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Performance, carcass traits, and meat fatty acid profile and quality of Anglo-Nubian kids fed diets supplemented with vegetable oils

Andréia Cristina Toniolo Chávari[1], Raquel Ornelas Marques[1], Helen Fernanda Barros Gomes[2*], Gil Ignacio Lara Cañizares[3], Evelyn Prestes Brito[1], Raquel Vasconcelos Lourençon[4], Paulo Roberto de Lima Meirelles[1], Heraldo Cesar Gonçalves[1]

[1] Universidade Estadual Paulista, Faculdade de Medicina Veterinária e Zootecnia, Botucatu, SP, Brasil.
[2] Universidade Federal de Rondonópolis, Rondonópolis, MT, Brasil.
[3] Instituto Federal do Rio Grande do Sul, Bento Gonçalves, RS, Brasil.
[4] University Langston, Langston, OK, USA.

ABSTRACT - The objective of this study was to evaluate the inclusion of vegetable oils in goat kid diets on performance, carcass traits, and meat composition, quality, and fatty acid profile. Forty-eight Anglo Nubian kids were evaluated in a completely randomized experimental design with four treatments, namely, control diet and diets including 2.5% canola, sunflower, or soybean oils. The animals were slaughtered at 30 kg live weight and performance, carcass and meat quality, centesimal composition, and fatty acid profile were evaluated. The treatments did not influence carcass yield or meat color. Among the saturated fatty acids, only caprylic, palmitic, and heptadecanoic acids differed among the treatments, whereas total saturated fatty acids decreased in the sunflower oil treatment. Monounsaturated fatty acids were not influenced by lipid supplementation. Among the polyunsaturated fatty acids (PUFA), linoleic acid was highest in the sunflower oil-treated group. Total PUFA were higher for the soybean oil-supplemented group, but similar to that achieved with sunflower oil. The highest omega-6 content was obtained with dietary inclusion of sunflower oil, whereas conjugated linoleic acid, atherogenicity index, and hypocholesterolemic:hypocholesterolemic ratio improved with the inclusion of sunflower and soybean oils. Supplementation with vegetable oils improves the fatty acid profile of kid meat without affecting animal performance. Better results are obtained with sunflower and soybean oils; therefore, it is up to the producer to choose the diet according to its cost.

Keywords: caprine, lipid supplementation, meat quality

***Corresponding author:**
gomes.helen@ufr.edu.br

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1. Introduction

With the exception of some regions such as the Northeast, goat meat is not commonly consumed in Brazil, which is possibly due to the low supply of the product to the market or lack of consumers' knowledge about its properties. However, this meat appears to be a promising product in light of the constant search for healthy, functional foods with a low-fat content, especially saturated fat, which is related to the incidence of cardiovascular diseases.

In this respect, goat meat offers an advantage, as one of the peculiarities of this species is the deposition of 50-60% of body fat in the abdominal cavity (Simela et al., 1999), resulting in a carcass with little subcutaneous, intermuscular, and intramuscular fat. Because nutritional value and visual and sensory

attributes such as color, tenderness, and juiciness are also consumer requirements and directly affect the acceptance of the meat, these must be considered in assessments of the product.

According to Bas and Morand-Fehr (2000), the amount and type of lipid used in the diet considerably influence the quantity, distribution and composition of the animal's body fat, which is one of the important factors in determining carcass and meat quality. Supplementation with vegetable oils has been investigated as a way to increase the energy density of the diet as well as improve the fatty acid profile of ruminant meat and milk, since these oils contain a high proportion of unsaturated in relation to saturated fatty acids (SFA) and are more digestible than animal-derived lipid sources (Costa et al., 2009). Consequently, they have different effects on the lipid profile of the obtained product.

One of the obstacles to the use of vegetable oils in ruminant diets is the ruminal biohydrogenation process. According to Doreau et al. (2011), this process results in differences in the fatty acid composition of the feed ingested from that absorbed by the animal. Thus, strategies to change the fatty acid profile of ruminant-derived products involve knowledge about the ruminal biohydrogenation process to enable desirable fatty acids to compose the final product.

In view of the dearth of research evaluating the effect of lipid supplementation on the attributes of goat meat, it is important to study supplementation with fatty acids in goat diets, because changes that lead to decrease the saturated and increase polyunsaturated fatty acids can bring direct health benefits to consumers of these products.

2. Material and Methods

The trial was undertaken in Botucatu, São Paulo, Brazil (22°53'08" S and 48°26'42" O, and 837 m altitude), after approval by the local ethics committee (approval no. 29/2012 - CEUA).

Forty-eight Anglo-Nubian goat kids were used in the study. Immediately after birth, the kids were weighed and identified, and standard umbilical-cord care procedures were performed. The kids remained with their mothers for colostrum ingestion and subsequently separated and allocated to collective stalls according to the treatments.

After weaning, the kids started receiving the experimental diets, which were formulated as recommended by the NRC (2007) to meet the nutritional requirements of growing goat kids under a daily weight gain of 200 g. The Small Ruminant Nutrition System computer program, based on the Cornell Net Carbohydrate and Protein System structure (Cannas et al., 2004) for sheep, was used to determine the nutritional composition of the diets, which is based on a ruminal simulation.

The diets were composed of 20% bermudagrass hay and 80% concentrate. Four treatments were tested, namely, control diet and control diet + 2.5% canola, sunflower, or soybean oils (dry matter [DM] basis) (Table 1). This percentage was chosen, as it does not present toxicity to ruminal microorganisms and because it is a quantity that can be used without major problems by the rural producer.

For the chemical composition analysis, samples of each ingredient were collected whenever the concentrates were prepared, and diet samples were collected after the respective oil and hay were incorporated into the concentrate. These samples (±200 g each) were collected, packed in labeled plastic bags, and frozen until laboratory analysis.

For the analysis, after thawing at room temperature, the diet samples were dried at 55 °C in a forced-air oven for 72 h, processed through a knife mill with a 1-mm sieve, and packed in plastic bags. The DM, mineral matter (MM), crude protein (CP), ether extract (EE), cellulose, and lignin (LIG) contents were determined according to AOAC International (Cunniff, 1995), whereas the neutral (NDF) and acid (ADF) detergent fiber contents were measured in accordance with the methodology proposed by Van Soest (1991). The total digestible nutrients (TDN) content was determined as described by Weiss (1999), as follows:

$$TDN = 0.98 \times (100 - NDF - CP - MM - EE - 1) + 0.93 \times CP + 2.25 \times EE \times 0.75 \times (NDF - LIG) \times \left(1 - \left(\frac{LIG}{NDF}\right) \times 0.667\right) - 7$$

The amount of feed to be supplied was adjusted daily, aiming at 10% orts in the trough.

Major fatty acids in the oils and experimental diets were measured by the extraction method, following the technique proposed by Rodríguez-Ruiz et al. (1998) (Table 2).

The kids were weighed at weaning and then weekly until reaching 30 kg live weight to determine performance, based on the following traits: time (days) to reach a live weight of 30 kg and average daily weight gain. Upon reaching slaughter weight, the animals were subjected to a solid-feed deprivation period of 16 h and weighed afterwards. Kids were subsequently slaughtered at a commercial abattoir located in the municipality of São Manual, approximately 20 km from the experiment site, after being stunned by electronarcosis, following the normal flow adopted by the establishment. Because the kids

Table 1 - Treatment and ingredient chemical composition

Ingredient (%)	Treatment			
	Control	Canola oil	Sunflower oil	Soybean oil
Coast cross hay	20.00	20.00	20.00	20.00
Corn	64.85	47.07	47.07	47.07
Soybean bran	11.40	8.86	8.86	8.86
Wheat bran	0.00	17.84	17.84	17.84
Limestone	1.27	1.27	1.27	1.27
Mineral supplement[1]	1.52	1.52	1.52	1.52
Ammonium chloride	0.51	0.51	0.51	0.51
Monensin	0.44	0.44	0.44	0.44
Oil	0.00	2.50	2.50	2.50

Ingredient	Chemical composition (%)								
	DM	MM	MP[2]	EE	NDF	ADF	CEL	LIG	TDN
Corn	84.62	0.05	10.20	3.88	15.03	3.56	3.44	0.95	89.87
Soybean bran	84.92	0.21	27.80	1.94	21.33	6.80	7.32	0.8	83.83
Wheat bran	84.66	0.17	15.02	3.20	43.58	10.14	9.30	2.43	80.04
Coast cross hay	89.97	6.64	6.53	1.00	84.03	45.09	45.62	7.91	55.61
Treatment									
Control	84.74	0.14	12.45	3.04	33.01	11.18	10.91	1.26	83.99
Canola	85.38	0.18	13.15	6.05	35.80	13.42	11.96	3.82	84.04
Sunflower	85.61	0.19	12.73	6.01	38.09	13.85	12.98	3.87	83.44
Soybean	85.33	0.17	12.97	5.93	36.51	13.63	12.19	3.29	84.36

DM - dry matter; MM - mineral matter; MP - metabolizable protein; EE - ether extract; NDF - neutral detergent fiber; ADF - acid detergent fiber; CEL - cellulose; LIG - lignin; TDN - total digestible nutrients.
[1] Composition per kg of product: calcium, 200 g; phosphorus, 70 g; fluorine, 700 mg; sodium, 100 g; sulfur, 10 g; magnesium, 5,000 mg; cobalt, 25 mg; copper, 440 mg; chromium, 6 mg; iron, 340 mg; iodine, 48 mg; manganese, 1,480 mg; selenium, 20 mg; zinc, 3,010 mg; vitamin A, 25,0000 IU; vitamin D3, 4,0000 IU; vitamin E, 350 IU.
[2] Metabolizable protein by Cornell Net Carbohydrate and Protein System structure (Cannas et al., 2004) for sheep.

Table 2 - Fatty acid composition in dietary oils

Fatty acid (%)	Oil			Diet			
	Canola	Sunflower	Soybean	Control	Canola	Sunflower	Soybean
C14:0 (myristic)	0.08	0.08	0.09	0.10	0.10	0.11	0.11
C16:0 (palmitic)	5.11	6.43	11.47	16.64	11.80	13.35	9.88
C18:0 (stearic)	2.31	3.04	2.99	2.63	2.42	2.94	2.95
C18:1 (oleic)	63.13	27.89	25.44	33.44	44.88	31.68	31.71
C18:2 (linoleic)	18.30	60.89	52.70	43.73	34.22	48.62	50.22
C18:3n6 (γ-linolenic)	0.55	0.19	0.24	0.00	0.50	0.27	0.12
C18:3n3 (linolenic)	6.66	0.13	4.92	1.72	3.61	1.38	3.12
Others	2.45	1.07	1.36	1.17	1.61	1.28	1.32

were only sent to the abattoir in lots of at least five animals, some of them were slaughtered at weights slightly above 30 kg.

Hot carcass weight was obtained immediately after slaughter. Carcasses were chilled for 24 h at 4 °C, and then cold carcass weight was determined and final pH (24 h) was measured in the *Longissimus lumborum* muscle. pH was measured by the direct method, using a pH meter coupled to a probe with a fine penetration tip that was inserted into the muscle, in the lumbar region, after carcasses were chilled in a cold room.

Carcasses were sawn lengthwise and the left half was weighed and divided into the following five cuts, as proposed by Yáñez et al. (2007): leg, separated between the penultimate and last lumbar vertebrae; loin, separated between the first and the penultimate lumbar vertebrae, with the abdominal wall; shoulder, encompassing scapula, humerus, radius, ulna, and carpus region; ribs, between the last cervical vertebra and the first thoracic vertebra; and neck, region corresponding to the seven cervical vertebrae. These cuts were weighed individually to determine the proportion of each cut relative to the left half carcass.

The *Longissimus lumborum* muscle was exposed between the 12th and 13th ribs, and its transverse area was outlined on transparent paper to measure ribeye area. This variable was determined with the aid of software SPLAN - Sistema de Planimetria (Silva et al., 1993), which evaluates the object using a digitizing table and provides the area in square centimeters. The same muscle was separated and used for analyses of centesimal composition, quality, and fatty acid profile of the meat.

Meat color was determined using a Minolta CR portable handheld colorimeter operating in the CIELab system, which measures the L* (lightness) a* (redness), and b* (yellowness) components. This variable was measured at three distinct points on the inner surface of the samples.

To measure the cooking loss, part of the *Longissimus lumborum* muscle was cut into three pieces of approximately 3-cm thick, which were weighed, packed in plastic bags, and kept in a water bath at 85 °C for approximately 45 min. The samples were removed from the water bath and, after cooling to 25 °C, weighed again to determine cooking loss, which was calculated as the difference in weight of the samples before and after cooking, following the methodology of Honikel (1998).

Six cylinder-shaped sub-samples were extracted from the cooked samples for analysis of shear force. Cylinders were positioned with the fibers oriented perpendicular to the Warner-Bratzler blade, which was coupled to a TA-XPLUS-30 texture analyzer. Results were expressed in kgf.

To evaluate the chemical composition and fatty acid profile, samples were thawed, and subcutaneous fat and connective tissue were removed and ground through a processor to obtain a homogeneous mass.

Procedures described in AOAC (2007) were performed to determine moisture (method 39.1.02), EE (method 30.1.05), ash (method 39.1.09), and protein (method 39.1.19; micro Kjedahl, for total nitrogen) contents of the meat. The protein content was calculated as the total nitrogen content multiplied by factor 6.25.

To evaluate the fatty acid profile, lipids were extracted with chloroform/methanol (2:1) according to methodology of Folch et al. (1957). Fatty acid methyl esters were analyzed using a gas chromatograph (GC-17A, Shimadzu) equipped with a flame ionization detector, a “Split/splitless” injector, and a fused silica capillary column containing polyethylene glycol as the stationary phase (DB-Wax, 60 m × 0.25 mm, J&W Scientific). The following chromatographic conditions were applied: injector temperature of 230 °C and initial column temperature of 80 °C for 2 min at a rate of 3 °C/min, which was then raised to 180 °C at a rate of 30 °C/min, held at this temperature for 30 min and then raised to 200 °C at a rate of 3 °C/min, and held at this temperature for 108 min. The detector temperature was 240 °C; helium was used as carrier gas, with a total flow of 8.0 mL/min; and the sample split ratio was 1:50. To identify fatty acids, retention times were compared with those of methyl ester standards (Sigma-Aldrich), whereas quantification was achieved by area normalization, with results expressed as a percentage of area of each acid over the total fatty acid area (%), in accordance with the methodology of Hartman and Lago (1973).

From the obtained fatty acid profile, total levels of ω3 and ω6 fatty acids, conjugated linoleic acid (CLA), SFA, monounsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA), and the ω6:ω3, MUFA:SFA, and PUFA:SFA ratios were determined. The following nutritional quality indices of the lipid fraction were also determined: atherogenicity index, using the formula [(C12:0 + (4 × C14:0) + C16:0)] / (MUFA + ω6 + ω3), and thrombogenicity index, using the formula = (C14:0 + C16:0 + C18:0) / [(0.5 × MUFA) + (0.5 × ω6) + (3 × ω3) + (ω3/ω6)], both proposed by Ulbricht and Southgate (1991); and the hypocholesterolemic:hypercholesterolemic fatty acid ratio, by the formula = (C18:1cis9 + C18:2ω6 + C20:4ω6 + C18:3ω3 + C20:5ω3 + C22:6ω3) / (C14:0 + C16:0), following Santos-Silva et al. (2002).

The experiment was laid out in a completely randomized design. Results were subjected to analysis of variance (Model I) using SAEG statistical software (UFV, 2000). Means were compared by Tukey's test ($P<0.05$).

Model I:

$$Y_{ij} = \mu + T_i + e_{ij},$$

in which Y_{ij} = observed value of the trait in animal receiving treatment i; μ = constant inherent to all observations; T_i = effect of treatment i (i = 1: inclusion of 2.5% canola oil; 2: inclusion of 2.5% soybean oil; 3: inclusion of 2.5% sunflower oil; and 4: control); and e_{ij} = random error associated with observation Y_{ij}.

3. Results

Average DM intake per treatment was 0.570 kg for the group fed canola oil, 0.683 for the group fed sunflower oil; 0.586 for the group fed soybean oil, and 0.602 for the control group. Supplementation with vegetable oils did not influence production performance (Table 3).

The average time taken by the kids to reach the pre-established weight of 30 kg for slaughter was 282 days, which is higher than the expected 150-180 days, due to the low average daily weight gain.

Slaughter weight differed between the treatments, with the highest values (32.91 kg) obtained by the animals fed diet with sunflower oil. This group also produced the heaviest carcasses among the evaluated treatments (Table 4).

Table 3 - Average performance of Anglo Nubian kids

Variable	Mean	Treatment			
		Control	Canola	Sunflower	Soybean
D_30 kg (days)	282	239	319	295	277
Daily gain (kg)	0.107	0.124	0.091	0.106	0.107

D_30 kg - days until 30 kg body weight.

Table 4 - Slaughter weight, carcass, and cut yield in relation to the half carcass of Anglo Nubian kids

Variable	Mean	Treatment			
		Control	Canola	Sunflower	Soybean
Slaughter weight (kg)	31.16	31.31ab	29.74b	32.91a	30.82ab
Hot carcass weight (kg)	15.49	15.39ab	14.85b	16.31a	15.42ab
Cold carcass weight (kg)	14.79	14.76ab	14.10b	15.61a	14.68ab
Carcass yield (%)	47.47	47.19	47.41	47.66	47.63
Loin area (cm^2)	12.99	13.36	11.95	13.47	13.18
Half left carcass (kg)	7.40	7.40	7.05	7.76	7.40
Leg (%)	30.63	30.49	30.75	30.84	30.43
Loin (%)	12.75	13.03	12.56	13.21	12.21
Arm (%)	21.07	20.66	20.94	21.30	21.39
Ribs (%)	26.67	27.49	26.38	25.88	26.94
Neck (%)	8.91	8.28	9.20	9.22	8.96

However, despite the differences in slaughter weight, carcass commercial yield (dressing percentage) and ribeye area were similar between the treatments, averaging 47.47% and 12.99 cm^2, respectively.

Centesimal composition also was not influenced by lipid supplementation. The average meat composition of the evaluated animals included 21.79% protein and 2.98% lipids, although the coefficient of variation of the last item was slightly higher (Table 5).

Cooking loss was high, averaging 36.74% of the weight. Nonetheless, the shear force values were within the acceptable range for goats, averaging 7.38 kgf. Meat color was also not influenced by lipid supplementation.

Thirty-six fatty acids were identified in the general fatty acid profile of the *Longissimus lumborum* muscle, the most abundant of which were oleic (C18:1n9c; 37.58%), palmitic (C16:0; 24.06%), and stearic (C18:0; 17.03%) acids (Tables 6 and 7). No differences were detected for MUFA composition (Table 7).

Among the PUFA (Table 8), changes were only seen for linoleic acid (C18:2n6c) content. The diets with sunflower and soybean oils showed a higher C18:2 content compared with the control and canola oil diets, which provided linoleic acid contents of 6.93 and 6.87%, respectively.

Table 5 - Composition, pH value, cooking loss, shear force, and meat color of Anglo Nubian goats fed diets supplemented with vegetable oils

Variable	Mean	Treatment			
		Control	Canola	Sunflower	Soybean
Moisture (%)	74.41	74.32	74.20	74.66	74.48
Ash (%)	1.10	1.08	1.11	1.12	1.10
Crude protein (%)	21.79	21.81	21.85	21.67	21.83
Ether extract (%)	2.98	3.30	3.19	2.78	2.66
pH	5.6	5.7	5.4	5.5	5.6
Cooking loss (%)	36.74	36.55	36.40	38.06	35.94
Shear force (kgf)	7.38	7.62	7.20	7.78	6.90
a*	17.86	17.80	17.69	18.60	17.34
b*	4.40	4.39	4.53	4.67	4.02
L*	36.66	36.40	37.02	37.49	35.72

a* - variation on red; b* - variation on yellow; L* - variation in luminosity.

Table 6 - *Longissimus* dorsi saturated fatty acids as a function of treatments

Saturated fatty acid (%)	Mean	Treatment			
		Control	Canola	Sunflower	Soybean
C6:0 (caproic)	0.04	0.03	0.04	0.05	0.04
C8:0 (caprylic)	0.09	0.07b	0.14a	0.08ab	0.07b
C10:0 (capric)	0.03	0.04	0.01	0.03	0.04
C12:0 (lauric)	0.01	0.01	0.01	0.02	0.02
C13:0 (tridecanoic)	0.10	0.11	0.11	0.10	0.10
C14:0 (myristic)	2.43	2.75	2.57	2.15	2.25
C16:0 (palmitic)	24.06	26.09a	24.44ab	22.80b	22.92b
C17:0 (heptadecanoic)	2.03	2.98a	1.78b	1.74b	1.60b
C18:0 (stearic)	17.03	17.12	17.24	15.94	17.81
C20:0 (arachidic)	0.35	0.37	0.36	0.37	0.30
C21:0 (heneicosanoic)	0.12	0.02	0.02	0.38	0.06
C22:0 (behenic)	0.08	0.00	0.02	0.27	0.01
C23:0 (tricosanoic)	0.12	0.11	0.24	0.09	0.04
Total saturated fatty acids	46.50	49.71a	46.99ab	44.04b	45.25ab

Means followed by the same letter do not differ for treatment by Tukey's test (P>0.05).

The ω3 contents were not influenced by treatments (Table 9); however, for ω6, treatments with sunflower and soybean oils resulted in higher mean values than control treatment.

The CLA content of meat increased when sunflower and soybean oils were included in goat kid diets.

Based on the evaluated lipid quality indices, dietary inclusion of sunflower and soybean oils provided the best result, as atherogenicity values decreased while the hypocholesterolemic:hypercholesterolemic

Table 7 - *Longissimus lumborum* monounsaturated fatty acids as a function of treatments

Monounsaturated fatty acid (%)	Mean	Treatment			
		Control	Canola	Sunflower	Soybean
C16:1 (palmitoleic)	2.61	3.17	2.54	2.42	2.31
C17:1 (heptadecenoic)	0.03	0.01	0.01	0.07	0.01
C18:1n9t (elaidic)	0.26	0.25	0.17	0.24	0.36
C18:1n9c (oleic)	37.58	36.19	39.09	37.91	37.13
C20:1 (eicosenoic)	0.61	0.54	0.70	0.64	0.56
C22:1n9 (erucic)	0.13	0.08	0.09	0.26	0.09
C24:1 (nervonic)	0.11	0.07	0.01	0.35	0.02
Total monounsaturated fatty acids	41.36	40.35	42.65	41.91	40.54

Table 8 - *Longissimus lumborum* polyunsaturated fatty acids as a function of treatments

Polyunsaturated fatty acid (%)	Mean	Treatment			
		Control	Canola	Sunflower	Soybean
C18:2n6t (linolelaidic)	0.19	0.21	0.05	0.17	0.33
C18:2n6c (linoleic)	5.82	4.46c	5.03bc	6.93a	6.87ab
C20:2 (eicosadienoic)	0.50	0.28	0.15	0.32	1.28
C22:2 (docosadienoic)	0.10	0.14	0.15	0.08	0.01
C18:3n3 (linolenic)	0.19	0.20	0.16	0.19	0.21
C18:3n6 (γ-linolenic)	0.16	0.16	0.03	0.31	0.13
C20:3n3 (eicosatrienoic)	0.59	0.38	0.77	0.47	0.72
C20:3n6 (eicosatrienoic)	0.79	0.61	0.81	1.03	0.71
C20:4n6 (arachidonic)	1.55	1.42	1.43	1.74	1.62
C20:5n3 (eicosapentaenoic)	0.60	0.84	0.46	0.43	0.66
Total polyunsaturated fatty acids	10.56	8.76b	9.08b	11.79ab	12.63a

Means followed by the same letter do not differ for treatment by Tukey's test (P>0.05).

Table 9 - Contents of ω3, ω6, CLA; MUFA:SFA, PUFA:SFA ratios; and nutritional quality indexes of the lipid fraction of the *Longissimus lumborum* as a function of treatments

Fatty acid	Mean	Treatment				CV (%)
		Control	Canola	Sunflower	Soybean	
ω3	1.44	1.48	1.41	1.20	1.68	18.69
ω6	8.51	6.85c	7.36bc	10.19a	9.66ab	11.81
ω6:ω3	8.27	6.35	6.46	11.27	8.98	27.33
CLA	6.01	4.67b	5.08b	7.10a	7.20a	11.50
MUFA:SFA	0.90	0.84	0.91	0.96	0.91	4.15
PUFA:SFA	0.23	0.18c	0.20bc	0.27ab	0.28a	3.05
IA	0.67	0.79a	0.67ab	0.59b	0.62b	3.38
IT	1.52	1.72	1.52	1.38	1.47	7.10
HH	1.76	1.51b	1.73ab	1.92a	1.87a	5.05

ω3 - omega 3; ω6 - omega 6; CLA - conjugated linoleic acid; MUFA - monounsaturated fatty acids; SFA - saturated fatty acids; PUFA - polyunsaturated fatty acids; IA - atherogenicity index; IT - thrombogenicity index; HH - hypocholesterolemic:hypercholesterolemic fatty acid ratio; CV - coefficient of variation.
Means followed by the same letter do not differ for treatment purposes by Tukey's test (P>0.05).

fatty acid ratio increased. For those traits, control treatment generated the worst outcome, while the dietary inclusion of canola oil provided results similar to those obtained with the other treatments.

The thrombogenicity index did not differ among the treatment groups, possibly due to the lack of differences in the MUFA, ω3, and ω6:ω3 values, which are used in its calculation.

4. Discussion

Although the diets were formulated to provide a daily weight gain of 200 g, the goat kids did not meet the expectations, which might have been due to the overestimated potential gains of the breed (Anglo Nubian) used in this study, which has shown historical gains of 113.77 to 137 g/day, according to Gomes et al. (2011) (who evaluated ½ Anglo Nubian + ½ Alpine crossbred goats). Another explanation for the low weight gain may be related to diarrhea that affected the goats in the first months of life and impaired weight gain in the phase when it is most marked, although goats had been vaccinated against main diseases. However, despite the low weight gain, treatments did not influence this trait.

The observed differences in live weight at slaughter between the treatment groups are due to the wait for the formation of lots of five animals to be sent to the slaughterhouse, which resulted in the slaughter of some animals weighing more than 30 kg. Consequently, average weight also increased, especially in the group fed sunflower oil. This difference influenced hot and cold carcass weights, as these variables are strongly dependent on slaughter weight; nevertheless, these differences disappeared in the evaluation of carcass yield and ribeye area. This similarity can be explained by the law of anatomical harmony, whereby carcasses with similar weights have similar proportions (cited by Grande et al., 2011).

The average moisture, ash, protein, and fat contents remained within the ranges described in the literature: 64.74-80.25% moisture (Schönfeldt et al., 1993; Beserra et al., 2000), 0.99-1.10% ash (Schönfeldt et al., 1993; Beserra et al., 2000), 15.90-27.24% protein (Schönfeldt et al., 1993; Beserra et al., 2000), and 1.12-8.52% EE (Beserra et al., 2000; Madruga et al., 2008).

Few studies have evaluated the effect of lipid supplementation on goat meat. Grande et al. (2011) also found no differences in chemical composition of meat in an experiment evaluating the inclusion of oilseed grains in diet of Saanen kids and canola, sunflower, and castor oils in diet of Dorper × Santa Inês lambs. The authors attributed this result to the lower susceptibility to changes in meat when compared with the effect on the composition of milk, as well as differences pertaining to animal genetics and supplementation level, different from what was observed in this study.

The average meat pH determined in this study is within the recommended range of 5.48-6.03 for goat meat (Sen et al., 2004; Madruga et al., 2005) and far from the values that characterize DFD (dark, firm, dry) meat.

Loss of fluid from cooking is a measure directly related to the yield of meat at the time of consumption, and thus, lower values are desired for this variable. It is known that cooking losses are higher in goat meat than in sheep meat due to the lower fat content of the former. In the current study, the overall mean for this trait was 36.74%, and the lack of differences between the treatment groups is due to the similar fat contents found in the meat of the animals despite lipid supplementation.

Shear force, which determines the degree of meat tenderness, averaged less than 8 kgf. Thus, according to Souza et al. (2004), the meat can be classified as soft. Meat tenderness is the most appreciated attribute at the time of consumption, and lipid supplementation maintained this characteristic unchanged in the evaluated animals.

For the color parameter, the meat of kids showed red (a*) and yellow (b*) values within the characteristic patterns of this animal species due to the low intramuscular fat content. The lack of treatment effects on this trait might have been due to lack of changes in meat fat content, which in turn was provided by lipid supplementation. Additionally, these are young animals, in which less intramuscular fat deposition occurs when compared with adult animals.

When compared with the control group, the animals that received diet with sunflower oil showed a 11.4% lower total SFA content in their meat, whereas the mean values obtained with canola and soybean oil treatments were similar to those achieved with the other diets.

This change in total SFA content reflects the variations of each saturated fatty acid within the treatments. Individually, only caprylic (C8:0), palmitic (C16:0), and heptadecanoic (C17:0) acids differed between the treatments. Of these, only palmitic acid is important for consumer health, since it is considered a hypercholesterolemic fatty acid. Thus, the inclusion of sunflower and soybean oils in diet of kids improved the quality of the meat lipid profile in terms of promoting a reduction in palmitic acid levels, which, according to Bessa et al. (2005) and Boles et al. (2005), usually occurs when lipids rich in UFA are provided in the animal diet.

Canola oil is rich in oleic acid (C18:1n9c), and the diet supplemented with this oil had an 11% higher content of this fatty acid compared with the control diet. However, the oleic acid content of the meat of animals that received that treatment was not influenced. According to Bessa et al. (2005) and Boles et al. (2005), high-PUFA diets promote a reduction in oleic acid levels in the tissues of ruminants, which may result from the absence of C18:0 (stearic acid) to be desaturated by Δ-9 desaturase (Sampath and Ntambi, 2005), which in turn is caused by incomplete biohydrogenation of PUFA in the rumen (Harfoot and Hazlewood, 1997).

The diets containing sunflower and soybean oils presented a higher C18:2 content compared with the control treatment and diet with canola oil, which explains the similar means for these treatments, as also observed in experiments with lambs (Bessa et al., 2005; Boles et al., 2005; Bessa et al., 2007).

The control and canola oil diets showed the lowest total PUFA contents, whereas the diet containing soybean oil exhibited the highest values of those fatty acids. Supplementation with sunflower oil promoted PUFA means similar to those seen in the other treatments. Treatments with inclusion of sunflower and soybean oils contained the highest level of linoleic acid (Table 2), which was the only acid whose content changed between the treatments. This greater contribution from the diet possibly saturated the enzymatic biohydrogenation system and allowed the passage of intact linoleic acid for intestinal absorption (Bomfim et al., 2011), besides leading to a differentiated PUFA content in these treatments. This result is rather relevant, as this fatty acid belongs to the ω6 group, which is essential for humans. In addition to increasing individually in the treatments with sunflower and soybean oils, it was responsible for the increase in the total PUFA content of the meat, which is desired by consumers.

Changes in ω3 and ω6 levels are possibly due to the greater contribution from the diet, as the oils tested here possess a relevant amount of these fatty acids. Due to the lower ω6 content of the diet, the control and canola oil treatments showed similar means.

Though essential, ω3 and ω6 fatty acids must be balanced in the food and/or diet, since, according to Enser et al. (2000), excessive ω6 promotes the production of eicosanoids with a strong thrombotic tendency, predisposing the consumer to coronary heart disease. In this respect, the sunflower and soybean oil treatments did not have good effects on meat quality.

The increased CLA levels in meat are a consequence of the linoleic acid content present in these oils. Linoleic acid is the main precursor of CLA in the ruminal biohydrogenation process, which allowed the increase in its levels in the final product when compared with the canola oil and control treatments. Thus, when aiming to increase the CLA content of ruminant meat, sunflower and soybean oils are the best recommendation.

The MUFA:SFA ratio did not differ between the treatments, possibly because the observed small differences in total SFA content were not sufficient to induce changes in this ratio, considering that the total MUFA content was not changed by diets. However, the highest PUFA:SFA ratio was obtained with the diet containing soybean oil and the lowest with control treatment. The variations between the four treatments reflect almost exactly the observed variations in total PUFA content.

The quality indices of the lipid fraction characterize the degree of risk of the diet/food to human health, and diets or foods with low atherogenicity and thrombogenicity indices and high

hypocholesterolemic:hypercholesterolemic ratios are desired to minimize the deleterious effects on health. Therefore, the inclusion of sunflower and soybean oils provided a better result due to the reduced atherogenicity index and increased in hypocholesterolemic:hypercholesterolemic ratio, which can be considered interesting from the nutritional standpoint.

5. Conclusions

Dietary supplementation with 2.5% canola, sunflower, or soybean oils improves the meat fatty acid profile without influencing performance, carcass characteristics, meat composition, or meat quality of goats. Therefore, it can be indicated as a way to provide the consumer market with a product with "functional" characteristics, improving the polyunsaturated fatty acids and linoleic acids content of the meat.

Compared with canola oil, sunflower and soybean oils provide goat meat with a better fatty acid profile. As such, they are the most suitable for obtaining products with a nutritionally better lipid profile for the consumer, and it is up to the producer to choose which oil to use depending on the cost of the diets.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Conceptualization: H.C. Gonçalves. Data curation: R.V. Lourençon. Formal analysis: G.I.L. Cañizares, R.V. Lourençon, P.R.L. Meirelles and H.C. Gonçalves. Investigation: A.C.T. Chávari, R.O. Marques and E.P. Brito. Methodology: G.I.L. Cañizares, P.R.L. Meirelles and H.C. Gonçalves. Project administration: A.C.T. Chávari and R.O. Marques. Supervision: A.C.T. Chávari and R.O. Marques. Writing-original draft: A.C.T. Chávari and R.O. Marques. Writing-review & editing: H.F.B. Gomes.

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