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Fatty acid profile of meat from broiler chickens fed with different oil sources

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Additional keywords

Animal Feed.
Broiler Performance.
n-6/n-3 Ratio.

SUMMARY

The aim of this study was to evaluate the effect of different oils (soybean, sunflower, canola, and chicken) in chicken feed, created for broiler performance. The contents of fatty acid profile, cholesterol in chicken meat parts (breast and thigh) and their respective performance as broilers were analyzed. The 1,000 males Cobb broiler chickens to obtain 42-day-old, they have been solely fed with a specific diet, and after this period slaughtered. Chickens utilized as control were slaughtered at 21-day-old, this chickens classified as default were fed a commercial diet. The broiler performance, cholesterol content and physicochemical composition of feed diet in the chicken meat cuts (skinless breast, breast with skin and skinless thigh) are reported as not affected by specifying alimentation. Fatty acid profile of feed diet varied from each oil used in the formulation, where lower values of saturated fatty acid (SFA) verified in feed formulated with canola and sunflower oils. In chicken meat, the results for skinless thigh, skinless breast, and breast with skin, were similar to the fatty acid profiles, only varying the type of feed treatment. After samples analysis, the polyunsaturated fatty acid (PUFA), that appear in greater concentration, are 18:2n-6 and 18:3n-3. Accordingly, cuts from chickens fed with sunflower and soybean oils evidenced higher levels of 18:2n-6. Variously, cuts from chicken fed with canola oil demonstrated highest levels of 18:3n-3, when compared with others treatments. Considering the balance of n-6/n-3 and concentration of unsaturated fatty acid in chicken meat, chickens fed with canola oil expressed greater nutritional characteristics.

Palabras clave adicionales

Alimentación animal.
Rendimiento de los Pollos de Engorde.
Razón n-6/n-3.

Perfil de ácidos grasos de la carne de pollos alimentados con diferentes fuentes de aceites

RESUMEN

El objetivo de este estudio es evaluar el efecto de diferentes aceites (soja, girasol, canola y pollo) en el alimento para pollos, creados para el rendimiento de los pollos de engorde. Se analizaron los contenidos de perfil de ácidos grasos, colesterol en carne de pollo y sus respectivos rendimientos como pollos de engorde. Los 1,000 machos de pollos de engorde de Cobb de 42 días de vida, solo fueron alimentados con una dieta específica, y después de este período fueron sacrificados. Los pollos utilizados como control se sacrificaron a los 21 días de edad, estos pollos se alimentaron a base de una dieta comercial. Se informa que el rendimiento del pollo de engorde, el contenido de colesterol y la composición fisicoquímica de la alimentación en los cortes de carne (pechuga sin piel, piel de la pechuga y muslo sin piel) se ven afectados por la alimentación específica. El perfil de ácidos grasos de la dieta varió dependiendo de cada aceite utilizado en la formulación, encontrándose valores más bajos de ácidos grasos saturados (SFA) para los aceites de canola y girasol. En la carne de pollo, los resultados para el muslo sin piel, la pechuga sin piel y la piel de la pechuga fueron similares a los perfiles de ácidos grasos, variando solo el tipo de tratamiento de alimentación. Después del análisis de las muestras, los ácidos grasos poliinsaturados (PUFA), que aparecen en mayor concentración, son 18: 2n-6 y 18: 3n-3. Por lo tanto, los cortes de pollos alimentados con aceites de girasol y soja evidenciaron niveles más altos de 18: 2n-6. Variablemente, los cortes de pollo alimentados con aceite de canola, mostraron niveles más altos de 18: 3n-3, en comparación con otros tratamientos. Considerando el equilibrio de n-6 / n-3 y la concentración de ácido graso insaturado en la carne de pollo, los pollos alimentados con aceite de canola presentaron mejores características nutricionales.

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INTRODUCTION

In recent years, the consumption of chicken meat has become more popular, mainly due to their nutritional characteristics. Presenting high protein content (over 20%), low-fat content (less 5%) and relatively high concentration of Polyunsaturated Fatty Acid (PUFA), as it may be some of the nutritional character-

istics more important present on chicken meat (Bonoli et al. 2007; Nkukwana et al. 2014).

Consumption of unsaturated fatty acid, highlighting the PUFA, has shown potential benefits to consumer's health. A higher consumption of saturated fatty acid (SFA) than PUFA associated with the consumption imbalance of n-6/n-3 fatty acid, have been correlated to cardiovascular disease, cancer, inflammatory and autoimmune diseases (Simopoulos 2004; Wood et al. 2004). The diet possibly has a significant influence on meat composition, especially broiler chickens. Thus, studies have reported the influence of an animal's diet on fatty acid profile of chicken meat (Bonoli et al. 2007; Gatrell et al. 2015; Nkukwana et al. 2014; Rymer, Hartnell & Givens 2011; Sun et al. 2012).

The effect of feeding with different fat sources (tallow, olive oil, sunflower oil, and linseed oil) on the fatty acid profile and abdominal fat deposition in chicken meat were evaluated by Crespo & Esteve-Garcia (2000). In this study, the addition of sources of saturated and monounsaturated fatty acid in the diet of broiler chicken resulted in an increase of abdominal fat with higher content of PUFA, different from those fed with sources of polyunsaturated fatty acid. However, PUFA content in the breasts chicken was higher in meat from chickens fed with sunflower oil and linseed oil. These differences are assigned to diverse metabolic pathways of lipids, which results in a distinct distribution in lipid composition in certain animal's carcass portions.

Beckerbauer et al. (2001) also reported changes in fatty acid composition in the chicken meat just after adding oil to the feed of broiler chicken. The use of oils with high PUFA content, such as soybean and sunflower, have as a result a decrease in the levels of myristic acid (14:0) and oleic acid (18:1n-9), and an increase in content of linoleic acid (18:3n-6) level present in adipose tissue of chickens.

Sell, Jin & Jeffrey (2001) demonstrated in their study, that there is a linear increment of 18:3n-6 level in the meat, according to this research, this happens when chickens have a feed rich in linoleic acids, such as soybean oil.

The objective of this study was to evaluate the effect of the addition of different oils (soybean, sunflower, canola and chicken) in the chickens feed to broiler performance, fatty acid profile, and cholesterol in chicken meat parts (breast and thigh).

Table I. Percentage and calculated composition of chicken experimental feed diet (Porcentaje y composición calculada de la dieta experimental de alimentos para pollos).

Element	%
Corn, grain	56.46
Soybean bran – 45%	35.15
Oils[1]	5.00
Dicalcium phosphate	1.66
Calcitic limestone	1.02
Salt	0.33
DL-methionine	0.17
Vitamin supplement[2]	0.10
Mineral supplement[3]	0.10
Antioxidant (BHT)	0.01
TOTAL	100.00
Calculated values	
Metabolic energy (Mcal kg^{-1})	3100
Crude protein (%)	20.00
Calcium (%)	0.91
Phosphorous (%)	0.42
Fibre (%)	3.29
Lysine (%)	1.08
Methionine + cystine (%)	0.81

[1]Oils added at 5% level: soybean, sunflower, canola and chicken oil obtained from poultry slaughterhouse.
[2]Vitaminic supplement / growing stage®: Guarantee levels for kg of product: Vit. A-2,000,000 UI; Vit. D-400,000 UI; Vit. E-5,000 UI; Vit. K_3-600 mg; Vit. B_1-400 mg; Vit. B_2-1,200 mg; Vit. B_6-800 mg; Folic acid-200 mg; Nicotinic acid-6,000 mg; Biotin-20 mg; Pantothenic acid-2,400 mg; Choline 52,000 mg; Vit. B_{12}-3,000 mg; Se-80 mg; Methionin-372,400 mg; Antioxidant (BHT)-19,600 mg; Coccidiostat-100,000 mg; Growth Promoter-10,000 mg; Carrier q.s.p.-1,000 g.
[3]Mineral supplement®: Guarantee levels for kg of product: Fe-1,000,000 mg; Mn-16,000 mg; Zn-100,000 mg; Cu-20,000 mg; Co-2,000 mg; I-2,000 mg, Carrier q.s.p.-1.000 g.

MATERIAL AND METHODS

Sampling and housing

An experimental farm, located at the Maringa State University, Paraná, Brazil, served as a place to perform the experiment. 1,000 males Cobb chickens, have been chosen and randomly distributed between 4 treatments, separated in 5 groups, where were allocated 50 animals/treatment/group.

These chickens have received commercial diet until 21-day-old, soybean oil was the main source of lipid on this diet. Then, two animals were casually selected, and slaughtered, to utilize as controls, because the addition of soybean oil was evaluated in chickens at growing stage. In the growing stage (subsequently 21 days), the chicken received the alimentation formulated with different oil sources: soybean, canola, sunflower or chicken. The poultry slaughterhouse provided the chicken oil.

Diet stipulated was isoproteic (20% of crude protein) and isoenergetic (3,100-kcalME kg^{-1}). The chicken's alimentation established as *ad libitum*. The diet composition and physicochemical analyses are described below in **Tables I** and **II**, respectively.

The chicken weight of two birds/treatment/group (total 40 birds) was measured at the beginning and at the end of growing stage to determinate their fattening performance. The same birds at 42-day-old were submitted to the commercial procedures of slaughtering, according to Brazilian Legislation (Brazil 1998), that establish the given sequence: electrical stunning, bleeding, defeathering, evisceration and carcass water-cooling. The time from slaughtering to carcass debo-

Table II. Physicochemical composition of diet feed rich with different oils (Composición fisicoquímica de la alimentación dietética con diferentes aceites).

Parameters	Oils			
	Canola	Soybean	Sunflower	Chicken
Moisture (%)	12.11[a] ± 0.36	12.28[a] ± 0.09	11.88[a] ± 0.06	12.27[a] ± 0.67
Ash (%)	5.37[a] ± 0.00	5.38[a] ± 0.00	5.37[a] ± 0.00	5.36[a] ± 0.02
Protein (%)	19.87[a] ± 0.12	19.72[a] ± 0.27	20.05[a] ± 0.05	19.90[a] ± 0.34
Lipids (%)	7.92[a] ± 0.07	7.94[a] ± 0.03	7.92[a] ± 0.04	7.97[a] ± 0.10

Means ± standard deviation (n = 3).
Letters equal in the same column indicate that there is no difference between treatments (P> 0.05).

ning was about 1.5-hour *post-mortem*. The cuts from the chicken parts: breast, the skin of breast and thigh were stored in polyethylene packaging (N_2 atmosphere) and frozen (-18 °C) up to the moment of analyses. Then previously unfrozen under refrigeration (5 °C) by 12 hours, next minced in a food processor (FAET, Multipratic, Brazil) and homogenized in a porcelain mortar.

Physicochemical composition

Moisture and ash were realized by gravimetric methods, and protein contents by Kjeldahl according to AOAC (2006). The lipids content were extracted with a mixture of chloroform:methanol (1:2, v/v) according to Bligh & Dyer (1959). About 10.0 g (± 0.1 mg) of the sample were included in 60 mL of chloroform:methanol mixture and stirred during 2 minutes. After these, an addition of 20 mL of chloroform was made into the mixture and stirred for 30 seconds; 20 mL of distillate water was included in the mixture and stirred for more 30 seconds. The filtration was performed in vacuum condition on a Büchner funnel with a qualitative filter paper. The residue of the mixture was washed with 20 mL of chloroform then stirred for 2 minutes and the filtration process repeated. The filtrate was transferred to a separating funnel. After phase separation, the inferior phase containing, chloroform and the fatty matter, was collected, the solvent evaporated in a rotatory evaporator (801, Fisatom, Brazil) with bath at 30 °C ± 2°C. The determination of lipid content made by gravimetric methods. The lipid extraction of feed diet was accomplished similarly to Bligh & Dyer (1959) with moisture correction to 80%.

Transesterification of Fatty Acids

Transesterification of fatty acid was prepared accordingly to the method 5509 of International Organization for Standardization (1978). After the procedure to obtain the lipid content, 100 mg of the grease matter were transferred to tubes of 10 mL with screw cap; added 2 mL of n-heptane, and stirred until complete dissolution of the sample. Posterior these, 2 mL of 2 mol L^{-1} KOH in methanol were added to the mixture and it was submitted at vigorous agitation until obtaining the slightly turbid solution. After phase separation, the superior phase containing n-heptane and Fatty Acid Methyl Esters (FAME) was collected, transferred to vials of 5 mL, and stored in a freezer (-18 °C) for posterior chromatography analyses.

Chromatography Analyses of Fatty Acids Methyl Esters (FAME)

FAME was analysed by gas chromatographer 14-A (Shimadzu, Japan) equipped with a flame ionization detector (FID) and a fused silica capillary column (50 m x 0.25 mm) with 0.20 µm of Cabowax 20M. The carrier gas was hydrogen (1.2 mL min^{-1}), make-up gas was nitrogen (30 mL min^{-1}), and flame gases were hydrogen and synthetic air (30 and 300 mL min^{-1}, respectively). The split was 1:100 and the column temperature was set at 150 °C for 5 min, and then raised to 240 °C, at a rate of 2 °C min^{-1}. The injector and detector temperatures were set at 220 °C and 245 °C, respectively. For the determination of peak areas, an Integrator-Processor CG-300 (Scientific Instruments CG) were used, and peak identification defined by comparison of retention times with FAME standards (Sigma, USA).

Cholesterol extraction

Extraction and quantification of cholesterol were performed according to the method descriptor by Al-Hasani, Hlavac & Carpenter (1993) with modifications. 10 mL 60% KOH aqueous solution were added to 5 g (± 0,1 mg) of the sample, followed by 30 mL an alcoholic mixture (ethanol, methanol and isopropanol, 90:5:5, v/v/v). The mixture went through a reflux process for about an hour. After the reflux, samples were placed in a cold-water bath until reaching a room temperature. The following step was adding 100 mL of hexane in the mixture and continuously stirred for 10 minutes. Then, 25 mL of distilled water was added and the solution resultant, again, stirred for 15 minutes and transferred to a separating funnel. After phase separation, 25 mL superior phase was collect for posterior removal of solvent in a rotatory evaporator with bath at 30 °C ± 2 °C. The residue re-dissolved with 2 mL solution of internal standard in hexane (0.2 mg mL^{-1} 5α-cholestane, Sigma, EUA). Performing gas chromatography as a resource for cholesterol quantification.

Chromatography Analyses and Cholesterol Quantification

The cholesterol content was analyzed by gas chromatographer 14-A (Shimadzu, Japan), equipped with flame ionization detector (FID) and fused silica capillary column (25 m x 0.25 mm) with 0.20 µm of SE-30. The injector, column and detector temperatures were set at 260, 300 and 300 °C, respectively. Hydrogen as carrier gas (1.5 mL min^{-1}) and nitrogen as make-up gas (25 mL min^{-1}). The flow rate of 30 and 300 mL min^{-1} determined for flame gases, H_2 and synthetic air, respectively. The split was 1:150. The Integrator-Processor CG-300 (Scientific Instruments CG) performed the peak integration and cholesterol identification ac-

complished by comparison of 5α-cholestane standard (Sigma, USA).

Statistical Analysis

The performance results were analyzed by SAEG software (1982). Others results provided by using analysis of variance (ANOVA) and Tukey test at 5% of significance, using the software Statistica 7.0 (Statsoft, EUA, 2004).

RESULTS AND DISCUSSION

Characterization of Feed Diet and Broiler Chicken Performance

Fatty acid profiles of feed formulated to the grown stage of chickens **(Table III)** show palmitic acid (16:0) is the saturated fatty acid (SFA) in greater proportion, varying from 8.00 to 19.91%. 16:0 content was lower and did not show differences in feed formulated with canola and sunflower oils, differing (P≤ 0.05) of feeds formulated with soybean and chicken oils that were statistically equal (P> 0.05). These results suggest that canola and sunflower oils allowed smaller saturated fat sources in chicken feed.

The oleic acid (18:1n-9) was the monounsaturated fatty acid (MUFA) in the highest concentration in all feed formulations, and this result was higher (P≤ 0.05) in samples with canola oil (56.25%) than sunflower, chicken and soybean oils, respectively. Among the polyunsaturated fatty acid (PUFA) were detected linoleic acid (18:2n-6) in higher proportion in feed formulations. Values of 18:2n-6 were lower (P≤ 0.05) in the feed with canola oil (27.01%) and greater in the feed with sunflower oil (51.46%). Values of gamma linoleic acid (18:3n-6) were not found in the feed with canola and chicken oil and varied from 0.74 to 1.41% for soybean and sunflower, respectively.

The PUFA/SFA ratio varied from 1.43 to 2.83 for feed formulated with chicken oil and canola oil, respectively. Feed diets formulated with chicken oil were different (P≤ 0.05) to feeds elaborated with vegetable oils that were statistically equal.

The n-6/n-3 ratio was different between all the treatments (P≤ 0.05) varying from 7.40 to 62.20 to feed with canola oil and sunflower oil, respectively.

These results demonstrated that the addition of vegetable oils in feed chicken resulted in the highest PUFA/SFA ratios. Additionally, significant changes can be observed in the SFA composition, where lower values were obtained from feeds formulated with canola and sunflower oils than feeds with chicken and soybean oils.

The results of broiler chicken performance **(Table IV)** show relative standard deviation (RSD) lower than 2%, indicating low variation between the treatments with different kinds of oil added to the chicken feed diet. Rymer, Hartnell & Givens (2011) evaluated the effect of the addition of soybean oil rich of 18:4n-3 in the feed on the deposition of n-3 fatty acid in chicken meat and, similarly did not find differences in broiler chicken performance. Sell et al. (2001) also did not find the difference in the performance of the broiler chickens fed with different concentrations of conjugated linoleic acid, applied to broiler chicken and laying hens in their study. Similar results of final weight, gain weight, food consumption and feed conversion were reported by Crespo & Esteve-Garcia (2000) which studied dietary

Table III. Fatty acid profile of experimental feed diet (Perfil de ácidos grasos de la dieta experimental).

Fatty acid	Soybean	Canola	Sunflower	Chicken
14:0	$0.11^{b} \pm 0.00$	Nd	$0.11^{b} \pm 0.01$	$0.39^{a} \pm 0.00$
16:0	$19.91^{a} \pm 1.22$	$8.00^{b} \pm 0.39$	$8.87^{b} \pm 0.26$	$19.34^{a} \pm 0.10$
16:1n-9	$0.39^{a} \pm 0.01$	Nd	$0.14^{b} \pm 0.00$	$0.31^{a} \pm 0.00$
16:1n7	Nd	Nd	Nd	3.69 ± 0.04
18:0	$3.11^{b} \pm 0.09$	$2.80^{b} \pm 0.09$	$3.72^{a,b} \pm 0.04$	$4.61^{a} \pm 0.01$
18:1n-9	$23.59^{c} \pm 0.30$	$56.25^{a} \pm 0.20$	$32.50^{b} \pm 0.17$	$35.28^{b} \pm 0.06$
18:1n7	$1.43^{b} \pm 0.01$	$2.43^{a} \pm 0.01$	$0.93^{c} \pm 0.03$	$1.55^{b} \pm 0.06$
18:2n-6	$47.16^{b} \pm 0.77$	$27.01^{d} \pm 0.22$	$51.46^{a} \pm 0.62$	$33.24^{c} \pm 0.12$
18:3n-6	$0.74^{b} \pm 0.02$	Nd	$1.41^{a} \pm 0.03$	Nd
18:3n-3	$3.65^{a} \pm 0.08$	$3.51^{a} \pm 0.05$	$0.85^{c} \pm 0.08$	$1.60^{b} \pm 0.01$
PUFA	$51.54^{a} \pm 0.08$	$30.52^{b} \pm 0.23$	$53.73^{a} \pm 0.09$	$34.84^{b} \pm 0.13$
MUFA	$25.33^{d} \pm 0.78$	$58.69^{a} \pm 0.20$	$33.57^{c} \pm 0.63$	$40.83^{b} \pm 0.09$
SFA	$23.13^{a} \pm 1.25$	$10.80^{b} \pm 0.40$	$12.70^{b} \pm 0.31$	$24.33^{a} \pm 0.11$
n-6	$47.90^{b} \pm 0.08$	$27.01^{d} \pm 0.22$	$52.87^{a} \pm 0.09$	$33.24^{c} \pm 0.13$
n-3	$3.65^{a} \pm 0.08$	$3.51^{a} \pm 0.05$	$0.85^{c} \pm 0.08$	$1.60^{b} \pm 0.01$
PUFA/SFA	$2.04^{a} \pm 0.12$	$2.83^{a} \pm 0.10$	$2.22^{a} \pm 0.03$	$1.43^{b} \pm 0.01$
n-6/n-3	$13.13^{d} \pm 0.28$	$7.40^{c} \pm 0.12$	$62.20^{a} \pm 6.02$	$20.77^{b} \pm 0.15$

Results were expressed as percentage of total fatty acids. PUFA: Polyunsaturated Fatty acids; MUFA: Monounsaturated Fatty Acids; ND: not detected.
Letters different in the same row indicated significant difference (≤ 0.05) by Tukey test.

Table IV. Effect of different oil source in feed diet on broiler chicken performance in the period from 22 to 42-day-old (Efecto de diferentes aceites en la dieta del pollo en el período de 22 a 42 días).

Variables	Treatments (oils)				
	Soybean	Sunflower	Canola	Chicken	RSD %
Final weight (g)	2670	2660	2680	2650	1.33
Gain weight (g)	1790	1780	1800	1770	1.97
Food intake (g)	3240	3220	3260	3220	1.52
Feed conversion (g g^{-1})	1.81	1.80	1.81	1.81	1.89

Means (n = 40).
Relative Standard Deviation (RSD).

Table V. Physicochemical composition of the skinless breast from chicken fed different oils (Composición fisicoquímica de la pechuga sin piel de un pollo alimentado con diferentes aceites).

	Oils				
Parameters	Control	Canola	Soybean	Sunflower	Chicken
Moisture (%)	75.82 ^{a} ± 0.31	75.94 ^{a} ± 0.54	75.81 ^{a} ± 0.48	75.75 ^{a} ± 0.40	75.50 ^{a} ± 0.49
Ash (%)	1.04 ^{a} ± 0.03	1.04 ^{a} ± 0.01	1.06 ^{a} ± 1.02	1.05 ^{a} ± 0.02	1.04 ^{a} ± 0.01
Proteins (%)	22.42 ^{a} ± 0.60	22.67 ^{a} ± 0.96	22.91 ^{a} ± 0.62	22.26 ^{a} ± 0.42	23.38 ^{a} ± 0.98
Lipids (%)	1.76 ^{a} ± 0.11	1.88 ^{a} ± 0.32	1.70 ^{a} ± 0.29	1.78 ^{a} ± 0.59	1.80 ^{a} ± 0.42
Cholesterol (mg/100g)	Nr	50.26 ^{a} ± 1.82	51.18 ^{a} ± 0.29	50.72 ^{a} ± 0.82	50.84 ^{a} ± 0.65

Means ± standard deviation (n=5). Letters equal in the same row indicate that there is no difference between treatments (P>0.05) by Tukey test.
Nr= Not realized.

fatty acid profile and how can modify abdominal fat deposition in broiler chickens.

Physicochemical characterization of chicken meat

Moisture, ash, protein, lipids and cholesterol of skinless breast, breast with skin and skinless thigh of chicken samples submitted to different feed treatments represented in **Tables V, VI** and **VII**, respectively. The parameters analyzed showed that there was no difference (P> 0.05), indicating that the addition of oils reported in this study did not affect the chemical composition of chicken meat. Crespo & Esteve-Garcia (2000) also not observed significant influence in protein and lipid concentration of breast and thigh from broiler chickens fed with tallow, olive oil, sunflower oil, and linseed oil as lipids sources.

Fatty Acid Profile of Chicken Meat

As observed in the feed diet analyses, the 16:0 was the SFA found in greater concentration. 16:0 values were different (P≤ 0.05) in the samples of the skinless thigh, with lower values in cuts from chickens fed with sunflower oil (16.91%) that not differed of chickens fed with canola (16.52%) and soybean oil (18.09%) **(Table VIII)**. 16:0 concentrations were lower (P≤ 0.05) in skinless breast samples from chickens fed with canola and sunflower oils (18.42 and 18.83%) than chickens fed with chicken oil (22.39%), and these results were similar (P>0.05) in samples from chickens control and from chickens fed with soybean oil **(Table IX)**. Similar results obtained in the breast with skin samples for 16:0 concentrations **(Table X)**. These results were similar to reported by Crespo & Esteve-Garcia (2000) which obtained the lowest values of 16:0 in tissues from chicken fed with olive, sunflower and linseed oil. Greater results were reported by Soares et al. (2009) for 16:0 in skinless chicken breast samples collected in a commercial poultry slaughterhouse, varying from 24.33 to 25.72%. The commercial chicken feed has soybean oil as predominant lipid source, which justifies

Table VI. Physicochemical composition of the skinless thigh from chicken fed different oils (Composición fisicoquímica del muslo sin piel del pollo alimentado con diferentes aceites).

Parameters	Oils				
	Control	Canola	Soybean	Sunflower	Chicken
Moisture (%)	76.20 ^{a} ± 0.77	76.51^{a} ± 0.89	76.16^{a} ± 0.88	75.55^{a} ± 1.18	76.95^{a} ± 0.64
Ash (%)	1.01 ^{a} ± 0.05	1.02^{a} ± 0.03	1.02^{a} ± 0.03	1.03^{a} ± 0.05	1.02^{a} ± 0.02
Proteins (%)	20.01 ^{a} ± 0.44	18.98^{a} ± 0.54	19.49^{a} ± 0.28	19.60^{a} ± 0.53	19.33^{a} ± 0.24
Lipids (%)	5.40 ^{a} ± 0.19	5.24^{a} ± 0.86	5.51^{a} ± 0.70	5.48^{a} ± 1.24	5.54^{a} ± 0.87
Cholesterol (mg/100g)	Nr	66.32^{a} ± 0.01	65.51^{a} ± 0.57	66.19^{a} ± 0.91	66.40^{a} ± 0.05

Means ± standard deviation (n = 5). Letters equal in the same row indicate that there is no difference between treatments (P> 0.05) by Tukey test.
Nr= Not realized.

Table VII. Physicochemical composition of breast with skin from chicken fed different oils (Composición fisicoquímica de pechuga con piel de pollo alimentada con diferentes aceites).

Parameters	Oils				
	Control	Canola	Soybean	Sunflower	Chicken
Moisture (%)	75.29 ^{a} ± 0.65	75.73^{a} ± 0.71	75.58 ^{a} ± 0.67	76.00 ^{a} ± 0.78	75.47 ^{a} ± 0.68
Ash (%)	1.03 ^{a} ± 0.02	1.02 ^{a} ± 0.01	1.03 ^{a} ± 0.02	1.03 ^{a} ± 0.01	1.03 ^{a} ± 0.02
Proteins (%)	20.99 ^{a} ± 0.39	20.91 ^{a} ± 0.92	20.76 ^{a} ± 0.44	22.04 ^{a} ± 1.24	20.66 ^{a} ± 0.57
Lipids (%)	5.61 ^{a} ± 0.17	5.43 ^{a} ± 0.29	5.34 ^{a} ± 0.33	5.34 ^{a} ± 0.95	5.80 ^{a} ± 0.44
Cholesterol (mg/100g)	Nr	54.30 ^{a} ± 1.34	53.97 ^{a} ± 1.92	54.51 ^{a} ± 2.27	54.14 ^{a} ± 1.24

Means ± standard deviation (n = 5). Letters equal in the same row indicate that there is no difference between treatments (p > 0.05) by Tukey test.
Nr= Not realized.

Table VIII. Fatty acids compositions of samples skinless thigh from chicken control and from chicken fed with different oils (Composiciones de ácidos grasos de muestras de muslo sin piel de control de pollo y de pollo alimentado con diferentes aceites).

Fatty acid	Control	Soybean	Canola	Sunflower	Chicken
14:0	0.32^{b} ± 0.01	0.33^{b} ± 0.02	0.31^{b} ± 0.04	0.35^{b} ± 0.05	0.42^{a} ± 0.05
16:0	19.46$^{a.b}$ ± 0.03	18.09$^{b.c}$ ± 0.53	16.52^{c} ± 0.75	16.91^{c} ± 0.78	20.08^{a} ± 0.80
16:1n-9	0.64^{a} ± 0.04	0.48$^{a.b}$ ± 0.04	0.56$^{a.b}$ ± 0.12	0.44^{b} ± 0.06	0.55$^{a.b}$ ± 0.03
16:1n7	4.28$^{a.b}$ ± 0.24	3.42$^{a.b.c}$ ± 0.30	2.70^{c} ± 0.43	2.90$^{b.c}$ ± 0.80	4.69^{a} ± 0.75
i17:0	0.61^{a} ± 0.01	0.24^{b} ± 0.02	0.16^{c} ± 0.02	0.24^{b} ± 0.02	0.17^{c} ± 0.02
17:0	0.21^{a} ± 0.01	0.11^{b} ± 0.03	0.11^{b} ± 0.02	0.12^{b} ± 0.01	0.14^{b} ± 0.02
17:1n-9	Nd	0.08^{a} ± 0.02	0.07^{a} ± 0.01	Nd	0.09^{a} ± 0.01
18:0	5.59$^{a.b}$ ± 0.17	5.29^{b} ± 0.39	5.41$^{a.b}$ ± 0.43	5.86$^{a.b}$ ± 0.70	6.55^{a} ± 0.29
18:1n-9	35.03^{b} ± 0.09	30.31^{c} ± 0.96	41.47^{a} ± 0.89	29.51^{c} ± 1.19	35.56^{b} ± 0.97
18:1n7	2.33$^{a.b}$ ± 0.03	1.90$^{b.c}$ ± 0.26	2.62^{a} ± 0.13	1.54^{c} ± 0.26	2.20$^{a.b}$ ± 0.11
18:2n-6	27.95^{b} ± 0.06	35.19^{a} ± 1.40	24.88^{b} ± 0.63	38.49^{a} ± 2.35	26.74^{b} ± 1.36
18:3n-6	0.21^{a} ± 0.01	0.26^{a} ± 0.10	0.22^{a} ± 0.09	0.24^{a} ± 0.06	0.26^{a} ± 0.04
18:3n-3	1.92^{c} ± 0.03	2.60^{b} ± 0.06	2.95^{a} ± 0.15	1.20^{d} ± 0.22	1.47^{d} ± 0.07
20:3n-9	0.99^{a} ± 0.04	0.27^{c} ± 0.03	0.50^{b} ± 0.05	0.38^{c} ± 0.06	0.32^{c} ± 0.02
20:4n-6	0.11^{c} ± 0.01	1.31^{a} ± 0.30	1.27^{a} ± 0.25	1.70^{a} ± 0.30	0.58^{b} ± 0.09
22:4n-6	0.34^{a} ± 0.04	0.14$^{b.c}$ ± 0.03	0.25$^{a.b}$ ± 0.05	0.11^{c} ± 0.02	0.18$^{b.c}$ ± 0.07
PUFA	31.52^{b} ± 0.08	39.76^{a} ± 1.44	30.07^{b} ± 0.71	42.13^{a} ± 2.38	29.55^{b} ± 1.48
MUFA	42.28^{b} ± 0.26	36.18^{c} ± 1.04	47.43^{a} ± 1.00	34.39^{c} ± 1.46	43.09^{b} ± 1.23
SFA	26.19^{a} ± 0.17	24.06^{b} ± 0.67	22.5^{b} ± 0.86	23.48^{b} ± 1.05	27.36^{a} ± 0.85
n-6	28.61^{b} ± 0.07	36.90^{a} ± 1.43	26.62^{b} ± 0.69	40.54^{a} ± 2.37	27.76^{b} ± 1.48
n-3	1.92^{c} ± 0.03	2.60^{b} ± 0.06	2.95^{a} ± 0.15	1.20^{d} ± 0.22	1.47^{d} ± 0.07
PUFA/SFA	0.75$^{b.c}$ ± 0.21	1.10$^{a.b}$ ± 0.08	0.63^{c} ± 0.04	1.22^{a} ± 0.15	0.69^{c} ± 0.16
n-6/n-3	14.88^{c} ± 0.31	14.22^{c} ± 0.54	9.03^{d} ± 0.32	33.84^{a} ± 1.02	18.93^{b} ± 1.04

Results are expressed as percentage of total fatty acids. PUFA: Polyunsaturated Fatty acids; MUFA: Monounsaturated Fatty Acids; ND: not detected.
Letters different in the same row indicated significant difference (≤ 0.05) by Tukey test.

the greater values of 16:0 in control, soybean oil and chicken oil and their similarity. Thus, the addition of sunflower and canola oils in the feed of broiler chicken can reduce the SFA content of chicken meat.

The 18:1n-9 level was the MUFA in greater concentration in all the samples analyzed. Differences in 18:1n-9 values were observed (P≤ 0.05) in the skinless thigh **(Table VIII)**, with greater value in chicken fed with canola oil (41.47%), followed by chicken oil (35.56%) and control (35.06%), and finally soybean oil (30.31%) and sunflower oil (29.51%) the lowest values. Chicken skinless breast **(Table IX)** presented 18:1n-9 values that varied from 40.45 to 28.22%, statistically different (P≤ 0.05) with a similar variation of the same treatments cited for the skinless thigh.

The 18:2n-6 and 18:3n-3 were the PUFAs present in greater concentration in samples analyzed. Skinless thigh samples presented higher values of 18:2n-6 **(Table VIII)** from the chicken fed with sunflower oil (38.49%) followed by soybean oil (35.19%) that were

Table IX. Fatty acids compositions of samples skinless breast from chicken control and from chicken fed with different oils (Composiciones de ácidos grasos de muestras de pechugas sin piel del control de pollo y de pollo alimentado con diferentes aceites).

Fatty acid	Control	Soy	Canola	Sunflower	Chicken
14:0	$0.31^{b} \pm 0.01$	$0.36^{a.b} \pm 0.03$	$0.35^{b} \pm 0.03$	$0.38^{a.b} \pm 0.04$	$0.45^{a} \pm 0.05$
16:0	$20.02^{a.b} \pm 0.31$	$20.14^{a.b} \pm 1.05$	$18.42^{b} \pm 1.10$	$18.83^{b} \pm 0.73$	$22.39^{a} \pm 1.29$
16:1n-9	$0.59^{a} \pm 0.00$	$0.48^{b.c} \pm 0.04$	$0.61^{a} \pm 0.04$	$0.43^{c} \pm 0.05$	$0.54^{a.b} \pm 0.03$
16:1n7	$2.80^{a.b} \pm 0.18$	$2.27^{a.b} \pm 0.51$	$2.37^{a.b} \pm 0.37$	$2.23^{b} \pm 0.83$	$3.81^{a} \pm 0.70$
i17:0	$0.21^{a.b} \pm 0.02$	$0.12^{b} \pm 0.07$	$0.17^{a.b} \pm 0.01$	$0.25^{a} \pm 0.04$	$0.19^{a.b} \pm 0.02$
17:0	$0.14^{a} \pm 0.02$	$0.19^{a} \pm 0.07$	$0.12^{a} \pm 0.01$	$0.12^{a} \pm 0.02$	$0.15^{a} \pm 0.02$
17:1n-9	Nd	$0.12^{a} \pm 0.05$	$0.07^{a} \pm 0.01$	$0.09^{a} \pm 0.01$	$0.10^{a} \pm 0.02$
18:0	$7.46^{a} \pm 1.26$	$5.74^{a.b} \pm 0.51$	$5.37^{b} \pm 0.49$	$6.14^{a.b} \pm 0.70$	$6.79^{a.b} \pm 0.17$
18:1n-9	$34.57^{b} \pm 0.40$	$29.63^{c.d} \pm 1.35$	$40.45^{a} \pm 1.45$	$28.22^{d} \pm 1.94$	$33.38^{b.c} \pm 1.38$
18:1n7	$2.48^{a.b} \pm 0.32$	$1.99^{b.c} \pm 0.23$	$2.71^{a} \pm 0.14$	$1.62^{b.c} \pm 0.29$	$2.40^{a.b} \pm 0.31$
18:2n-6	$25.85^{b} \pm 1.64$	$33.92^{a} \pm 1.20$	$23.99^{b} \pm 1.10$	$37.31^{a} \pm 2.09$	$25.24^{b} \pm 1.69$
18:3n-6	$0.20^{a} \pm 0.00$	$0.25^{a} \pm 0.06$	$0.18^{a} \pm 0.06$	$0.28^{a} \pm 0.08$	$0.23^{a} \pm 0.05$
18:3n-3	$1.80^{c} \pm 0.05$	$2.32^{b} \pm 0.16$	$2.88^{a} \pm 0.21$	$1.13^{d} \pm 0.20$	$1.47^{c.d} \pm 0.24$
20:3n-9	$0.65^{a} \pm 0.02$	$0.21^{c} \pm 0.03$	$0.47^{b} \pm 0.03$	$0.51^{a.b} \pm 0.13$	$0.25^{c} \pm 0.01$
20:4n-6	$0.68^{b} \pm 0.01$	$1.55^{a.b} \pm 0.35$	$1.52^{a.b} \pm 0.49$	$2.27^{a} \pm 0.61$	$2.36^{a} \pm 0.44$
22:4n-6	$2.23^{a} \pm 0.03$	$0.21^{b} \pm 0.06$	$0.34^{b} \pm 0.09$	$0.20^{b} \pm 0.05$	$0.25^{b} \pm 0.07$
PUFA	$31.41^{b} \pm 1.64$	$38.46^{a} \pm 1.26$	$29.37^{b} \pm 1.23$	$41.69^{a} \pm 2.19$	$29.80^{b} \pm 1.77$
MUFA	$40.45^{b} \pm 0.54$	$34.99^{c} \pm 1.46$	$46.20^{a} \pm 1.50$	$32.59^{c} \pm 2.13$	$40.24^{b} \pm 1.58$
SFA	$28.15^{a.b} \pm 1.30$	$26.54^{b.c} \pm 1.17$	$24.43^{c} \pm 1.21$	$25.72^{b.c} \pm 1.01$	$29.96^{a} \pm 1.31$
n-6	$28.96^{b} \pm 1.64$	$35.93^{a} \pm 1.25$	$26.02^{b} \pm 1.21$	$40.06^{a} \pm 2.18$	$28.08^{b} \pm 1.75$
n-3	$1.80^{c} \pm 0.05$	$2.32^{b} \pm 0.16$	$2.88^{a} \pm 0.21$	$1.43^{c} \pm 0.20$	$1.47^{c} \pm 0.24$
PUFA/SFA	$1.11^{b.c} \pm 0.27$	$1.45^{a.b} \pm 0.15$	$1.20^{b.c} \pm 0.02$	$1.62^{a} \pm 0.02$	$0.98^{c} \pm 0.01$
n-6/n-3	$16.11^{c} \pm 0.27$	$15.48^{c} \pm 0.06$	$9.04^{d} \pm 0.31$	$36.47^{a} \pm 0.83$	$19.49^{b} \pm 0.03$

Results are expressed as percentage of total fatty acids. PUFA: Polyunsaturated Fatty acids; MUFA: Monounsaturated Fatty Acids; ND: not detected.
Letters different in the same row indicated significant difference (≤ 0.05) by Tukey test.

statistically equal (P>0.05) from each other and different from other treatments. Skinless thigh samples from control, chicken fed with canola oil and chicken fed with chicken oil presented the lower values of 18:2n-6 and statically equal (P>0.05). The same variation between the treatments about the 18:2n-6 was observed from skinless breast samples **(Table IX)** and from breast with skin **(Table X)** with greater values from chicken fed sunflower oil (37.31 and 38.22%, respectively) and chicken fed with soybean oil (33.92 and 34.83%, respectively). The behaviour of 18:3n-3 levels was opposed that observed by 18:2n-6 levels for all cuts, where greater values were obtained in chicken fed with canola oil for skinless thigh (2.95%), skinless breast (2.88%), and breast with skin (3.02%), all followed by chicken fed with soybean oil. This behavior of 18:2n-6 and 18:3n-3 levels can be explained by the pathway metabolism of lipids, where the competition of Δ-5 and Δ-6 desaturase enzymes between n-3 and n-6 fatty acid in tissues results in different values of these acids (Crespo & Esteve-Garcia 2000). Similar results were reported by Bonoli et al. (2007) where higher and lower values of linoleic and palmitic acids, respectively, were obtained in cuts from chicken fed with vegetable oils compared with cuts from chicken fed with animal fat.

The PUFA/SFA ratio varied from 0.63 to 1.22 for skinless thigh; from 0.98 to 1.70 for skinless breast; and from 1.23 to 1.70 for the breast with skin; with greater values found in samples from chicken fed with sunflower oil. These results were superior at 0.4 the minimal recommendation for the PUFA/SFA ratio by the Department of Health United Kingdom (Wood et al. 2004).

The n-6/n-3 ratio varied from 9.03 to 33.84 for skinless thigh; from 9.04 to 36.47 for skinless breast; and from 8.46 to 32.69 for the breast with skin; with the greatest value found in samples from chicken fed with sunflower oil and the lowest value for those chickens fed canola oil. The n-6/n-3 ratio and their influence on health have been studied. The metabolism of n-6 and n-3 are similar with several enzymes common in the two mechanisms; however, the products resulting from each mechanism are different. The products from n-6 metabolism are inflammatory mediators, while the products of n-3 metabolism are anti-inflammatory mediators. Thus, the ratio between n-6 and n-3 is important to the balance of these mediators, and over the years that ratio has decreased due the confirmation that Δ-6-desaturase enzyme has greater affinity by n-6. The n-6/n-3 ratio 4 is the Italian recommendation and considered ideal by several authors (Bonoli et al.

Table X. Fatty acids compositions of samples breast with skin from chicken control and from chicken fed with different oils (Ácidos grasos composiciones de muestras de pechuga con piel de control de pollo y de pollo alimentado con diferentes aceites).

Fatty acid	Control	Soy	Canola	Sunflower	Chicken
14:0	$0.38^{a.b} \pm 0.04$	$0.36^{b} \pm 0.04$	$0.38^{a.b} \pm 0.03$	$0.38^{a.b} \pm 0.04$	$0.47^{a} \pm 0.05$
16:0	$18.62^{b} \pm 0.53$	$18.90^{a.b} \pm 1.03$	$17.98^{b} \pm 0.89$	$17.96^{b} \pm 0.90$	$21.03^{a} \pm 0.67$
16:1n-9	$0.47^{b} \pm 0.07$	$0.48^{b} \pm 0.04$	$0.64^{a} \pm 0.05$	$0.45^{b} \pm 0.06$	$0.56^{a.b} \pm 0.01$
16:1n7	$3.42^{a.b} \pm 0.30$	$3.18^{a.b} \pm 0.42$	$2.77^{b} \pm 0.45$	$2.66^{b} \pm 0.59$	$4.42^{a} \pm 0.65$
i17:0	$0.71^{a} \pm 0.04$	$0.24^{b} \pm 0.02$	$0.21^{b} \pm 0.00$	$0.27^{b} \pm 0.03$	$0.06^{c} \pm 0.01$
17:0	$0.31^{a} \pm 0.02$	$0.14^{b} \pm 0.05$	$0.14^{b} \pm 0.02$	$0.14^{b} \pm 0.03$	$0.19^{b} \pm 0.02$
17:1n-9	Nd	$0.06^{b} \pm 0.02$	$0.07^{b} \pm 0.00$	Nd	$0.17^{a} \pm 0.03$
18:0	$6.77^{a} \pm 0.21$	$5.06^{b.c} \pm 0.39$	$4.83^{c} \pm 0.46$	$5.65^{b.c} \pm 0.52$	$6.06^{a.b} \pm 0.30$
18:1n-9	$34.26^{c} \pm 1.13$	$30.73^{d} \pm 0.90$	$41.50^{a} \pm 0.65$	$29.50^{e} \pm 1.63$	$34.96^{b} \pm 0.97$
18:1n7	$2.34^{a.b} \pm 0.15$	$1.84^{b.c} \pm 0.27$	$2.48^{a} \pm 0.10$	$1.51^{c} \pm 0.32$	$2.08^{a.b} \pm 0.13$
18:2n-6	$28.96^{b} \pm 0.43$	$34.83^{a} \pm 1.76$	$24.55^{b} \pm 1.34$	$38.22^{a} \pm 2.49$	$26.38^{b} \pm 1.76$
18:3n-6	$0.25^{b} \pm 0.02$	$0.25^{b} \pm 0.03$	$0.13^{c} \pm 0.05$	$0.35^{a.b} \pm 0.04$	$0.37^{a} \pm 0.05$
18:3n-3	$1.31^{c} \pm 0.09$	$2.66^{a} \pm 0.24$	$3.02^{a} \pm 0.19$	$1.22^{c} \pm 0.08$	$1.82^{b} \pm 0.19$
20:3n-9	$0.92^{a} \pm 0.05$	$0.25^{c} \pm 0.03$	$0.45^{b} \pm 0.04$	$0.33^{b.c} \pm 0.07$	$0.33^{b.c} \pm 0.06$
20:4n-6	$0.25^{b} \pm 0.01$	$0.87^{a.b} \pm 0.17$	$0.72^{a.b} \pm 0.17$	$1.24^{a} \pm 0.28$	$1.26^{a} \pm 0.54$
22:4n-6	$1.04^{a} \pm 0.05$	$0.11^{b} \pm 0.03$	$0.13^{b} \pm 0.03$	$0.11^{b} \pm 0.03$	$0.10^{b} \pm 0.02$
PUFA	$32.73^{b} \pm 0.45$	$38.98^{a} \pm 1.78$	$29.00^{b} \pm 1.37$	$41.47^{a} \pm 2.51$	$31.98^{b} \pm 1.86$
MUFA	$40.47^{b} \pm 1.18$	$36.29^{c} \pm 1.03$	$47.46^{a} \pm 0.80$	$34.13^{c} \pm 1.76$	$46.18^{a} \pm 1.20$
SFA	$26.79^{a} \pm 1.18$	$24.73^{a.b} \pm 1.10$	$23.54^{b.c} \pm 1.00$	$24.40^{a.b} \pm 1.04$	$21.84^{c} \pm 0.67$
n-6	$30.50^{b} \pm 0.44$	$36.06^{a} \pm 1.77$	$25.53^{c} \pm 1.35$	$39.92^{a} \pm 2.51$	$29.82^{b.c} \pm 1.85$
n-3	$1.31^{c} \pm 0.09$	$2.66^{a} \pm 0.24$	$3.02^{a} \pm 0.19$	$1.22^{c} \pm 0.08$	$1.82^{b} \pm 0.19$
PUFA/SFA	$1.32^{a} \pm 0.51$	$1.58^{a} \pm 0.01$	$1.23^{a} \pm 0.02$	$1.70^{a} \pm 0.01$	$1.47^{a} \pm 0.02$
n-6/n-3	$23.31^{b} \pm 0.46$	$13.58^{d} \pm 0.42$	$8.46^{e} \pm 0.16$	$32.69^{a} \pm 0.30$	$16.62^{c} \pm 0.22$

Results are expressed as percentage of total fatty acids. PUFA: Polyunsaturated Fatty acids; MUFA: Monounsaturated Fatty Acids; ND: not detected.
Letters different in the same row indicated significant difference (≤ 0.05) by Tukey test.

2007; Simopoulos 2004) and have excessive amounts of omega-6 fatty acids compared with the diet on which human beings evolved and their genetic patterns were established. Although the ratio n-6/n-3 presented in this study have been greater than an ideal recommendation, is known that chicken meat has a low content of n-3 acids and not represent an important source in the diet.

CONCLUSIONS

The addition of oil sources (soybean, canola, sunflower and chicken) in feed chicken did not affect the broiler chicken performance nor the physicochemical composition of chicken meat (skinless thigh, skinless breast and breast with skin). The fatty acid profile of the different tissues reflected dietary fatty acid profile. Chicken fed with canola oil resulted in chicken meat with greatest 18:1n-9 and 18:3n-3, important MUFA and PUFA respectively. In contrast, chicken fed with sunflower oil resulted in chicken meat with greatest PUFA concentrations, principally 18:2n-6. These results were similar to all cuts (skinless thigh, skinless breast and breast with skin). Thus, considering the balance of n-6/n-3 and concentration of unsaturated fatty acid in chicken meat obtained in this study, the meat from chicken fed with canola oil showed greater nutritional characteristics.

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