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Muscle fiber area, collagen and fatty acid profile of goat meat

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Abstract. The present study was conducted to evaluate the effect of breed group, slaughter weight, and sex on the muscle fiber area, collagen percentage, and fatty acid profile of goat kid meat. A total of 74 animals (Alpine; ½ Boer + ½ Alpine; ½ Nubian + ½ Alpine; ¾ Boer + ¼ Alpine; and three-cross [¼ Boer + ¼ Alpine + ¼ Nubian]) were used. One animal was selected per slaughter weight, sex, and breed group to evaluate the fatty acid profile. One-third of the animals was slaughtered upon reaching 25, 30, and 35 kg. The experimental design was completely randomized and Tukey's test was used to compare the means. There was no difference for muscle fiber area or collagen percentage between the tested parameters, indicating similar texture of the meat from the evaluated animals. Sex influenced the C14:0, C16:0, C16:1, C20:3n3, C20:5n3, and omega-3 fatty acids, whereas breed group influenced the levels of C18:2n6c, C20:0, C24:1, and CLA cis. Slaughter weight did not affect the fatty acid profile, but the sex × slaughter weight interaction influenced the levels of C18:0, unsaturated fatty acids, and the polyunsaturated/saturated fatty acid ratio. Male and heavier animals produce the best meat in terms of nutrition.
Keywords: breed, Capra hircus, fat, muscle, quality, tenderness

Introduction

According to FAOSTAT (2017), evidence indicates that the goat meat market in Brazil is growing. Nevertheless, because the acceptance of this meat is strongly influenced by local customs and preferences, it is impossible to determine a

universal standard for goat meat quality (Argüello et al., 2005). The texture of meat is known to be important for its acceptance by consumers, and this qualitative aspect is influenced by a set of characteristics related to muscle fibers, connective tissue, and fat composition.

Muscle fibers are surrounded by an extracellular matrix in which collagen participates. Despite being present in low quantities, this protein influences meat tenderness (Bailey, 1985). As the animal develops, its muscle fibers enter the phase of hypertrophy and their area increases with slaughter weight. This increase in area may be related to the increase in hardness of meat (Crouse et al., 1991), since, as the animal grows (age/weight), the number of cross-links also changes, making its meat more resistant to cutting and chewing (Arima, 2006). According to Flores & Bermell (1988), male animals tend to have a higher collagen content than females. In addition to a pleasant texture, consumers are seeking foods that are beneficial to health. This has increased the demand for low-fat meats, as meat is one of the main sources of dietary lipids and is related to cardiovascular diseases due to its considerable levels of saturated fatty acids.

However, lipids are essential, as they participate in several biological functions of the body (Mancini-Filho, 1996). Therefore, the supply of lipids through the diet should not be fully suppressed, but rather controlled, and it is fundamental to know the fatty acid profile of meat to understand the properties of this food for the consumer (Santos Filho et al., 2001).

Given this scenario, the present study was conducted to examine the effect of breed group, slaughter weight, and sex on muscle fiber area, collagen content, and fatty acid profile of goat meat, in view of the demands of the consumer market for soft, quality meat.

Materials and Methods

Experiment site

The experiment was carried out in Botucatu-SP, Brazil; at the geographic coordinates of 22O53`08`` S and 48O26`42`` W, 837 m asl, after approval by the local ethics committee (approval no. 139/2009 - CEUA).

A total of 74 goat kids from five breed groups were used, namely: Alpine; ½ Boer + ½ Alpine; ½ Anglo Nubian + ½ Alpine; ¾ Boer + ¼ Alpine; and the three-cross ¼ Boer + ¼ Alpine + ½ Anglo Nubian. The animals reached the pre-established slaughter weights of 25, 30, and 35 kg at the average ages of 145, 168, and 193 days, respectively.

After birth, the kids received necessary care and colostrum, which was offered individually twice daily, for three days. After colostrum supply, goat milk feeding became collective and was provided artificially twice daily until the 10th day. From the 11th day, milk was provided only once daily, in the morning. The amount of milk supplied daily per kid did not exceed 1.5 L, and weaning occurred at 60 days of age. From the second week onward, the goats had a mash concentrate available ad libitum.

The animals began the experiment at an average age of 28 days, when they were housed in 10 collective pens according to breed group and sex. Then, they started to receive an experimental diet containing 70% concentrate and 30% bermudagrass hay. The concentrate, which was formulated according to the NRC (1981) requirements to provide a daily gain of 150 g, was composed of 49% maize, 38% soybean meal, 10% cottonseed meal, 2% limestone, and 1% mineral mixture. This diet would ensure the following levels of chemical components: 90.64% dry matter, 21.35% crude protein, 2.34% ether extract, 5.41% ash, 56.03% nitrogen-free extract, 70.71% total digestible nutrients, 45.85% neutral detergent fiber, and 21.97% acid detergent fiber.

The kids were weighed weekly, in the morning, before the milk feeding. One-third of the animals in each group were slaughtered on the week they reached the average weights of 25, 30, and 35 kg, to evaluate meat traits.

Upon reaching the pre-established slaughter weight, the animals were deprived of solid feed for 24 h and then weighed to determine slaughter weight. Next, they were slaughtered in a commercial abattoir, following the normal flow of the establishment. After evisceration, the carcasses were refrigerated at 4 °C for 24 h and, subsequently, samples of the semitendinosus muscle were collected, frozen “in loco” in n-Hexane, cooled in liquid nitrogen at -196 °C, and stored in a freezer at -80 °C for later determination of muscle fiber area and collagen percentage. To evaluate the fatty acid profile, 30 animals were selected and the longissimus lumborum muscle was removed from the respective carcasses, wrapped in aluminum foil, and frozen.

Determination of muscle fiber area and collagen content

To determine the muscle fiber area, slides were prepared with 10-µm histological sections obtained in a cryostat microtome at -20 °C, which were subjected to Hematoxylin-Eosin staining, as described by Lillie (1954). The cross-sectional area of approximately 200 fibers of each animal was then measured using an Image Analysis System (Leika Qwin).

In the same frozen sections of muscle, cytochemical staining was performed to study the collagen fibers, using the Picrosirius-Hematoxylin and reticulin techniques. The amount of collagen was measured in 10 randomly chosen fields of the slide, each with an area of 68,233.16 µm², and the result was expressed as a percentage of area.

Samples of the longissimus lumborum muscle were thawed and the subcutaneous fat and connective tissue were removed. Then, the samples were homogenized in a processor/crusher until a homogeneous mass was obtained, before lipid profile analysis.

The lipids were extracted with chloroform/methanol (2:1), following the methodology of Folch et al. (1957). Fatty acid methyl esters were analyzed in a gas chromatograph (Shimadzu, model GC - 17A) equipped with a flame ionization detector, a split/splitless injector, and fused silica capillary column containing polyethylene glycol as stationary phase (DB- Wax, 60 m × 0.25 mm, J&W Scientific), under the following chromatographic conditions: injector temperature of 230 °C. The initial column temperature was set at 80 °C for 2 min at a rate of 3 °C per minute, which was then raised to 180 °C at a rate of 30 °C/min, held for 30 min, raised to 200 °C at a rate of 3 °C/min, and held for 108 min. The detector temperature was 240 °C; helium was used as the carrier gas, with a total flow of 8.0 mL/min; and the sample split ratio was 1:50. To identify the 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 each acid area over the total fatty acid area (%), following the methodology of Hartman & Lago (1973).

Statistical analysis

The traits of muscle fiber area and collagen percentage were analyzed considering the five breed groups, three slaughter weights, two sexes, and their interactions, in a completely randomized design (Model I). Tukey's test ($P<0.05$) was applied for mean comparison.

For the fatty acid profile, the five breed groups, three slaughter weights, two sexes, and the slaughter weight × sex interaction were considered, in a completely randomized design (Model II). Means were compared using Tukey's test ($P<0.05$). Because the data did not show normal distribution, they were transformed (by adding 1 and extracting the square root).

MODEL I:

$$Yijkl = \mu + SWi + BGj + Sk + SW * BGij + SW * Sik + BG * Sjk + SW * BG * Sijk + eijkl$$

MODEL II:

$$Yijkl = u + SWi + BGj + Sk + SW*Sik = eijkl,$$

in which Yijkl = trait observed in animal l, of sex k, of breed group j, and evaluated/slaughtered at weight i; □= constant inherent to the data; SWi = effect of slaughter weight/evaluation i (i = 1: 25, 2: 30, and 3: 35 kg); BGj = effect of breed group j (j = 1: Alpine; 2: ½ Boer × Alpine; 3: ½ Anglo Nubian × Alpine; 4: ¾ Boer × ¼ Alpine; and 5: three-cross [¼ Alpine × ¼ Anglo Nubian × ½ Boer]); Sk = effect of sex k (k = 1: male; 2: female); SW*BGij = interaction effect between slaughter weight/evaluation i and breed group j; SW*Sik= interaction effect between slaughter weight/evaluation i and sex k; BG*Sjk = interaction effect between breed group j and sex k; SW*BG*Sijk = interaction effect between slaughter weight i, breed group j, and sex k; and eijkl = error associated with observation Yijkl ~ NID (0;).

The correlation coefficient (r) between muscle fiber area and collagen area percentage was calculated using the formula below:

$$\rho_{XY} = \frac{\sigma_{XY}}{\sqrt{\sigma_X^2 \sigma_Y^2}} \ ,$$

in which = correlation coefficient between the traits of X and Y; = sum of the product of X and Y; = square sum of X; and = square sum of Y.

The correlation coefficient was tested using the t-test at the 5% probability level:

$$t = \frac{\rho}{\sqrt{1-\rho^2}} \sqrt{n} \ ,$$

in which n = number of degrees of freedom of the residual.

Statistical analyses were performed in SAEG software version 8.0 (UFV, 2000) was used.

Results and discussion

The traits of muscle fiber area and collagen percentage measured in the semitendinosus muscle did not differ between the breed groups, slaughter weights, sexes, or in response to their interactions. Muscle fiber area and the percentage of collagen area showed overall means of 2,488 μm² and 6.60%, respectively (Table 1).

The percentage of collagen in goat meat did not differ between genders and slaughter weights (Table 2). The correlation value between muscle fiber area and collagen percentage was -31.21. Although significant ($P<0.01$), it is considered low, indicating that both traits are independent.

Thirty-seven fatty acids were identified in the general fatty acid profile of the longissimus lumborum muscle from the male and female goats of the different breed groups and slaughter weights used in this study (Table 3). The most abundant fatty acids in the goat meat were oleic acid (C18:1n9c; 55.15%), palmitic acid (C16:0; 20.45%), and stearic acid (C18:0; 5.5%).

The proportions of lauric (C14:0), palmitic (C16:0), palmitoleic (C16:1), and eicosapentaenoic (C20:5n3) acids differed between the sexes (Table 4). Linoleic (C18:2n6c), arachidic (C20:0), and nervonic (C24:1) acids showed differences between the breed groups (Table 5). There was a significant sex × slaughter weight interaction effect for stearic acid (C18:0) (Table 6).

Males showed higher levels of palmitoleic (C16:1), eicosatrienoic (C20:3n3), eicosapentaenoic (C20:5n3), and ω3 acids and lower levels of myristic (C14:0) and palmitic (C16:0) acids than females.

Linoleic (C18:2n6c) and arachidic (C20:0) acid levels (Table 7) were higher in the Alpine goats than in the ¾ Boer + ¼ Alpine animals, and the latter showed no differences from the other breed groups. The C24:1 fatty acid content was highest in the three-cross animals and lowest in the ½ Alpine +

½ Anglo Nubian and ¾ Boer + ¼ Alpine groups. The Alpine and ½ Boer + ½ Alpine breed groups did not differ from the others in the level of this fatty acid.

The meat from the animals used in this study (Table 6) showed higher proportions of monounsaturated fatty acids (MUFA), which averaged 62.28%, followed by saturated fatty acids (SFA), with an average of 32.49%, which did not differ between the studied factors. However, polyunsaturated fatty acids (PUFA), whose overall mean was 3.97%, were affected by the sex × slaughter interaction (Table 7).

There was no difference in the amounts of ω-3 and ω-6 between the studied parameters. These variables averaged 2.85 and 0.33, respectively.

In terms of CLA, the goat meat showed mean values of 0.06 and 0.04 for the CLA cis and CLA trans isomers, respectively, with the former being significant for the breed groups (Table 7).

There was a sex × slaughter weight interaction effect for stearic acid (C18:0), PUFA, and PUFA/SFA ratio (Table 7). In the females, stearic acid (C18:0) levels were higher at the slaughter weight of 25 kg than at 30 kg, and the latter did not differ from the result obtained at the weight of 35 kg.

At the slaughter weight of 25 kg, there was no difference for stearic acid (C18:0), PUFA, or PUFA/SFA between the sexes. However, as their weight increased (30 and 35 kg), the males showed higher ratios.

Because they are specialized in milk production and due to their thinner musculature, the Alpine goats were expected to have fibers with a larger area and in smaller number than animals of breeds specialized in meat production. This is because, according to reports of Rehfeldt et al. (2000), the postnatal growth rate of the individual muscle fiber is lower when there is a high number of fibers in the muscle and vice-versa, indicating that the number of muscle fibers is inversely correlated with muscle fiber area at the end of the intensive growth period. The cut of the semitendinosus muscle in the Alpine animals revealed a larger fiber diameter when compared visually with the ½ Boer × ½ Alpine goats. However, there was no difference for this parameter (Figure 1), which may be associated with the fact that the animals were still young and did not have their musculature fully developed.

Although there was no difference in collagen content in this study, Sainz & Araújo (2001) stated that several traits of meat, including connective tissue accumulation, are influenced by age, genotype, sex, use of anabolic steroids, and the diet (Figure 2).

The lack of differences between the sexes for muscle fiber area is in agreement with the data described by Dias (2009) for ½ Dorper Santa × ½ Inês lambs. Similarly, collagen percentage showed no significant difference between the sexes (Table 2).

In physiological terms, male animals usually show a higher growth speed and greater muscle tissue deposition than females (Santello et al., 2010). This is attributed to testosterone, which stimulates muscle cell hypertrophy (Bhasin et al., 2003). Again, the absence of differences in the present study may be associated with the young age of the animals used, with the males still producing low levels of this hormone.

There was no difference for muscle fiber area between the studied slaughter weights. This finding is contrary to the reports of Argüello et al. (2005), who compared the muscle fiber area of three muscles in Majorera goats slaughtered at 6 and 10 kg. These researchers observed increases of 28.55%, 39%, and 40.2% in the muscle fiber area of the longissimus dorsi, semimembranosus, and triceps brachii muscles, respectively. In an experiment with ½ Dorper ± ½Santa Inês lambs slaughtered at 28, 32, and 36 kg, Dias (2009) also found an increase in the semitendinosus muscle fiber area as the slaughter weight increased. Yamaguchi et al. (1993) explained that it is the weight of an animal, and not its age, that determines its muscle fiber area, and this increase is attributed to muscle hypertrophy.

The percentage of collagen area did not differ between the slaughter weights. Studies with goats that demonstrate the influence of slaughter weight on collagen content are scarce. Gonzalez et al. (1983) and Owen et al. (1983) reported that the slaughter of castrated male Criollo goats weighing 24 kg, instead of 8 kg, had no negative effect on the investigated physical or chemical traits (including collagen). Similarly, Argüello et al. (2005) found no difference in the amount of collagen in the meat of goats slaughtered at different weights.

The general fatty acid profile of the longissimus lumborum muscle of the goat kids, which revealed greater abundance of oleic acid (C18:1n9c) and palmitic acid (C16:0), is in agreement with that described by Madruga et al. (2008) in the meat of Saanen goats receiving different levels of concentrate feed. The content of the most abundant fatty acids in goat meat also followed the same order of data reported by Grande et al. (2009) in the meat of ¾ Boer + ¼ Saanen goats fed diets with oilseeds and also by Banskalieva et al. (2000), in a review on the fatty acid composition of goat muscle and fat tissue.

Teitelbaum & Walker (2001) reported that oleic acid appears to be beneficial in reducing total plasma cholesterol and LDL cholesterol in humans. This is because the Δ9-desaturase enzyme catalyzes the insertion of a double bond between carbon atoms 9 and 10, converting stearic acid to oleic acid, which is an unsaturated fatty acid. In view of the result obtained for this fatty acid in this study, goat meat proves to be an excellent option as a healthy meat considering the cholesterol aspect, which greatly concerns the population.

Mahgoub et al. (2002) found lower levels of palmitic (C16:0) among other fatty acids in males,

which is in agreement with the current results. Likewise, Johnson et al. (1995) reported a higher palmitoleic acid (C16:1) content in males. Contrary to the present findings, Banskalieva et al. (2000) reported that females have a lower myristic acid (C14:0) content in their meat than males.

No reports were found on eicosatrienoic acid (C20:3n3), eicosapentaenoic (C20:5n3) acid or ω3 fatty for data comparison. According to Banskalieva et al. (2000), the differences in fatty acid composition between sexes described in the literature are still inconsistent, and the effects of sex on fatty acid composition in different livestock species are small and can be explained in terms of differences in total fat content.

Male animals show greater muscle and less adipose tissue deposition when compared with females. According to Bhasin et al. (2003), this characteristic is attributed to testosterone, which acts on stem cells inhibiting the differentiation of the adipogenic lineage.

Dhanda et al. (2003) studied the fatty acid profile of six breed groups (Boer × Angora; Boer × Feral; Boer × Saanen; Feral × Feral; Saanen × Angora; and Saanen × Feral) and found differences between them for all fatty acids, except myristic (C14:0) and stearic (C18:0). However, the authors pointed out that there are few publications comparing the fatty acid profile of different goat breed groups, thus validating the importance of the data obtained in this study.

The obtained data on the proportions of monounsaturated and saturated fatty acids are similar to those published by Rhee et al. (2000), Hashimoto et al. (2007), and Grande et al. (2009).
The PUFA/SFA ratio was also influenced by the sex × slaughter weight interaction and had an overall mean of 0.13, which is below the minimum of 0.45 recommended by the U.K. Department of Health for the total diet. In general, the PUFA/SFA ratio is lower in ruminants due to the biohydrogenation of unsaturated fatty acids from the diet by rumen microorganisms (French et al., 2000). In this process, because they are chemically more unstable and therefore do not pass through the bacterial membrane, unsaturated fats from the diet are hydrogenated by hydrogenase enzymes. Then, they are converted into saturated fats (Baldwin & Allison, 1983), resulting in a lower PUFA/SFA ratio. Although this process occurs, some unsaturated fatty acids in the diet pass intact through the rumen, being absorbed and deposited in the adipose tissue of the animal.

Foods with a PUFA/SFA ratio below 0.45 are considered undesirable to the diet because they induce an increase in blood cholesterol (Department of Health and Social Security, 1984). Dhanda et al. (2003) obtained PUFA/SFA values between 0.60 and 0.77 in six goat breed groups. Werdi Pratiwi et al. (2007) investigated the fatty acid profile of Feral goats slaughtered at different weights and observed values ranging from 0.1 to 0.3. Madruga et al. (2008) studied different levels of concentrate and obtained a variation from 0.10 to 0.13 for this ratio, whereas Grande et al. (2009) observed values between 0.14 and 0.23 in the meat of ¾ Boer + ¼ Saanen goats fed diets with different oilseed grains.
Unlike ω-3, the average ω-6 did not vary with the studied parameters. However, the proportions of 2.85 for ω-3 and 0.33 for ω-6 differ from the 0.83 and 8.43 obtained by Grande et al. (2009) for the respective acids. Although essential, high amounts of ω-6 may favor inflammatory processes that lead to arteriosclerosis, as there is a tendency to increase platelet aggregation (Young et al., 1998). Thus, small levels of this fatty acid in meat are desirable to establish an ω-6/ω-3 ratio less than 4.0 for the prevention of cardiovascular disease risks (Department of Health and Social Security, 1994). Accordingly, the value of 0.14 obtained for this ratio in this study, promotes the meat of the evaluated animals to the category of “potentially healthy”. Grande et al. (2009) obtained ω-6/ω-3 ratios between 5.52 and 10.85 in the longissimus lumborum muscle of goats fed diets with grains of different oilseeds.

Mendoza et al. (2005) stated that the differences in the CLA contents may be due to the relative size of the rumen-reticulum, differences in the ruminal microbiota and its metabolism, and also the intake and rumination behaviors.

Given the higher proportion of stearic acid in the females; the lack of difference for the other PUFA and PUFA/SFA between the sexes; and the fact that PUFA favor a reduction in the concentration of low-density lipoproteins (Oda, et al., 2004), the meat from male animals appears to be healthier for consumers.

Table 1. Muscle fiber area and percentage of collagen area in the Semitendinosus muscle of goats from different racial groups

Characteristics	Means	Alpine	½ Boer x ½ Alpine
Fiber (μm²)	2,488	2,888	2,307
Collagen (% area)	6.60	7.50	6.41

[1]Threcross = ¼ Boer + ¼ Alpine + ½ Anglo Nubian. VC: variation coeficient.

Table 2. Muscle fiber area and percentage of collagen in goat meat of different genders and slaughter weights

Characteristics	Means	Gender		Slaughter weight (kg)			VC
		Male	Female	25	30	35	
Fiber (μm²)	2,488	2,304	2,672	2,289	2,507	2,667	26.93
Collagen (% area)	6.60	6.15	7.04	7.05	6.17	6.57	23.34

Table 3. Averages of fatty acid composition in the *Longissimus lumborum* muscle of male and female goats, Alpine, ½ Boer + ½ Alpine, ¾ Boer + ¼ Alpine, ½ Anglo Nubian + ½ Alpine, ¼ Boer + ¼ Alpine + ½ Anglo Nubian, slaughtered with 25, 30 and 35 kg

Fatty Acid	Name	Means (%)	VC
C4:0	Butyric acid	0.10	5.18
C6:0	Capricious acid	0.09	7.57
C8:0	Caprylic acid	0.10	7.32
C10:0	Capric acid	0.04	2.67
C11:0	Undecanoic acid	0.13	4.06
C12:0	Lauric acid	0.07	5.97
C13:0	Tridecanoic acid	0.55	8.57
C14:0	Miristic acid	1.74	5.12
C14:1	Myristoleic acid	0.54	25.95
C15:0	Pentadecanoic acid	1.41	14.55
C15:1	Pentadecanoic acid cis 10	1.34	14.72
C16:0	Palmitic acid	20.45	4.99
C16:1	Palmitoleic acid	2.10	18.11
C17:0	Marginal acid	1.43	15.52
C17:1	heptadecanoic acid cis 10	0.46	10.02
C18:0	Stearic acid	5.50	10.20
C18:1n9t	Elaidic acid	0.66	15.40
C18:1n9c	Oleic acid	55.16	5.55
C18:2n6t	Linolelaidic acid	0.04	4.58
C18:2n6c	Linoleic acid	0.06	4.21
C18:3n6	γ- linolenic acid	0.08	8.33
C18:3n3	α- linolenic acid	0.14	7.88
C20:0	Arachidic acid	0.27	8.29
C20:1	Eicosanoidic acid cis 11	1.31	32.60
C20:2	Eicosadienic acid cis 11, 14	0.52	22.54
C20:3n3	Eicosatrienoic acid cis 11, 14, 17	2.33	18.13
C20:3n6	Eicosatrienoic acid cis 8, 11, 14	0.10	8.93
C20:4n6	Arachidonic acid	0.11	5.80
C20:5n3	Eicosapentanoic acid cis 5, 8, 11, 14, 17	0.29	5.63
C21:0	Heneicosanoic acid	0.05	4.93
C22:0	Behenic acid	0.05	4.54
C22:1n9	Eurucic acid	0.05	7.55
C22:2	Docosadienic acid cis 13, 16	0.19	8.19
C22:6n3	Docosahexaenoic acid cis 4, 7, 10, 13, 16, 19	0.08	6.37
C24:0	Lignoceric acid	0.17	6.16
C24:1	Nerve acid	0.11	4.41
C23:0	Tricosanoic acid	0.0009	0.14

Table 4. Fatty acid averages in goat meat according to gender

Fatty acids	Name	Means (%)	Gender	
			Male	Female
C14:0	Myristic acid	1.74	1.58 b	1.90 a
C16:0	Palmitic acid	20.45	19.19 b	21.75 a
C16:1	Palmitoleic acid	2.10	2.58 a	1.66 b
C20:3n3	Eicosatrienoic acid cis 11, 14, 17	2.33	2.90 a	1.80 b
C20:5n3	Eicosapentanoic acid cis 5, 8, 11, 14, 17	0.29	0.36 a	0.21 b
ω3	Omega 3	2.85	3.52 a	2.23 b

*Means followed by the same letter, in line, do not differ statistically at the 5% level according the Tukey test.

Tabela 5. Fatty acid proportions in goat meat as a function of racial group

Fatty acids	Name	Means	Racial Group				
			Alpine	½ Boer x Alpine	½ Anglo Nubian x ½ Alpine	¾ Boer x ¼ Alpine	Threecross[1]
C18:2n6c	Linoleic acid	0.06	0.18 a	0.03 ab	0.07 ab	0.01 b	0.03 ab
C20:0	Arachidic acid	0.27	0.53 a	0.30 ab	0.21 ab	0.11 b	0.20 ab
C24:1	Nerve acid	0.11	0.07 ab	0.17 ab	0.02 b	0.04 b	0.24 a

*Means followed by the same letter, in line, do not differ statistically at the 5% level according the Tukey test.
[1]Threecross = ¼ Boer + ¼ Alpine + ½ Anglo Nubian.

Table 6. Fatty acids proportion and nutritional quality indexes of the lipid fraction in the *Longissimus lumborum* muscle of male and female goats from different racial groups and slaughter weights

	(%)	Racial group					Slaughter weight (kg)			Gender		Effects			
Fatty acids		Alpine	½ Boer x Alpine	½ Anglo nubian x ½ Alpine	¾ Boer x ¼ Alpine	Three Cross	25	30	35	Male	Female	Racial group	Slaughter weight	Gender	G x SW
Saturated fatty acids	32.49	33.77	32.27	31.83	32.14	32.45	32.10	32.92	32.45	32.41	32.57	ns	ns	ns	ns
MUFA	62.28	59.68	62.35	63.32	64.00	62.10	62.79	61.87	62.20	61.27	63.31	ns	ns	ns	ns
PUFA	3.97	5.14	4.00	3.76	3.06	4.01	3.71	4.02	4.19	4.94	3.09	ns	ns	ns	*
ω3	2.85	3.28	3.39	2.76	2.28	2.59	2.82	2.94	2.78	3.52 a	2.23 b	ns	ns	*	ns
ω6	0.33	0.80	0.17	0.44	0.09	0.19	0.33	0.23	0.43	0.38	0.28	ns	ns	ns	ns
MUFA/SFA	1.92	1.77	1.93	1.99	2.0	1.92	1.97	1.88	1.92	1.90	1.95	ns	ns	ns	ns
PUFA/SFA	0.13	0.16	0.12	0.12	0.10	0.13	0.12	0.13	0.13	0.15	0.10	ns	ns	ns	*
ω6/ω3	0.14	0.29	0.06	0.16	0.10	0.12	0.13	0.12	0.18	0.14	0.15	ns	ns	ns	ns
CLA cis	0.06	0.18 a	0.03 ab	0.07 ab	0.01 b	0.03 ab	0.06	0.05	0.09	0.07	0.05	*	ns	ns	ns
CLA trans	0.04	0.11	0.01	0.07	0.004	0.002	0.04	0.01	0.06	0.05	0.03	ns	ns	ns	ns

*Means followed by the same letter, in line, do not differ statistically at the 5% level according the Tukey test.
CLA = Conjugated linoleic acid.
Threecross= ¼ Boer + ¼ Alpino + ½ Anglo Nubiano.

Table 7. Gender x slaughter weight interaction in the fatty acid profile of the *Longissimus lumborum* muscle of goats

Fatty acids	Name	Gender	Slaughter weight (kg)		
			25	30	35
C18:0	Stearic acid	Male	5.81 Aa	7.07 Aa	7.07 Aa
		Female	5.55 Aa	3.54 Bb	4.38 Bab
PUFA		Male	3.62 Aa	5.50 Aa	5.81 Aa
		Female	3.80 Aa	2.72 Ba	2.76 Ba
PUFA/SFA		Male	0.12 Aa	0.17 Aa	0.19 Aa
		Female	0.12 Aa	0.08 Ba	0.08 Ba

Averages followed by the same capital letter in the columns and lower-case letter in lines, do not differ statistically at the level of 5% by the Tukey test.

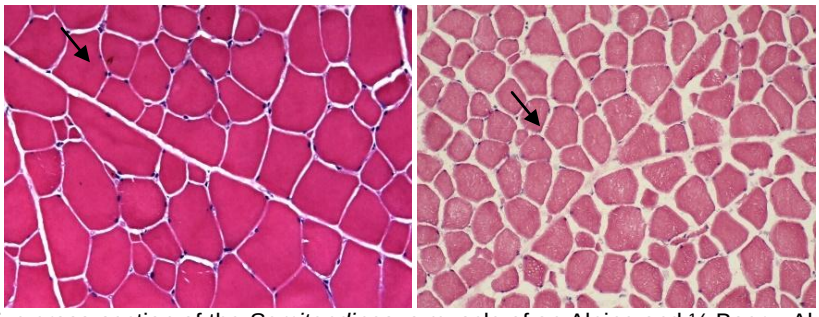

Figure 1. Illustrative cross-section of the *Semitendinosus* muscle of an Alpine and ½ Boer x Alpine, respectively, showing the muscle fibers.

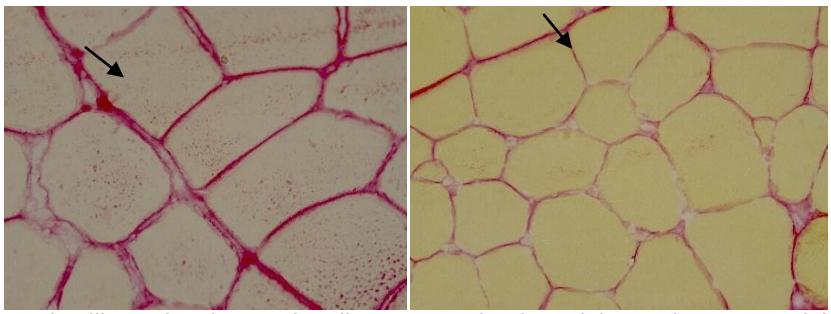

Figure 2. Cross section illustrating the Semitendinosus muscle of an Alpine and ½ Boer x Alpine, respectively, showing collagen.

Conclusion

Breed group, slaughter weight, and sex do not influence the muscle fiber area or collagen percentage of goat meat and, consequently its tenderness. Therefore, regardless of sex or breed group, the slaughter of heavier animals—which is interesting for farmers, as they will produce larger carcasses and be better remunerated—can be adopted without major qualitative changes to the meat.

The fatty acid profile of meat is influenced by breed group, slaughter weight, and sex. Male and heavier animals have healthier meat in terms of fatty acids, which may be more interesting for the consumer market.

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