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Original

Effect of genotype, finishing system, and sex on physiochemical characteristics of goat meat

Efeito do genótipo, do sistema de terminação e do sexo, sobre as características físico-químicas da carne de cabritos

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Abstract

Seventy-eight kids of both sexes and five genotypes were used: Alpine, ½ Boer + ½ Alpine (½ BA), ¾ Boer + ¼ Alpine, ½ Anglo-nubian + ½ Alpine and "tricross" (½ Anglo-nubian + ¼ Boer + ¼ Alpine) with initial average weight of 14.1 ± 2.5. The objective was to evaluate the effect of genotype, finishing system, and sex on the physiochemical characteristics of goat meat. Finishing systems were: ST1 – kid + dam in pasture and ST2 – weaned kid and feedlot. Kids in ST1 were kept in an area with Panicum maximum cv. Tanzania, and after grazing, water and mineral salt/mix were fed ad libitum to the animals. The animals in ST2 were confined in collective pens distributed according to genotypes and received diet with 16% CP and 73% TDN. The values of pH, a* (red content), Cooking Loss (CL), and Ether Extract (EE) percentage were influenced by genotype. Values for red content (a*) and L* (brightness), CL and percentages of moisture, protein, EE, and ash were influenced by the finishing system. Longissimus dorsi muscle from animals ½ BA exhibited better physiochemical characteristics. For greater tenderness and higher percentages of fat, consumers should choose female kid goat meat.

Keywords: *chemical composition; goats; quality.*

Resumo

Foram utilizados 78 cabritos de ambos os sexos e de cinco genótipos: raça Alpina, ½ Boer + ½ Alpina, ¾ Boer + ¼ Alpina, ½ Anglo-nubiana + ½ Alpina e tricross (½ Anglo-nubiana + ¼ Boer + ¼ Alpina), com peso médio inicial de 14,1 ± 2,5 kg. Objetivou-se avaliar os efeitos do genótipo, do sistema de terminação e do sexo sobre as características físico-químicas da carne. Os sistemas de terminação foram constituídos: ST1 – cabrito + mãe em pasto e ST2 - cabrito desmamado confinado. Os cabritos do ST1 foram mantidos em piquetes formados com Panicum maximum cv. Tanzânia e os do ST2 receberam dieta completa com 16% PB e 73% NDT. Os valores de pH, a* (teor de vermelho), Perda de Peso ao Cozimento (PPC) e porcentagem de Extrato Etéreo (EE) foram influenciados pelo genótipo. Os teores de vermelho (a*) e L* (luminosidade), PPC e porcentagens de umidade, proteína, EE e cinzas foram influenciados pelo sistema de terminação. O músculo longissimus dorsidos animais ½ BA apresentou as melhores características físico-químicas. Se a preferência do consumidor for por uma carne mais macia e com maior teor de gordura, as fêmeas são mais indicadas.

Palavras-chave: *composição centesimal; caprinos; qualidade.*

1 Introduction

Goat meat presents a great market potential since it is characterized by a low intramuscular and subcutaneous fat content (BABIKER; EL KHIDIR; SHAFIE, 1990; JOHNSON et al., 1995, SHERIDAN; HOFFMAN; FERREIRA, 2003) indicating that it can be considered a nutritionally desirable alternative to red meat of other species (JOHNSON et al., 1995). However, in Southeast Brazil, its consumption is still limited due to low offer, lack of standardization of quality, and incentive deficiency.

In order to maintain high production and a high quality final product, a strategy would be exploring genetic diversity of goat species. Breeds with potential to increase profitability are those with heavier weights at maturity and genetic propensity for meat production, such as the Boer breed (SHRESTHA; FAHMY, 2007).

It is well know that goat genotype can have a significant effect on meat quality (DHANDA; TAYLOR; MURRAY, 2003; BESERRA et al., 2004; PRATIWI; MURRAY; TAYLOR, 2007; MADRUGA et al., 2008). In addition to genotype, animal performance and meat quality can be affected by the feeding system (TITI et al., 2000; SHERIDAN; HOFFMAN; FERREIRA, 2003).

The characteristics of meat from goats raised in intensive conditions have been studied more than those of goats raised in extensive conditions (BANSKALIEVA; SAHLU; GOETSCH, 2000; TSHABALALA et al., 2003).

According Del Campo et al. (2008), the challenge is to produce a finishing strategy to improve the product without modifying the peculiar characteristics acquired during extensive

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grazing conditions (low-cost production and healthy meat for human consumption) and without compromising the animal welfare or the environment. Finishing systems in cattle have been extensively studied over the years with varied results on carcass traits and meat quality. Many studies have compared the meat tenderness and color of animals from extensive systems to those fed concentrated diet (FRENCH et al., 2000; REALINI et al., 2004). Many other studies reported no differences in quality and acceptability in meat from animals finished on pastures and concentrates (FRENCH et al., 2001; VESTERGAARD et al., 2000). This variability in results indicates that further research is necessary to establish the reasons for these differences.

The objective of this work was to study the influence of genotype, finishing system, and sex on physiochemical characteristics of goat longissimus dorsi meat.

2 Material and methods

Seventy-eight goat kids of both sexes from five genotypes were used and were divided into two finishing systems (Table 1).

After birth, the goat kids were housed in pens together with their dams and were fed hay and concentrate ad libitum, while the dams had free access to pasture. After 60 days of age, they were divided into two finishing systems: ST1 – goat kid + dam in pasture and ST2 – weaned goat kid and feedlot.

Ten paddocks of approximately 550 m^2 established with Panicum maximum cv. Tanzania were used. The period of occupation of each paddock was of three days, with rest of 27 days. Each paddock had an automatic drinking fountain and a shadowed rest area of free access. Goat kids from finishing system 1 were kept on pasture from 9 AM to 5 PM; after the grazing period, they were housed in pens and were offered water and mineral salt ad libitum.

Animals of finishing system 2 were confined in 5 collective pens in according to genotype and had free access to water.

The complete diet offered ad libitum to animals of finishing system 2 was composed of 30% oat hay, 30% corn grain ground, 28% soybean meal, 8% wheat meal, 1% limestone, 1% dicalcium phosphate, and 2% mineral supplement. Goat kids received two daily meals, at 8 AM and 4 PM.

The specific mineral supplement for goats (amount.kg^{-1} of product) was composed of sulfur 200 g, magnesium 150 g, zinc 47210 mg, iron 27000 mg, copper 20000 mg, manganese 1200 mg, cobalt 1400 mg, iodine 1250 mg, and selenium 315 mg.

Chemical analysis of complete diet and forage was performed using the methods described by Silva and Queiroz (2006) and is presented in Table 2.

Goat kids slaughter occurred one week after they had completed 120 days of age. Animals were slaughtered in a commercial slaughterhouse after a 16 hours solid fasting. The average age was of 128.4 ± 7.9 days, and they were slaughtered and dressed following normal commercial procedures.

For analyses, samples of longissimus dorsi muscle were removed from the loins from the left half carcasses after separation of commercial cuts.

Muscle pH was measured through direct method using a pH meter (INGOLD-WTW-pH 91) with a glass electrode probe inserted in longissimus dorsi muscle in the lumbar area after storing the carcasses for a chilling period of 24 hours at 1-4 °C.

Color was measured 24 hours after slaughter using a portable colorimeter Minolta CR400. The meter was calibrated using a black and white tile. Color was expressed in terms of CIE values for lightness (L*), redness (a*), and yellowness (b*).

The water holding capacity was measured using the method described by Hamm (1960). WHC was expressed as percentage of drip loss, calculated as WHC% = (initial weight – final weight)/initial weight.

The same piece of muscle was used for shear force, color, and cooking loss measurements. Each piece of steak was placed in a plastic bag and cooked in a thermostatically controlled

Table 2. Chemical composition of complete diet and forage.

Chemical composition	Complete diet	Forage
Dry matter (%)	94.59	24.31
Mineral matter (%)	9.27	3.39
Crude protein (%DM)	16.47	12.91
Ether extract (%DM)	3.10	1.48
Total carbohydrates (%DM)[1]	70.82	82.22
Neutral detergent fiber (%DM)	25.14	66.46
Ácid detergent fiber (%DM)	15.17	40.93
Non fiber carbohydrates (%DM)[2]	38.14	15.22
Total digestible nutrients (%DM)[2]	73.77	66.34
Metabolizable energy(Mcal.kg^{-1} DM)[3]	2.66	2.39
Calcium (%DM)	1.72	0.85
Phosphorus (%DM)	0.45	0.45

[1]Obtained from the equation proposed by SNIFFEN et al. (1992). [2]Obtained from the equation proposed by NRC (2001). [3]Obtained from estimative of TDN and by the relations: 1 kg of NDT = 4.409 Mcal of DE and ME = 81.7% DE (NATIONAL…, 2001).

Table 1. Distribution of animals according to genotype, finishing system, and sex.

	Finishing system				
	Goat kid + dam in pasture (ST1)		Weaned goat kid and feedlot (ST2)		
Genotype	Male	Female	Male	Female	Total
Alpine	4	3	3	3	13
½ Anglo-nubian + ½ Alpine	4	3	5	3	15
½ Boer + ½ Alpine	4	3	3	4	14
¾ Boer + ¼ Alpine	3	6	4	5	18
"tricross"[1]	4	5	5	4	18
Total	19	20	20	19	78

[1]"tricross" - ½ Anglo-nubian + ¼ Boer + ¼ Alpine.

water bath at 85 °C for 45 minutes. Cooked samples were taken from the bag, dried with paper towel to remove excess surface moisture, and held at constant temperature. Cooking loss was evaluated by weight changes before and after cooking, expressed as percentage of the initial weight of the sample. (HONIKEL, 1998). A minimum of three samples with 1 × 1 × 2 cm were obtained from each steak (FRONING; BABJI; MATHER, 1978). Each sample was sheared perpendicular to the grain of the muscle fiber using a Warner-Bratzler shear blade coupled to a texturemeter (Texture Analyzer TA-XPLUS-30) with a triangular whole cut to determine the peak force (kgf.cm^{-2}) to shear the samples (AMERICAN..., 1995). An average shear force was calculated and recorded for each steak.

The chemical composition was determined using the procedures described by Association... (2000).

The experimental design for the determination of physiochemical characteristics was a 5 × 2 × 2 factorial with genotype, finishing system, and sex as dependent variables. Data were analyzed using statistical analyses and general linear models procedure in SAS (1999), according to the following model:

where: Y_{ijkl} = characteristic evaluated in animal l in terms of sex k, genotype j and submitted to finishing system i; μ = constant inherent to observations Y_{ijkl}; FS_i = effect of finishing system, where i = 1: goat kid + dam on pasture and 2: weaned goat kid and feedlot; G_j = effect of genotype j, where j = 1: Alpine breed, 2: ½ Boer + ½ Alpine, 3: ¾ Boer + ¼ Alpine, 4: ½ Anglo-nubian + ½ Alpine, 5: “tricross” (½ Anglo-nubian + ¼ Boer + ¼ Alpine); S_k = effect of sex k, where = 1: male and 2: female; $FS*G_{ij}$ = effect of interaction of finishing system i and genotype j; $FS*S_{ik}$ = effect of interaction of finishing system i and sex k ; $G*S_{kj}$ = effect of interaction of sex k and genotype j; e_{ijkl} = error associated to observation Y_{ijkl} $(0, \sigma^2_e)$.

3 Results and discussion

The effects of genotype, finishing system, and sex on parameters of final pH and color (L*, a* and b*) of goat kids longissimus dorsi muscle are shown in Table 3.

Mean values of final pH varied from 5.62 to 6.02, which are in accordance with data from the literature on goat meat: 5.97 to 6.32 (BESERRA et al., 2001), 5.96 to 6.03 (MADRUGA et al., 2005), and which corroborates the statement that pH of goat meat is higher than that of red meat of other species (LAWRIE, 2005).

Final pH was influenced by genotype, and the ½ AA and ½ BA animals presented higher values compared with other genotypes (Table 3). These results can be attributed to different responses of pre-slaughter handling stress for each genotype indicating that, possibly, the ½ AA and ½ BA animals were more susceptible to some type of pre-slaughter handling stress. According to Immonen, Ruusunen and Puolanne (2000), muscle glycogen is the main metabolic substrate responsible for post mortem lactic acid accumulation and thus for normal pH decrease. Results obtained in the present study are in accordance with those found by Swan et al. (1998), who evaluating physical and chemical properties of goat meat raised on pasture observed a final pH of 6.04 for animals of Boer breed and 5.78 for Boer × Cashmere crosses. Webb, Casey and Simela (2005) in a review article on goat meat quality suggest that the ultimate pH values are generally highly prone to stress.

The L* (lightness) value showed significant differences among the finishing systems studied. Animals in the feedlot finishing system had higher values (Table 3), which is consistent with those reported by Schroeder et al. (1980) that evaluated feedlot cattle meat and verified higher lightness values in the meat of those animals than those of animals finished on pasture. However, such values are not in accordance with other findings of Johnson and McGowan (1998), who found that the finishing system did not influence L* values.

The mean value for the a* (redness) was 12.20 and showed significant differences among the genotype and finishing system. ½ AA animals presented higher redness values compared with “tricross” animals. This result can be attributed to final pH value observed in ½ AA animals (6.02) when compared with “tricross” (5.58). According to Aberle et al. (1994), higher pH in 24 hours postmortem results in darker meat (higher redness). In the present study, the variation in redness (a*) value can be related to the capacity of genotype to influence proportion among the myoglobin forms (desoximyoglobin and oxymyoglobin). Similar to the findings in the present study, a significant effect of genotype on goat meat color has been reported by Monte et al. (2007) and Madruga et al. (2008).

Goat kids finished on pasture presented higher values of redness (a*) compared with those of feedlot animals, in accordance with Priolo, Micol and Agabriel (2001), who, in a review article on the effect of feeding systems based on grass on meat color, concluded that the meat of animals finished on pasture is darker (higher redness) than the meat of animals finished with concentrates, associated to high final pH. However, in the present study, the final pH of the two finishing systems was similar indicating that the differences are probably due to

Table 3. Means for pH, L* (lightness), a* (redness), and b* (yellowness), in *longissimus dorsi* muscle from goats, according to genotype, finishing system, and sex.

	Parameters			
	pH	L*	a*	b*
Genotype				
Alpina	5.62^{b}	36.93	12.30^{ab}	3.21
½ Anglo-nubian + ½ Alpine	6.02^{a}	36.10	12.60^{a}	2.76
½ Boer + ½ Alpine	5.89^{a}	37.31	11.76^{ab}	3.03
¾ Boer + ¼ Alpine	5.66^{b}	36.97	12.56^{ab}	3.13
“Tricross”	5.58^{b}	36.19	11.76^{b}	3.59
Finishing system				
Goat kid + dam on pasture (ST1)	5.77	35.56^{b}	12.47^{a}	2.98
Goat kid weaned and feedlot (ST2)	5.74	37.84^{a}	11.93^{b}	3.31
Sex				
Male	5.77	36.84	12.17	3.15
Female	5.74	36.56	12.23	3.14
Mean	5.75	36.70	12.20	3.14
Coefficient of variation	4.02	3.55	6.99	26.57

Means followed by different letter differ statistically by Tukey test ($p < 0.05$).

the more intense physical activity and iron concentration in the muscle of animals finished on pasture, in cattle meat, according to Vestergaard, Okabjerg and Henckel (2000). When evaluating the quality of lamb meat, Cañeque et al. (2003) observed darker meat in animals on pasture.

As show in Table 4, water holding capacity ranged from 22 to 30%, wich is within the normal range for goat meat (DHANDA; TAYLOR; MURRAY, 2003; TODARO et al., 2004), and showed significant differences among the genotypes. ¾ BA Animals presented lesser loss of nutritional value of meat due to the smallest amount of exudate. According to Hamm (1982), water holding capacity is caused, mainly, by water immobilization inside the miofibrilar system. The water holding capacity data, however, is in accordance with other findings of Kadim et al. (2003), who verified in Oman kid goat meat values of WHC in longissimus dorsi muscle from 33.3 to 41.0%.

Longissimus dorsi muscle from kid goats of Alpine breed had higher Cooking Loss (CL) compared with that of ½ BA and ¾ BA animals, and similar to that of ½ AA and tricross animals (Table 4). Cooking loss was influenced by water holding capacity and, as seen in Table 4, Alpine breed presented the lowest water holding capacity, and consequently they had greater volume of sarcoplasmic fluids and higher cooking loss. Kannan, Kouakou and Gelaye (2001) evaluated Spanish goats in pasture, fed supplemented diet, and slaughtered at 8 months, and they verified a CL of 14.2%. However, differences in cooking loss, observed by several authors, can be attributed to different cooking times and temperatures and final pH.

Longissimus dorsi muscle from animals finished on pasture had higher cooking loss than that of l. dorsi from feedlot goats (Table 4), probably due to greater volume of sarcoplasmic fluids in longissimus dorsi muscle. Cooking loss data also differs from the results found by Schönfeldt et al. (1993), who observed lower CL in goats than in lambs, and they attributed those results to the largest amount of fat present in the lamb muscle.

Means for shear force varied from 6.21 to 7.40 kgf.cm^{-2} and showed significant differences between the sexes (Table 4). Johnson et al. (1995), Dhanda, Taylor and Murray (1999) and Ryan et al. (2007) found averages of 6.0; 4.3 and 5.8 kgf.cm^{-2}, respectively. In the literature, great variations are found in the results from different authors, and they can be attributed to differences in nutrition, age, cooking time and temperature, and final pH. In this study, females presented lower values of shear force, when compared to males. Investigating sex and castration effects on bovine meat composition, Purchas (1991) concluded that a high final pH in bulls was an important factor in meat tenderness. However, in the present study, no difference was observed between the sexes for final pH value, and the less tenderness observed in the meat of males can be attributed to the smallest amount of covering fat thus becoming more susceptible to cooking shortening and less tenderness after cooking. Johnson et al. (1995) and Simela, Webb and Frylinck (2004) concluded that the female goat meat is more tenderness compared with the meat of males of same species.

Moisture percentage varied (74.63-76.37%) and showed significant differences among the genotypes and finishing systems (Table 5), which is in agreement with the results found by Babiker, El Khidir and Shafie (1990); Dhanda, Taylor and Murray (2003); however these values are higher than those found by Dias et al. (2008). ½ AA animals presented higher percentage of moisture compared with ½ BA and "tricross" genotypes, and they were similar to that of Alpine breed and ¾ BA animals. According to Lawrie (2005), the least understood intrinsic factor that affects muscle constitution is individual variation between animals. Even between animals of same sex, considerable differences are found in moisture percentages and intramuscular fat.

Longissimus dorsi muscle from animals finished on pasture had higher moisture percentage compared with that of feedlot animals (Table 5). This is in agreement with the findings of Mtenga and Kitaly (1990), who reported that longissimus

Table 4. Means for Water Holding Capacity (WHC), Cooking Loss (CL), and shear force (SF) in *longissimus dorsi* muscle from goats, according to genotype, finishing system, and sex.

	Parameters		
	WHC (%)	CL (%)	SF (kgf.cm^{-2})
Genotype			
Alpine	22.62^{c}	35.85^{a}	6.90
½ Anglo-nubian + ½ Alpine	25.73^{bc}	35.28^{ab}	7.40
½ Boer + ½ Alpine	27.15^{ab}	33.69^{bc}	6.77
¾ Boer + ¼ Alpine	30.77^{a}	33.34^{c}	7.01
"Tricross"	26.92^{b}	35.20^{abc}	6.21
Finishing system			
Goat kid + dam on pasture (ST1)	26.53	36.23^{a}	6.89
Weaned goat kid and feedlot (ST2)	26.74	33.01^{b}	6.82
Sex			
Male	26.08	34.70	7.22^{a}
Female	27.20	34.65	6.49^{b}
Mean	26.64	34.67	6.86
Coefficient of variation	14.11	5.58	21.03

Means followed by different letter differ statistically by Tukey test ($p < 0.05$).

Table 5. Means for moisture (MOI), Crude Protein (CP), Ether Extract (EE), and ash in *longissimus dorsi* muscle from goats, according to genotype, finishing system, and sex.

	Parameters (%)			
	MOI	CP	EE	Ash
Genotype				
Alpine	75.75^{ab}	22.16	1.17^{c}	1.05
½ Anglo-nubian + ½ Alpine	76.13^{a}	22.00	1.43^{bc}	1.07
½ Boer + ½ Alpine	75.11^{b}	22.51	2.21^{a}	1.06
¾ Boer + ¼ Alpine	75.34^{ab}	22.00	1.65^{b}	1.09
"Tricross"	75.17^{b}	22.12	1.54^{bc}	1.05
Finishing system				
Goat kid + dam on pasture (ST1)	76.37^{a}	21.60^{b}	1.18^{b}	1.05^{b}
Weaned goat kid and feedlot (ST2)	74.63^{b}	22.72^{a}	2.02^{a}	1.08^{a}
Sex				
Male	75.68	22.11	1.35^{b}	1.07
Female	75.32	22.21	1.86^{a}	1.06
Mean	75.50	22.16	1.60	1.06
Coefficient of variation	1.28	3.96	24.22	5.32

Means followed by different letter differ statistically by Tukey test ($p < 0.05$).

dorsi muscle of kid goats on pasture without supplementation presented greater moisture compared to animals with supplementation.

Longissimus dorsi muscle from feedlot-finished animals had higher percentage of crude protein compared with that of animals finished on pasture. These results indicate that feedlot-finished animals responded to nutritional plan depositing more muscular protein (Table 5).

The ether extract content showed significant differences among the genotype, finishing system, and sex (Table 5). The values are lower to those found by Babiker, El Khidir and Shafie (1990) for goats slaughtered at 35 kg live weight and fed complete diet. ½ BA genotype presented higher percentage of ether extract in longissimus dorsi muscle compared with that of the other genotypes. The results obtained in the present study agree with those of Madruga et al. (2005), who observed higher percentage of ether extract in the muscle of crossbreed Boer animals compared with that of SRD animals.

Longissimus dorsi muscle from feedlot-finished animals had higher percentage of ether extract compared with that of animals finished on pasture. According to Lawrie (2005), usually, percentages of body and intramuscular fat increase with nutritional level (Table 5).

Females had higher percentage of ether extract in longissimus dorsi than males. According to Palacíos, Lozano and Martinez (2000), this result can be attributed to differences in the growth and development between females and males resulting from sexual hormone effects that influence growth speed and animal tissue components deposition (muscle, fat, and bone). In general, males have less intramuscular fat compared with females. Similar results have been found by Rodríguez et al. (2008) in Assaf lambs.

Ash percentage varied (1.05-1.09%) and showed significant differences among the finishing systems. Feedlot kid goats had a higher value for ash compared with kid goats finished on pasture due to low moisture percentage and, consequently, higher protein and fat percentages.

4 Conclusion

Genotypes influenced physiochemical characteristics of goats' longissimus dorsi muscle. The best results were found in the meat of ½ BA animals.

If the consumer's preference is greater tenderness and higher percentage of fat, female meat is the best option.

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