77.22 ± 2.51	76.44 ± 2.44	75.0 ± 2.34	76.3 ± 2.25
Dry matter mass fraction	22.78 ± 0.55	23.56 ± 0.65	25.0 ± 0.54*	23.7 ± 0.51
Fat mass fraction	0.96 ± 0.04	2.34 ± 0.07**	1.62 ± 0.06**	1.67 ± 0.05**
Ash mass fraction	0.99 ± 0.02	0.98 ± 0.03	0.98 ± 0.02	0.98 ± 0.02
Protein mass fraction	20.83 ± 0.44	20.24 ± 0.64	22.4 ± 0.52*	21.05 ± 0.73
Thighs				
Moisture mass fraction	74.38 ± 2.37	75.23 ± 2.46	74.82 ± 2.39	76.06 ± 2.26
Dry matter mass fraction	25.62 ± 0.51	24.77 ± 0.52	25.18 ± 0.40	23.94 ± 0.46*
Fat mass fraction	3.24 ± 0.05	3.05 ± 0.04*	3.84 ± 0.07***	2.66 ± 0.05***
Ash mass fraction	0.97 ± 0.01	0.97 ± 0.02	0.96 ± 0.02	0.97 ± 0.01
Protein mass fraction	21.41 ± 0.37	20.75 ± 0.39	20.38 ± 0.29	20.31 ± 0.44

Note: *P-value ≤0.05; **P-value ≤0.01 relative to the control group.

diet was effective in terms of crude fat and crude ash content in the breast as well as dry matter, crude fat and crude ash content in leg meat.

In terms of fat content in the breast, broilers from group C were inferior to the animals from group CA-I by 1.38% ($p \leq 0.01$), group CA-II by 0.66% and group CA-III by 0.71%. This was probably due to the dose-dependent effect of aldehyde on carbohydrate-fat metabolism in the body of broiler chickens, in part by increasing glucose absorption and improving insulin sensitivity in adipose and skeletal muscle tissue. It was found that protein mass fraction in the breast was higher in group CA-II than in groups C, CA-I and CA-III by 1.57%, 2.16 and 1.35%, respectively. Foreign colleagues also found a slightly lower protein content when introducing medium doses of essential oils (20.22 g/100 g), while in the control group this value was significantly ($p < 0.05$) lower (18.51 g/100 g) [23].

The highest amount of fat in the thighs was found in the young animals from group CA-II, which exceeded the similar indicator in the control group by 0.6% ($p \leq 0.01$). Broilers in the control group had superiority over the experimental groups CA-I and CA-III in the concentration of fat in the thighs by 0.19 and 0.58%, respectively ($p \leq 0.01$).

The introduction of cinnamaldehyde into the broiler diet contributed to a slight decrease in the concentration of essential and nonessential amino acids in the breast (Table 3).

Table 3. Amino acid content in the breast of broiler chickens, % ($n = 5$)

Indicator	Treatment			
	C	CA-I	CA-II	CA-III
Arginine	6.0 ± 0.12	5.4 ± 0.18*	5.5 ± 0.16*	6.0 ± 0.16
Lysine	7.4 ± 0.20	7.3 ± 0.13	7.1 ± 0.14	7.3 ± 0.17
Tyrosine	4.9 ± 0.19	4.3 ± 0.15*	3.9 ± 0.18**	4.6 ± 0.20
Phenylalanine	3.3 ± 0.08	3.2 ± 0.07	3.1 ± 0.06	3.3 ± 0.11
Histidine	3.3 ± 0.05	2.8 ± 0.06***	2.7 ± 0.07***	3.2 ± 0.06
Leucine + isoleucine	11.1 ± 0.11	10.7 ± 0.18	10.2 ± 0.22**	10.8 ± 0.13
Methionine	2.7 ± 0.06	2.1 ± 0.09***	2.1 ± 0.10**	2.4 ± 0.07*
Valine	4.7 ± 0.10	4.4 ± 0.11	4.1 ± 0.09**	4.4 ± 0.13
Proline	3.1 ± 0.07	3.0 ± 0.08	2.9 ± 0.05*	2.8 ± 0.05**
Threonine	3.8 ± 0.12	3.3 ± 0.15*	3.3 ± 0.07**	3.5 ± 0.09
Serine	3.4 ± 0.12	2.9 ± 0.05**	2.9 ± 0.09*	3.1 ± 0.13
Alanine	7.8 ± 0.20	7.3 ± 0.17	7.0 ± 0.14*	7.5 ± 0.15
Glycine	3.7 ± 0.11	3.6 ± 0.09	3.6 ± 0.10	3.7 ± 0.08

Note: * P-value ≤ 0.05; ** P-value ≤ 0.01 relative to the control group.

Thus, in the muscles of animals from groups CA-I and CA-II, the lowest concentration of arginine, methionine, valine was noted, on average lower by 0.6% relative to group C. A similar pattern was observed for the content of tyrosine, histidine, and serine, which was lower by 0.6% to 1%, 0.5% to 0.6%, and 0.5% relative to the control, respectively. Interestingly, in animals that were fed cinnamaldehyde in the amount of 100 mg, a lower content of dry

matter, protein and amino acids such as lysine and tryptophan was found, compared to young animals that received the supplement with a dosage of 50 mg. This may be due to high concentrations of chemical compounds (aldehyde), which may block lysine and tryptophan residuals in digestive enzymes [24].

Supplementation of broiler chickens with cinnamaldehyde resulted in minor changes in major element composition of breast (Table 4).

Thus, the sodium level increased significantly in group CA-II by 70.25% ($p \leq 0.01$) and in group CA-III by 19.48% ($p \leq 0.01$) relative to group C. The control broilers were inferior in terms of accumulation of iron in the breast by 36.23% and zinc by 17.94% compared to the animals from groups CA-I and CA-III. The smallest amount of essential and conditionally essential elements was deposited in breast from group CA-II, such as manganese by 19.75%, cobalt by 50%, nickel by 47.61% and chromium by 30.24% compared to group C.

Young animals from the experimental groups CA-I and CA-III exceed the animals from group C in accumulation of the essential amino acid arginine in the thighs by 0.4 and 0.2%, respectively (Table 5).

The proportion of essential amino acids (histidine, serine, glycine) in the thighs of poultry from group CA-I decreased by 0.3% relative to group C. It has been proven that phytoncides improve not only the quality of meat, but also its amino acid composition and fatty acid profile [25,26]. The proportion of polyunsaturated fatty acids (PUFA) in the total fat of the breast and legs, as well as in the abdominal fat, was positively affected by additives containing 2% and 2.5% *Boswellia serrata*, improving the dietary parameters of meat (n-3/n-6, S/P, TI, AI and HH) [27]. Gomathi et al. [28] recommend including cinnamon oil in the diet of domestic poultry, which will help to increase the content of unsaturated fatty acids and reduce the content of saturated fatty acids in the carcass. The introduction of encapsulated cinnamaldehyde improved meat quality and intestinal health by reducing the Warner-Bratzler shear force in meat, increasing the villi-to-crypt ratio in the intestine, and favorable microbiota composition in the ileum and cecum [29].

In terms of calcium content in the thighs, broilers from groups CA-II and CA-III exceeded the control by 1.2 times or 16.6% (Table 6).

Similar data were obtained in the experiments by Popović et al [23] and Galli et al. [30], with the content of Ca and P significantly improving in the groups in which the essential oil mixture was used as a food additive. The introduction of cinnamaldehyde in low and medium doses contributed to an increase in the nickel content by 63.63% and 51.51% compared to the control. In terms of copper content in thighs, the young animals from group CA-I had an advantage over group C of 0.23 mg/kg (by 11.79%). The maximum concentration of chromium was observed in group CA-II, which was 10.69% higher than in group C.

Table 4. Chemical element content in the breast of broiler chickens ($n = 5$)

Element	Treatment			
	C	CA-I	CA-II	CA-III
Major elements, g/kg				
Ca	0.26 ± 0.01	0.23 ± 0.01	0.29 ± 0.01	0.27 ± 0.01
P	9.33 ± 0.28	8.98 ± 0.29	8.28 ± 0.28	8.45 ± 0.32
K	16.31 ± 0.57	14.95 ± 0.45	13.78 ± 0.50	14.23 ± 0.63
Na	1.95 ± 0.07	2.18 ± 0.07	3.32 ± 0.10*	2.33 ± 0.10*
Mg	1.17 ± 0.04	1.14 ± 0.04	1.04 ± 0.03	1.08 ± 0.05
Essential and conditionally essential elements, mg/kg				
B	1.58 ± 0.05	1.47 ± 0.11	1.57 ± 0.06	1.55 ± 0.12
Fe	41.42 ± 1.86	56.43 ± 1.75*	35.39 ± 1.59	50.13 ± 1.55
Zn	27.42 ± 1.34	30.96 ± 1.18	32.34 ± 1.33*	28.05 ± 0.90
Se	0.69 ± 0.155	0.68 ± 0.230	0.76 ± 0.126	0.62 ± 0.284
Mn	0.81 ± 0.03	0.76 ± 0.02*	0.65 ± 0.02*	0.69 ± 0.02*
Co	0.02 ± 0.001	0.02 ± 0.001	0.01 ± 0.001*	0.02 ± 0.001
Ni	0.42 ± 0.017	0.41 ± 0.016	0.22 ± 0.013*	0.32 ± 0.021*
Cu	1.39 ± 0.04	1.38 ± 0.06	1.32 ± 0.05	1.11 ± 0.04*
Cr	2.48 ± 0.082	1.94 ± 0.163*	1.73 ± 0.052*	1.77 ± 0.195*

Note: * P-value ≤ 0.05 relative to the control group.

Table 5. Amino acid content in the thighs of broiler chickens, % ($n = 5$)

Indicator	Treatment			
	C	CA-I	CA-II	CA-III
Arginine	5.1 ± 0.08	5.5 ± 0.07**	5.1 ± 0.05	5.3 ± 0.05*
Lysine	6.8 ± 0.12	7.0 ± 0.14	6.6 ± 0.15	6.8 ± 0.12
Tyrosine	3.3 ± 0.06	3.2 ± 0.05	3.0 ± 0.08**	3.2 ± 0.12
Phenylalanine	3.1 ± 0.07	3.0 ± 0.08	2.9 ± 0.05	3.0 ± 0.10
Histidine	2.6 ± 0.05	2.3 ± 0.08*	2.4 ± 0.06*	2.5 ± 0.05
Leucine + isoleucine	10.0 ± 0.22	10.0 ± 0.25	9.5 ± 0.24	9.8 ± 0.19
Methionine	2.1 ± 0.06	2.2 ± 0.07	2.1 ± 0.07	2.3 ± 0.10
Valine	3.9 ± 0.10	4.0 ± 0.09	3.8 ± 0.11	4.0 ± 0.12
Proline	2.9 ± 0.09	3.0 ± 0.07	2.8 ± 0.08	2.9 ± 0.09
Threonine	3.1 ± 0.11	3.3 ± 0.07	3.1 ± 0.06	3.3 ± 0.08
Serine	2.8 ± 0.07	3.1 ± 0.06*	2.8 ± 0.09	3.0 ± 0.10
Alanine	6.1 ± 0.14	6.3 ± 0.11	5.8 ± 0.15	6.1 ± 0.12
Glycine	3.5 ± 0.09	3.8 ± 0.13*	3.3 ± 0.08	3.6 ± 0.11

Note: * P-value ≤ 0.05; ** P-value ≤ 0.01 relative to the control group.

Table 6. Chemical element content in the thighs of broiler chickens ($n = 5$)

Element	Treatment			
	C	CA-I	CA-II	CA-III
Major elements, g/kg				
Ca	0.30 ± 0.01	0.27 ± 0.01	0.25 ± 0.01*	0.25 ± 0.01*
P	8.16 ± 0.30	8.09 ± 0.29	7.89 ± 0.25	8.28 ± 0.29
K	14.43 ± 0.48	13.72 ± 0.47	13.95 ± 0.43	14.93 ± 0.48
Na	2.46 ± 0.08	2.48 ± 0.07	2.45 ± 0.08	2.57 ± 0.10
Mg	1.00 ± 0.03	0.98 ± 0.03	0.98 ± 0.03	1.03 ± 0.03
Essential and conditionally essential elements, mg/kg				
B	1.63 ± 0.10	1.58 ± 0.09	1.40 ± 0.06	1.46 ± 0.06
Mn	0.78 ± 0.03	0.78 ± 0.02	0.73 ± 0.03	0.65 ± 0.02*
Co	0.02 ± 0.001	0.02 ± 0.001	0.02 ± 0.002	0.01 ± 0.001*
Fe	46.41 ± 1.53	46.32 ± 1.53	43.52 ± 2.09	38.48 ± 1.65
Zn	54.95 ± 1.87	62.20 ± 2.18	58.63 ± 2.70	54.98 ± 1.81
Ni	0.22 ± 0.009	0.36 ± 0.012*	0.39 ± 0.020*	0.23 ± 0.012
Cu	1.95 ± 0.10	2.18 ± 0.09*	1.68 ± 0.06	1.50 ± 0.05
Cr	1.87 ± 0.060	1.96 ± 0.074	2.07 ± 0.089*	1.31 ± 0.039

Note: * P-value ≤ 0.05 relative to the control group.

Conclusion

Based on the experimental data obtained on determining the efficiency of using cinnamaldehyde as a feed additive for agricultural poultry, a positive effect on the chemical composition of meat, the content of essential elements and amino acids was established. Thus, the introduction of cinnamaldehyde into the basic diet in the amount of 30 mg/kg of feed contributed to an increase in slaughter yield by 0.9%, the mass fraction of protein and fat in the breast by 1.5% and 0.66%, and the amount of zinc by 17.9% relative to the control.

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