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Physicochemical traits and mineral concentrations in meat of broiler chickens fed diets with granulated fats of palm oil (prilled fats and calcium soaps)

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ABSTRACT

This study evaluated physicochemical characteristics and mineral composition in meat of broiler chickens fed diets containing prilled fats of palm oil (PFPO) and/or calcium soaps of palm oil (CaSPO) replacing vegetable oil (VO). Meat samples of breast and thigh were obtained from 40 carcasses randomly selected from 200 male broiler chickens previously fed diet containing PFPO and/or CaSPO for 42 days in a 2×2 factorial randomized design. Two levels of (0 and 50%) of treatment (n=10) were used for PFPO and CaSPO each. The level was the substitution of VO for granulated fats. Breast meat had lower ether extract in birds fed PFPO diets (main effect, p=0.02). Water, crude protein, pH, lightness (L*), redness (a*) and yellowness (b*) were not influenced by treatment. In thigh meat, the concentrations of water, ash and ether extract showed an interaction effect (PFPO×CaSPO). Crude protein concentration, (L*) and (a*) were not influenced by treatment. Granulated fats (PFPO or CaSPO) increased the yellowness value (b*; main effect). The meat of breast or thigh showed interaction effect for calcium (PFPO×CaSPO); calcium concentration was lower in the meat of chickens fed diets with PFPO. Sodium was lower in meat of chickens fed diets with PFPO (main effect). Results revealed that granulated fats of palm oil (CaSPO or PFPO) had a small influence on the physicochemical characteristics of meat from broiler chickens. Calcium or ether extract in meat were reduced with PFPO addition in the diets.

Keywords: Broiler chicken, Meat, Palm oil, Prilled fats, Saponified fats

Common lipids in poultry diets include animal fats, vegetable oils, and a combination of both (Baião and Lara 2005). Lipids in diets enhance the quality and productivity of broiler chickens (Abdulla *et al.* 2019, Jaapar *et al.* 2020). There is considerable interest among nutritionists in improving the use of lipids in diets for broiler chickens to enhance economic profits and meat quality. The value of metabolizable energy of lipids in poultry diets is associated with fatty acids saturation, chain length, free fatty acids, impurities, and levels of fat and calcium in the diet (Ravindran *et al.* 2016)). In broiler chickens, there is a greater lipids digestibility for soybean oil (mostly unsaturated fats) than tallow (mostly saturated fatty acids) (Tancharoenrat *et al.* 2014).

In some countries, palm oil is less expensive than oils derived from oilseeds or animal fats (Parveez *et al.* 2021). However, palm oil has some restrictions. Broiler chickens receiving diets with palm oil exhibited lower fat digestibility and greater saturated fatty acids level in breast meat than chickens receiving diets with rapeseed oil or sunflower oil (Khatun *et al.* 2018, Skřivan *et al.* 2018). In addition, Khatun *et al.* (2018) observed similar digestibility and carcass characteristics in broiler chickens receiving diets with mixtures of palm and sunflower oils; they suggested this alternative for using palm oil in broiler chicken diets. In agreement, another study found enhanced productive performance or economic profit with 50% replacement of palm oil for omega-3-rich rapeseed oil in diets for broiler chickens (Sudharsan *et al.* 2020).

Granulated fats generated by saponification are included in diets for ruminants (Salinas *et al.* 2006). Saponification of palm oil produces calcium salts of palm oil (CaSPO), a granular fat that in some countries is less expensive than conventional oils from oilseeds used in poultry diets. Replacement of CaSPO for vegetable oil in poultry diets did not reduce productive performance (Villanueva-Lopez *et al.* 2020) or carcass weight in broiler chickens (Nájera-Pedraza *et al.* 2023).

Prilled fats of palm oil (PFPO) are small spheres of encapsulated fat (tiny pearls of 1 to 2 mm in diameter) that contain 99% lipids with 85 to 90% palmitic acid (C16:0). The PFPO are primarily included in diets for ruminants. There is limited research information about the use of PFPO in the feeding of broiler chickens. Compared to

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palm oil, PFPO has improved the apparent digestibility of lipids and decreased diarrhea in weaned pigs (Ren *et al.* 2020). Productive performance and nutrient digestibility were augmented with the addition of 1% of PFPO in broiler chickens (Jaapar *et al.* 2020). The productive performance or carcass evaluations were not affected by vegetable oil replacements for PFPO in the feed of broiler chickens (Nájera-Pedraza *et al.* 2023).

To the best of our knowledge, there is very limited information on the meat physicochemical characteristics or mineral composition using CaSPO and/or PFPO in the diets of broiler chickens as a partial substitution of VO. We hypothesized that diets with PFPO, CaSPO, and VO have different effects on the physicochemical characteristics or mineral composition in meat of broiler chickens. This study aimed to evaluate the physicochemical characteristics and mineral composition of meat in broiler chickens fed diets containing CaSPO and PFPO as partial replacements for conventional VO.

MATERIALS AND METHODS

This study was conducted at the poultry farm of the College of Veterinary Medicine and Animal Science of the Autonomous University of Tamaulipas, Ciudad Victoria, Mexico. The place is situated at 23°44′06″N and 97°09′50″W, at an altitude of 323 m. The average annual rainfall is 926 mm, and the yearly mean temperature is 24°C. These climatic features correspond to the dry subtropics (ACw). The average ambient temperature during the experiment was 20.2±2.0°C.

In the study, two hundred, 1-day-old male Ross 308 broiler chickens of 41.9±1.07 g (mean ± SD) bought from a commercial hatchery, were used. The chicks were allocated to 20 pens with concrete floors covered with ground grass straw. Each treatment (diet) incorporated 50 birds assigned at random divided in five pens in a completely randomized design with twenty-four hours of light. The density was ten birds per square meter. Water and feed were offered ad libitum. The birds were vaccinated on day 7 of the trial against fowlpox (wing puncture) and Newcastle (ocular) using the La Sota strain.

Two feeding phases were considered: 1–21 (starter) and 22–42 days of age (finisher). There were four treatments (T) each for starter and finisher diets. The experimental diet composition was same except for the lipid source: in T1 it was 100% VO, T2 50% VO + 50% CaSPO, T3 50% VO + 50% PFPO, and T4 50% CaSPO + 50% PFPO. The diets were formulated based on the National Research Council (NRC 1994) recommendations for poultry, as well as other studies on broiler chickens (Infante-Rodríguez *et al.* 2016, Infante-Rodríguez *et al.* 2020), (Table 1).

On the last day of the feeding trial, two chickens per pen (ten birds per treatment) were randomly selected to be slaughtered by cervical dislocation according to Official Mexican Act (NOM-033-SAG/ZOO-2014) to obtain carcasses without viscera. The breasts and thighs were separated and frozen (-20 °C) for further evaluation. For analysis, meat samples were obtained from the muscles: pectoralis major in breast, and iliotibialis in thigh. The laboratory analysis of the samples was carried out in the laboratory of the Department of Animal Nutrition, of the Antonio Narro Autonomous Agrarian University, Saltillo, Mexico. The proximate composition was determined according to AOAC (2000) procedures, and included moisture, crude protein, ether extract, and ash. All results were expressed on wet matter basis. The moisture was

Table 1. Ingredient and nutrient compositions of the experimental diets, for the starter phase (start, 1 to 21 days of age) and for the finisher phase (finish, 22 to 42 days of age)

	0% PFPO				50% PFPO			
	0% CaSPO (T1)		50% CaSPO (T2)		0% CaSPO (T3)		50% CaSPO (T4)	
Ingredient (%)	Start	Finish	Start	Finish	Start	Finish	Start	Finish
Sorghum grain	58.9	65.6	58.9	65.6	58.9	65.6	58.9	65.6
Soybean meal	33.7	26.4	33.7	26.4	33.7	26.4	33.7	26.4
Vegetable oil (VO)	3.4	3.7	1.7	1.85	1.7	1.85	0	0
PFPO	0	0	0	0	1.7	1.85	1.7	1.85
CaSPO	0	0	1.7	1.85	0	0	1.7	1.85
Premix[1,2]	4	4	4	4	4	4	4	4
Pigment		0.33		0.33		0.33		0.33
Total	100	100	100	100	100	100	100	100
Nutrient composition								
Crude protein, %	21.4	18.7	21.4	18.7	21.4	18.7	21.4	18.7
Metabolizable energy, kcal/kg	3040	3120	3040	3120	3040	3120	3040	3120

CaSPO: Calcium soaps of palm oil, PFPO: Prilled fats of palm oil, Premix: monocalcium phosphate, calcium carbonate, common salt, growth promoter (BDM and 3-nitro), sodium monensin, mineral oil, ethoxyquin, retinol (vitamin A-acetate), cholecalciferol-D3 (vitamin D3), α-tocopheryl acetate (vitamin E), vitamin K3, riboflavin (vitamin B2), cobalamin (vitamin B12), niacin (vitamin B3), calcium D-pantothenate (vitamin B5), choline chloride (vitamin B4), butylated hydroxytoluene (BHT). [1]Premix for starter phase: calculated to contain: 21.40% Ca, 8.10% total P, 3.40% Na, 0.80% L-lysine chlorhydrate, and 4.15% DL-methionine. [2]Premix for finisher phase: calculated to contain: 19.80% Ca, 3.7% total P, 3.7% Na, 4.3% L-lysine chlorhydrate and 5.2% DL-methionine determined by drying 1 g of meat sample in an oven at 100 to 105°C for 24 h. The Kjeldahl was used for crude protein determination (N x 6.25). The Soxhlet procedure was used for crude fat extraction with ether of petroleum, considering previous acidification (50 mL hydrochloric acid 4 mol/L and digested for 40 min). Ash was determined by igniting the meat sample in a muffle furnace (Thermolyne Thermo Scientific, model 1500FD 1535M) at 600°C for 2 h. Results were expressed as a percentage on a wet matter basis.

The pH was determined in meat samples thawed for 24 h at 4°C. The samples (1 g) were macerated in a mortar, distilled water was added, and filtrated through four layers of cheesecloth, rinsing the mortar with distilled water; the total water was 10 mL. The pH of the filtrate was recorded with a pH meter (Mod HI98127, Hanna instruments, Rumania), previously calibrated in buffer solutions at ambient conditions.

Meat samples thawed for 24 h at 4°C were used for color determination using a spectrophotometer (KONICA MINOLTA model CROMA METER CR-400, Japan) considering the scale CIELAB. Four replicated measurements were recorded to have a representative value of color for the meat samples. The color values were for Hunter L* (lightness), a* (redness), and b* (yellowness).

Minerals determination of breast and thigh samples were made according to the AOAC (2000) procedures. Minerals, except phosphorus, were determined in an atomic absorption spectroscopy (VARIAN model AA-1275 series). Phosphorus was determined according to the procedure by Fick *et al.* (1979) using a spectrophotometer UNICO model UV2150.

Statistical analyses: Data were subjected to analysis of variance (ANOVA) in a completely randomized design with factorial arrangement of 2 × 2 (PROC GLM of SAS; SAS Institute Inc, Cary, NC). The main effects were two PFPO levels (0 and 50%) and two CaSPO levels (0 and 50%), as well as the interaction between these effects. Significance was declared at $p \leq 0.05$.

RESULTS AND DISCUSSION

Physicochemical traits of breast meat: The influence of fat sources in the diets of broiler chickens on the physicochemical characteristics of breast meat is shown in Table 2. Water, CP, and ash concentration in breast meat were not affected by treatments ($p>0.05$). The breast meat of broiler chickens fed PFPO had lower EE (main effect, $p=0.02$) than the breast meat of broiler chickens with no PFPO in the diets. Treatments did not show difference among them for pH, L*, a*, and b* ($p>0.05$).

The added fats were at a similar level in the experimental diets; therefore, it is not clear what caused the lower EE in breast muscle of chickens fed diets with PFPO (T3 and T4). Other researchers have documented a higher EE in chicken meat as EE in diets increases (Bogosavljević-Bošković *et al.* 2010, Legawa *et al.* 2018). In part the differences in

Table 2. Meats physicochemical traits of broiler chickens fed diets formulated with different fat sources

	0% PFPO		50% PFPO			*p* value main effect		
	0% CaSPO (T1)	50% CaSPO (T2)	0% CaSPO (T3)	50% CaSPO (T4)	SEM	PFPO	CaSPO	PFPO × CaSPO
			Breast´s meat					
Water, %	76.67±1.30	76.09±0.75	75.38±1.22	75.82±0.89	0.34	0.12	0.89	0.30
Crude protein; %	23.59±1.79	24.24±2.07	23.76±1.40	25.26±0.76	0.50	0.41	0.15	0.56
Ash, %	1.16±0.04	1.14±0.03	1.15±0.03	1.12±0.02	0.009	0.45	0.07	0.72
Ether extract, %	1.46±0.50	1.32±0.24	1.02±0.27	0.98±0.31	0.10	0.02	0.57	0.73
pH	5.79±0.17	5.82±0.16	5.78±0.08	5.74±0.17	0.04	0.51	0.93	0.62
L	49.99±2.98	49.08±2.05	50.55±1.35	50.57±2.58	0.73	0.34	0.67	0.66
a	3.00±1.08	3.43±0.63	2.49±0.77	2.47±0.67	0.26	0.06	0.58	0.55
b	7.48±2.52	10.61±1.96	9.50±2.35	10.57±3.84	0.87	0.44	0.11	0.42
			Thighs' meat					
Water, %	78.31±0.68	76.94±0.39	77.62±0.75	77.52±0.68	0.20	0.86	0.02	0.04
Crude protein; %	22.01±1.26	22.45±0.74	22.21V0.95	22.63±0.75	0.30	0.66	0.32	0.98
Ash, %	1.10±0.04	1.01±0.05	1.02±0.03	1.05±0.02	0.01	0.26	0.08	<0.01
Ether extract, %	2.31±0.53	2.27±0.40	1.88±0.45	1.56±0.21	0.13	<0.01	0.35	0.05
pH	6.16±0.13	5.86±0.05	6.02±0.16	6.00±0.07	0.04	1.0	<0.01	0.02
L	47.07±1.17	47.02±2.64	48.67±1.61	47.92±2.48	0.65	0.20	0.67	0.71
a	5.88±1.37	6.03±0.66	6.57±0.88	5.92±1.87	0.40	0.61	0.66	0.49
b	7.35±1.36	10.55±1.83	10.47±1.50	11.61±1.15	0.47	≤0.01	≤0.01	0.14

CaSPO: Calcium soaps of palm oil, PFPO: Prilled fats of palm oil the amount of fat deposited in the breast of broiler chickens could be attributed to greater absorption of unsaturated fats (soybean oil) than saturated fats (palm oil, Rodriguez-Sanchez *et al.* (2021)). In agreement with the current study, Al-Abdullatif *et al.* (2023) found greater fat deposition in the breast of broiler chickens fed diets with unsaturated fats (rice oil) that saturated fat (palm oil). Gálvez *et al.* (2020) reported EE in the breast meat of broiler chickens close to that in the current study; however higher EE levels were reported by various authors (Souza *et al.* 2011, Milicevic *et al.* 2015, Abdulla *et al.* 2017, De Oliveira *et al.* 2016). There are no previous reports regarding the influence of PFPO in diets on EE concentrations in breast meat of broiler chickens.

Energy density of diets may also influence the broiler's meat lipid concentration. It was reported that the increase in energy level of diets has reduced lipid concentration in pectoral muscle of broiler chickens (Marcu *et al.* 2012, Marcu *et al.* 2013, Infante-Rodríguez *et al*. 2016). In the current study, the fat source was the only source of variation in diets, and factors like chemical form of fatty acids in the different fat sources could be related to the lower lipid level in breasts of chickens fed diets with PFPO (T3 and T4). More studies on digestion and metabolism on this theme are warranted to elucidate this effect.

The value of lightness (L*) varied from 49.1 to 50.6. These values are within the normal range of breast meat of broiler chickens. Qiao *et al.* (2001) reported that lightness (L*) values in breast meat are considered normal in range from 48 to 53; values <48 are darker and >53 are lighter.

In the present study, the redness (a*) of breast meat varied from 2.47 (T4) to 3.43 (T2). Although Qiao *et al.* (2001) considered 4 as normal redness (a*) value in breast meat; others have reported redness (a*) values approaching our values (Ozturk *et al.* 2010, Cheng *et al.* 2017). Redness is associated with myoglobin concentration in meat, and reported values vary widely, including negative values (-1.31, Gálvez *et al.* 2020) to values of 6.89 (Abdulla *et al.* 2017).

The yellowness (b*) in breast meat of the present study varied from 7.48 (T1) to 10.60 (T2). According to Qiao *et al.* (2001) the yellowness (b*) value, considered normal in meat of the breast was 5.56; although Qiao *et al.* (2002) considered 9.68 as a normal value, which is close to the values obtained in the present study. Data from Gálvez *et al.* (2020) showed a variation from 7.90 to 20.8 for yellowness values, depending on production system of broiler chickens.

In the current study water concentration of breast meat varied from 75.38% (T3) to 76.69% (T1); crude protein from 23.59% (T1) to 25.26% (T4), and ash from 1.12% (T4) to 1.16% (T1). These results agree with various studies in broiler chickens under different feeding and management conditions where breast meat has had small changes in moisture, crude protein and ash (Milicevic *et al.* 2015, De Oliveira *et al.* 2016, Abdulla *et al.* 2017).

The pH of breast meat in the present study varied from 5.74 to 5.82. These values are considered normal for breast meat of broiler chickens given various diets (Souza *et al.* 2011, Abdulla *et al.* 2017, Gálvez *et al.* 2020). Glycogen metabolism postmortem causes pH reduction, and it is lower at 24 h than 15 min after slaughter (Abdulla *et al.* 2017).

Physicochemical traits of thigh meat: The influence of fat presentation in the diets of broiler chickens on physicochemical characteristics of thigh meat are shown in Table 2. Crude protein concentration of thigh meat was not affected by treatment (p>0.05). Water, ash, ether extract concentrations and pH had an interaction effect (PFPO × CaSPO; p≤0.05). For diets without PFPO, the inclusion of CaSPO (T2) reduced the concentrations of water, ash, and pH; however, in diets with PFPO, CaSPO (T4) reduced the ether extract concentration of thigh meat. The variables of "L" or "a" were not influenced by treatment (P>0.05). Inclusion of PFPO or CaSPO in diets increased the variable "b" value in thigh meat of the chickens (main effect, p≤0.01).

In the current study, water concentration in thigh meat varied from 78.31% to 76.94%, corresponding to diets with VO only (T1) and diets with VO + CaSPO (T2); these values approach values from 76.14% to 77.23% observed by Souza *et al.* (2011), and the values are lower than those reported by Ozturk *et al.* (2012).

In the current study, crude protein in thigh meat varied from 22.00% to 22.63% with no difference among treatments; these values are in line with the values from 21.3% to 22.6% observed by De Oliveira *et al.* (2016). Nevertheless Souza *et al.* (2011) reported CP values from 19.4% to 19.8% in thigh meat of broiler chickens reared under different production systems.

In the present study, ash in thigh meat varied from 1.09% (T1) to 1.00% (T2). There are no previous reports on the influence of granulated fats of palm oil on ash in broiler chicken meat. Probably CaSPO could reduce mineral deposition in broiler chicken tissues. Calik *et al.* (2019) found lower ash levels in the bones of broiler chickens fed diets with calcium soaps of tallow than birds fed diets with vegetable oil. In addition, lower ash levels in the bones of broiler chickens have been observed in diets supplemented with palmitic acid than those supplemented with oleic acid (Atteh and Leeson 1983).

Ether extract in thigh meat varied from 1.56% (T4) to 2.31% (T1). Prilled fat contains abundant saturated fatty acid, where palmitic acid is the major component, while CaSPO has predominantly palmitic acid and substantial monounsaturated 18-carbon fatty acids (Grummer 1988). Thus, diets with more abundant unsaturated fatty acids (T1 and T2) promoted higher fat depositions in thighs. This effect could be related to the fact that relatively saturated fat such as PFPO slows gastrointestinal transit time (Grimesd *et al.* 1996). It is also reported in broiler chickens that ileal digestibility of the ether extract has been improved in diets containing soy oil as compared with those containing palm fat powder (Allahyari-Bake and Jahanian 2017); thus, the

Table 3. Meat mineral concentrations of broiler chickens fed diets formulated with different fat sources

Mineral (ppm)	0% PFPO		50% PFPO			*p value* main effect		
	0% CaSPO (T1)	50% CaSPO (T2)	0% CaSPO (T3)	50% CaSPO (T4)	SEM	PFPO	CaSPO	PFPO × CaSPO
				Breast´s meat				
Potassium	3399±282	3453±971	3100±599	3003±350	198	0.19	0.93	0.78
Sodium	11682±323	12050±141	6864±268	6948±111	72	≤0.01	0.04	0.18
Cupper	1.83±0.42	2.27±0.27	2.17±0.25	1.29±0.76	0.15	0.14	0.32	≤0.01
Iron	19.05±12.39	10.86±1.59	9.22±0.99	11.19±2.29	2.01	0.11	0.29	0.09
Zinc	8.65±1.57	9.69±2.23	9.38±1.10	8.63±1.63	0.53	0.83	0.85	0.25
Magnesium	133.6±59.3	158.2±64.8	69.5±27.0	287.2±112.1	22.92	0.33	≤0.01	≤0.01
Calcium	862±109	1403±251	93±14	91±11	43.44	0.001	≤0.01	≤0.01
Phosphorus	2166±162	2307±184	2489±189	2695±202	58	≤0.01	0.05	0.70
				Thighs' meat				
Potassium	2759±458	2371±376	2218±290	2413±252	111	0.13	0.54	0.08
Sodium	11823±140	9985±2585	7391±297	6960±153	412	0.001	0.06	0.24
Cupper	2.32±0.21	2.14±0.26	2.69±0.27	1.10±0.22	0.07	<0.01	<0.01	<0.01
Iron	15.17±3.59	10.96±2.44	10.05±1.87	9.77±1.56	0.78	0.01	0.06	0.09
Zinc	17.43±3.42	18.33±3.93	17.02±5.76	15.16±1.75	1.25	0.32	0.78	0.44
Magnesium	106.4±21.2	68.0±26.5	575.5±634.1	59.8±22.2	100.46	0.12	0.06	0.11
Calcium	1383±522	445±476	98±23	286±480	134	<0.01	0.06	<0.01
Phosphorus	2088±251	2119±244	2158±152	2173±103	62	0.48	0.79	0.92

CaSPO: Calcium soaps of palm oil, PFPO: Prilled fats of palm oil

addition of PFPO could hamper the deposition of fat in the thighs.

In the current study, pH in thigh meat varied from 5.86 (T2) to 6.16 (T1). Souza *et al.* (2011) found pH values from 5.96 to 6.14 in thigh meat of broiler chickens of different strains; values very close to those found in the current study. In both cases, the higher pH was for thigh meat with higher moisture concentration. However, in the Hassan *et al.* (2018) study, pH of meat of broiler chickens did not change with increasing moisture concentration. In the present study, pH was greater in in thigh meat of chickens in T1 than in animals of T2, and water also was greater in T1 than in T2; however, pH and water concentrations had only minimal differences among animals for T3 and T4 that had PFPO. This might suggest that PFPO has lower influence on water concentration and pH than CaSPO when it substituted VO in the diet of chickens.

Lightness (L*) and redness (a*) did not vary in the thigh meat of birds receiving different diets. However, yellowness (b*) was lower in chickens fed diets with VO only (T1) compared with treatments containing granulated fats of palm oil (T2, T3, and T4). Probably, pigments such as carotenoids could be released during the industrial process of raw palm oil to produce the granulated fat of palm oil as CaSPO or PFPO. More research in this theme is warranted. We did not find previous reports regarding pH influence on color in thigh meat; however, greater dark color in breast meat with higher pH has also been found by others (Qiao *et al.* 2002, Gálvez *et al.* 2020).

Mineral concentrations in breast and thigh: The influence of diets on mineral concentrations in breast meat of broiler chickens are shown in Table 3. The potassium, iron, and zinc concentrations in breast meat of broiler chickens were not influenced by treatment (p>0.05). The cupper, magnesium, and calcium concentrations had an interaction effect (PFPO×CaSPO; p≤0.05). Greater sodium (main effect, p=0.04) or phosphorus (main effect, p=0.05) concentrations were observed in the breast meat of broiler chickens fed the diet with CaSPO; while lower sodium, with higher phosphorus concentrations were observed in the breast meat of broiler chickens fed the diet with PFPO (main effect, p≤0.01).

The influence of diets on mineral concentrations in thigh meat of broiler chickens are shown in Table 3. Potassium, iron, zinc, magnesium, and phosphorus concentrations in thigh meat of broiler chickens did not differ (p>0.05) among treatments. Cupper or calcium concentrations had an interaction effect (PFPO×CaSPO, p≤0.05). Sodium or iron concentrations were lower (main effect, p≤0.01) in thigh meat of broiler chickens fed diets with PFPO (T3, T4) than in diets without PFPO (T1, T2).

The results of the present study could indicate that the calcium concentration of saponified fat (CaSPO) did positively influence calcium deposition in breast meat of chickens fed the T2 diet when compared to T1 diet (VO). We did not find bibliographic data to explain why the

CaSPO diet (T2) induced higher Ca deposition in meat of broiler chickens than the VO diet (T1).

Meat of breast and thigh of broiler chickens fed the diets with PFPO (T3 and T4), exhibited lower calcium concentration than birds consuming the diets with VO or CaSPO (T1 and T2). This result could be in part related to lower calcium concentration in PFPO than in CaSPO. The PFPO is formed by 99% crude fat while CaSPO contains 9% to 14% of ash; CaSPO is produced by saponification of palm oil with calcium hydroxide, resulting in a granulated fat rich in calcium, which presumably had more calcium available for absorption. The high palmitic acid concentration in prilled fat (PFPO) is another factor that could have contributed to lower calcium concentration in meat of broiler chickens fed diets with PFPO (T3 and T4). Palm oil in diets for broiler chickens has reduced calcium digestibility (Abdulla *et al.* 2019) and its deposition in bones (Abdulla *et al.* 2017). According to Atteh and Leeson (1983), saturated fatty acids like palmitic and stearic acids reduce calcium digestibility mainly by soap formation, while unsaturated fatty acids like oleic and linoleic acids form soaps of higher digestibility.

The different lipid sources in the diets of the current study influenced calcium deposition in the meat of broiler chickens, and these calcium changes may influence the changes in other minerals like phosphorus and magnesium, probably by the interaction of calcium with phosphorus or magnesium. The information on this theme is limited and more research is warranted.

In conclusion, meat of broiler chickens fed diets containing PFPO exhibited lower ether extract concentration than meat of chickens offered CaSPO or VO only. Lightness (L*), redness (a*), and yellowness (b*) showed small influence from dietary treatments, but lipid sources in diets altered the mineral composition of meat of broiler chickens. Therefore, the partial replacement of vegetable oil with CaSPO could be a way to produce calcium and magnesium-enriched meat from broiler chickens. Further research is warranted to elucidate the effects of the different granulated fats in the diets on fatty acids profile and other meat characteristics of broiler chickens.

REFERENCES

AOAC. 2000. *Official Methods of Analysis* of AOAC International. 17th edn. Association of Official Analytical Chemists International, Gaithersburg, USA.

Abdulla N R, Loh TC, Akit H, Sazili A Q, Foo H L, Kareem K Y, Mohamad R and Abdul Rahim R. 2017. Effects of dietary oil sources, calcium and phosphorus levels on growth performance, carcass characteristics and bone quality of broiler chickens. *Journal of Applied Animal Research* **45**: 423-29.

Abdulla N R, Loh T C, Foo H L, Alshelmani M I and Akit H. 2019. Influence of dietary ratios of n-6: n-3 fatty acid on gene expression, fatty acid profile in liver and breast muscle tissues, serum lipid profile, and immunoglobulin in broiler chickens. *Journal of Applied Poultry Research* **28**: 454-69.

Allahyari-Bake S and Jahanian R. 2017. Effects of dietary fat source and supplemental lysophosphatidylcholine on performance, immune responses, and ileal nutrient digestibility in broilers fed corn/soybean meal- or corn/wheat/soybean meal-based diets. *Poultry Science* **96**: 1149-58.

Al-Abdullatif A, Hussein E, Suliman G, Akasha M, Al-Badwi,M, Ali H and Azzam M. 2023. Evaluating rice bran oil as a dietary energy source on production performance, nutritional properties and fatty acid deposition of breast meat in broiler chickens. *Foods* **12**: 366. https://doi.org/10.3390/foods12020366

Atteh J O and Leeson S. 1983. Effects of dietary fatty acids and calcium levels on performance and mineral metabolism of broiler chickens. *Poultry Science* **62**: 2412-19.

Baião N C and Lara L J C. 2005. Oil and fat in broiler nutrition. *Brazilian Journal of Poultry Science* 7: 129-41.

Bogosavljević-Bošković S, Pavlovski Z, Petrović M D, Dosković V and Rakonjac S. 2010. Broiler meat quality: Proteins and lipids of muscle tissue. *African Journal of Biotechnology* **9**: 9177-82.

Calik A, Yalcin S, Küçükersan S, Saçakli P, Yildiz G, Ramay, M S, Ahlat O, Erbay-Elibol F K and Taban S. 2019. Effects of calcium soaps of animal fats on performance, abdominal fat fatty acid composition, bone biomechanical properties, and tibia mineral concentration of broilers. *Kafkas Üniversitesi Veteriner Fakültesi Dergisi* **25**: 61-70.

Cheng Y, Chen Y, Li X, Yang W, Wen C, Kang Y, Wang A and Zhou Y. 2017. Effects of synbiotic supplementation on growth performance, carcass characteristics, meat quality and muscular antioxidant capacity and mineral contents in broilers. *Journal of Science Food and Agriculture* **97**: 3699-705.

De Oliveira J, Avanço S V, Garcia-Neto M and Ponsano E H G. 2016. Composition of broilers meat. *Journal of Applied Poultry Research* **25**(2): 173-81.

Fick K, Mc Dowell L, Miles P H, Wilkinson N S, Funk J D and Conrad J H. 1979. *Methods of mineral analysis for plant and animal tissues*. 2nd ed. Department of Animal Science, University of Florida, Gainesville. USA.

Gálvez F, Domínguez R, Maggiolino A, Pateiro M, Carballo J, De Palo P, Barba F G and Lorenzo J M. 2020. Meat quality of commercial chickens reared in different production systems: industrial, range and organic. *Annals of Animal Science* **20**: 263-85.

Grimesd J L, Maurices V, Lightseyt F and Gaylord G. 1996. Dietary prilled fat and layer chicken performance and egg composition. *Poultry Science* **75**: 250-53.

Grummer R R. 1988. Influence of prilled fat and calcium salt of palm oil fatty acids on ruminal fermentation and nutrient digestibility. *Journal of Dairy Science* **71**: 117-23.

Hassan S S, Attia Y A, Abd-El-Hamid A E H E, Nagadi S A and El-Ashry A. 2018. Impact of increasing dietary oil concentrations with a constant energy level on the tolerance of broiler chickens to a high ambient temperature. *Revista Mexicana de Ciencias Pecuarias* **9**: 220-39.

Infante-Rodríguez F, Salinas-Chavira J, Montaño-Gómez M F, Manríquez-Nuñez O M, González-Vizcarra V M, Guevara-Florentino O F and Ramírez De León J A. 2016. Effect of diets with different energy concentrations on growth performance, carcass characteristics and meat chemical composition of broiler chickens in dry tropics. *SpringerPlus* **5**: 937. https://doi.org/10.1186/s40064-016-3608-0

Infante Rodríguez F, Domínguez Muñoz M Á, Montaño Gómez M F, Hume M E, Anderson R C, Manríquez Núñez O M, López-Acevedo E A, Bautista-Martínez Y and Salinas

Chavira J. 2020. Effect of protein concentrations in the diet on productive performance, carcass characteristics, and meat chemical composition of broiler chickens in the dry subtropics. *Nova scientia* **12**(25). https://www.scielo.org.mx/scielo.php?pid=S2007-07052020000200110&script=sci_abstract&tlng=en

Jaapar M S, Alshelmani M I, Humam A M, Loh T C, Fos H L and Akit H. 2020. Effect of feeding prilled palm fat with lyso-lecithin on broiler growth performance, nutrient digestibility, lipid profile, carcass and meat quality. *Poultry Science Journal* **8**: 43-50.

Khatun J, Loh T C, Akit H, Fos H L and Mohamad R. 2018. Influence of different sources of oil on performance, meat quality, gut morphology, ileal digestibility and serum lipid profile in broilers. *Journal of Applied Animal Research* **46**: 479-85.

Legawa A T, Wattanachant C and Wattanasit S. 2018. Carcass characteristics and meat quality of broilers fed with crude glycerin originated from palm oil and wasted vegetable oil in diets. *Acta Scientiarum. Animal Sciences* **40**(e39585): 1-6. Doi: 10.4025/actascianimsci.v40i1.39585

Marcu A, Vacaru-Opriş I, Marcu A, Nicula M, Dronca D and Kelciov B. 2012. The influence of feed energy and protein level on meat quality at "Hubbard F15" broiler chickens. *Animal Science and Biotechnology* **45**: 432-39.

Marcu A, Vacaru-Opriş I, Dumitrescu G, Marcu A, Petculescu C L, Nicula M, Dronca D and Kelciov B. 2013. Effect of diets with different energy and protein levels on breast muscle characteristics of broiler chickens. *Animal Science and Biotechnology* **46**: 333-40.

Milicevic D, Trbovic D, Petrovic Z, Jakovac-Strajn B, Nastasijevic I and Koricanac V. 2015. Physicochemical and functional properties of chicken meat. *Procedia Food Science* **5**: 191-94.

Nájera-Pedraza O G, Mellado-Bosque M A, García-Martínez J E, Encina-Domínguez J A and Salinas-Chavira J. 2023. Replacement of conventional vegetable oil with granulated fats of palm oil prilled fats and calcium soaps in broiler chicken diet: performance and carcass traits. *Brazilian Journal of Poultry Science* **25**: 1-8.

National Research Council (NRC). 1994. *Nutrient requirements of poultry*, 9th ed. National Academy Press Washington DC. USA

NOM - *Norma Oficial Mexicana*. Métodos para dar muerte a los animales domésticos y silvestres [NOM-033-SAG/ZOO-2014]. 2014. Available from: https://www.gob.mx/profepa/documentos/norma-oficial-mexicana-nom-033-sag-zoo-2014-metodos-para-dar-muerte-a-los-animales-domesticos-y-silvestres

Ozturk E, Ocak N, Coskun I, Turhan S and Erener G. 2010. Effects of humic substances supplementation provided through drinking water on performance, carcass traits and meat quality of broilers. *Journal of Animal Physiology and Animal Nutrition* **94**: 78-85.

Ozturk E, Ocak N, Turan A, Erener G, Altop A and Cankaya S. 2012. Performance, carcass gastrointestinal tract and meat quality traits and selected blood parameters of broilers fed diets supplemented with humic substances. *Journal of Science and Food Agriculture* **92**: 59-65.

Parveez G K A, Tarmizi A H A, Sundram S, Loh S K, Ong-Abdulla M, Palam, K D P, Salleh K M, Ishak S M and Idris Z. 2021. Oil palm economic performance in Malaysia and R&D progress in 2020. *Journal of Oil Palm Research* **33**: 181-214.

Qiao M, Fletcher D L, Smith D P and Northcutt J K. 2001. The effect of broiler breast meat color on pH, moisture, water-holding capacity, and emulsification capacity. *Poultry Science* **80**: 676-80.

Qiao M, Fletcher D L, Northcutt J K and Smith D P. 2002. The relationship between raw broiler breast meat color and composition. *Poultry Science* **81**: 422-27.

Ravindran V, Tancharoenrat P, Zaefarian F and Ravindran G. 2016. Fats in poultry nutrition: Digestive physiology and factors influencing their utilisation. *Animal Feed Science and Technology* **213**: 1-21. http://dx.doi.org/10.1016/j.anifeedsci.2016.01.012

Ren C X, Wang Y J, Lin X F, Yang F, Chen J, Song H Q, Shi K, Song J S, Chen F, Zhang S H and Guan W T. 2020. Palm oil encapsulated by homogenizing and spray drying enhances nutrient digestibility and attenuates diarrhoea of piglets. *Animal Feed Science and Technology* **266**: 114503. https://doi.org/10.1016/j.anifeedsci.2020.114503

Rodriguez-Sanchez R, Tres A, Sala R, Soler M D, Guardiola F and Barroeta A C. 2021. Effects of free-fatty-acid content and saturation degree of the dietary oil sources on lipid-class content and fatty-acid digestibility along the gastrointestinal tract in broilers from 22 to 37 days of age. *Poultry Science* **100**:101261. https://doi.org/10.1016/j.psj.2021.101261

Salinas J, Ramirez R G, Domínguez M M, Reyes-Bernal N, Trinidad-Larraga N and Montano M F. 2006. Effect of calcium soaps of tallow on growth performance and carcass characteristics of Pelibuey lambs. *Small Ruminant Research* **66**(1-3): 135-39.

Skřivan M, Marounek M, Englmaierová M, Čermák L, Vlčková J and Skřivanová, E. 2018. Effect of dietary fat type on intestinal digestibility of fatty acids fatty acid profiles of breast meat and abdominal fat and mRNA expression of lipid-related genes in broiler chickens. *PloS ONE* **13**(4): e0196035.

Souza X R, Faria P B and Bressan M C. 2011. Proximate composition and meat quality of broilers reared under different production systems. *Brazilian Journal of Poultry Science* **13**: 15-20.

Sudharsan C, Murugan S S, Chacks B, Juliet S, Nair S N, Bency A and Muneer A K. 2020. Influence of dietary substitution of palm oil by rapeseed oil at different levels on growth performance and economics of broilers. *Indian Journal of Animal Research* **55**: 445-50.

Tancharoenrat P, Ravindran V, Zaefarian F and Ravindran G. 2014. Digestion of fat and fatty acids along the gastrointestinal tract of broiler chickens. *Poultry Science* **93**: 371-79.

Villanueva-Lopez D A, Infante-Rodríguez F, Nájera-Pedraza O G, Barrios-García H B and Salinas-Chavira J. 2020. Effect of dietary frying fat vegetable oil and calcium soaps of palm oil on the productive behavior and carcass yield of broiler chickens. *Brazilian Journal of Poultry Science* **22**: 1-8.