

Fatty acid profile, nutrient composition, characteristics, and sensory traits of broiler chicken meat fed a diet containing heat-treated hemp seed cake and phytase

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ABSTRACT

Research on sustainable alternative feed ingredients is important to reduce the significant dependence on expensive soybean meal. In this study, the effects of heat-treated hemp seed cake (HSC) and phytase supplementation on the nutritional composition, fatty acid profile, physicochemical properties, and sensory traits of broiler chicken meat were evaluated. A total of 210 unsexed Ross day-old chicks were randomly allocated to seven dietary treatments with six replicates each: soybean meal-based diet (control), 15% HSC with or without phytase (1000 FTU/kg), autoclaved HSC (120°C, 10 min) with or without phytase and oven-heated HSC (120°C, 20 min) with or without phytase. Meat dry matter, crude protein, crude fat and ash contents were not affected by dietary treatments. Thigh meat pH was lower ($P < 0.05$) for autoclaved HSC, and lower ($P < 0.05$) for phytase-supplemented unheated HSC diet compared to the control. HSC supplementation enhanced breast meat redness and yellowness and increased thigh meat lightness and yellowness ($P < 0.05$) without affecting breast meat lightness. The inclusion of HSC decreased total saturated fatty acids, increased polyunsaturated fatty acids, omega-3 and omega-6 contents and resulted in a lower omega-6/omega-3 ratio ($P < 0.05$). Unheated HSC negatively impacted breast meat appearance, odor and chewiness ($P < 0.05$) while heat-treated HSC did not impair meat sensory quality compared to control diet. In conclusion, feeding 15% of HSC with or without phytase could partially replace soybean meal without negative impacts on meat quality and improve the fatty acid profile of broiler meat.

Keywords: *Cannabis sativa L*, Hemp seed, Meat quality, Polyunsaturated fatty acids, Poultry.

INTRODUCTION

The exploration of high-quality and sustainable alternative feed ingredients is a major challenge in the modern poultry industry, due to the high dependence on soybean meal as an expensive protein source. One potential feed ingredient is hemp seed cake (HSC) from the by-product of the hemp seed oil extraction process.

HSC contains high protein (34.10%), neutral detergent fiber/NDF (39.50%), acid detergent fiber/ADF (27.50%), and monounsaturated fatty acid/MUFA (13.58%), and polyunsaturated fatty acid/PUFA (75.25%), including omega-3 (19.08%) and omega-6 (56.18%), with alpha-linolenic acid (ALA) as the main component of omega-3 (Semwogerere *et al.*, 2020; Occhiuto *et al.*, 2022). The PUFA content in HSC is of

interest as it can improve the fat profile of chicken meat, making it healthier for consumers.

Chicken meat with high omega-3 content has better functional value and provides health benefits such as lowering the cardiovascular disease in humans (Sumiati *et al.*, 2022). However, the utilization of high levels of HSC in poultry feed has adverse effects on poultry performance. It was reported that utilization of 8-12% HSC can reduce egg production of laying hens (Ozturk *et al.*, 2024), while a 15% level in broiler diets caused a decrease in final body weight (Ondrej *et al.*, 2015). This effect is believed to be due to the high fiber and anti-nutrient composition that results in low nutrient digestibility and absorption (Sittiya *et al.*, 2020). Thermal methods and enzyme addition have been reported to overcome this problem. Thermal processes, including oven heating and autoclaving, are known to alter the structure of proteins and fats in feedstuffs, as well as improve the stability and availability of nutrients. Konca *et al.* (2019) reported that hemp seed heated at 120 °C for 60 min performed better than raw hemp seed treatment. Darmawan and Ozturk (2025a) found that autoclaved HSC resulted in better broiler performance than the oven-heated HSC group.

The inclusion of phytase enzymes in grain-based poultry feed formulations is also an important strategy to improve nutrient bioavailability. Phytase functions to hydrolyze phytate compounds, which are naturally present in plant-based feed ingredients and bind essential minerals, including phosphorus and calcium (Ptak *et al.*, 2015). Phytate hydrolysis by phytase enzymes can increase mineral release, support the beneficial gut microbes' growth, increase bone strength, and carcass yield of broilers (Ptak *et al.*, 2015; Mahmoud *et al.*, 2024; Darmawan and Ozturk, 2025b). Moreover, supplementation of phytase improved meat tenderness, water-holding capacity, and juiciness (Maynard *et al.*, 2023; Putri *et al.*, 2025). These improvements are likely attributable to enhanced nutrient digestibility and mineral utilization, which can influence muscle development, lipid metabolism and ultimately meat quality. However, information on the combined effects of heat-treated HSC and phytase supplementation on the nutritional and sensory quality of broiler chicken

meat is still limited. Thus, the novelty of the present study was to evaluate the combined effects of two heat treatment methods applied to HSC (autoclave at 120 °C for 10 min and oven heating at 120 °C for 20 min) in combination with phytase supplementation (1000 FTU/kg feed) on the fatty acid profile, nutritional composition and sensory characteristics of a broiler chicken meat. Therefore, this study aimed to evaluate the impact of heat treatment (autoclaving at 120 °C for 10 min and oven heating at 120 °C for 20 min) of HSC, as well as the inclusion of phytase enzyme (1000 FTU/kg feed) on the fatty acids profile, nutrient content, and sensory parameters of broiler meat.

MATERIALS AND METHODS

Animals and Treatments

All procedures were approved by the Ondokuz Mayıs University Ethics Committee (No: 57/2022). Unsexed Ross day-old chicks (210 birds) were reared for 42 days in closed floor cages. The chicks were randomly divided into 42 experimental plots measuring 1.00 m × 1.30 m × 0.5 m, each containing five chicks. The study used a completely randomized design with seven treatments and six replications. Vezir hemp seeds from Samsun Province were cold-pressed to obtain HSC. HSCs were mashed before autoclaving and oven-drying.

The basal ration was prepared from main ingredients of corn, soybean meal, and HSC (Table 1), and formulated based on the nutrient requirements of broiler chickens from NRC recommendations in starter (1-10 days), grower (11-21 days), and finisher (22-42 days) phases. The rations were fed in mash form ad libitum, along with the availability of clean drinking water at all times. The treatments were as follows:

T1: soybean meal-based diet, T2: diet containing 15% HSC, T3: T2 diet supplemented with 1000 FTU/kg phytase enzyme, T4: diet containing 15% autoclaved HSC (120 °C for 10 min), T5: T4 diet supplemented with 1000 FTU/kg phytase enzyme, T6: diet containing 15% oven-heated HSC (120 °C for 20 min), and T7: T6 diet supplemented with 1000 FTU/kg phytase enzyme.

Lighting was provided for a full 24 hours in the first three days of rearing to aid adaptation, then reduced to 20 hours of light and 4 hours of

Table 1. Broiler Chicken Diet Formula and Its Nutrient Content (as fed)

Feedstuff (%)	Starter		Grower		Finisher	
	Control	HSC	Control	HSC	Control	HSC
Yellow maize	53.20	48.30	59.00	54.00	65.18	60.20
Soybean meal (44%)	39.5	29.00	34.50	24.00	29.00	18.50
HSC (37%)	0	15.00	0	15.00	0	15.00
Vegetable oil	3.15	4.00	3.202	4.00	2.80	3.60
Limestone	0.80	0.80	0.58	0.60	0.56	0.57
Dicalcium phosphate	2.17	2.12	1.76	1.68	1.42	1.39
Premix*	0.10	0.10	0.10	0.10	0.10	0.10
NaCl	0.37	0.37	0.37	0.37	0.37	0.37
L-Lysine sulfate	0.22	0.02	0.18	0.01	0.27	0.05
DL-Methionine	0.31	0.27	0.27	0.23	0.26	0.22
L-Threonine	0.18	0.01	0.04	0.01	0.04	0.01
Total	100	100	100	100	100	100
Nutrient**						
Crude protein (%)	23.5	23.5	21.5	21.6	19.5	19.5
Metabolizable energy (kcal/kg)	2982	2981	3061	3058	3107	3106
Ether extract (%)	3.60	4.01	3.80	4.30	3.06	4.06
Methionine +cystine (%)	1.00	1.00	0.92	0.92	0.86	0.86
Lysine (%)	1.32	1.32	1.18	1.19	1.10	1.08
Ca (%)	0.95	0.95	0.78	0.76	0.65	0.66
Available P (%)	0.50	0.501	0.43	0.42	0.36	0.36

*The premix composition per kilogram of feed: 3,000 IU cholecalciferol, 12,000 IU retinol, 60 mg α -tocopherol, 4 mg menadione, 10 mg riboflavin, 3 mg thiamine, 50 mg niacin, 4 mg pyridoxine, 14 mg calcium -D-pantothenate, 0.030 mg cyanocobalamin, 0.25 mg biotin, 250 mg choline chloride, 2 mg folic acid, and minerals of 15 mg copper (Cu), 120 mg manganese (Mn), 50 mg iron (Fe), 1.5 mg iodine (I), 100 mg zinc (Zn), 0.3 mg selenium (Se), and 0.1 mg cobalt (Co). **Based on calculation. HSC: hemp seed cake.

dark per day until harvested. The ambient temperature in the cages was set at 33-34°C for the first week, then reduced gradually each week until it reached 24-25°C at the end of the fourth week and was maintained until harvest. The Gumboro vaccine program was administered orally on day 10, and litter maintenance was carried out routinely to prevent excess moisture and maintain comfortable chickens.

Nutrient Composition of Breast Meat Measurement

Samples were taken from the caudal and cranial muscles of 2 broilers in each replicate. The meat was then homogenized using a shredder. Moisture content, crude protein, and crude fat were measured based on AOAC (2000). Crude protein was determined using the standard Kjeldahl method, and crude fat was extracted with petroleum ether using the Soxhlet method.

Meat Color and pH Value Measurement

The color and pH value of the pectoral and thigh muscles were measured after slaughter and de-feathering. Measurements were taken at 3 points for each sample, and the average value was calculated. Lightness (L^*), yellowness (b^*), and redness (a^*) values were determined from 2 broilers from each replicate using a Chroma Meter (CR300, Konica Minolta, Osaka, Japan). The meat pH value was measured with a digital pH meter (Testo 205). The pH probe was placed at a 45° angle to the pectoralis major muscle and rinsed with deionized water after each measurement.

Meat Sensory Measurement

The sensory characteristics evaluation was conducted on the breast muscles of six randomly selected male broiler chickens from each group (42 birds in total) after slaughter. Meat samples were vacuum-packed using food-grade plastic and stored at 4°C for five days. After the storage period, the samples were boiled in boiling water for 15 minutes in a sealed container without the addition of salt or seasoning (Doğan and Öztürk, 2019). The cooked meat was then presented warmly to the panelists in a test room with white fluorescent lighting.

The sensory assessment was conducted by trained panelists as per ISO 8586-1 standard at

Ondokuz Mayıs University. Parameters evaluation included appearance, hardness, odor, flavor, chewiness, juiciness, and overall perception. The evaluation was conducted using a 9-point hedonic scale (1 = strongly disliked, 9 = strongly liked), based on a modified methodology from Uhlirova *et al.* (2018).

Meat Fatty Acid Measurement

The fatty acids analysis was performed on the thigh meat of broiler chickens. On the 42nd day of rearing, six males from each treatment group (42 birds in total) were randomly selected for slaughter, and thigh meats were collected for analysis. The fatty acid composition was performed after total lipid extraction. Before chromatographic analysis, fatty acids in the samples were transformed into fatty acid methyl esters through a methylation process using boron trifluoride reagent in methanol. These were then extracted with heptane and analyzed using gas chromatography with a flame ionization detector. This lipid extraction and methylation conversion procedure was performed according to the standard method (Folch *et al.*, 1957).

Statistical Analysis

The sample size was determined using G*Power software (version 3.1.9.7). Data were analyzed using Analysis of Variance. Tukey's test was applied when $P < 0.05$. Data were provided as mean, standard error of the mean (SEM), and P-value.

RESULTS AND DISCUSSION

Nutrient Content and pH Value of Broiler Meat

HSC supplementation did not affect breast meat L^* values ($P > 0.05$) but increased a^* and b^* values ($P < 0.05$). In thigh meat, HSC improved L^* ($P < 0.01$) and b^* values ($P < 0.05$) (Table 2). These results indicated that autoclaved (120 °C; 10 min) and oven-heated (120 °C; 20 min) HSC had no detrimental effect on the nutritional quality of breast and thigh meat. Konca *et al.* (2019) showed that heat-treated hemp seed meal (120 °C; 60 min) provided more positive results on laying hen performance compared to the utilization of fresh hemp seed meal. Moreover, Rehman and Shah (2005) reported that autoclave

heating (121°C; 20 min) reduced 36% of tannins and 33% of phytic acid in legumes. They also reported that the protein structure was not damaged at this temperature level, and instead, the digestibility of carbohydrates and proteins increased.

The pH of meat is important as it affected many meat properties, including water-holding capacity (WHC), tenderness, freshness, shelf life, and color (Mir *et al.*, 2017), where a decrease in pH results in more moist and tender meat (Mancinelli *et al.*, 2022). It is reported that the ideal pH value in chicken meat is 5.6 to 6.4 (Durmuş *et al.*, 2023), while the pH of breast meat in our study was within this range. The lower pH values exhibited by the autoclaved HSC diets (T4, T5) may be due to the digestibility and nutrient metabolism of the HSC. Similar to previous studies, the use of hempseed oil also reduced pH values and had a favorable effect on meat quality (Kanbur and Göçmen, 2021). Autoclaved HSC improved the nutrient digestibility, such as protein and cellulose, by breaking down complex structures, including antinutritional factors. Meanwhile, phytase degraded phytate complexes and increased the release of bound phosphorus and other minerals (Lucca *et al.*, 2017). This process likely increased the fermentation rate in the gut, resulting in higher short-chain fatty acids production, such as lactic acid, which in turn created an acidic environment and affected muscle pH. Furthermore, with autoclave heating, carbohydrates and proteins from HSC can be more easily digested and absorbed. This contributed to increased energy for the chicken and affects the glycogen content in the meat. The process of glycolysis produced lactic acid and resulted in a decrease in the pH value (Chauhan *et al.*, 2019).

Meat Color and Sensory Characteristics

Feeding with unheated HSC significantly reduced ($P<0.05$) the appearance, odor, and chewiness of breast meat compared to the control treatment. In contrast, feeding 15% heated HSC improved meat appearance, odor, and flavor compared to the control group ($P<0.05$) and did not differ from the soybean meal-based diet. (Table 3). A previous study by Štátník *et al.* (2019) found that inclusion of 15% hemp seed

meal in the diet did not influence the L^* value of broiler meat, while significantly increasing the a^* and b^* values compared to the 5% hemp seed meal group. However, this finding contrasts with Tufarelli *et al.* (2023), who reported that feeding 5-10% hemp seed meal did not influence the L^* , a^* , and b^* of breast meat. Lee *et al.* (2022) reported that the standard values are $L^*>62$ (pale), $56\leq L^*\leq 62$ (normal), and $L^*<56$ (dark). Therefore, the breast muscle color of broilers was classified as normal in this study. However, feeding with 15% HSC resulted in higher L^* values between 61.17-62.24 in thigh muscles and were similar to those of Štátník *et al.* (2019), where L^* values varied between 62-64 by using 15% hemp seed meal in the diet. In this study, the increase in the L^* value of thigh meat was closely related to the decrease in pH. When the meat pH decreased, the water-holding capacity of the muscle decreased significantly. It led to the release of water from the muscle tissue to the surface, thereby increasing light reflection and making the meat appear brighter (Ruedt *et al.*, 2023). Moreover, increasing L^* value can be attributed to the increased formation of metmyoglobin in the muscle. At low pH, myoglobin in meat tended to be in a more oxidized form, such as metmyoglobin, and contributed to increased lightness (Hoa *et al.*, 2020). The color of meat is one of the determining factors of consumer preference when purchasing poultry meat products. Consumers prefer darker meat with lower L^* values and higher a^* and b^* values compared to paler meat. Poultry meat color is easily affected by feed manipulation, especially carotenoids in feed, which can increase pigmentation in poultry muscle. The yellow color of meat can be attributed to the richness of carotenoids (β -carotene, α -carotene, lutein, and zeaxanthin) in the feed, which HSC contains high levels of lutein (40.07 mg/kg) and β -carotene (9.8 mg/kg) (Oancea *et al.*, 2023).

A previous study reported that feeding 15% expeller hempseed in feed tends to reduce the chewiness, flavor, and juiciness of broiler breast meat (Štátník *et al.*, 2019). Feed containing HSC without heating can reduce several sensory values of breast meat (appearance, odor, and chewiness) of broiler chickens, probably due to the high content of

Table 2. Nutrient Content and Characteristics of Broiler Chicken Meat Fed Diets Supplemented with HSC and Phytase Enzyme

Parameters	T1	T2	T3	T4	T5	T6	T7	SEM	P value
Breast									
pH	6.51	6.38	6.32	6.36	6.34	6.58	6.41	0.03	0.16
Dry matter (%)	26.41	26.31	26.82	27.10	26.93	27.12	27.21	0.11	0.16
Crude protein (%)	23.61	23.53	23.91	24.20	24.21	24.34	24.32	0.12	0.16
Crude fat (%)	1.42	1.55	1.56	1.5	1.52	1.55	1.48	0.02	0.19
Ash (%)	1.34	1.31	1.32	1.39	1.32	1.33	1.36	0.01	0.67
<i>L*</i>	52.70	56.32	56.41	56.12	56.53	56.10	56.62	0.21	0.07
<i>a*</i>	3.16 ^a	3.68 ^b	3.81 ^b	3.97 ^b	4.10 ^b	3.93 ^b	4.14 ^b	0.09	0.02
<i>b*</i>	1.31 ^a	1.97 ^b	2.14 ^{bc}	2.38 ^{bc}	2.63 ^c	2.46 ^{bc}	2.49 ^{bc}	0.14	<0.01
Thigh									
pH	6.60 ^b	6.40 ^{ab}	6.30 ^a	6.36 ^a	6.37 ^a	6.50 ^{ab}	6.40 ^{ab}	0.02	<0.01
Dry matter (%)	23.63	24.42	24.36	24.4	23.92	23.80	23.82	0.16	0.81
Crude protein (%)	19.62	19.94	20.15	20.35	19.74	19.80	19.82	0.11	0.85
Crude fat (%)	2.62	3.11	2.94	2.72	2.79	2.67	2.66	0.07	0.56
Ash (%)	1.36	1.39	1.34	1.35	1.43	1.33	1.37	0.02	0.85
<i>L*</i>	59.71 ^a	62.22 ^b	61.93 ^b	61.42 ^b	62.24 ^b	61.80 ^b	62.21 ^b	0.39	<0.01
<i>a*</i>	5.92	5.33	5.54	5.59	5.53	5.42	5.17	0.085	0.44
<i>b*</i>	4.51 ^a	5.37 ^b	5.59 ^b	5.89 ^b	6.10 ^b	6.14 ^b	5.92 ^b	0.087	0.02

T1: soybean meal-based diet, T2: diet with 15% HSC, T3: T2 + phytase enzyme (1000 FTU/kg), T4: diet with 15% autoclaved HSC (120 °C for 10 min), T5: T4 + phytase enzyme (1000 FTU/kg), T6: diet with 15% oven-heated HSC (120 °C for 20 min), T7: T6 + phytase enzyme (1000 FTU/kg). ^{abc} Means in the same row, without a common letter are different at $p < 0.05$. SEM: Standard error of the mean

Table 3. Sensory Traits of Broiler Breast Meat Fed HSC and Phytase Enzymes

Parameters	T1	T2	T3	T4	T5	T6	T7	SEM	P value
Appearance	8.04 ^c	7.22 ^a	7.43 ^{ab}	7.67 ^{bc}	7.78 ^{bc}	7.50 ^{bc}	7.83 ^{bc}	0.05	<0.01
Odor	7.93 ^b	7.46 ^a	7.50 ^a	7.57 ^{ab}	7.72 ^{ab}	7.72 ^{ab}	7.74 ^{ab}	0.04	<0.01
Hardness	7.87 ^b	7.70 ^{ab}	7.57 ^{ab}	7.48 ^a	7.46 ^a	7.56 ^{ab}	7.39 ^a	0.04	<0.01
Juiciness	7.46 ^{ab}	7.20 ^a	7.43 ^{ab}	7.53 ^{abc}	7.74 ^{bc}	8.09 ^c	7.67 ^{abc}	0.06	<0.01
Chewiness	7.78 ^c	7.20 ^b	7.37 ^{ab}	7.44 ^{abc}	7.61 ^{abc}	7.44 ^{abc}	7.35 ^{ab}	0.04	<0.01
Flavor	7.74 ^b	7.26 ^a	7.43 ^{ab}	7.46 ^{ab}	7.65 ^b	7.67 ^b	7.54 ^{ab}	0.04	<0.01
Overall	7.80 ^c	7.34 ^a	7.45 ^{ab}	7.51 ^{abc}	7.66 ^{bc}	7.66 ^{bc}	7.59 ^{abc}	0.03	<0.01

T1: soybean meal-based diet, T2: diet with 15% HSC, T3: T2 + phytase enzyme (1000 FTU/kg), T4: diet with 15% autoclaved HSC (120 °C for 10 min), T5: T4 + phytase enzyme (1000 FTU/kg), T6: diet with 15% oven -heated HSC (120 °C for 20 min), T7: T6 + phytase enzyme (1000 FTU/kg). ^{abc} Means in the same row, without a common letter are different at p<0.05. SEM: Standard error of the mean .

Table 4. Saturated Fatty Acid Content of Thigh Meat of Broiler Chickens Fed HSC and Phytase Enzyme

Saturated fatty acids	T1	T2	T3	T4	T5	T6	T7	SEM	P value
Lauric acid (C12:0)	0.05 ^c	0.03 ^{ab}	0.03 ^{bc}	0.03 ^{bc}	0.03 ^{ab}	0.02 ^a	0.03 ^{ab}	0.002	<0.01
Pentadecanoic acid (C15:0)	0.18	0.19	0.19	0.19	0.17	0.16	0.17	0.006	0.81
Tricosanoic acid (C23:0)	0.05	0.05	0.03	0.08	0.03	0.05	0.03	0.006	0.39
Heicosanoic acid (C21:0)	0.35 ^c	0.04 ^a	0.16 ^b	0.08 ^{ab}	0.12 ^{ab}	0.09 ^{ab}	0.10 ^{ab}	0.197	<0.01
Arachidic acid (C20:0)	0.38 ^a	0.47 ^{ab}	0.62 ^b	0.50 ^{ab}	0.51 ^{ab}	0.48 ^{ab}	0.47 ^{ab}	0.018	0.03
Capric acid (C10:0)	0.01	0.01	0.01	0.01	0.15	0.01	0.01	0.019	0.47
Heptadecanoic acid (C17:0)	0.51	0.48	0.67	0.75	0.47	0.58	0.6	0.029	0.08
Stearic acid (C18:0)	13.45	11.89	12.35	13	12.51	11.44	11.86	0.203	0.10
Myristic acid (C14:0)	0.84 ^b	0.76 ^b	0.73 ^{ab}	0.79 ^b	0.69 ^{ab}	0.54 ^a	0.67 ^{ab}	0.024	0.01
Lignoceric acid (C24:0)	1.68	1.43	1.32	1.5	1.18	1.5	1.46	0.057	0.37
Palmitic acid (C16:0)	17.23 ^b	16.03 ^{ab}	15.11 ^a	17.73 ^b	17.14 ^b	14.80 ^a	16.61 ^{ab}	0.243	<0.01
Caprylic acid (C8:0)	0.01	0.01	0.01	0.03	0.01	0.01	0.01	0.003	0.54
Total	34.74 ^c	31.45 ^{ab}	31.20 ^{ab}	34.64 ^c	32.93 ^{bc}	29.75 ^a	32.01 ^b	0.395	<0.01

T1: soybean meal-based diet, T2: diet with 15% HSC, T3: T2 + phytase enzyme (1000 FTU/kg), T4: diet with 15% autoclaved HSC (120 °C for 10 min), T5: T4 + phytase enzyme (1000 FTU/kg), T6: diet with 15% oven -heated HSC (120 °C for 20 min), T7: T6 + phytase enzyme (1000 FTU/kg). ^{abc} Means in the same row, without a common letter are different at p<0.05. SEM: Standard error of the mean.

unsaturated fatty acids (PUFA) that are easily oxidized, thus triggering an unfavorable aroma and reducing the appearance quality. On the other hand, heating reduces the content of antinutritional factors such as phytates and enzyme inhibitors, which inhibit the absorption of essential minerals (phosphorus, calcium, magnesium) important for muscle building and meat quality (Rehman and Shah, 2005). In addition, heating also changes the structure of proteins, resulting in easier digestibility and increased availability of amino acids needed to support muscle and meat tissue growth. In this study, the effects of heating were shown to increase the juiciness of the meat and contribute to a juicy and more appealing texture for consumers. Furthermore, heating process in HSC may inactivate lipase enzymes that play a role in the hydrolysis of fats into free fatty acids (FFA), thus inhibiting the formation of rancidity-causing compounds and further reducing the negative effects on sensory quality (appearance, taste, and odor).

Fatty Acid Content of Broiler Thigh Meat

Feeding HSC decreased the total saturated fatty acid (SFA) content of thigh meat ($P < 0.05$) (Table 4). Meat from birds fed HSC contained lower total monounsaturated fatty acids (MUFA) than meat from the control group ($P < 0.05$) (Table 5). Feeding 15% HSC increased total PUFA in broiler thigh meat (Table 6), similar to the report of Tufarelli *et al.* (2023) that there was an increase in PUFA (omega-3, omega-6) in broiler meat fed hemp seed meal. In addition, PUFA fatty acids were significantly increased in chicken eggs by feeding 12% HSC (Ozturk *et al.*, 2024). Indeed, hemp seed meal is known for its high PUFA content, particularly omega-6 and omega-3, which are essential for animal and human health (Franek *et al.*, 2022). Hemp seed meal contains 13.58% MUFA, 75.25% PUFA, 56.18% omega-6, and 19.08% omega-3 (Occhiuto *et al.*, 2022). When HSCs were included in broiler diets, these fatty acids were absorbed and accumulated in muscle tissue, which contributed to higher PUFA concentrations. Furthermore, the significant increase in omega-6 fatty acids, specifically linoleic acid and cis-8,11,14 eicosatrienoic acid, may also be related to fatty acid metabolic

processes in the broiler body. The increased levels of omega-3 and omega-6 indicate that broilers efficiently metabolize and incorporate these fatty acids into their tissues and reflect a direct effect of the fatty acids from HSC. Therefore, the addition of HSC to poultry diets may positively impact the nutritional composition of meat, making it richer in essential fatty acids for consumers. Furthermore, the observed increase in omega-3, specifically ALA, EPA, and DHA, is important for the nutritional development of broiler meat. Omega-3 fatty acids have anti-inflammatory properties and cardiovascular benefits in humans, making their increased presence in broiler meat important for consumer health (Simopoulos, 2018). In this study, the omega-6 to omega-3 ratio decreased from the control group (4.84) to the HSC group (3.41-3.92), indicating an increased dominance of omega-3 at 15% HSC. Indeed, approximately 70% of total fatty acids are LA and ALA, and the omega-6 to omega-3 ratio of 2 to 3 has been ideal for human health (Simopoulos, 2018).

Hempseed is notable for its high PUFA content with an omega-6 to omega-3 ratio of 3:1 (Ambroziak and Wenda-Piesik, 2025). The effect of hempseed on higher omega-3 production was assumed to be due to higher feeding of ALA as well as higher $\Delta 5$ and $\Delta 6$ desaturase and elongase activities (Mancinelli *et al.*, 2022). ALA and LA are precursors of omega-3 and omega-6, respectively, which cannot be synthesized by animals and humans; therefore, they have been designated as essential fatty acids. The main omega-3s are ALA, EPA, and DHA, while omega-6 is arachidonic acid (AA). The conversion of ALA to EPA competes with the conversion of LA to AA, as it requires the same enzyme (Harris, 2018). Competition for desaturase and elongase in the synthesis of omega-3 and omega-6 affects the concentration in tissues. Thus, animals fed a diet rich in omega-6 yield more LA, such as AA, compared to ALA (EPA, DHA) (Mancinelli *et al.*, 2022).

CONCLUSION

The heating process of HSC and the addition of phytase do not affect the nutritional content of broiler chicken meat. Feeding 15% of HSC increases the polyunsaturated fatty acids,

Table 5. Monounsaturated Fatty Acid Content of Thigh Meat of Broiler Chickens Fed HSC and Phytase Enzyme

Fatty acids (MUFA)	T1	T2	T3	T4	T5	T6	T7	SEM	P value
Nervonic acid (C24:1)	0.10 ^{ab}	0.17 ^c	0.11 ^{ab}	0.08 ^a	0.14 ^{bc}	0.09 ^a	0.11 ^{ab}	0.008	0.02
Palmitoleic acid (C16:1)	0.62 ^b	0.05 ^a	0.06 ^a	0.05 ^a	0.05 ^a	0.04 ^a	0.05 ^a	0.057	0.03
Cis_10_heptadecenoic acid (C17:1)	0.23	0.24	0.24	0.24	0.22	0.23	0.24	0.007	0.44
Cis_11_eicosenoic acid (C20:1)	0.87	0.42	0.89	0.61	0.82	0.78	0.78	0.048	0.10
Myristoleic acid (C14:1)	0.23 ^c	0.14 ^{ab}	0.17 ^b	0.14 ^{ab}	0.12 ^{ab}	0.09 ^a	0.12 ^{ab}	0.01	<0.01
Oleic acid (C18:1n9c)	26.62 ^c	24.63 ^{ab}	25.43 ^{bc}	24.70 ^{ab}	24.94 ^{abc}	23.44 ^a	23.60 ^a	0.276	0.02
Elaidic acid (C18:1n9t)	1.09	1.06	0.79	1.12	1.02	1.08	1.02	0.03	0.05
Total	29.72 ^c	26.71 ^{ab}	27.60 ^b	26.94 ^{ab}	27.20 ^{ab}	25.62 ^a	25.81 ^a	0.300	0.001

T1: soybean meal-based diet, T2: diet with 15% HSC, T3: T2 + phytase enzyme (1000 FTU/kg), T4: diet with 15% autoclaved HSC (120 °C for 10 min),

T5: T4 + phytase enzyme (1000 FTU/kg), T6: diet with 15% oven -heated HSC (120 °C for 20 min), T7: T6 + phytase enzyme (1000 FTU/kg). ^{abc} Means in the same row, without a common letter are different at p<0.05. SEM: Standard error of the mean.

Table 6. Polyunsaturated Fatty Acid Content of Thigh Meat of Broiler Chickens Fed HSC and Phytase Enzyme

Fatty acids (PUFA)	T1	T2	T3	T4	T5	T6	T7	SEM	P value
Linolelaidic acid (C18:2n6t)	1.33 ^a	1.98 ^{ab}	1.29 ^a	1.04 ^a	2.40 ^b	2.49 ^b	2.07 ^{ab}	0.15	0.02
cis_58111417_eikosapentaenoik (C20:5n3)	0.46	0.46	0.6	0.41	0.44	0.49	0.49	0.02	0.43
Linoleic acid (C18:2n6)	19.22 ^a	23.83 ^b	22.62 ^b	22.20 ^b	22.30 ^b	24.80 ^b	23.79 ^b	0.38	<0.01
Cis_13_16_docosadienoic acid (C22:2)	0.05	0.04	0.04	0.04	0.03	0.03	0.03	0.003	0.56
Arachidonic acid (C20:4n6)	5.02	3.6	4.09	4.69	3.86	5.02	4.61	0.16	0.08
Cis_11_14_eicosadienoic acid (C20:2)	1.24	1.28	1.31	1.11	1.15	1.36	1.3	0.04	0.77
Cis_8_11_14_eicosatrienoic acid (C20:3n6)	0.03 ^a	1.19 ^{ab}	1.05 ^{bc}	2.02 ^c	1.17 ^{bc}	0.94 ^{ab}	0.92 ^{ab}	0.13	<0.01
Alpha linolenic acid (C18:3n3)	4.51 ^a	7.26 ^b	6.78 ^b	7.34 ^b	6.51 ^b	6.95 ^b	6.79 ^b	0.19	<0.01
Cis_4_7_10_13_16_19_docosahexaenoic (C22:6n3)	0.96	0.81	1.04	0.8	0.79	1.34	1.03	0.06	0.15
Cis_11_14_17_eicosatrienoic acid (C20:3n3)	0.13 ^a	0.15 ^a	0.29 ^b	0.13 ^a	0.19 ^{ab}	0.24 ^{ab}	0.21 ^{ab}	0.01	<0.01
Gamma linolenic (C18:3n6)	0.42	0.61	0.23	0.47	0.68	0.48	0.64	0.05	0.22
Total	35.3 ^a	41.1 ^{bc}	39.3 ^b	38.26 ^b	39.5 ^b	44.1 ^c	41.8 ^{bc}	0.58	<0.01

T1: soybean meal-based diet, T2: diet with 15% HSC, T3: T2 + phytase enzyme (1000 FTU/kg), T4: diet with 15% autoclaved HSC (120 °C for 10 min),

T5: T4 + phytase enzyme (1000 FTU/kg), T6: diet with 15% oven -heated HSC (120 °C for 20 min), T7: T6 + phytase enzyme (1000 FTU/kg). ^{abc} Means in the same row, without a common letter are different at p<0.05. SEM: Standard error of the mean.

redness, and yellowness of broiler meat. Heated HSC does not impair the sensory quality of meat and has the potential to replace soybean meals.

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