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Original Article

Replacement of Conventional Vegetable Oil with Granulated Fats of Palm Oil (Prilled Fats and Calcium Soaps) in Broiler Chicken Diet: Performance and Carcass Traits

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ABSTRACT

This study evaluated the productive performance and carcass characteristics of broiler chickens fed diets containing prilled fats of palm oil (PFPO) or calcium soaps of palm oil (CaSPO) replacing vegetable oils (VO). A total of two hundred 1-day-old male Ross 308 chickens were allocated in a 2 × 2 randomized factorial design. Diets included 2 PFPO levels (0 and 50%) and 2 CaSPO levels (0 and 50%). The level was the percentage of substitution of VO by granulated fats. The study had two phases (starter and finisher), each lasting 21 days. In the starter phase, PFPO did not influence (main effects; $p>0.05$) feed intake and body weight gain, but improved (main effect; $p=0.03$) feed conversion. In the finisher phase and the total study, PFPO had no effect ($p>0.05$) on these productive variables. Throughout the study, CaSPO did not influence feed intake (main effect; $p>0.50$), but decreased weight gain and had a negative effect on feed conversion (main effects; $p<0.05$). There was no influence of fats (PFPO or CaSPO) on carcass yield, breast, drumsticks plus thighs, and wings (main effects; $p>0.05$). Chickens fed CaSPO had lower (main effect; $p=0.02$) carcass weight. The only PFPO × CaSPO interaction ($p=0.04$) was for back yield. Results showed that PFPO or CaSPO could be employed in formulating broiler chicken diets, as they are less expensive than conventional VO. Partial substitution of VO for PFPO had minimal effect on productive variables, although partial dietary inclusion of CaSPO might slightly reduce the production of broiler chickens.

INTRODUCTION

Broiler chickens produced intensively have high energy requirements that are not met with cereal grains such as corn or sorghum; therefore, lipids are included in diets to increase caloric density, in order to meet these high growth energy requirements (Infante-Rodriguez *et al.*, 2016). Animal fats, vegetable oils, and a mixture of both are the most common sources of lipids in poultry diets (Baião & Lara, 2005).

Vegetable oils from oilseeds, with their higher concentrations of essential fatty acids such as linoleic and linolenic acids, improve the productive performance of broiler chickens (Itzá-Ortiz *et al.*, 2008). Palm oil is one of the most abundant oils in the world; it is mainly used in the food industry, but its use as animal feed is limited. In some areas of the world, palm oil is as competitive in price as other vegetable oils or animal fats (Parveez *et al.,* 2021).

Previous research found adequate productive performance of broiler chickens fed palm oil (Valencia *et al.*, 1993). It was later reported that calcium soaps of palm oil (CaSPO) are produced by saponification and used in ruminant feeding (Salinas *et al.*, 2006). Because of the granulated form of CaSPO, their incorporation into broiler chicken diets is simple, and they are resistant to oxidation. Besides, in some places, CaSPO are cheaper than conventional lipid sources used in formulations for broiler chickens.

Dewi *et al.* (2011) reported that 5% CaSPO in broiler chickens' diet increased feed intake, while the incorporation of 15% CaSPO reduced feed intake. However, the final live weight was not influenced by CasPO level in the diet. In our previous work (Villanueva-Lopez *et al.,* 2020), we reported similar productive performance in broiler chickens fed diets in which vegetable oil or recycled fats were replaced with CaSPO. We concluded that CaSPO represents an alternative to partially replace conventional vegetable oils (VO) in diets for broiler chickens, particularly in countries where CaSPO are cheaper than traditional VO; however, reports on this topic are very limited. In our previous work (Villanueva-Lopez *et al.*, 2020), we used CaSPO and recycled fats in the chicken´s diet, while the current study tested CaSPO and PFPO in chicken feeding. To the best of our knowledge, there is no previous research using PFPO in broiler chicken feeding.

Prilled fats of palm oil (PFPO) are produced during the palm oil process. During this procedure, palm oil is cleaned and distilled to generate a fat with 99% crude fat, which contains 85 to 90% palmitic acid (C16:0). This fat is industrially processed, being encapsulated and producing small spheres (tiny pearls) of 1 to 2 mm in diameter. PFPO are used in ruminant feeding but reports of its use in non-ruminant animals are scarce. In weaned pigs, greater ether extract digestibility in the total digestive tract and a lower incidence of diarrhea have been found when PFPO are added to diet when compared to diets containing palm oil (Ren *et al.*, 2020). In broiler chickens, body weight gain, feed conversion rate, and nutrient digestibility have improved with the substitution of 1% palm oil with PFPO; however, 5% PFPO reduced the productive variables of broiler chickens (Jaapar *et al.*, 2020).

Nowadays, conventional vegetable oils from oilseeds are expensive; thus, replacements are necessary to substitute VO from oilseeds without altering the productive variables of broiler chickens, with CaSPO being an alternative. On the other hand, PFPO may not be cheaper than conventional VO; however, with its high energy concentration and easy incorporation into diets for broiler chickens, PFPO could be an alternative to replace conventional VO. There is no previous report using both CaSPO and PFPO in broiler chickens' diets as a partial substitution of VO. Therefore, the objective of the present study was to evaluate the productive performance and carcass characteristics of broiler chickens fed diets with calcium soaps and prilled fats from palm oil as a replacement for conventional vegetable oil.

MATERIALS AND METHODS

Study area

The study was carried out at the poultry farm of the College of Veterinary Medicine and Animal Science of the Autonomous University of Tamaulipas, Ciudad Victoria, Tamaulipas (a subtropical area in northeastern Mexico). The site is located at 23°44'06"N and 97°09'50"W, at an altitude of 323 m. The mean annual rainfall is 926 mm, and the yearly average temperature is 24 °C (INEGI, 2017). These climatic characteristics are typical for the dry subtropics (ACw).

Animals and diets

All animal care and management procedures were approved by the Bioethics Committee of the College of Veterinary Medicine and Animal Science of the Autonomous University of Tamaulipas (reference 001-20-CI).

Two hundred, 1-day-old male Ross 308 broiler chickens weighing 41.9±1.07 g (mean ± SD) were obtained from a commercial hatchery. Each treatment (diet) included 50 birds randomly assigned to five replicates of ten animals each. During the whole experiment, birds were housed in 20-floor pens with ground grass straw as bedding material. Twenty-four hours of light per day were provided during the whole trial. Each pen had an automatic drinker and a manually filled feeder. Space allocation was of ten birds per square meter. Water and feed were offered *ad libitum*. Birds were vaccinated on day 7 of the trial against fowlpox (wing puncture) and Newcastle (ocular) using the La Sota strain.

Chickens were raised following standard commercial practices. Two feeding phases were used: 1–21 (starter) and 22–42 days of age (finisher). There were four treatments (T) for starter and finisher diets. The only difference between experimental diet compositions was the lipid source: in T1 it was 100% vegetable oil (VO), whereas T2 included 50% VO + 50% Ca soap of palm oil (CaSPO), T3 contained 50% VO + 50% prilled fat of palm oil (PFPO), and T4 had 50% CaSPO + 50% PFPO. Diets were prepared according to the recommendations of the National Research Council (NRC, 1994) for poultry (Tables 1 and 2).

Table 1 – Ingredient and nutrient compositions of the experimental diets (%) for the starter phase (1-21 days of age).

	0% PFPO		50% PFPO	
Ingredients	0% CaSPO	50% CaSPO	0% CaSPO	50% CaSPO
Sorghum grain	58.9	58.9	58.9	58.9
Soybean meal	33.7	33.7	33.7	33.7
Vegetable oil (VO)	3.4	1.7	1.7	0
PFPO	0	0	1.7	1.7
CaSPO	0	1.7	0	1.7
Premix*	4	4	4	4
Total	100	100	100	100
Nutrient composition				
Crude protein, %	21.4	21.4	21.4	21.4
Metabolizable energy, kcal/kg	3040	3040	3040	3040

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). Calculated to contain: 21.40% Ca; 8.10% total P; 3.40% Na; 0.80% L-lysine hydrochloride; and 4.15% DL-methionine. The premix for the starter phase of broiler chickens is manufactured and distributed by Trouw Nutrition, Mexico, S.A. de C.V.

Table 2 – Ingredient and nutrient compositions of the control diets (%) for the finisher phase (22-42 days of age).

	0% PFPO			
Ingredients	0% CaSPO	50% CaSPO		50% CaSPO
Sorghum grain	65.6	65.6		65.6
Soybean meal	26.4	26.4		26.4
Vegetable oil (VO)	3.7	1.85	1.85	0
PFPO	0	0		1.85
CaSPO	0	1.85		1.85
Premix*	4	4		4
Pigment	0.33	0.33		0.33
Total	100	100		100
Nutrient composition				
Crude protein, %	18.7	18.7		18.7
Metabolizable energy, kcal/kg	3120	3120		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). Pre-mix calculated to contain: 19.80% Ca; 3.7% total P; 3.7% Na; 4.3% L-lysine hydrochloride; and 5.2% DL-methionine. The premix for the finisher phase of broiler chickens is manufactured and distributed by Trouw Nutrition, Mexico, S.A. de C.V.

Body weight and feed intake were measured weekly and the feed conversion ratio (FCR; feed intake, g/weight gain, g) was calculated. At the end of the feeding trial, two chickens per cage were randomly selected to be sacrificed by cervical dislocation according to official Mexican law (NOM-033-SAG/ZOO-2014) for carcass traits determination. Carcass weight without viscera was used to estimate hot carcass yield. The carcass was then dissected for major cuts: breast, thighs and drumsticks, wings, and back.

Statistical analyses

The data obtained were analyzed using a completely randomized design with a factorial arrangement of 2 × 2. 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. The values of 0 and 50 represent the percentage of substitution of VO for each granulated fat of palm oil (PFPO or CaSPO). The experimental design is shown in the following scheme.

Prilled fats	Calcium fats	Treatment
0% PFPO	0% CaSPO	T1 = (0% PFPO + 0% CaSPO), n=5
0% PFPO	50% CaSPO	T2 = (0% PFPO + 50% CaSPO), n=5
50% PFPO	0% CaSPO	T3 = (50% PFPO + 0% CaSPO), n=5
50%PFPO	50% CaSPO	T4 = (50% PFPO + 50% CaSPO), n=5

For productive performance calculation (weight gain, feed intake, and feed conversion ratio), the replicate was considered to be the average of broiler chickens in each pen; while for carcass evaluation, it was the average of two birds (selected at random) per pen. The carcass yield was determined as carcass weight (g)/live weight (g). Significance was declared at $p \leq 0.05$. Statistical analyses were conducted using the GLM procedure of SAS (2007).

RESULTS

Growth performance

The influence of fat sources on the productive performance of broiler chickens is shown in Figures 1, 2, and 3. In the starter phase (1 to 21 d), the prilled fat of palm oil did not influence chicken feed intake or body weight gain (p>0.05), but improved (main effect; p=0.03) feed conversion ratio; it was 12.2% better for chickens receiving diets with PFPO than for chickens without PFPO in their diets. In its turn, the inclusion of CaSPO oil did not influence feed intake (p=0.63), but it decreased (main effect; p<0.01) body weight gain by 9.4% compared to birds fed diets without CaSPO. The inclusion of CaSPO also adversely affected (main effect; p=0.03) feed conversion ratio, which was 11.5% better for chickens without CaSPO in their diets.

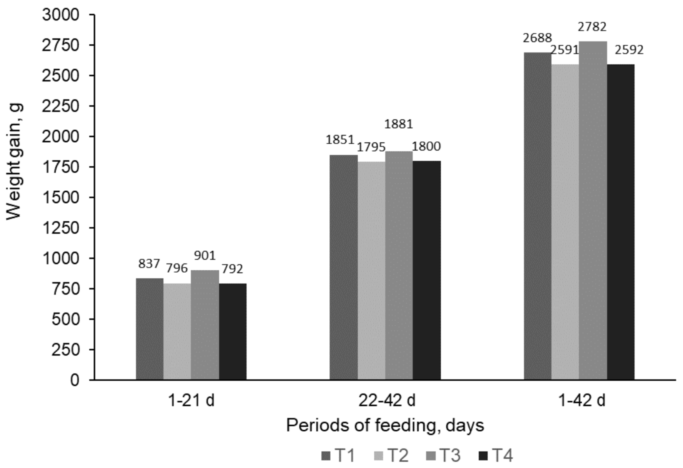

Figure 1 – Weight gain of broiler chickens in the study. T1 = Control (0% CaSPO + 0% CaSPO); T2 = 0% PFPO + 50% CaSPO; T3 = 50% PFPO + 0% CaSPO; T4 = 50% PFPO + 50% CaSPO. CaSPO = calcium soaps of palm oil; PFPO= Prilled fats of palm oil. Probabilities of main effects for PFPO, CaSPO, and for the interaction (PFPO × CaSPO), were 0.09, <0.01, and 0.06 (SEM = 11.7) respectively for the starter phase. In the same order for the finisher phase were 0.57, 0.04, and 0.68 (SEM = 21.1). For the entire period, the values were 0.22, <0.01, and 0.23 (SEM = 26).

The percentage changes in the weight gain of chickens for the main effect of CaSPO were estimated considering the average weight gain of animals fed diets with 0% CaSPO (T1 and T3) relative to birds fed diets with 50% CaSPO (T2 and T4). These averages for the starter phase were 869 g and 794 g (9.4% of change), 1866 g and 1797.5 g for the finisher phase (3.8% of change), and 2735 g and 2591.5 g for total period (5.5% of change).

In the finisher phase (22 to 42 d), the inclusion of PFPO did not alter feed intake, body weight gain, or feed conversion ratio (p>0.05). Similarly, CaSPO did not influence feed intake (p=0.21). The body weight gain of chickens decreased (p=0.04) by 3.8% with the inclusion of CasPO. The inclusion of CaSPO oil adversely affected (main effect; p=0.03) feed conversion ratio; it was 8.4% better for chickens without CaSPO in their diets.

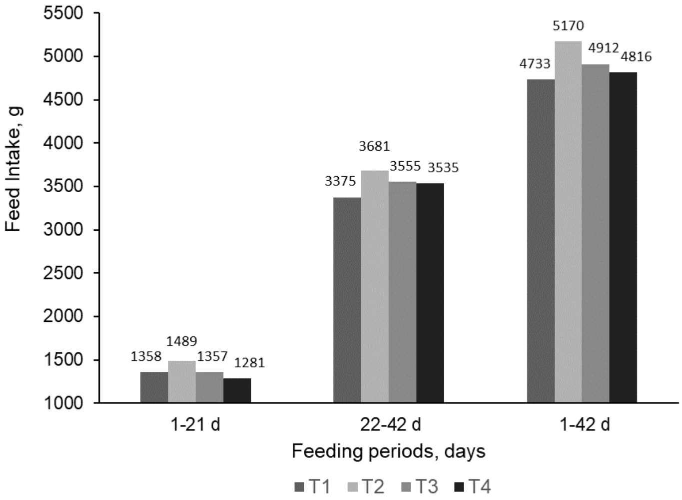

Figure 2 – Feed intake of broiler chickens in the study. T1 = Control (0% CaSPO + 0% CaSPO); T2 = 0% PFPO + 50% CaSPO; T3 = 50% PFPO + 0% CaSPO; T4 = 50% PFPO + 50% CaSPO. CaSPO = calcium soaps of palm oil; PFPO= Prilled fats of palm oil. Probabilities for the starter phase of the main effects for PFPO, CaSPO, and for the interaction (PFPO × CaSPO), were 0.09, 0.63, and 0.09 (SEM = 40.3), respectively. In the same order, for the finisher phase, these were 0.88, 0.21, and 0.16 (SEM = 78.2). For the entire period, the values were 0.51, 0.21, and 0.06 (SEM = 93).

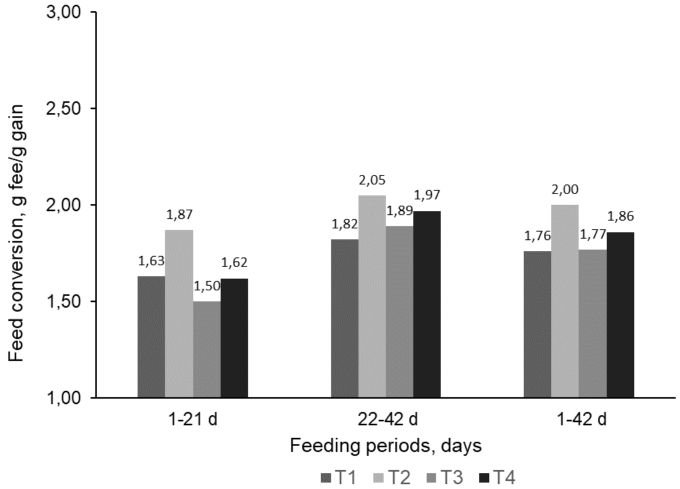

Figure 3 – Feed conversion of broiler chickens in the study. T1 = Control (0% CaSPO + 0% CaSPO); T2 = 0% PFPO + 50% CaSPO; T3 = 50% PFPO + 0% CaSPO; T4 = 50% PFPO + 50% CaSPO. CaSPO = calcium soaps of palm oil; PFPO= Prilled fats of palm oil. Probabilities of the main effects for PFPO, CaSPO, and the PFPO × CaSPO interaction were 0.03, 0.03 and 0.42 (SEM = 0.05), respectively, for the starter phase. In the same order, for the finisher phase, these were 0.89, 0.03, and 0.26 (SEM = 0.05). For the entire period, the values were 0.26, <0.01, and 0.23 (SEM = 0.04).

The percentage changes of feed conversion of chickens for the main effect of CaSPO were estimated considering the feed conversion of animals fed diets with 0% CaSPO (T1 and T3) relative to birds fed diets with 50% CaSPO (T2 and T4). These averages for the starter phase were 1.57 and 1.75 (11.5% of change); for the finisher phase, 1.86 and 2.01 (8.4% of change); and for the total period, 1.77 and 1.93 (9.4% of change).

The percentage changes of feed conversion of chickens for the main effect of PFPO were estimated considering the feed conversion of animals fed diets with 0% PFPO (T1 and T2) relative to birds fed diets with 50% PFPO (T3 and T4). These averages for the starter phase were 1.75 and 1.56 (12.2% change).

In the total study (1-42 d), the inclusion of PFPO did not influence (p>0.05) chicken feed intake, body weight gain, or feed conversion ratio. The inclusion of CaSPO did not influence feed intake (p=0.21) as well; however, it decreased (main effect; p<0.01) the body weight gain of chickens by 5.5% in comparison to those not receiving CaSPO. Moreover, the inclusion of CaSPO adversely affected (main effect; $p<0.01$) feed conversion ratio; it was 9.4% better for chickens without CaSPO in their diets.

Carcass characteristics

Treatment effects on the carcass characteristics of broiler chickens are shown in Table 3. There was no influence of the treatment on carcass, breast, drumsticks plus thighs, or wings yields ($p>0.05$). PFPO did not influence carcass weight; however, broiler chickens fed dietary CaSPO had lower ($p=0.02$) carcass weight. The only PFPO × CaSPO interaction ($p=0.04$) was for back yield; in diets without PFPO, the supplementation with CaSPO decreased back yield; the opposite occurred in diets containing PFPO with CaSPO.

DISCUSSION

Growth performance

The inclusion of CaSPO in diets decreased body weight gain and adversely influenced the feed conversion ratio of broilers during the whole study. These results disagree with Villanueva-Lopez *et al.* (2020), who reported that the replacement of VO with CaSPO did not alter the productive behavior of broiler chickens. This difference is probably because Villanueva-Lopez *et al.* (2020) used VO in addition to dietary recycled fats, while the present study did not use the latter.

A possible explanation of the results in the present study is that CaSPO may have a lower energy concentration. Palm oil reacts with calcium salts during the saponification process, increasing ash concentration in the final CaSPO product in 9% to 14%, which decreases caloric density and adversely affects chicken growth. CaSPO ether extract in the present study was 81.5%, while VO contains 99% ether extract and, therefore, has a greater caloric density. The lack of beneficial effects of calcium salts of fats on the productive response of broiler chickens was also reported by Mosavat (2011), using calcium soaps of soybean oil, and by Çalik *et al.* (2019), using calcium soaps of tallow, while in the present study calcium soaps of palm oil were used.

Table 3 – Carcass characteristics of broiler chicken fed diets formulated with different fat sources.

	0% PFPO		50% PFPO			*p*-value main effect		
Carcass evaluation	0% CaSPO	50% CaSPO	0% CaSPO	50% CaSPO	SEM	PFPO	CaSPO	PFPO × CaSPO
Hot carcass weight, g	2120	2037	2187	1989	0.04	0.87	0.02	0.32
Carcass yield, %1	78.5	77.4	77.9	77.4	0.50	0.67	0.25	0.69
Breast yield, %	40.7	39.4	39.8	37.6	0.63	0.15	0.06	0.58
Leg-thigh yield, %	27.4	29.4	29.9	29.4	0.59	0.17	0.37	0.14
Wing yield, %	10.8	10.7	10.2	11.4	0.34	0.92	0.27	0.17
Back yield, %	20.6	19.7	18.9	20.7	0.39	0.54	0.49	0.04

CaSPO = calcium soaps of palm oil; PFPO= Prilled fats of palm oil.

[1]Percentage of carcass yield = (carcass weight, g / live weight, g) × 100.

Other factors that may lower CaSPO energy concentration compared with VO are the presence of free fatty acids in CaSPO, produced during palm oil saponification, and the high percentage of saturated fatty acids in palm oil (mainly palmitic acid). In broiler chickens, intestinal absorption of triglycerides is very efficient compared with free fatty acids (Sklan, 1979; Baião & Lara, 2005), due to greater micelle formation in triglycerides than in free fatty acids (Garrett & Young, 1975), and the energy decrease with increasing free fatty acids and saturated fatty acids in broiler chickens (Wiseman & Salvador, 1991). These results agree with Wu *et al.* (2011), who reported an inverse relationship between the level of free fatty acids in yellow grease and broiler chicken productive performance.

Regarding the saturation of fatty acids, palm oil has negatively affected the productive performance of broiler chickens compared with lipids with lower saturated fatty acids concentrations like sunflower oil (Khatun *et al.*, 2018) or rapeseed oil (Sudharsan *et al.*, 2021). However, reductions in productive performance in broiler chickens have not always been reported when diets contain saturated or free fatty acids. Waldroup *et al.* (1995) reported that the free fatty acids level of blended fats did not adversely influence chicken productive performance. Poorghasemi *et al.* (2013) observed improved productive performance and carcass yields in broiler chickens fed diets with saturated fats (tallow) combined with unsaturated fats (canola or sunflower oil). In the current study, VO was partially substituted by CaSPO, and this probably had a beneficial effect on the intestinal absorption of free fatty acids from CaSPO.

Nowadays, the conventional VO of oilseeds is expensive, with constant price increments. Palm oil in the form of calcium soaps could replace the traditional VO, particularly in countries where it is cheaper than conventional VO. However, small reductions in the productive variables of broiler chickens with dietary CaSPO could be expected. In the present study, the production costs of broiler chickens fed different lipid sources were not determined. Still, these economical determinations are necessary when choosing the diet ingredients for the producers of chicken meat.

Dietary PFPO did not influence the productive variables of broiler chickens in the present study. These findings disagree with Jaapar *et al.* (2020). They reported improvements in body weight gain, feed conversion ratio, and nutrient digestibility when 1% of palm oil was replaced with PFPO in diets for broiler chickens. It is difficult to explain these differences because of the limited research on this topic. VO and PFPO contain 99% ether extract, so the main difference between VO and PFPO is their fatty acid content. The vegetable oil from oilseeds contains mainly unsaturated fatty acids as glycerides, while PFPO contain about 85% of palmitic acid (C16), mainly as a free fatty acid. Moreover, VO of oilseeds is liquid at room temperature, while PFPO are solid small spheres (1 to 2 mm in diameter). These differences were not reflected in the productive variables of broiler chickens for the finishing phase or the total study; however, dietary PFPO offered to chickens enhanced the feed conversion ratio in the starter phase. We did not determine fatty acid digestion and absorption from the diets. Therefore, research is warranted on digestion, absorption, and deposition of fatty acids in body tissues of broiler chickens fed diets containing the different lipid sources used in the current study.

Carcass characteristics

The carcass characteristics of chickens in the current study are consistent with the productive variables of broiler chickens. Carcass characteristics were generally not influenced by the substitution of VO for PFPO. These two lipid sources could have similar energy concentrations, capable of promoting similar tissue growth in chickens. The information on this topic is limited, and further research is warranted on carcass characteristics and meat chemical composition, particularly regarding the fatty acids profile deposited in the carcass of broiler chickens fed VO or PFPO.

The inclusion of CaSPO in diets reduced broiler chickens' body weight gain and carcass weight. In contrast, Villanueva-Lopez *et al.* (2020) reported beneficial effects of dietary CaSPO on the breast yield of broiler chickens. As previously mentioned, recycled fats were used , in the study of Villanueva-Lopez *et al.* (2020), whereas this type of fats was not used in the present study. Instead, PFPO was used, which might have higher energy density than recycled fats and reflect in carcass weight reduction of chickens fed CaSPO. In other studies, carcass characteristics or abdominal fat were not affected by dietary calcium soaps of oilseeds or tallow (Malá *et al.*, 2004; Tabeidian & Sadeghi, 2006; Mosavat *et al.*, 2011; Çalik *et al.*, 2019).

CONCLUSIONS

It was concluded that the inclusion of CaSPO in diets decreased the productive behavior of broiler chickens. In the other case, PFPO could partially replace conventional VO in broiler diets without influencing their productive performance. Carcass evaluations reveled that dietary CaSPO reduced carcass weight compared to VO or PFPO. Carcass characteristics were not influenced by dietary PFPO. Further research on digestion and lipid deposition in the tissue of broiler chickens fed diets containing PFPO, CaSPO, and VO is warranted.

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DECLARATION OF INTEREST STATEMENT

The authors reported no potential conflict of interest.

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