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Research Article

Chemical and fatty acid composition of broiler meat as affected by dietary supplementation of tobacco seed and sweet red pepper seed cakes - a pilot study

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Abstract

This pilot study was designed to investigate the effect of tobacco seed cake and sweet red pepper seed cake supplemented in amount of 0.5% to the diet of broilers on the chemical composition and fatty acid profile of breast and thigh meat. A total of 54 male broilers were involved in the experiment. The birds were divided into three dietary groups: CON – basal diet, T1 – basal diet+0.5% tobacco seed cake, T2 basal diet + 0.5% sweet red pepper seed cake. Each group contained 6 replicate cages with 3 birds per cage. The trial lasted 35 days. The results revealed that the diet of the broilers affected significantly the protein ($p=0.0479$) and fat ($p=0.0148$) of the breast with higher protein content in T1 and lower fat content in T2 in comparison to CON ($p<0.05$). The lower intramuscular fat content in the breast of T2 was associated with significant decrease in C14:0 ($p=0.0200$) along with decline in C18:1 ($p=0.0041$) and MUFA ($p=0.0056$). The dietary treatments induced considerable changes in the polyunsaturated fatty acids in the breast and thigh meat. The breast of the both groups fed seed cakes showed marked increase in most of the long chain individual and n-6 PUFA, while the total and n-3 PUFA were considerably augmented in T2. The thighs had increased content of C18:2n-6, C18:3n-6 and C18:3n-3, particularly in the broilers receiving tobacco seed cake. The lipid nutritional indices were not affected by the diet and remained in the recommended ranges, except n-6/n-3 that strongly exceeded the recommended 4-5/1.

Keywords

tobacco seed cake, sweet red pepper seed cake, broilers, meat, fatty acids

Abbreviations

AI – atherogenic index; FAME – fatty acid methyl esters; h/H – hypo-/hypercholesterolemic fatty acids;

MUFA – monounsaturated fatty acids; PUFA – polyunsaturated fatty acids; SFA – saturated fatty acids;

TI – thrombogenic index

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Introduction

Meat is an important constituent of a balanced human diet. With the increasing demands of the consumers towards healthy nutrition the preferences have showed a clear advantage for the white meats, such as chicken meat. This has been clearly confirmed by its steadily growing levels of global production and consumption (FAO 2024). Chicken meat is affordable, with no religious and social constraints (Hayat et al. 2023), and offers a favourable nutritional profile with well-established and scientifically proven links to good health (Marangoni et al. 2015). Both chemical composition and the fatty acid profile of meat are essential for its healthy value and can be modified through adoption of various feeding strategies. Current agricultural and food supply chains generate significant amounts of plant-derived by-products, spanning from initial cultivation to final industrial processing (Dimitrova-Dicheva et al. 2026). In recent years, the use of agroindustrial by-products as feed ingredient or supplements in the poultry diets have increased and their effect on the meat quality in broilers have been extensively reviewed (Sugiharto and Nuengjamnong 2025). Seed cakes and meals are obtained after oil extraction, milling and food processing. They are an alternative source of cheaper plant protein for the poultry diets. They reduce the feed costs, however their application require caution due to high fiber content and anti-nutritional factors. In poultry nutrition, sunflower cake (Berwanger et al. 2017), sesame cake (da Silva et al. 2025; Reuben et al. 2025) appear to be promising protein sources. Tobacco and pepper are vital agricultural commodities belonging to the family *Solanaceae*. While tobacco remains a major global non-food cash crop, peppers (*Capsicum* species) serve as essential worldwide spice and vegetable crops valued for food, nutrition, and trade. After processing of these crops, their seeds remain as a by-product containing significant amount of biologically active compounds, thus revealing good potential for inclusion in feeds. So far, studies that investigated the effect of the meals and cakes derived from seeds of both crops are rather scarce. Tobacco seed cake was associated with decreased daily gain while no adverse effect on meat quality in lambs (Fatica et al. 2025) and did not impair the growth performance and health status in piglets (Rossi et al. 2013). In broilers, An et al. (2007) after

thorough analysis and assessment of the nutritional profile showed no negative effect of sweet red pepper seed meal in amount up to 10% on the growth performance and physiological response. In order to explore the potential as an alternative protein source, this pilot study was designed to assess the initial effects of tobacco and sweet pepper seed cakes supplemented in amount 0.5 % to the diet on the chemical composition and fatty acid profile in broilers meat. The amount of supplemented seed cakes was selected based on their high fiber content and assumed considerable levels of antinutritional factors that might affect the health of the birds. Due to the exploratory nature of the study, certain limitations of its design are the small sample size, and the scope restricted to a single production cycle in controlled conditions that will require further validation in industrial environments.

Materials and Methods

Experimental birds, housing and diets. The trial was carried out in the experimental poultry facility of the Institute of Animal Science-Kostinbrod, Bulgaria, with a total of 54 one-day old male Ross 308 broilers. The birds were randomly allocated to three treatment groups, each consisting of 6 replicate cages with 3 birds per cage ($n=18$). The dietary groups were formed as follows: CON – fed basal diet, T1 – fed basal diet + 0.5% tobacco seed cake (5 g.kg^{-1} feed), T2 – fed basal diet + 0.5% sweet red pepper seed cake (5 g.kg^{-1} feed). The cakes were supplied by the Institute of Food Preservation and Quality, Plovdiv, Bulgaria. They were obtained after cold pressing of the seeds of tobacco ecotype Krumovgrad and sweet red pepper of variety Plovdivska kapiya and further ground to be suitable for mixing with the feed. The chemical and fatty acid composition of the cakes are presented in Table 1. The basal feed was prepared by Viand JVC, Bulgaria (Table 2) and its nutrient composition was assessed in the laboratory of the enterprise.

Both feed and cakes were further analyzed for fatty acid profile (Table 3).

All the broilers had *ad libitum* access to feed and fresh water. The trial lasted 35 days in premises equipped with artificial fluorescent light and forced ventilation. Heating was achieved through local brooders on each cage.

Table 1. Chemical composition of the tobacco seed cake and sweet red pepper seed cake

Cakes	Moisture, %	Crude protein, %	Crude fat, %	Crude fiber, %	Crude ash, %	Nitrogen free extracts, %	Ca, %	P, %
Tobacco seed cake	7.59	35.59	9.30	25.92	5.01	16.59	0.181	1.099
Sweet red pepper seed cake	5.84	21.33	12.92	32.03	3.29	24.59	0.093	0.492

Table 2. Composition of the basal diet

Component	Content, %
Wheat	42.83
Soybean meal	31.10
Maize	10.00
Soya full fat toasted	5.00
Sorghum	5.00
Sunflower oil	1.60
Monocalcium phosphate	1.00
Limestone	0.85
Molasses	0.50
DL-Methionine	0.33
L-Lysine	0.29
Amino acids	0.25
Sodium bicarbonate	0.25
Salt	0.18
L-Threonine	0.11
Coccidiostat	0.05
Choline chloride	0.05
Lysolecithine	0.05
Essential oils + tributyrin	0.05
Antioxidants	0.01
Vitamin mineral premix	0.50
Chemical composition	
Crude protein, %	23.02
Crude fat, %	4.15
Crude fiber, %	2.77
Crude ash, %	5.15
Metabolizable energy, kcal.kg⁻¹	2975.45

*The tobacco seed and sweet red pepper seed cakes added on top of the complete diet

At hatching, the chickens were vaccinated against Newcastle disease, Marek disease, and infectious bronchitis. At 9 and 21 days of age, the broilers were vaccinated against infectious bursal disease.

Slaughtering and sampling. At the end of the trial, two birds per replicate cage were selected for slaughter from each group based on the average live

weight (2287.83 ± 135.70 g, 2221.33 ± 216.29 g, and 2258.00 ± 65.49 g for CON, T1 and T2, respectively). After stunning, decapitation, and bleeding, the carcasses were plucked, eviscerated, and their feet removed. The carcasses were kept at 4°C for 24h, and then were separated into breast, thigh, wings, back and neck. Half of the carcasses (1 bird per each replicate cage) were selected for analysis of meat quality and fatty acid profile. After removing the skin and bones, the breast and thighs of these carcasses were minced, packed and stored at -60°C until further analyses.

Table 3. Fatty acid composition of the basal diets and the cakes

Fatty acid, % FAME	Basal diet	Tobacco seed cake	Sweet red pepper seed cake
C14:0	0.05	N.D.	0.16
C16:0	12.68	7.26	9.80
C16:1	0.16	0.14	0.37
C17:0	N.D.*	0.09	N.D.
C18:0	4.04	2.08	1.67
C18:1	6.16	11.97	12.92
C18:2n-6	71.44	71.55	74.86
C18:3n-3	5.47	6.91	0.22
SFA	16.77	9.43	11.63
MUFA	6.32	12.11	13.29
PUFA	76.91	78.46	75.08

*N.D. - not detected; SFA=C14:0+C16:0+C17:0+C18:0; MUFA=C16:1+C18:1; PUFA=C18:2+C18:3

Methods. The chemical composition of the meat was assessed according to the methods of AOAC (2005) and included determination of moisture (AOAC Official Method 930.15), protein (AOAC Official Method 978.04), fat (AOAC Official Method 930.09), and ash (AOAC Official Method 920.153).

The fatty acid composition of the basal diet, cakes and meat was determined after lipid extraction

according to the method of [Bligh and Dyer \(1959\)](#) with slight modifications ([Vargas-Ramella et al. 2020](#)). Lipids were extracted from 10 g of the feed/muscle sample and homogenized with 10 mL of chloroform and 20 mL of methanol for 30 s. Following this, 10 mL of chloroform and 10 mL of NaCl (1% in distilled water) were added to the mixture and homogenized for 30 s. The samples were then centrifuged (4000 min⁻¹ for 10 min) and finally the chloroform layer was evaporated. The fatty acids were trans esterified as described by [Domínguez et al. \(2015\)](#) with some modifications: 20 mg of extracted fat dissolved in 1 mL of toluene was mixed with 2 mL of a sodium methoxide (0.5 N) solution, vortexed for 10 s, and left for 15 min at room temperature. Then, 4 mL of a H₂SO₄ solution (10% of H₂SO₄ in methanol) was added, vortexed for 10 s, and left for 5 min before adding 2 mL of saturated sodium bicarbonate solution. Fatty acid methyl esters were extracted as 1 mL of hexane was added to the samples, vortexed for 10 s, and the organic phase was transferred to an appropriate GC vial. Separation and quantification of the FAME were carried out using a gas chromatograph (CSI 200 series, Cambridge Scientific Instruments Ltd., Ely, UK) equipped with a split/splitless injector, capillary column (DM-2330:30 m × 0.25 mm × 0.20µm), flame ionization detector (FID). Hydrogen was used as a carrier gas with a flow of 1.5ml/min, with an injection split ratio of 20:1. The oven temperature was first set to 160°C for 0.2 min, then raised to 220°C at a rate of 5°C.min⁻¹ and then held for 5 min. The temperatures of the detector and injector were 230°C. Methyl esters were identified through comparison of the retention times of those in a Supelco 37 Component FAME mix standard. Fatty acids are presented as percentages of the total amount of the methyl esters identified. The amount of each fatty acid was used to calculate AI and TI ([Ulbricht and Southgate 1991](#)) as well as the ratio of h/H ([Santos-Silva et al. 2002](#)), using the following equations:

$$AI = (4 \times C14:0 + C16:0) / (MUFA + PUFA) \quad (1)$$

$$TI = (C14:0 + C16:0 + C18:0) / [(0.5 \times MUFA) + (0.5 \times n-6) + (3 \times n-3) + (n-3 / n-6)] \quad (2)$$

$$h/H = (C18:1 + PUFA) / (C14:0 + C16:0) \quad (3)$$

All the analyses in this trial were done in triplicates.

Statistical evaluation. Statistical processing was done using the JMP 17 Pro software package. Data were subjected to one-way ANOVA to assess the effect of the dietary treatment. The normality of distribution for the data was assessed by the Shapiro–Wilk test and QQ-plots of the residuals, whereas the homogeneity of the variances was checked by Levene test. The differences between the means in the groups were tested using the Tukey HSD test ($p < 0.05$). Data were presented as mean and standard error of the mean (SEM).

Results and Discussion

Chemical composition. Supplementing the diet of the broilers with 0.5% tobacco and pepper seed cakes affected significantly the protein ($p = 0.0479$) and fat ($p = 0.0148$) of the breast meat (Table 4). While differences in these traits were not significant among T1 and T2 groups, the group fed tobacco seed cake had higher protein content, and the birds supplemented with pepper seed cake exhibited lower fat content when compared to the control group ($p < 0.05$). For this study it is difficult to present comparison with results of others due to the critically limited number of similar research, particularly with poultry. While studies with the effect on pepper seed meal on the meat composition of farm animals and broilers were not available, in experiment with lambs receiving tobacco seed cake, [Fatica et al. \(2025\)](#) did not observe changes in the intramuscular fat content in two muscles, which is in line with our results, in regard to the comparison with the control group.

The decrease of the intramuscular fat content in the group receiving pepper seed cake was surprising. Intramuscular fat deposition in broilers is regulated by a complex network of genetic factors, carbohydrate and lipid metabolism pathways, and nutritional interventions ([Luo et al. 2022](#); [Song et al. 2025](#)). A possible explanation for the decrease of the intramuscular fat content is a suggested presence of antinutritional factors that might inhibit the lipid deposition in the muscles. The pepper seeds are particularly rich in phytic acid, tannins and flavonoids that remain active even after the processing and hence can interfere with the lipid absorption and deposition ([Tan et al. 2022](#); [Cosme et al. 2025](#)).

Table 4. Chemical composition of the breast and thigh meat of broilers as affected by the dietary supplementation of tobacco and pepper seed cakes (n=6)

	CON	T1	T2	SEM	P
Breast					
Protein, %	18.03 ^a	19.36 ^b	18.82 ^{ab}	0.847	0.0479
Fat, %	1.62 ^a	1.07 ^{ab}	0.88 ^b	0.396	0.0148
Moisture, %	77.27	76.47	77.19	0.813	0.2009
Ash, %	1.10	1.12	1.12	0.031	0.5446
Thigh					
Protein, %	16.39	16.27	16.11	0.656	0.7600
Fat, %	2.65	2.90	2.78	0.449	0.6214
Moisture, %	77.96	77.86	78.14	0.495	0.6120
Ash, %	1.05	1.02	1.01	0.042	0.2827

Values connected with different letters differ significantly ($p < 0.05$). CON-basal diet, T1-basal diet+0.5% tobacco seed cake; T2-basal diet+0.5% sweet red pepper seed cake.

On the other hand, the pepper seed cake had high total phenol content ($437.15 \pm 1.30 \text{ mg GAE} \cdot 100 \text{ g}^{-1}$ vs. $240.16 \pm 0.72 \text{ mg GAE} \cdot 100 \text{ g}^{-1}$ for the tobacco seed cake, unpublished data), and it might be supposed that they had reduced the intramuscular fat deposition. Studies have demonstrated that phenols act as natural phytochemical feed additives that influence lipid-metabolizing enzymes and genes (like PPAR γ and LPL) rather than causing generalized fat build up. They upregulate lipid transport and muscle-specific lipoprotein lipase while downregulating excessive hepatic lipogenesis (Huang et al. 2013; Zhang et al. 2025). These hypotheses however warrant further research with possibly larger samples of birds. The chemical composition of the thigh meat remained unaffected by the inclusion of both seed cakes in the broilers' diet revealing different response of the muscles due to the predominant fibre types and their metabolism (Weng et al. 2022).

Fatty acid profile. The fatty acid profile of the breast and thigh meat consisted of 20 identified fatty acids (Table 5). The results show different response of the muscle of these two parts in regard to the content and modification of the fatty acids as a result of the seed cake supplementation. Our results indicated that the effect of the seed cakes on the individual fatty acids was more pronounced in the breast than in thigh meat. In breast, the dietary supplementation with the cakes affected the percentage of the saturated C14:0 ($p = 0.0200$) and C18:0 ($p = 0.0322$), displaying

opposite patterns. The content of C14:0 was lower, while that of C18:0 was higher in T2, compared to CON ($p < 0.05$). The major saturated C16:0 was not affected by the seed cakes in the diet.

The effect of the dietary seed cakes on the individual monounsaturated fatty acids in the breast meat was presented by significant decrease ($p = 0.0041$) in the percentage of the C18:1 which was considerably lower in T2 when compared to CON. In line with the decreased levels of C18:1, the content of C16:1 tended to be lower in T2 ($p = 0.0561$). In thigh meat we did not observe any changes in the individual saturated and monounsaturated fatty acids.

In broilers fed different percentage of pepper seed oil meal, An et al. (2007) did not find any differences in the saturated and monounsaturated fatty acids in thighs, while in lambs fed tobacco seed cake, Fatica et al. (2025) reported decreased content of C16:0, and increased in C18:0. The changes in the saturated in the breast suggest potential beneficial influence of the seed cakes, particularly in the group fed pepper seed cake. Myristic (C14:0) and palmitic (C16:0) acids are hypercholesterolemic (Shramko et al. 2020), hence the decrease of the concentration of C14:0 and the lack of changes in C16:0 are desirable for a healthy diet. On the other hand, the increase of C18:0 should be treated with caution since while this fatty acid lowers the LDL it has been demonstrated that it might be proinflammatory and lipotoxic (Harvey et al. 2010).

Table 5. Fatty acid composition (%FAME) of the breast and thigh meat as affected by the dietary supplementation of tobacco and sweet red pepper seed cake (n=6)

Fatty acid	CON breast	T1 breast	T2 breast	SEM	<i>p</i>	CON thigh	T1 thigh	T2 thigh	SEM	<i>p</i>
C14:0	0.30 ^a	0.25 ^{ab}	0.23 ^b	0.038	0.0200	0.27	0.29	0.30	0.041	0.4072
C15:0	0.11	0.09	0.09	0.017	0.1790	0.09	0.09	0.09	0.009	0.4807
C16:0	17.53	17.33	17.67	0.912	0.8162	16.99	16.07	16.10	0.998	0.2238
C16:1	2.73	2.24	2.12	0.425	0.0561	2.58	2.66	2.65	0.332	0.9067
C17:0	0.22	0.21	0.19	0.062	0.6535	0.19	0.25	0.26	0.061	0.1296
C17:1	0.12	0.10	0.10	0.017	0.0858	0.11	0.12	0.11	0.019	0.6701
C18:0	7.57 ^a	8.54 ^{ab}	9.19 ^b	0.960	0.0322	8.31	7.72	8.25	0.628	0.2306
C18:1	31.11 ^a	28.43 ^{ab}	26.97 ^b	1.801	0.0041	31.29	30.59	30.17	1.719	0.5392
C18:2n-6	31.11	30.08	29.31	2.661	0.5165	31.27 ^a	33.96 ^b	33.19 ^{ab}	1.748	0.0478
C18:3n-6	0.30	0.27	0.25	0.069	0.4115	0.24 ^a	0.31 ^b	0.27 ^{ab}	0.044	0.0300
C18:3n-3	1.80	1.63	1.46	0.270	0.1216	1.82 ^a	2.07 ^b	1.99 ^{ab}	0.147	0.0253
C20:1	0.28	0.24	0.29	0.081	0.5544	0.29	0.25	0.23	0.064	0.2829
C20:2n-6	0.60 ^a	1.02 ^b	1.11 ^b	0.239	0.0041	0.50	0.46	0.49	0.099	0.7119
C20:3n-6	0.38 ^a	0.64 ^b	0.68 ^b	0.191	0.0317	0.33	0.28	0.36	0.117	0.4612
C20:4n-6	3.51 ^a	5.43 ^b	6.23 ^b	1.248	0.0054	3.41	2.91	3.31	0.707	0.4545
C20:5n-3	0.10	0.13	0.16	0.038	0.0858	0.09	0.08	0.08	0.025	0.5070
C22:4n-6	1.01 ^a	1.51 ^{ab}	1.79 ^b	0.431	0.0207	0.84	0.76	0.91	0.204	0.4386
C22:5n-6	0.22	0.38	0.40	0.143	0.1066	0.29 ^a	0.18 ^b	0.22 ^{ab}	0.060	0.0268
C22:5n-3	0.59 ^a	0.89 ^b	1.01 ^b	0.181	0.0034	0.62	0.59	0.57	0.194	0.8783
C22:6n-3	0.41 ^a	0.59 ^{ab}	0.75 ^b	0.211	0.0465	0.47	0.36	0.45	0.131	0.3303
SFA	25.73	26.42	27.37	1.569	0.2206	25.85	24.42	25.00	1.133	0.1260
MUFA	34.24 ^a	31.01 ^{ab}	29.48 ^b	2.179	0.0056	34.27	33.62	33.16	2.026	0.6398
PUFA	40.03 ^a	42.57 ^{ab}	43.15 ^b	1.944	0.0327	39.88	41.96	41.84	2.321	0.2532
n-6	37.13 ^a	39.33 ^b	39.77 ^b	1.778	0.0459	36.88	38.86	38.75	2.050	0.2047
n-3	2.90 ^a	3.24 ^{ab}	3.38 ^b	0.251	0.0180	3.00	3.10	3.09	0.324	0.8629

Values connected with different letters differ significantly ($P < 0.05$); CON-basal diet, T1-basal diet+0.5% tobacco seed cake; T2-basal diet+0.5% sweet red pepper seed cake.

SFA=C14:0+C15:0+C16:0+C17:0+C18:0; MUFA=C16:1+C17:1+C18:1+C20:1; PUFA=C18:2n-6+C18:3n-6+C18:3n-3+C20:2n-6+C20:3n-6+C20:4n-6+C20:5n-3+C22:4n-6+C22:5n-6+C22:5n-3+C22:6n-3; n-6=C18:2n-6+C18:3n-6+C20:2n-6+C20:3n-6+C20:4n-6+C22:4n-6+C22:5n-6; n-3= C18:3n-3+C20:5n-3+C22:5n-3+C22:6n-3

The significant decline of C18:1 and the trend towards decrease in C16:1 in the breast of the broilers in T2 corresponded to the lower intramuscular fat content of the breast of the broilers in this group and suggest inhibited action of desaturase enzymes. Following the changes in C18:1 and C16:1 in the breast meat, the total MUFA were significantly decreased by the dietary supplementation with seed meals ($P=0.0056$), particularly in T2 corresponding to the lower intramuscular fat content of the breast in this group (Cui et al. 2022). Both tobacco and pepper seed cakes had significant effect on the long chain C20:2n-6 ($p=0.0041$), C20:3n-6 ($p=0.0317$),

C20:4n-6 ($p=0.0054$) and C22:5n-3 ($p=0.0034$) leading to considerable increase of their percentage in T1 and T2 in comparison to CON ($p < 0.05$). Furthermore, the diet also affected the contents of C22:4n-6 ($P=0.0207$) and C22:6n-3 ($p=0.0465$), with highest values in T2 compared to CON ($p < 0.05$). In regard of the total amount of fatty acids, in breast we observed significant effect of the dietary supplements on PUFA ($p=0.0327$), n-6 ($p=0.0459$) and n-3 ($p=0.0180$). The breast meat of T2 exhibited higher content of PUFA and n-3. Furthermore, the dietary supplementation of the seed cakes was associated with higher n-6 percentage in T1 and T2 when compared to CON

($p<0.05$). In thighs we observed effect of the diet on the percentages of some individual polyunsaturated fatty acids. The seed cakes increased significantly the contents of C18:2n-6 ($p=0.0478$), C18:3n-6 ($p=0.0300$), C18:3n-3 ($p=0.0253$) with significant differences between T1 in comparison to CON ($p<0.05$). The percentages in these fatty acids also tended to be higher in T2 than CON. These results are similar to those of [An et al. \(2007\)](#) who reported significant increase in the contents of C18:2n-6 in the broilers following the elevation of the doses of red pepper seed meal. The authors assumed effective deposition of C18:2n-6 in the skeletal muscles of broilers. We also observed effect of the seed meals on the levels of C22:5n-6 ($p=0.0268$), however its percentage was lower in T1 compared to C ($p<0.05$). Despite the changes in the percentages of the individual polyunsaturated fatty acids, in thighs we did not observe any effect of the seed cake supplementation on the total amounts of PUFA, n-3 and n-6.

The increase in the contents of the polyunsaturated fatty acids in the groups fed seed cakes might be considered a positive effect of these supplements. The beneficial effect of PUFA on the human health and for prevention of various diseases and conditions especially those with long chain have been extensively demonstrated ([Djuricic and Calder 2021](#)).

In this study we did not observe any significant differences between groups in regards to the lipid nutritional indices in the breast and thigh meat (Table 6).

It can be noticed that the n-6/n-3 ratio is within the range 11.76-12.80 for the breast and 12.29-12.54 for the thighs. These values are far above the recommended 4-5/1 ([Mariamenatu and Abdu 2021](#)). This is not surprising for poultry and particularly broiler meat, due to the naturally high amount of C18:2n-6 that comes from the feed. Apart from the high values of n-6/n-3, the rest of the lipid nutritional indices in the breast and thigh meat exhibited values that are within the dietary recommendations for $P/S>0.4$ ([Pleadin et al. 2021](#)), $AI<0.5$ and $TI<1$ ([Dal Bosco et al. 2024](#)) regardless of the group. This indicates that the supplementation of the broilers' diet with 0.5% tobacco or pepper seed cakes has no potential negative effect the nutritional and healthy value of the broiler meat.

Table 6. Lipid nutritional indices of the breast and thigh meat of broilers as affected by the dietary supplementation of tobacco and sweet red pepper seed cakes

Breast	CON	T1	T2	SEM	P
n-6/n-3	12.80	12.13	11.76	0.783	0.1364
P/S	1.56	1.65	1.57	0.128	0.7566
AI	0.25	0.25	0.26	0.018	0.7802
TI	0.57	0.58	0.60	0.046	0.4271
h/H	3.99	4.09	3.92	0.278	0.8051
Thigh					
n-6/n-3	12.29	12.53	12.54	0.765	0.6907
P/S	1.43	1.72	1.67	0.146	0.1206
AI	0.24	0.23	0.23	0.016	0.2224
TI	0.57	0.53	0.54	0.037	0.1565
h/H	4.12	4.43	4.39	0.328	0.2091

Conclusions

The results of this pilot study suggest lack of potential negative effect of the supplementation of broilers' diet with 0.5% tobacco seed and sweet red pepper seed cake on the chemical composition and fatty acid profile of breast and thigh meat. The group receiving tobacco seed cake had higher protein content whereas pepper seed cake exhibited lower intramuscular fat content in the breast along with significant decrease of the hypercholesterolemic C14:0 and monounsaturated fatty acids. The dietary treatments induced significant changes in the polyunsaturated fatty acids, with different response in the breast and thigh meat. The breast of the groups fed seed cakes showed marked increase in the long chain individual PUFA, total PUFA, n-6 and n-3, while the thighs had increased content of C18:2n-6, C18:3n-6 and C18:3n-3, particularly in the broilers receiving tobacco seed cake. No detrimental effect of the diet was found in regard to the lipid nutritional indices. The results of this study are preliminary and the potential beneficial effects of the seed cakes supplemented to the diet of broilers warrant further research to be confirmed. Future works should focus on thorough investigation of their nutritional profile to identify possible

antinutritional factors, as well as to elucidate the mechanisms of their effect on the intramuscular fat and fatty acid deposition. Moreover, different doses and larger samples should be involved in future trials in order to find the optimal dose for practical application of these by-product to produce high quality broilers meat.

Author Contributions

Conceptualization, V.N., N.N., E.P., and T.P.; methodology, E.P., and T.P.; formal analysis E.P., T.P. and K.D.; investigation, V.N., N.N., E.P., T.P., K.D.; resources, V.N., N.N. and E.P.; data curation, T.P., K.D.; writing—original draft preparation, T.P., K.D.; writing—review and editing, V.N.; project administration, V.N. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement

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Informed Consent Statement

Not applicable.

Data Availability Statement

The original contributions presented in this study are included in the article. Further inquiries can be directed to the corresponding authors.

Conflicts of Interest

The authors declare no conflicts of interest.

References

An B., Im H., Kang, C. Nutritional values of red pepper seed oil meal and effects of its supplementation on performances and physiological responses of broiler chicks. *Asian-Australasian Journal of Animal Sciences*, 2007, 20(6): 971-975.
<https://doi.org/10.5713/ajas.2007.971>

AOAC Official Methods of Analysis. 18th ed. , Arlington, VA, USA: Association of Official Analytical Chemists. 2005.

Berwanger E., Nunes R.V., Pasquetti T.J., Murakami A.E., de Oliveira T.M., Bayerle D.F., Frank R. Sunflower cake with or without enzymatic complex for broiler chickens feeding. *Asian-Australasian Journal of Animal Science*, 2017, 30(3): 410-416.
<https://doi.org/10.5713/ajas.15.0644>

Bligh E.G., Dyer, W.Y. A rapid method of total lipid extraction and purification. *Canadian Journal of Biochemistry and Physiology*, 1959, 37: 911-917.
<https://doi.org/10.1139/o59-099>

Cosme F., Aires A., Pinto T., Oliveira I., Vilela A., Gonçalves B. A Comprehensive review of bioactive tannins in foods and beverages: functional properties, health benefits, and sensory qualities. *Molecules*, 2025, 30(4): 800.
<https://doi.org/10.3390/molecules30040800>

Cui H., Liu L., Liu X., Wang Y., Luo N., Tan X., Zhu Y., Liu R., Zhao G., Wen J. A selected population study reveals the biochemical mechanism of intramuscular fat deposition in chicken meat. *Journal of Animal Science and Biotechnology*, 2022, 13(1): 54. <https://doi.org/10.1186/s40104-022-00705-3>

da Silva D.A., Ludke M.d.C.M., Ludke J.V., de Souza L.F.A., Barros M.R., dos Santos A.C.F., Costa F.S., Sérgio Peres, Valadares C.G., Coldebella A., da Silva E.P., Carvalho L.R.R.A., Ribeiro A.G. Effects of including sesame cake in broiler chicken feed: Performance, nutrient metabolizability, blood parameters, bone assessment, and profitability, *Poultry Science*, 2025, 104(11), 105842.
<https://doi.org/10.1016/j.psj.2025.105842>

Dal Bosco A., Cavallo M., Menchetti L., Angelucci E., Cartoni Mancinelli A., Vaudo G., Marconi S., Camilli E., Galli F., Castellini C.; et al. The Healthy fatty index allows for deeper insights into the lipid composition of foods of animal origin when compared with the atherogenic and thrombogenicity indexes. *Foods*, 2024, 13(10): 1568.
<https://doi.org/10.3390/foods13101568>

Dimitrova-Dicheva M., Balabanova T., Boyanova P., Ivanova I., Ivanova M., Balabanov A. Plant agro-food by-products as functional additives in dairy products: a review. *Food Science and Applied Biotechnology*, 2026, 9(1): 79-100.
<https://doi.org/10.30721/fsab2026.v9.i1.656>

- Djuricic I., Calder P.C. Beneficial outcomes of omega-6 and omega-3 polyunsaturated fatty acids on human health: an update for 2021. *Nutrients*, 2021, 13(7): 2421. <https://doi.org/10.3390/nu13072421>
- Domínguez R., Crecente S., Borrajo P., Agregan R., Lorenzo J.M. Effect of slaughter age on foal carcass traits and meat quality. *Animal*, 2015, 9(10): 1713-1720 <https://doi.org/10.1017/S1751731115000671>
- FAOSTAT 2024. Crops and livestock products. Available at: <https://www.fao.org/faostat/en/#data/QCL/visualize>
- Fatica A., Palazzo M., Tavaniello S., Peng M., Teshale D. B., Maiorano G., Salimei, E. Tobacco cv. Solaris seed cake as feed for light lambs: Growth performance, carcase traits and meat quality. *Italian Journal of Animal Science*, 2025, 24(1): 411-423. <https://doi.org/10.1080/1828051X.2025.2455501>
- Harvey K.A., Walker C.L., Xu Z., Whitley P., Pavlina T.M., Hise M., Zaloga G.P., Siddiqui R.A. Oleic acid inhibits stearic acid-induced inhibition of cell growth and pro-inflammatory responses in human aortic endothelial cells. *Journal of Lipid Research*, 2010, 51(12): 3470-3480. <https://doi.org/10.1194/jlr.M010371>
- Hayat M.N., Kumar P., Sazili A.Q. Are spiritual, ethical, and eating qualities of poultry meat influenced by current and frequency during electrical water bath stunning? *Poultry Science*, 2023, 102(9): 102838. <https://doi.org/10.1016/j.psj.2023.102838>
- Huang J., Zhang Y., Zhou Y., Zhang Z., Xie Z., Zhang J., Wan X. Green tea polyphenols alleviate obesity in broiler chickens through the regulation of lipid-metabolism-related genes and transcription factor expression. *Journal of Agricultural and Food Chemistry*, 2013, 61(36): 8565-8572. <https://doi.org/10.1021/jf402004x>
- Luo N., Shu J., Yuan X., Jin Y., Cui H., Zhao G., Wen J. Differential regulation of intramuscular fat and abdominal fat deposition in chickens. *BMC Genomics*, 2022, 23(1): 308. <https://doi.org/10.1186/s12864-022-08538-0>
- Marangoni F., Corsello G., Cricelli C., Ferrara N., Ghiselli A., Lucchin L., Poli A. Role of poultry meat in a balanced diet aimed at maintaining health and wellbeing: An Italian consensus document. *Food & Nutrition Research*, 2015, 59(6): 27606. <https://doi.org/10.3402/fnr.v59.27606>
- Mariamnatu A.H., Abdu E.M. Overconsumption of omega-6 polyunsaturated fatty acids (pufas) versus deficiency of omega-3 pufas in modern-day diets: the disturbing factor for their "balanced antagonistic metabolic functions" in the human body. *Journal of Lipids*, 2021, 12(3): 8848161. <https://doi.org/10.1155/2021/8848161>
- Pleadin J., Lešić T., Vujačić V., Milićević D., Buneta A., Šušnić S., Lukanić I., Krešić G. Comparison of chemical composition and fatty acid profile of traditional meat products from Croatia and Montenegro, *Journal of Food Quality*, 2021, 44(7): 5586436. <https://doi.org/10.1155/2021/5586436>
- Reuben D. T., Istifanus G., Uway F. R. Bitrus M. S., Nenchin P. L., Philip J. C., Otitoju A. P., Joshua P. G., Kopdora, S. W., Sele P. C., Vongdip N. G., Adaji G.A., Yunusa U., Luka W. 2025. Nutritional content of sesame (*Sesamum indicum* L.) seed cake and its growth performance on broiler chickens. *Asian Journal of Advances in Agricultural Research*, 2025, 25 (10): 30-44. <https://doi.org/10.9734/ajaar/2025/v25i10678>
- Rossi L., Fusi E., Baldi G., Fogher C., Cheli F., Baldi A., Dell'Orto V. Tobacco seeds by-product as protein source for piglets. *Open Journal of Veterinary Medicine*, 2013, 3(1): 73-78. <https://doi.org/10.4236/ojvm.2013.31012>
- Santos-Silva J., Bessa R. J. B., Santos-Silva F. Effect of genotype, feeding system and slaughter weight on the quality of light lambs – II. Fatty acid composition of meat. *Livestock Production Science*, 2002, 77(2-3): 187-192 [https://doi.org/10.1016/S0301-6226\(02\)00059-3](https://doi.org/10.1016/S0301-6226(02)00059-3)
- Shramko V.S., Polonskaya Y.V., Kashtanova E.V., Stakhneva E.M., Ragino Y.I. The Short overview on the relevance of fatty acids for human cardiovascular disorders. *Biomolecules*, 2020, 10(8):1127. <https://doi.org/10.3390/biom10081127> .
- Song J., Lv Z., Guo Y. Research advances in intramuscular fat deposition and chicken meat quality: genetics and nutrition. *Journal of Animal Science and Biotechnology*, 2025, 16(1):100. <https://doi.org/10.1186/s40104-025-01234-5>
- Sugiharto S., Nuengjamnong C. An update review on the use of agro-industrial byproducts on carcass and meat quality of broiler chickens. *Discover Food*, 2025, 5(7): 203. <https://doi.org/10.1007/s44187-025-00509-0>
- Tan Z., Halter B., Liu D., Gilbert E.R., Cline M.A. Dietary flavonoids as modulators of lipid metabolism in poultry. *Frontiers in Physiology*, 2022, 13(4): 863860. <https://doi.org/10.3389/fphys.2022.863860>

Ulbricht T.L., Southgate D.A.T. Coronary heart disease: Seven dietary factors. *Lancet*, 1991, 338(10): 985-992. [https://doi.org/10.1016/0140-6736\(91\)91846-m](https://doi.org/10.1016/0140-6736(91)91846-m)

Vargas-Ramella M., Pateiro M., Barba F.J., Franco D., Campagnol P.C.B., Munekata P.E.S., Tomasevic I., Domínguez R., Lorenzo J.M. Microencapsulation of healthier oils to enhance the physicochemical and nutritional properties of deer pâté. *LWT Food Science and Technology*, 2020, 125(5): 109223. <https://doi.org/10.1016/j.lwt.2020.109223>

Weng K., Huo W., Li Y., Zhang Y., Zhang Y., Chen G., Xu Q. Fiber characteristics and meat quality of different muscular tissues from slow- and fast-growing broilers. *Poultry Science*, 2022, 101(1): 101537. <https://doi.org/10.1016/j.psj.2021.101537>

Zhang X., Jin S., Luo Q., Li X., Yin Y., Huang T., Zhao Y. Effects of ferulic acid on meat quality and fat metabolism in broilers. *Poultry Science*, 2025, 104(12): 106014. <https://doi.org/10.1016/j.psj.2025.106014>