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Meat quality of Criollo Cordobes goat kids produced under extensive feeding conditions. Effects of sex and age/weight at slaughter

A. Bonvillani[1], F. Peña[2]*, V. Domenech[2], O. Polvillo[3], P. T. García[4] and J. J. Casal[5]

[1] *Departamento de Producción Animal. Facultad de Agronomía y Veterinaria. Universidad de Río Cuarto. Argentina*
[2] *Departamento de Producción Animal. Universidad de Córdoba. 14071 Córdoba. Spain*
[3] *Departamento de Investigación Agraria. Universidad de Sevilla. Spain*
[4] *ITA-CIA - INTA-Castelar. Argentina*
[5] *CICVyA - INTA-Castelar. Argentina*

Abstract

The aim of this work was to study meat quality and fatty acid profiles in the *longissimus* muscle from Criollo Cordobes (CC) suckling kids, and to determine the effect of sex and age/weight at slaughter on these characteristics. Forty suckling kids, 20 intact males and 20 females, were randomly assigned to two groups: I (60 ± 2 days old and live weight ≤ 11 kg) and II (90 ± 3 days old and live weight > 11 kg). Sex had a significant influence on meat colour, Warner-Bratzler shear force, cooking losses, water holding capacity and intramuscular fat content, while the age/weight had a significant influence on cholesterol and tenderness. The main fatty acids identified from the intramuscular fat were oleic (30.1-32.6%), palmitic (19.6-21.0%) and stearic (13.5-16.3%). Levels of saturated and unsaturated fatty acid ranged from 40.1% to 41.9% and from 57.6% to 59.1%, respectively. Meat from CC kids is pale red, tender, juicy and the intensity of flavour and aroma were medium-high.

Additional key words*:* fatty acid, goat meat, sensory analysis, suckling.

Resumen

Calidad de la carne de cabritos lactantes de raza Criollo Cordobés. Efecto del sexo y edad/peso al sacrificio

El objetivo del presente trabajo fue estudiar la calidad de la carne y el perfil de ácidos grasos del m. *longissimus* de cabritos lactantes Criollo Cordobés, y el efecto del sexo y edad/peso al sacrificio en estas características. Cuarenta cabritos (20 machos y 20 hembras) fueron asignados al azar a dos grupos: I (60 ± 2 días de edad y peso vivo ≤ 11 kg) y II (90 ± 3 días de edad y peso vivo > 11 kg). El sexo influyó significativamente en el color, terneza instrumental, capacidad de retención de agua y pérdidas por cocinado de la carne y en la cantidad de grasa intramuscular del m. *longissimus*, mientras que la edad/peso al sacrificio influyó significativamente en el contenido en colesterol y en la terneza de la carne. Los ácidos grasos mas abundantes identificados en la grasa intramuscular fueron el oleico (30,1-32,6%), el palmítico (19,6-21,0%) y el esteárico (13,5-16,3%). El contenido en ácidos grasos saturados e insaturados se situó entre el 40,1% y el 41,95% y desde el 57,6% al 59,1%, respectivamente. La carne de los cabritos Criollo Cordobés era tierna, jugosa y de color rosa claro, y su aroma y flavor fueron de intensidad media-alta.

Palabras clave adicionales: ácidos grasos, análisis instrumental y sensorial, carne de cabrito lechal.

* Corresponding author: palpebfl@uco.es
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Abbreviations used: CC (Criollo Cordobes), DHY (dressed hot yield), EBW (empty body weight), HCW (warm carcass weight), IMF (intramuscular fat), LTL (m. longissimus thoracis and lumborum), LWS (live weight at slaughter), MUFA (monounsaturated fatty acids), PUFA (polyunsaturated fatty acids), SFA (saturated fatty acids), WBS (Warner-Bratzler shear force), WHC (water holding capacity).

Introduction

The goat population of Argentina is approximately 4.4 million (SAGPyA, 2005) distributed throughout the country but located, primarily (55% of the total livestock), in the north and central zones. In these regions, the Creole goat is the most frequently raised genotype, under extensive grazing systems on natural grassland with shrubs and forest and with little or no feed supplementation (Maubecin, 1976). The main commercial product of this system is the kid (10-12 kg live weight, 45-90 days old). In the province of Cordoba (central-western Argentine) there are approximately 174,000 goats (accounting for 4.4% of the national census), being the Criollo Cordobes, a local genotype resulting of adaptation of the Creole goats to the environmental conditions, the most common (70%) breed.

Previous studies have shown that consumers' perception on meat healthiness is related to its fat content and fatty acid composition (Fisher *et al*., 2000). Based on this understanding, there is an increasing tendency for consumers to prefer low fat meat, especially in developed countries. Goat meat has gained acceptance because of its low intramuscular fat, mainly saturated fatty acids, and cholesterol levels when compared to similar cuts in beef and mutton (Mahgoub *et al*., 2002); characteristics that are influenced by sex and age/weight at slaughter of the animal (Park and Washington, 1993; Todaro *et al.,* 2002; Marichal *et al*., 2003). Several reports have been published on the characteristics of goat meat and factors that influence its composition and acceptability (Potchoiba *et al*., 1990; Schönfeldt *et al.,* 1993, Carlucci *et al.,* 1998, Todaro *et al*., 2002; Marichal *et al*., 2003; Krystallis and Arvanitoyannis, 2006; Rodrigues and Teixeira, 2009). Consumers select meat in terms of characteristics such as its appearance (colour), tenderness and flavour (Kristallis and Arvanitoyannis, 2006), the most important characteristics that determine meat quality (Sañudo *et al.,* 1996).

Traditionally, kids have been slaughtered at 3-7 months old and 12-15 kg weight (De Gea *et al.,* 2005; Zimerman *et al*., 2008). In the last years, the market demands younger animals (30-65 days old and 6-11 kg live weight; Arias and Alonso, 2002), as their meat is considered a delicacy. Little is known about the quality of goat meat compared with other species, and specifically knowledge of meat quality of indigenous goats is limited, and practically no information is available on the meat characteristics from Criollo Cordobes suckling kids. Additionally, the quality of goat meat has recently become an important aspect in the marketing of goats in Argentina. Hence more information is needed on meat quality of native breeds. Moreover, information relating to the potential of increased age/weight at slaughter in goat kids will lead to maximize meat production and to evaluate effects on meat quality. Therefore, the objective of this study was to collect basic data on the physical and organoleptic characteristics of meat, and to determine the effect of sex and age/weight at slaughter on these traits of *longissimus* muscle from suckling Criollo Cordobes kids.

Material and methods

Animals and management, slaughter procedure and meat sampling

The study was conducted at Facultad de Agronomía y Veterinaria (Universidad Nacional de Río Cuarto, Córdoba, Argentina) located at 29-35° S 61-65° W.

A total of 40 suckling CC kids (20 females and 20 entire males) were selected at weaning (60 or 90 days of age and 9 to 13 kg of live weight; currently, these age/slaughter weights are the most interesting in Argentina) from commercial goat farms in Córdoba (Argentina) reared according to the traditional system of the region: grass-fed without supplementation. Kid goats are reared with their dams until weaning, and were randomly assigned to one of two groups: I (60 ± 2 days old and live weight ≤ 11 kg) and II (90 ± 3 days old and live weight > 11 kg). When kids reached the age/slaughter weight, they were separated from their dams and transported to the abattoir (5 km away). Immediately after arrival, kids were kept in covered yards and then fasted for 12 h with free access to water. They were then weighed (live weight at slaughter, LWS), and slaughtered (10 kids for group, and each group in 1 day) and dressed according to the method of Colomer-Rocher *et al*. (1988). Warm carcasses were weighed (HCW), suspended by the Achilles tendon and held at room temperature (12 ± 2°C) for 6 hours, to avoid cold shortening, and then chilled at 2°C (±2°C) until 24 h *post-mortem*. The gastro-intestinal content was weighed, and empty body weight (EBW) was calculated by deducting the weight of digesta from the fasted live weight at slaughter. Dressed hot yield (DHY) was calculated as: $100 \times$ LWS/EBW. After chilling, the carcasses were split down the dorsal midline, and *longissimus thoracis and lumborum* (LTL) muscle was removed from the left side of carcasses, and separately vacuum packaged, aged for 72 h and frozen and stored at –20°C for up to 1 week, prior physicochemical and sensory evaluations. The day before the analysis, the samples were thawed overnight at 4-5°C.

Physical analysis

Before packaging, meat colour and pH were determined from the *longissimus* muscle at 8 ± 2°C. The ultimate pH values (pH_{24}, measured at 24 h after slaughter) was measured directly in LTL (at the 12-13th rib site) using a penetrating glass electrode connected to a portable CRISON 506 pH-meter. Three measurements were taken for each carcass. Muscle colour was evaluated at the same site as for pH_{24} and after cutting the muscle surface to allow it to bloom for 1 h at 3°C in a plastic tray covered with a gas permeable film. Then muscle colour was measured, using the CIE-L^*, a^*, b^* system by a chromometer (ByK Gardner Colour View, model 9000, USA) following the recommendations (standard illuminant D65 and 10° standard angle observer) of AMSA (1991). Chroma or saturation $[(a^2 + b^2)^{1/2}]$ was calculated using a^* and b^* values according to Wyszecki and Stiles (1982). Values were registered from three different locations on the upper side of the steaks in order to obtain a representative average value of the meat colour. Water holding capacity (WHC), expressed as percentage of liquid expelled, was determined following the filter paper press methodology described by Zamorano and Gambaruto (1997).

For determination of cooking loss and Warner-Bratzler shear force (WBS) values, samples were weighed and then cooked into a plastic bag in a water bath at 75°C until an internal temperature of 71°C was achieved. After cooling, the samples were taken from the bags, dried with filter paper and reweighed. Cooking loss was expressed as the percentage loss related to the initial weigh. Then 3-5 muscle cores (1 × 1 × 3 cm) were cut parallel to the long axis of the muscle fibres and WBS values were taken on the cores using an Instron apparatus (Instron Ltd., UK) equipped with a Warner-Bratzler shear device, as in AMSA (1995). The texture analyzer was set with a 25 kg load cell and a crosshead speed of 200 mm min^{-1}.

Cholesterol and fatty acid analysis

Total intramuscular fat (IMF) content of LTL muscle (from 10 g of meat) was determined (AOAC, 1992) by using a Tekator analyzer (Foss Tekator AB Soxtec 2050). IMF for fatty acid and cholesterol determinations was extracted (from 5 g of meat) as described by Folch *et al*. (1957). Total cholesterol was measured after saponification with 4% KOH in absolute ethanol, using an enzymatic and colorimetric reactive (BioSystem S. A., Argentine). Fatty acid methyl esters were prepared according to the method of Pariza *et al*. (2001) and measured using a Chrompack CP 900 gas chromatograph (Middleburg, Netherland) equipped with a flame ionization detector and fitted with a silica capillary column CP-Sil 88 (100 m, 0.25 mm *i.d.,* 0.2 µm film thickness, Chrompack Inc., Middleburg, The Netherlands), using N_2 as carrier gas (2.5 psi). The oven temperature was programmed at 70°C for 4 min, increased from 70 to 170°C at a rate of 13°C min^{-1} and then increased from 170 to 200°C at 1°C min^{-1}. The injection port and detector temperature were maintained at 250°C. Tricosanoic acid methyl ester (C23:0 ME) at 10 mg mL^{-1} was used as an internal standard. Individual fatty acids were identified by comparing their retention times with those of an authenticated standard fatty acid mix Supelco 37 (Sigma Chemical Co. Ltd., Poole, UK). Individual fatty acids were corrected by their relative response factor (using the value of the internal standard) and expressed as a percentage of total fatty acids identified. Fatty acids were grouped as follows: saturated (SFA), monounsaturated (MUFA) and polyunsaturated (PUFA). The following ratios were calculated: PUFA/SFA, n-6/n-3 and 18:0+18:1/16:0.

Sensory analysis

Sensory evaluation was carried out on LTL muscle samples by six trained panellists. Portions of 100 g were cooked using the same cooking method as for shear force measurements. Every steak was then trimmed of any external connective tissue, cut into approximately 1 × 1 cm sub-samples, transferred into a pre-warmed glass beaker, covered and placed into an oven at 60°C to equilibrate their temperature prior to being served. Samples were coded and the serving sequence was randomised. The attributes were assessed using a nine-point scale (IRAM, 1985; AMSA, 1995) for flavour intensity (9 = extremely intense; 1 = extremely bland); initial and overall tenderness (9 = extremely tender; 1 = extremely tough); juiciness (9 = extremely juicy; 1 = extremely dry); aroma (9 = extremely desirable; 1 = extremely undesirable); and amount of connective tissue (9 = no perceptible; 1 = abundant perceptible).

Statistical analysis

The effects of genotype and slaughter weight group on meat quality and fatty acid profiles of IMF were analysed by ANOVA using the General Linear Model (GLM) procedures of the Statistica statistical package (Statistica, 2001). No significant sex by age/slaughter weight interaction was noted for the parameters evaluated in this study. Therefore only main effects have been presented and discussed.

Results

Table 1 shows the significance of the effects of the sex and age/weight at slaughter on the carcass and meat quality. In the present study, neither the sex nor the age/weight at slaughter influenced DHY and pH.

Meat colour from CC kid goats, with an average L^* value of 41.1, average a^* value of 11.2 and average b^* value of 15.5, can be valued or classified as pale red. Meat from male kids displayed higher ($p < 0.01$) L^* values and lower ($p < 0.05$) a^* values than females. The effect of age/weight at slaughter was not significant ($p > 0.05$) for muscle colour values.

Evaluation of factors affecting instrumental texture is particularly important in goat meat because of its lower WBS compared with sheep and beef. The WBS, evaluated as the maximum shear force necessary to cut the meat perpendicular to the fibres, ranged 4.6 to 6.7 kg cm^{-2}. The toughness of meat was higher ($p < 0.01$) in males than females (6.5 kg cm^{-2} *vs.* 4.6 kg cm^{-2}). Considering that the Warner-Bratzler force values exceeding 5.5 kg would often be considered objectionably tough by both trained panel and consumers, males' meat could be classified as less tender. A decrease in WBS with increasing age/weight at slaughter has been noted in both sexes, although the differences among age/weight groups were not statistically significant ($p > 0.05$).

Water holding capacity (WHC) is a term originally used to describe the ability of muscle to bind water under a set of conditions. The average values of WHC (29.5%, Table 1) showed that kids of both sexes have a high water retention capacity, typical of meat from young animals. The WHC was affected ($p < 0.05$) by sex, but not by age/weight at slaughter. Meat from female kids had a lower ($p < 0.05$) WHC than the one from male kids (28.5% *vs.* 30.5%, respectively).

Cooking losses ranged from 19.1 to 25.4%, which is within the normal range for goat meat. LTL muscle from female kids had lower ($p < 0.05$) cooking loss compared to male kids (20.3% *vs.* 24.8%). In contrast,

Table 1. Effect of sex and age/weight at slaughter on meat quality characteristics of *longissimus* muscle from Criollo Cordobes kids

	Sex		Age/Weight		*p* values	
	Females	Males	Group I	Group II	Sex	Age/Weight
LWS (kg)	11.33 ± 0.57	11.12 ± 0.19	10.52 ± 0.45	11.77 ± 0.36	0.103	0.001
EBW (kg)	9.81 ± 0.44	9.70 ± 0.18	9.07 ± 0.39	10.40 ± 0.31	0.105	0.001
HCW (kg)	5.48 ± 0.28	5.34 ± 0.11	5.02 ± 0.29	5.80 ± 0.39	0.197	0.001
DHY (%)	55.90 ± 0.35	55.10 ± 0.60	54.95 ± 0.41	55.75 ± 0.46	0.548	0.167
pH	5.72 ± 0.02	5.73 ± 0.02	5.74 ± 0.02	5.71 ± 0.03	0.289	0.326
L^*	39.53 ± 0.63	42.71 ± 0.59	41.25 ± 0.90	40.86 ± 0.81	0.009	0.392
a^*	11.85 ± 0.24	10.62 ± 0.28	11.16 ± 0.20	11.39 ± 0.45	0.036	0.280
b^*	15.61 ± 0.61	15.47 ± 0.37	15.18 ± 0.75	16.00 ± 0.57	0.641	0.372
Chroma	19.61 ± 0.51	18.80 ± 0.36	18.86 ± 0.66	19.68 ± 0.33	0.216	0.263
WBS (kg cm^{-2})	4.57 ± 0.24	6.45 ± 0.30	5.32 ± 0.24	5.67 ± 0.58	0.006	0.227
WHC (%)	28.48 ± 0.55	30.54 ± 0.45	29.23 ± 0.43	29.93 ± 0.76	0.041	0.253
Cooking losses (%)	20.26 ± 1.37	24.76 ± 1.33	23.22 ± 2.02	22.02 ± 1.07	0.011	0.111

LWS: live weight at slaughter. EBW: empty body weight. HCW: hot carcass weight. DHY: dressing yield. WBS: Warner-Bratzler shear force. WHC: water holding capacity.

Table 2. Effect of sex and age/weight at slaughter on intramuscular fat (IMF) content (g 100 g^{-1} meat) and cholesterol levels (mg 100 g^{-1} meat), and intramuscular fatty acid composition (% total fatty acids) of *longissimus* muscle from Criollo Cordobes kids

	Sex		Age/Weight		*p* values	
	Females	Males	Group I	Group II	Sex	Age/Weight
IMF	0.89 ± 0.09	1.15 ± 0.08	0.98 ± 0.14	0.96 ± 0.09	0.051	0.112
Cholesterol	63.73 ± 0.86	63.92 ± 0.61	64.90 ± 1.19	61.15 ± 0.58	0.947	0.024
SFA	41.12 ± 0.84	41.11 ± 0.63	40.20 ± 0.85	41.50 ± 0.59	0.192	0.789
MUFA	33.44 ± 1.73	36.09 ± 0.78	34.62 ± 1.60	35.11 ± 1.47	0.053	0.330
PUFA	25.54 ± 0.90	21.72 ± 0.79	24.20 ± 1.28	22.70 ± 1.08	0.170	0.320
n-6	18.95 ± 1.06	16.04 ± 0.37	17.67 ± 1.20	17.21 ± 1.11	0.234	0.483
n-3	6.15 ± 0.25	4.91 ± 0.53	6.11 ± 0.48	5.83 ± 0.58	0.875	0.257
CLA	0.84 ± 0.05	0.97 ± 0.16	0.93 ± 0.13	0.85 ± 0.13	0.346	0.157
MUFA/SFA	0.82 ± 0.04	0.87 ± 0.02	0.81 ± 0.04	0.81 ± 0.05	0.169	0.473
PUFA/SFA	0.60 ± 0.06	0.53 ± 0.03	0.57 ± 0.05	0.56 ± 0.04	0.118	0.120
n-6/n-3	3.08 ± 0.32	3.29 ± 0.19	2.83 ± 0.37	2.92 ± 0.38	0.460	0.513
18:0+18:1/16:0	2.31 ± 0.05	2.14 ± 0.07	2.28 ± 0.08	2.22 ± 0.06	0.299	0.481

SFA: saturated fatty acids. MUFA: monounsaturated fatty acids. PUFA: polyunsaturated fatty acids. CLA: conjugated linoleic acid.

the percentage of cooking loss was similar between Group I and Group II.

Table 2 shows the means and standard errors for IMF and cholesterol levels, and fatty acid composition of the LTL muscle from CC kids according to sex and age/weight at slaughter. IMF content in both sexes was within 0.9 to 1.2 g 100 g^{-1} of muscle. The total intramuscular fat of males was proportionally higher ($p = 0.051$) than females (1.15 g 100 g^{-1} *vs.* 0.89 g 100 g^{-1}). No significant age/weight at slaughter effects were found for IMF percentages.

Total cholesterol content ranged from 59.1 g 100 g^{-1} to 63.9 g 100 g^{-1}, and no significant differences between gender were found, whereas the means decreased ($p < 0.05$) with increasing age/weight at slaughter.

The fatty acid composition of meat sampled from female and male goats is presented in Table 2 and Table 3. Twenty fatty acids were identified, which consisted of seven SFA, four MUFA and nine PUFA. The major fatty acids identified in the intramuscular fat were C18:1, C16:0 and C18:0, with percentages of 30.1-32.9%, 19.6-21.0% and 13.5-16.3%, respectively, which accounted for 63.2-66.7% of total fatty acids. The percentages of capric (0.4% *vs.* 0.1%), lauric (0.7% *vs.* 0.5%) and miristic (3.6% *vs.* 2.7%) fatty acids were significantly higher in male goats than in female goats, while female goats had higher proportions of stearic (16.1% *vs.* 13.8%) and linoleic (10.5% *vs.* 8.6%) fatty acids. The age/weight at slaughter influenced the percentage of miristic fatty acid.

The proportions of SFA, MUFA, PUFA and desirable fatty acids (18:0 + MUFA + PUFA) ranged within ranged 40-42%, 33-36%, 22-26% and 72-75.0%, respectively. The MUFA/SFA, PUFA/SFA (C18 + C18:1)/C16 and n-6/n-3 ratios ranged 0.8-0.9, 2.1-2.3, 0.5-0.6 and 2.8-3.3. Neither sex nor age/weight at slaughter influenced these variables.

Table 4 shows the mean scores and standard errors for organoleptic quality of goat meat. In the present study, sensory panel scores from all attributes ranged from 6 to 7 (a nine-point scale). The sex did not affect ($p > 0.05$) sensory scores of the LTL muscle, while the analysis of variance showed that only the initial tenderness scores, among the six sensorial attributes analysed, were significantly different among the two age/weight groups. The scores for initial tenderness were higher in younger goats (Group I), and subsequently it decreased with the progression of slaughter age/weight.

Discussion

The present results regarding the live weight and dressing yield of male and female goat kids were similar to the ones reported for suckling kids in Argentina (Gallinger *et al.*, 1994; Rossanigo *et al.*, 1996; De Gea *et al.*, 2005; Domingo *et al.*, 2008; Zimerman *et al.*, 2008). However, the DHY reported in this study was higher than those other goat breeds slaughtered at similar weight (Dhanda *et al.*, 2003a;

Table 3. Effect of sex and age/weight at slaughter on intramuscular fatty acid composition (% total fatty acids) of *longissimus* muscle from Criollo Cordobes kids

	Sex		**Age/Weight**		***p* values**	
	Females	**Males**	**Group I**	**Group II**	**Sex**	**Age/Weight**
10:0	0.12 ± 0.01	0.42 ± 0.03	0.25 ± 0.02	0.31 ± 0.04	0.001	0.122
12:0	0.49 ± 0.07	0.73 ± 0.06	0.63 ± 0.09	0.57 ± 0.02	0.059	0.735
14:0	2.71 ± 0.23	3.62 ± 0.10	3.12 ± 0.10	3.34 ± 0.11	0.041	0.046
14:1	0.25 ± 0.06	0.35 ± 0.02	0.35 ± 0.07	0.26 ± 0.03	0.281	0.514
15:0	0.49 ± 0.05	0.52 ± 0.03	0.47 ± 0.02	0.55 ± 0.07	0.834	0.451
16:0	20.07 ± 0.44	20.96 ± 0.25	20.05 ± 0.29	20.99 ± 0.27	0.142	0.574
16:1	2.12 ± 0.38	2.25 ± 0.07	2.10 ± 0.15	2.47 ± 0.16	0.801	0.329
17:0	1.21 ± 0.11	1.05 ± 0.04	1.18 ± 0.08	1.00 ± 0.04	0.159	0.328
17:1	0.74 ± 0.06	0.64 ± 0.04	0.68 ± 0.06	0.71 ± 0.08	0.140	0.491
18:0	16.05 ± 0.35	13.81 ± 0.26	14.91 ± 0.33	14.89 ± 0.23	0.034	0.427
18:1n-9	30.37 ± 0.68	32.81 ± 0.41	31.50 ± 0.53	31.63 ± 0.52	0.083	0.723
18:2n-6	10.46 ± 0.31	8.60 ± 0.27	9.49 ± 0.24	9.75 ± 0.26	0.046	0.423
18:3n-3	2.02 ± 0.15	1.50 ± 0.16	1.79 ± 0.12	1.64 ± 0.03	0.070	0.705
20:2n-6	0.55 ± 0.07	0.57 ± 0.05	0.58 ± 0.09	0.50 ± 0.04	0.897	0.639
20:3n-6	0.78 ± 0.11	0.55 ± 0.05	0.74 ± 0.07	0.54 ± 0.09	0.048	0.197
20:4n-6	5.88 ± 0.15	5.41 ± 0.22	5.69 ± 0.11	5.52 ± 0.14	0.434	0.731
20:5n-3 (EPA)	2.14 ± 0.12	1.66 ± 0.11	2.06 ± 0.07	1.77 ± 0.09	0.058	0.874
22:4n-6	0.78 ± 0.09	0.85 ± 0.08	0.96 ± 0.05	0.63 ± 0.05	0.816	0.146
22:5n-3 (DPA)	2.37 ± 0.11	1.97 ± 0.11	2.31 ± 0.13	1.97 ± 0.09	0.154	0.095
22:6n-3 (DHA)	0.64 ± 0.06	0.63 ± 0.05	0.61 ± 0.08	0.68 ± 0.03	0.782	0.075

Marichal *et al*., 2003). In the present study, DHY did not differ ($p > 0.05$) between sexes, contrary to the results reported by Johnson *et al*. (1995), which could be due to sex differences in DHY can be observed at heavier hot carcass weights, as reported by Hogg *et al.* (1992) and Colomer-Rocher *et al*. (1992).

The pH_{24} of LTL muscle, within the range recorded in the studies reviewed by Webb *et al*. (2005), was not affected by age/weight at slaughter. In this study, LWS did not affect the pH_{24}, while Núñez González *et al*. (1983) and Marichal *et al*. (2003) recorded a decrease in ultimate pH with the increase of live weight in entire (6 to 25 kg) and castrate (12 to 24 kg) male kids, respectively.

Meat colour from CC kid goats, with an average L^* value lower than those recorded by Argüello *et al*. (2005) from Majorera kid goats fed with goat milk and slaughtered at 6 and 10 kg, can be valued or classified as pale red. The sex differences on meat color agree with Simela *et al*. (2004), and which could be partly due to female carcasses cooled slowly than those of intact males.

Table 4. Effect of sex and age/weight at slaughter on sensory attributes of *longissimus* muscle from Criollo Cordobes kids

	Sex		**Age/Weight**		***p* values**	
	Females	**Males**	**Group I**	**Group II**	**Sex**	**Age/Weight**
Flavour	7.04 ± 0.07	7.16 ± 0.08	6.80 ± 0.06	7.21 ± 0.12	0.509	0.825
Initial tenderness	6.61 ± 0.17	6.76 ± 0.09	6.88 ± 0.09	6.57 ± 0.13	0.446	0.042
Overall tenderness	6.56 ± 0.15	6.67 ± 0.07	6.76 ± 0.11	6.52 ± 0.12	0.540	0.148
Juiciness	6.62 ± 0.28	6.11 ± 0.14	6.16 ± 0.17	6.53 ± 0.19	0.115	0.414
Aroma	6.96 ± 0.07	7.01 ± 0.06	6.95 ± 0.13	7.00 ± 0.08	0.246	0.117
Connective tissue	6.92 ± 0.08	7.05 ± 0.08	6.91 ± 0.11	7.05 ± 0.12	0.159	0.875

Flavour intensity (9 = extremely intense; 1 = extremely bland); initial and overall tenderness (9 = extremely tender; 1 = extremely tough); juiciness (9 = extremely juicy; 1 = extremely dry); aroma (9 = extremely desirable; 1 = extremely undesirable); and amount of connective tissue (9 = no perceptible; 1 = abundant perceptible).

The findings of Argüello *et al.* (2005) are consistent with the general thinking that, as maturity increases, goat meat becomes darker. These authors found an association between LWS and lightness, the 10-kg animals being darker than those slaughtered at 6 kg. In the present work, the no significant differences between age/weight groups, in line with previous studies (Todaro *et al.*, 2002; Marichal *et al.*, 2003), could be due to the weight range used in our study.

The WBS values from Criollo Cordobes were similar to those reported by Johnson *et al.* (1995) and Marichal *et al.* (2003); but lower compared to other studies (Babiker *et al.*, 1990; Dhanda *et al.*, 2003a; Santos *et al.*, 2007) and higher than those reported Núñez González *et al.* (1983) in Criollo goats slaughtered at 8 kg to 24 kg. The higher toughness of meat from male kids and group II is in accordance with earlier findings (Hogg *et al.*, 1992; Johnson *et al.*, 1995; Dhanda *et al.*, 2003a; Marichal *et al.*, 2003; Simela *et al.*, 2004). Considering that the Warner-Bratzler force values exceeding 5.5 kg would often be considered objectionably tough by both trained panel and consumers (Shackelford *et al.*, 1991), males' meat could be classified as of low tenderness.

The water holding capacity (WHC) means, linked to sensory properties of meat such as juiciness and flavour (Schönfeldt *et al.*, 1993; Hedrick *et al.*, 1994), were in the range of previous studies (Argüello *et al.*, 1999; Marichal *et al.*, 2003; Bañón *et al.*, 2006). This value showed that kids of both sexes have a high water retention capacity, typical of meat from young animals (Todaro *et al.*, 2002). A decrease in WHC with an increase in slaughter weight of kids has been reported by Marichal *et al.* (2003). In the present experiment, an opposite trend was observed, but the differences are not statistically significant ($p > 0.05$). This might be due to the lower range of weights for slaughter in our study (9-15 *vs.* 6-25 kg). On the other hand, on work done by Argüello *et al.* (2005), LWS did not have a significant effect on the WHC.

With respect to cooking losses, the present results agree with those of Dhanda *et al.* (2003a) and Todaro *et al.* (2004). The sex had the most important effect on cooking losses. LTL muscle from female kids had lower ($p < 0.05$) cooking loss compared to male kids (20.3% *vs.* 24.8%), while the percentage of cooking losses was similar among Group I and Group II.

As reported by Marichal *et al.* (2003), the weight at slaughter did not affect the quality (pH, colour, shear force and water retention capacity) of meat. According to this, it seems improbable that a little age/weight difference might causes differences in the composition of the meat.

IMF content was similar to the ones reported by Marichal *et al.* (2003) for Canary Caprine Groups kids slaughtered at 6 and 10 kg, and lower than those obtained from weaned goat kids (Bas *et al.*, 2005; Talpur *et al.*, 2008). These differences are possibly due to different breed and feeding practices, as breed and diet are two major factors affecting IMF content (Banskalieva *et al.*, 2000). Himself, the total cholesterol was close to the results reported by Almeida *et al.* (1997), 61.5 to 76.1 g 100 g^{-1}, and by Bañón *et al.* (2006), 0.67 to 0.68 mg g^{-1}, and are comparable to those found by Bas *et al.* (2005) in meat from goats raised on rangeland. The increase in cholesterol content with weight was reported by Madruga *et al.* (1999) and Beserra *et al.* (2004). Our results do not agree with these authors, because in the present study, the mean values decreased ($p < 0.05$) with increasing age/weight at slaughter, in agreement with Werdi Pratiwi *et al.* (2006a) in castrated Boer goats.

The predominance of unsaturated fatty acids in LTL muscle is in agreement with Johnson *et al.* (1995) and Bas *et al.* (2005), and the saturated/unsaturated fatty acids ratio was less to 1, in disagreement with Potchoiba *et al.* (1990) and Todaro *et al.* (2002), who estimated between 1 and 2. The n-6/n-3 ratio had values that may be considered appropriate, considering the value recommended for the human diet as a whole < 4, while the average PUFA/SFA ratio is slightly higher than the recommended > 0.45 (Enser *et al.*, 1998).

Beserra *et al.* (2004) after a principal component analysis applied to the fatty acid contents suggested that the variations in fatty acid profiles are mainly due to age/weight at slaughter, although in the present study there were no significant differences in the fatty acids profiles of LTL muscle between age/weight groups. In addition to the weight at slaughter (De Smet *et al.*, 2004), these differences could be attributed to type of feed (Potchoiba *et al*, 1990; Todaro *et al.*, 2002). The proportions of desirable fatty acids (18:0 + MUFA + PUFA) were within the range reported by other authors (Potchoiba *et al.*, 1990; Talpur *et al.*, 2008). It has been suggested that palmitic acid (C16:0) increases blood cholesterol, stearic acid (C18:0) has no effect, and oleic acid (C18:1) decreases blood cholesterol content. Banskalieva *et al.* (2000) suggested that the ratio of (C18 + C18:1)/C16 could be useful in describing the potential health effects of different types of lipids. In the present study this ratio was 2.23 for all animals, which was slightly higher than those reported for kids of Serrana, Bravia and Serrana × Bravia genotypes (Santos *et al*., 2007) and similar to those reported for the Girgentana breed (Todaro *et al*., 2002), slaughtered at 47 days of age.

In accordance with previous works (Potchoiba *et al*., 1990; Todaro *et al*., 2002), the major fatty acids identified in the intramuscular fat were C18:1, C16:0 and C18:0. The proportions of these fatty acids were in the range of those reported in goats (Banskalieva *et al*., 2000; Rhee *et al*., 2000; Beserra *et al*., 2004; Bas *et al*., 2005). The oleic acid had the highest percentage compared to other fatty acids, although the values recorded in this study were lower than those obtained by other authors (Rhee *et al*., 2000; Dhanda *et al*., 2003b; Bas *et al*., 2005; Werdi Pratiwi *et al*., 2006b). These differences are probably due to the use of different breeds (De Smet *et al*., 2004), diet (Bas *et al*., 2005; Lee *et al*., 2008) or slaughter weight (Sañudo *et al*., 1998), since a change in diet after weaning and the increased slaughter weight influence significantly the fatty acid profiles (Dhanda *et al*., 2003b; Beserra *et al*., 2004).

In the present study, sensory panel scores were similar to those reported by Babiker *et al*. (1990) and Dhanda *et al*. (2003b), and the sensory attributes were perceived by the members of the panel with medium-high intensity; better scores than those recorded by Germano Costa *et al*. (2008) in Blanca Serrana Andaluza breed. The effect of the sex on the sensory attributes is not clear. Kirton (1970) and Dawkins *et al*. (2000) found significant differences between sexes, while Germano Costa *et al*. (2008) and Madruga *et al*. (2008) did not. In the present study, sex did not affect ($p > 0.05$) sensory scores of the LTL muscle, although the meat from males had higher amount of IMF. The higher content of IMF in LTL muscle should produce differences in aroma, flavour and juiciness between sexes (Madruga *et al.,* 2002). Rodrigues and Teixeira (2009) observed than meat from Cabrito Transmontano males had greater juiciness, flavor quality and general acceptability than meat from females.

The scores for initial tenderness were higher in younger goats (Group I), and subsequently it decreased with the progression of slaughter age/weight. Dhanda *et al*. (2003a) recorded a similar effect, although the differences were not statistically significant ($p > 0.05$). The decrease in tenderness with age was reported by Schönfeldt *et al*. (1993) and Madruga *et al*. (2000), who found that meat of younger goats was more tender than that of older animals. The last authors indicate that the tenderness reduced with age due to toughening of myofibrilar proteins of meat and the presence of cross bridge which set up collagen molecules. The results for tenderness (Table 4) are supported by instrumental analysis for Warner-Bratzler shear force (Table 1).

According to the results obtained in this study, Criollo Cordobes kid meat was very lean, pale red in colour, tender, juicy and the intensity of flavour and aroma were medium-high. It had a low-medium shear force and a high water retention capacity. The cholesterol content of the meat was moderate and saturated/unsaturated fatty acid ratio was less than 1. In the present work, the age/weight at slaughter had little influence on the variables studied. Intramuscular fat content was low and showed a higher proportion of unsaturated fatty acids to saturated fatty acids. Meat from females was darker and redder, and showed a higher water-holding capacity and lower cooking loss and toughness that meat from male kids, while the meat from the males contained higher intramuscular fat and monounsaturated fatty acids compared to those from females. Only the cholesterol content and initial tenderness were significant different for age/weight groups.

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