



Physicochemical characteristics and fatty acid profile of meat from lambs with different genotypes and diets

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ABSTRACT - The objective of this study was to evaluate the chemical composition and fatty acid profile of meat from Santa Inês, Dorper × Santa Inês, and undefined-breed lambs finished in a feedlot system according to two forage:concentrate ratios (50:50 and 20:80) in the diet. Overall, 54 non-castrated animals were used (with an average initial weight of 23±1.5 kg at 150 days old) and were slaughtered when they reached 36 kg of live weight or 63 days of confinement. Diets with high concentrate levels favored meat production with higher protein content. Among the saturated fatty acids, only heptadecanoic (C17:0) and arachidic acids (C20:0) differed among the treatments. The amount of oleic acid detected in the meat ranged from 49.2 to 51.9 g/100 g, making this one of the most representative fatty acids. Regardless of the diet and genotype, the unsaturated fatty acid and desirable fatty acid levels in the lamb meat characterize it as of satisfactory quality for the consumer market.

Key Words: Dorper, genotype, lipids, meat quality, proximate composition, Santa Inês

Introduction

Currently, nutrient management practices based on scientific findings, and in accordance with the characteristics of each productive activity, have been used to finish lambs to produce more healthy and nutritious meat (Hummada et al., 2012). Based on inconclusive scientific results (Demirel et al., 2006; Lopes et al., 2014), it could be inferred that higher forage levels in lamb and goat diets during finishing promote greater polyunsaturated fatty acid ω3 deposition in the muscle tissue due to high levels of linolenic acid (C18:3) in the forage.

Thus, among the pre-slaughter factors that can promote changes in the physicochemical characteristics of lamb meat, genotype is an exceptional parameter that has not been fully evaluated (Martínez-Cerezo et al., 2005). With the increased use of the Santa Inês breed by Brazilian sheep breeders in recent decades and the introduction of the Dorper breed, which is recognized for its outstanding meat production potential, new prospects for developing the sheep industry have emerged in Brazil (Sousa et al., 2008). Terminal crossings between native genotypes and exotic breeds

with specific cutting characteristics, such as Dorper from Africa, have been suggested as important alternatives for increasing production as well as improving the productive characteristics, carcass quality, and meat quality of native cattle (Silva Sobrinho et al., 2005).

Additional information on the quality of meat of Santa Inês lambs, crossbred lambs from terminal crossings, such as Dorper × Santa Inês, and animals with undefined breeds (UDB) can help expand the demand for this product through the development of appropriate marketing strategies. Therefore, to provide information on adequate diets for finishing meat-producing sheep in Northeastern Brazil, this study evaluated the effect of two forage:concentrate ratios (50:50 and 20:80) in the diets of Santa Inês, Santa Inês × Dorper, and UDB lambs finished in a feedlot system by examining certain parameters, such as pH, carcass temperature, proximate composition, and the fatty acid profile of their meat.

Material and Methods

This study was performed in accordance with ethical standards and approved by the Ethics Research and Biosafety Committee of Universidade Federal da Paraíba.

Fifty-four non-castrated lambs were used, including 18 Santa Inês, 18 F₁ Dorper × Santa Inês, and 18 UDB. The lambs had an initial average weight of 23±1.5 kg and were, on average, 150 days old; they were individually distributed

Received February 5, 2015, and accepted April 15, 2015.

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<http://dx.doi.org/10.1590/S1806-92902015000700003>

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in cages measuring 0.80 × 1.20 m and were provided food and water. The adaptation period consisted of 14 days, and the lambs were weighted weekly to monitor body development. The animals were initially vaccinated against clostridial and worms through subcutaneous injection of 1% ivermectin.

The diets (Table 1) were isoproteic and provided twice a day (08.00 h and 17.00 h); the diets were formulated to meet the crude protein and metabolizable energy requirements that allowed the animal to gain 250 g/day in accordance with the recommendations in the NRC (2007). A 50 g/kg dry matter average intake relative to body weight was established and adjusted according to the leftovers from the previous day.

The diets consisted of two forage:concentrate ratios, 50:50 and 20:80, and the chemical composition of the ingredients used in the experimental diets was determined using the methods described in AOAC (2000) and Van Soest et al. (1991) (Table 2).

Table 1 - Ingredients and chemical composition of the diets according to the forage:concentrate ratio

Ingredient (g/kg)	Forage:concentrate ratio	
	20:80	50:50
Tifton hay	212	500
Ground corn	543	128
Soybean meal	208	168
Wheat bran	-	190
Soybean oil	20	-
Mineral salt ¹	5	5
Limestone	12	9
Chemical composition		
Dry matter (g/kg DM)	805	888
Crude protein (g/kg DM)	170	170
Metabolizable energy (Mcal/kg DM)	2.9	2.4
Total digestible nutrients (g/kg DM) ²	802	664
Neutral detergent fiber (g/kg DM)	273	520.5
Calcium (g/kg DM)	7.1	7.3
Phosphorus (g/kg DM)	3.2	4.3
Ether extract (g/kg DM)	48.9	22.9
Non-fibrous carbohydrates (g/kg DM)	482	247.4

¹ Mineral salt composition per kilogram: 147 g Na; 120 g Ca; 87 g P; 18 g S; 3,800 mg Zn; 3,500 mg Fe; 1,300 mg Mn; 870 mg F; 590 mg Cu; 300 mg Mo; 80 mg I; 40 mg Co; 20 mg Cr; 15 mg Se; 250 mg vit. A (IU); 100 mg vit. D (IU); 500 mg vit. E (IU).

² TDN = DCP + 2.25 × DEE + DNFC + DNDFap.

The non-fibrous carbohydrates (NFC) were determined using the equation proposed by Weiss (1999): % NFC = 100 - (%DNDFap + %CP + %EE + % ash), in which DNDFap, CP and EE are, respectively, digestible neutral detergent fiber (free of ash and protein), crude protein and ether extract. The Metabolizable energy (ME) values of the diets were calculated considering that 1 kg of total digestible nutrient (TDN) equals 4.409 Mcal of DE, and 1 Mcal of DE equals 0.82 Mcal of ME (Harris, 1970). The TDN levels were obtained from an equation proposed by Weiss (1999): TDN = DCP + 2.25 × DEE + DNFC + DNDFap, in which DCP, DEE, DNFC, and DNDFap are, respectively, the digestible crude protein, digestible ether extract, digestible non-fiber carbohydrates and digestible neutral detergent fiber (free of ash and protein).

The lambs were slaughtered when they reached 36±2.4 kg live weight or 63 days of confinement, and their weight was evaluated after an 18-h solid fasting period. The slaughter was performed in accordance with the standards of the Rules of Industrial and Sanitary Inspection of Animal Products (Brasil, 1997); the carcasses were hung by the tendons on appropriate hooks, which were spaced 17 cm from one another, and cooled in a cold storage chamber at 1±4 °C for 24 h. The carcasses were wrapped in transparent plastic bags to reduce the loss of surface moisture during the cooling process.

After the slaughter, the carcasses were stored in a cold chamber to determine the pH and temperature (T) using a digital potentiometer with a penetration electrode (DIGIMED, model pH 300M, São Paulo, Brazil) introduced into 2-4 cm deep cuts, made using a scalpel, in the *longissimus lumborum* muscle between the 4th and 5th lumbar vertebrae, avoiding contact with fat and connective tissues (where possible). The carcasses were measured immediately after slaughter (initial PH₀ and T₀), after 45 min (pH₄₅ and T₄₅) and after 24 h (pH₂₄ and T₂₄) using the methodology described by Cezar and Sousa (2007). After the carcasses cooled, the *longissimus lumborum* muscles were removed, vacuum-packaged and stored in a cold chamber at -18±1 °C for future laboratory analyses. The

Table 2 - Chemical composition of the diet ingredients (g/kg DM)

Ingredient	DM	CP	EE	ME ¹	TDN	NDF	NFC	MM
Tifton hay	889.6	89.6	16.3	2.01	555.9	787.8	74.4	67.2
Soybean meal	886.1	487.8	29.5	2.95	815.9	146.2	300.0	63.2
Ground corn	876.4	91.1	40.7	3.15	871.2	139.8	744.7	15.5
Wheat bran	890.0	166.3	35.3	2.61	721.9	443.0	339.3	55.8
Soybean oil	995.5	-	990.4	7.48	2072.7	-	-	-
Limestone	990.0	-	-	-	-	-	-	1000.0
Mineral salt	990.0	-	-	-	-	-	-	1000.0

DM - dry matter; CP - crude protein; EE - ether extract; ME - metabolizable energy; TDN - total digestible nutrients; NDF - neutral detergent fiber; NFC - non-fibrous carbohydrates; MM - mineral matter.

¹ Mcal/kg DM.

carcass fat percentage was indirectly estimated through a leg dissection (Purchas et al., 1991).

To perform the proximate composition analysis, the *longissimus lumborum* muscle samples were thawed at 4 ± 1 °C for 24 h and ground in an Arno® domestic blender for an average of 5 min until the meat reached complete material homogeneity; subsequently, the moisture, ash, and protein were measured using the methodology described in AOAC (2000; methods 985.41, 920 153 and 928.08, respectively), and the total lipids were measured using the methodology described by Folch et al. (1957).

The fatty acid profile was determined after extracting the total lipids and performing the esterification and methylation processes using the methodology described by Hartman & Lago (1973). Fatty acid methyl esters were separated and quantified on a gas chromatograph (GC-MASTER, Shimadzu, Brazil) and a fused silica capillary column (MEGABORE, J & W Scientific, USA) with a polyethylene glycol stationary phase; the column was 30 m long, with a 0.53 mm internal diameter and 0.25 mm film thickness. Hydrogen was the carrier gas, with a flow rate of 5 mL/min. One-microliter methyl ester aliquots were introduced in a split/splitless type injector at 200 °C. The following chromatographic conditions were applied: initial column temperature of 80 °C for 3 min, followed by an increase to 175 °C at a rate of 10 °C/min in the first ramp, where the temperature remained for 10 min. The column temperature was increased again to 200 °C at a rate of 10 °C/min, where the temperature remained for five minutes, resulting in 30 min of analysis. The flame ionization detector temperature was maintained at 220 °C. The chromatograms of the retention time and fatty acid methyl esters percentage area data were recorded using the PeakSimple software (ARI Instruments - USA). The fatty acids were identified and quantified in accordance with European Standard EN 14103:2001.

The experimental design was a completely randomized design with a 3×2 factorial arrangement (three genotypes

and two forage:concentrate ratios), with nine replicates per treatment. The following statistical model was used: $Y_{ijk} = \mu + \alpha_i + \beta_j + \alpha\beta_{ij} + \varepsilon_{ijk}$, in which Y_{ijk} is the value observed for the dependent variable studied; μ is the overall mean; α_i is the effect of genotype i ; β_j is the effect of diet j ; $\alpha\beta_{ij}$ is the genotype \times diet interaction; and ε_{ijk} is the random error associated with each observation. The means were compared using Tukey's test with a probability level of 0.05, using the GLM procedure from the SAS (Statistical Analysis System, version 8.1) package.

Results

The genotype was not characterized as a parameter that influenced the final weight, average daily weight gain, and confinement period (Table 3); however, these variables were influenced by diet. The diet with the 20:80 forage:concentrate ratio provided more satisfactory production rates (i.e., greater weight gain and shorter confinement period). The diets containing high concentrate levels and, therefore, higher caloric content, provided greater fat accumulation in the carcasses ($P < 0.05$).

The pH values were within the normal range (Table 4), which is consistent with data from Silva Sobrinho et al., (2005), who showed no cases of muscle glycogen storage depletion before slaughter; therefore, the genotypes studied showed reduced susceptibility to normal slaughter stress, which was corroborated by Sañudo et al. (1997). The initial carcass temperature of the lambs fed the diets containing 200 g/kg of forage (38.6 °C) was lower than that of lambs fed diets supplemented with 500 g/kg of forage (39.4 °C).

The moisture and lipid levels (Table 5) confirm the inverse relationship between these parameters. Carcasses with higher lipid concentrations usually have lower moisture levels. Among the genotypes studied, Santa Inês was characterized by lower lipid levels in the meat (2.2 g/100 g). Concentrate-rich diets (20:80) favored protein synthesis by

Table 3 - Mean values for weight variables, confinement period (CP) and fat content in the carcasses of Santa Inês (SI), Dorper \times Santa Inês (DP \times SI), and undefined breed (UDB) lambs according to the forage:concentrate ratio in the diet

Variable	Forage:concentrate ratio (D)		Genotype (G)			Significance		
	20:80	50:50	SI	DP \times SI	UDB	D	G	D \times G
IW (kg)	22.4 \pm 1.6	22.9 \pm 1.5	23.3 \pm 1.8	22.7 \pm 1.1	22.5 \pm 1.6	0.184	0.359	0.255
FW (kg)	36.6 \pm 2.6a	35.3 \pm 2.2b	36.6 \pm 2.5	35.5 \pm 2.3	35.7 \pm 2.6	0.027	0.167	0.158
TWG	17.3 \pm 2.7a	13.8 \pm 1.7b	15.1 \pm 2.7	15.3 \pm 2.7	16.2 \pm 2.9	0.044	0.256	0.353
ADWG (g)	258.2 \pm 58.9a	204.2 \pm 44.8b	240.6 \pm 61.4	223.0 \pm 53.7	229.9 \pm 62.1	0.038	0.159	0.262
CP (days)	56.3 \pm 7.1a	61.4 \pm 4.4b	56.8 \pm 7.1	60.7 \pm 5.3	59.1 \pm 6.4	0.019	0.364	0.269
Fat (g/100 g)	8.4 \pm 2.9a	6.5 \pm 2.3b	5.3 \pm 1.6c	9.8 \pm 2.9a	7.2 \pm 1.8b	0.024	0.039	0.133

a, b, c - means followed by different letters are significantly different by Tukey's test.

IW - initial weight; FW - final weight; TWG - total weight gain; ADWG - average daily weight gain.

the animal, as observed in the Santa Inês and UDB lamb meat. No difference ($P>0.05$) was observed between the protein levels in the meat from Dorper \times Santa Inês lambs; however, higher absolute levels were observed in the meat from animals fed a lower forage percentage, which yielded a significant interaction between the factors for this genotype.

With respect to the fatty acid profile (Table 6), myristic (C14:0) and palmitic acids (C16:0) are considered hypercholesterolemic (Bonanome and Grundy, 1988) and favor the formation of cardiovascular diseases (Chiara et al., 2002). The concentrations of these fatty acids ranged from 0.70 to 2.90 g/100 g and 14.34 to 16.06 g/100 g, respectively. French et al. (2003) reported that myristic acid (C14:0)

Table 4 - Hydrogen ion potential (pH) and carcass temperatures (T) of Santa Inês (SI), Dorper \times Santa Inês (DP \times SI), and undefined breed (UDB) lambs according to the forage:concentrate ratio in the diet

Variable	Forage:concentrate ratio (D)		Genotype (G)			Significance		
	20:80	50:50	SI	DP \times SI	UDB	D	G	D \times G
pH _{0h}	6.6 \pm 0.3b	6.8 \pm 0.2a	6.6 \pm 0.3	6.8 \pm 0.1	6.7 \pm 0.2	0.042	0.259	0.168
pH _{45 min}	6.5 \pm 0.2	6.5 \pm 0.2	6.4 \pm 0.2	6.5 \pm 0.1	6.6 \pm 0.2	0.474	0.354	0.457
pH _{24h}	5.5 \pm 0.1	5.5 \pm 0.1	5.5 \pm 0.1	5.5 \pm 0.1	5.5 \pm 0.1	0.169	0.356	0.262
T _{0h} (°C)	38.6 \pm 1.4b	39.4 \pm 0.6a	38.7 \pm 0.8	39.3 \pm 0.9	39.0 \pm 1.5	0.001	0.156	0.272
T _{45 min} (°C)	34.6 \pm 2.0	35.2 \pm 1.2	33.7 \pm 1.8b	35.8 \pm 1.2a	35.2 \pm 1.1a	0.153	0.003	0.166
T _{24h} (°C)	5.94 \pm 1.1a	5.28 \pm 0.4b	5.85 \pm 1.1	5.57 \pm 0.9	5.41 \pm 0.6	0.004	0.263	0.259

a, b - means followed by different letters are significantly different by Tukey's test.

Table 5 - Chemical composition of the meat from Santa Inês (SI), Dorper \times Santa Inês (DP \times SI), and undefined breed (UDB) lambs according to the forage:concentrate ratio in the diet

Variable (g/100 g)	SI		DP \times SI		UDB		Significance		
	20:80	50:50	20:80	50:50	20:80	50:50	D	G	D \times G
Moisture	73.9 \pm 1.6Ab	75.3 \pm 1.5Aa	72.3 \pm 0.7Bb	74.2 \pm 0.6Aa	73.4 \pm 0.6AB	72.6 \pm 1.2B	0.040	0.002	0.001
Lipid	2.2 \pm 1.0B	2.1 \pm 0.5B	3.8 \pm 1.2A	3.6 \pm 0.7A	3.9 \pm 0.7A	3.1 \pm 1.3AB	0.168	0.001	0.156
Protein	26.6 \pm 1.1a	24.0 \pm 1.4Bb	26.2 \pm 1.2	25.3 \pm 0.6A	27.2 \pm 0.8a	23.1 \pm 0.6Bb	0.003	0.253	0.002
Ash	0.8 \pm 0.07Bb	1.0 \pm 0.05Aa	1.2 \pm 0.05Aa	1.0 \pm 0.04Ab	0.9 \pm 0.06Bb	1.1 \pm 0.09Aa	0.001	0.002	0.001

a, b - means followed by different letters are significantly different by Tukey's test, according to the diet.

A, B - means followed by different letters are significantly different by Tukey's test, according to the genotype.

Table 6 - Composition and relationship between the fatty acids in the meat from Santa Inês (SI), Dorper \times Santa Inês (DP \times SI), and undefined breed (UDB) lambs according to the forage:concentrate ratio in the diet

Fatty acid (g/100 g)	Forage:concentrate ratio (D)		Genotype (G)			Significance		
	20:80	50:50	SI	DP \times SI	UDB	D	G	D \times G
C14:0 myristic	1.88 \pm 1.6	2.18 \pm 1.7	2.90 \pm 1.0	2.15 \pm 2.0	0.70 \pm 0.5	0.259	0.452	0.357
C16:0 palmitic	15.66 \pm 2.4	14.63 \pm 2.5	16.06 \pm 2.6	14.34 \pm 2.2	15.03 \pm 2.3	0.269	0.154	0.263
C16:1 palmitoleic	2.20 \pm 0.5	2.56 \pm 1.0	2.72 \pm 1.1	2.12 \pm 0.6	2.31 \pm 0.5	0.273	0.353	0.258
C17:0 heptadecanoic	0.45 \pm 0.1b	0.60 \pm 0.1a	0.45 \pm 0.1ab	0.59 \pm 0.1a	0.43 \pm 0.0b	0.034	0.019	0.156
C18:0 stearic	24.78 \pm 1.8	26.11 \pm 1.9	25.30 \pm 2.5	25.59 \pm 1.9	25.46 \pm 1.4	0.568	0.467	0.472
C18:1 oleic	51.45 \pm 2.8	50.23 \pm 3.8	49.20 \pm 3.6	51.36 \pm 3.0	51.95 \pm 2.8	0.371	0.378	0.254
C18:2 linoleic	3.77 \pm 1.0	3.93 \pm 1.0	4.01 \pm 1.3	3.80 \pm 0.9	3.72 \pm 0.7	0.159	0.153	0.025
C18:3 linolenic	0.68 \pm 0.4	0.82 \pm 0.3	0.91 \pm 0.4	0.79 \pm 0.4	0.58 \pm 0.2	0.464	0.752	0.566
C20:0 arachidic	0.96 \pm 0.3b	1.23 \pm 0.4a	1.32 \pm 0.5a	1.02 \pm 0.3ab	0.95 \pm 0.3b	0.002	0.001	0.010
SFA ¹	41.96 \pm 1.6	42.30 \pm 2.5	42.60 \pm 1.9	42.12 \pm 2.0	41.70 \pm 2.3	0.357	0.253	0.352
MUFA ¹	53.65 \pm 2.8	52.62 \pm 3.3	51.65 \pm 3.0	53.48 \pm 2.8	54.26 \pm 3.3	0.571	0.778	0.567
PUFA ¹	4.47 \pm 1.1	4.64 \pm 0.9	4.72 \pm 1.1	4.63 \pm 1.0	4.32 \pm 0.8	0.353	0.259	0.262
UFA ¹	57.87 \pm 1.8	57.34 \pm 2.0	55.90 \pm 3.1	57.73 \pm 2.2	58.24 \pm 2.2	0.866	0.652	0.754
MUFA/SFA	1.28 \pm 0.11	1.26 \pm 0.14	1.23 \pm 0.11	1.28 \pm 0.12	1.31 \pm 0.14	0.558	0.278	0.465
PUFA/SFA	0.11 \pm 0.03	0.11 \pm 0.02	0.11 \pm 0.03	0.11 \pm 0.04	0.10 \pm 0.03	0.456	0.459	0.654
UFA/SFA	1.38 \pm 0.1	1.33 \pm 0.2	1.29 \pm 0.2	1.38 \pm 0.1	1.40 \pm 0.1	0.559	0.758	0.558
DFA ²	82.60 \pm 2.8	82.44 \pm 2.9	80.72 \pm 3.3	83.24 \pm 2.1	83.60 \pm 2.1	0.852	0.556	0.774
ω 6/ ω 3	0.19 \pm 0.11	0.21 \pm 0.06	0.21 \pm 0.09	0.22 \pm 0.11	0.16 \pm 0.04	0.478	0.458	0.579
AI ³	0.30 \pm 0.09	0.33 \pm 0.12	0.37 \pm 0.13	0.31 \pm 0.11	0.27 \pm 0.05	0.259	0.152	0.261

¹ Sum of saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA), and unsaturated fatty acids (UFA).

² Desirable fatty acids = MUFA + PUFA + C18:0.

³ Atherogenicity index = [(C12:0 + (4 \times C14:0) + C16:0)]/the sum of unsaturated fatty acids.

a, b - means followed by different letters are significantly different, as determined using Tukey's test.

would have a more pronounced hypercholesterolemic effect among the saturated fatty acids. However, the meat from the lambs evaluated in this study showed a considerably reduced percentage of myristic acid in contrast to the high values observed by Díaz et al. (2005) in the meat of sheep produced in Spain, UK, Germany, and Uruguay.

Among the saturated fatty acids, only heptadecanoic (C17:0) and arachidic acids (C20:0) differed ($P < 0.05$) between the treatments. For C20:0, based on the interactions observed, its concentration was higher in the meat from the Santa Inês lambs fed the diet containing the 50:50 forage:concentrate ratio. This behavior would be expected for the other long-chain fatty acids based on the diets provided; however, likely due to the greater variability in the areas of these fatty acids in the chromatograms, no significant differences were observed ($P > 0.05$).

Discussion

The Dorper × Santa Inês lambs were characterized by higher carcass fat levels, followed by the lower percentages of the UDB and Santa Inês lambs, most likely due to the greater precocity of the crossbred Dorper lambs compared with the other genotypes studied (Madruga et al., 2006). According to Furusho-Garcia et al. (2004), crossing Santa Inês lambs with high-meat-producing breeds has been suggested as an important tool for increasing meat production and improving productive efficiency. According to Barros et al. (2005), Dorper × Santa Inês lambs finished in a feedlot system are an economically viable management practice in the Northeast region of the country; however, in this study, the lambs from this genetic group were not exceptional ($P > 0.05$) compared with the animals from the other groups surveyed.

Based on a relatively slow pH reduction in the first 45 min after slaughter (Table 4), an appropriate reduction in the glycolysis rate in the *post mortem* period was expected. Under normal conditions, the pH gradually declines after slaughter from values near neutrality in the living animal to 5.5 in the meat (Apple et al., 1995).

The initial pH (0 h), the pH 45 min after slaughter and the final pH (24 h) did not differ between the genetic groups; however, the pH_{0h} evaluated for the carcasses of lambs fed diets with the 50:50 forage:concentrate ratio was higher than that of the carcasses of animals fed the 20:80 forage:concentrate ratio. However, it is worth noting that such differences did not induce noticeable changes in the physical and chemical qualities of the meat.

The lower fat concentration in the carcass of the animals fed a high forage level (Table 3) more effectively favored

thermal energy conduction through the muscle tissues due to lower lipid barriers for heat dissipation (Oliveira et al., 2004), which was reflected in the higher temperatures at the time of evaluation. Furthermore, the meat with higher lipid levels (i.e., meat from Dorper × Santa Inês, 35.8 °C; and UDB, 35.2 °C) was characterized by greater temperature conservation and, therefore, higher temperature upon assessment 45 min after slaughter (Table 4). Oliveira et al. (2004) reported that the speed of biochemical changes in muscles during the *post-mortem* period (i.e., glycolysis and subsequent pH reduction) was faster at higher temperatures. Madruga et al. (2005) reported higher lipid concentrations in the meat from Santa Inês lambs fed diets supplemented with waterweed (6.93 g/100 g), pineapple stubble (8.09 g/100 g), and corn silage (8.38 g/100 g).

The absence of a significant effect of the diet on the lipid concentrations of sheep meat may be possibly due to the intermediate maturation, which has been observed in muscle tissue (Table 5), particularly in the *longissimus* muscle compared with fat deposits (Atti and Mahouachi, 2009).

Although the diets were isoproteic, the diets with a lower forage percentage may have led to higher synthesis of microbial protein and, consequently, greater muscle tissue production in the lambs, perhaps due to the varying proportions of other compounds, which resulted in different slaughter ages (Misra et al., 2006).

Generally, diets with higher forage contents yield higher acetic acid levels in the rumen environment compared with diets that contain higher concentrate percentages. At the cellular level, once absorbed by the ruminant, this acid is rapidly metabolized into acetyl CoA and can follow different metabolic pathways, including pathways that contribute to long-chain fatty acid synthesis for body lipids (Van Soest, 1994). These conditions may have favored the differences in the C17:0 and C20:0 percentages in the meat from lambs fed the different forage:concentrate ratios (Table 6). Values similar to those reported herein were found by Madruga et al. (2006) and Costa et al. (2009) in meat from Santa Inês and Dorper × Santa Inês lambs.

The forage intake generally reduces the transfer of dietary polyunsaturated fatty acids into ruminant muscle tissue because fiber stimulates ruminal activity and the biohydrogenation process (Lee et al., 2006). However, the reduced diet particle size promoted by the combination of the haying and grinding techniques used in this study likely increased the rate of food passage through the rumen (Bezerra et al., 2004). These conditions decreased biohydrogenation, which favors unsaturated fatty acid deposition in the meat, perhaps explaining the lack of differences ($P > 0.05$) in the levels of these fatty acids in

the meat from lambs supplemented with both forage: concentrate ratios (57.8×57.3 g/100 g).

Generally, diets with high concentrate levels have a lower pH in the rumen environment and modified microbial flora, with a lower number of protozoa and a higher number of bacteria that produce lactate (Owens et al., 1998), which promotes the accumulation of the C18:2 isomer (trans -10, cis-12) due to incomplete biohydrogenation. This isomer inhibits the $\Delta 9$ -desaturase enzyme (Baumgard et al., 2001), which inhibits the oleic acid (C18:1 trans 11) desaturation process in the muscle, resulting in its subsequent conversion to linoleic acid (C18:2 cis -9, trans 11), the major conjugated linoleic acid (CLA) isomer that exhibits anticarcinogenic properties. In this study, the percentage of linoleic acid was higher in the meat from Santa Inês lambs fed the diets containing 500 g/kg forage compared with the genotypes studied due to the interaction shown in Table 6.

The isocaloric substitution of saturated fatty acids for polyunsaturated fatty acids in the human diet reduces the total cholesterol and plasma low-density lipoprotein cholesterol (LDL) levels; however, excessive polyunsaturated fatty acid intake also reduces the cholesterol linked to high-density lipoproteins (HDL). Among the fatty acids, $\omega 3$ (C18:3) reduces hepatic triglycerides synthesis by reducing hepatic synthesis of very low-density lipoproteins (VLDL) and may reduce blood viscosity as well as promote greater endothelial relaxation and anti-arrhythmic effects (Sposito et al., 2007).

The percentage of C18:1 in the lamb meat ranged from 49.20 to 51.95 g/100 g of total fatty acids, making it the most representative fatty acid, as confirmed by Costa et al. (2009). According to these authors, monounsaturated fatty acids, mainly C18:1, have the same effect on cholesterolemia without lowering the HDL-c plasma levels and causing lipid oxidation (Sposito et al., 2007), which exemplifies the positive effects of diets with high percentages of these fatty acids.

The saturated fat levels in the meat from the SI and DP \times SI lambs represented 42 g/100 g of the total fatty acids; however, 25 g/100 g of these fatty acids were C18:0, which is a null effect. Currently, the ideal, beneficial diet for human health includes polyunsaturated/saturated fatty acids at a ratio above 0.4 (Wood et al., 2003), which is necessary to prevent diseases associated with saturated fat intake. The average result (0.11) obtained in this study is below this minimum recommended value, but the high C18:1 levels show a positive aspect on the meat quality of these lambs.

Determining these ratios or proportions have been suggested as a way to assess the risk that food can increase blood cholesterol levels. The meat from the three genetic

groups surveyed had a 0.2 $\omega 6$: $\omega 3$ ratio (Table 6), which is 50% less than the maximum recommended value (4.0) to eliminate the dietary risk of developing coronary heart diseases (Wood et al., 2003). The percentage of desirable fatty acids (DFA) is determined by the sum of the UFA plus stearic acid, and the atherogenicity index (AI) is defined as the sum of the lauric acid (C12:0), palmitic acid (C16:0), and four times the proportion of myristic acid (C14:0) amounts, divided by the total unsaturated fatty acids. DFA has been suggested as an indicator of dietary risk for cardiovascular disease due to the intake of certain meats. The percentages of DFA (31.5%) and AI (0.32) were more satisfactory than those obtained by Costa et al. (2009), who investigated the meat from Morada Nova, SI, and SI \times DP lambs fed similar diets.

Conclusions

Feedlot lamb diets with high concentrate levels favor production of meat with higher lipid levels, particularly for the Dorper \times Santa Inês and undefined-breed genotypes. Regardless of the genotype and diet, the meat lipid profiles, based on the unsaturated fatty acid and desirable fatty acid levels, show that this product is of satisfactory quality for the consumer market.

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