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Effects of diet and live weight at slaughter on kid meat quality

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Abstract

Forty male twin kids of the Majorera breed were used in a 2 × 2 design, in which the diet, suckled on dam (SD) or milk replacer (MR) and live weight at slaughter (6 or 10 kg) were the main variables. Muscle pH and colour (CIE, $L^*a^*b^*$) were determined in the *longissimus* (LD), *semimembranosus* (SM) and *triceps brachii* (TB) muscles, immediately after slaughter and chilling (24 h). Water-holding capacity, shear force, chemical composition (moisture, fat, protein and collagen content and solubility) were determined. Muscle fibre populations were also studied. SD kid meat was slightly more tender and juicy, and the Chroma value was lower than in MR animals. The meat from the kids that were slaughtered at 10 kg was significantly darker in all muscles tested and slightly less tender 6 kg LWS kid meat had more moisture and less protein than that of 10 kg LWS kids. Muscle fibre area was statistically higher in the 10-kg LWS kids. It was concluded that the meat quality of the heavier kids was not significantly different from that of the lighter kids and that slaughter at the greater weight would result in more meat being marketed.
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Keywords: Meat quality; Diet; Live weight at slaughter; Kids

1. Introduction

Naudé and Hofmeyr (1981) described the goat population as comprised of four types, i.e., fibre goats (e.g., Angora and Cashmere), dairy goats (e.g., Saanen, Toggenburg and Nubian), meat goats (e.g., Boer) and feral goats. The world's goat population was around 720 million in 2000, with annual meat production of around 4.2 million metric tonnes (FAO, 2003). The goat is an important meat animal in Africa, Asia, and the Far East, and is now emerging as an alternative, and attractive, source of meat in other parts of the world. In India, the local community specifically seeks meat from mature goats, whereas in France and Latin America, meat from young milk fed kids is considered a delicacy (Naudé & Hofmeyr, 1981). Acceptability of meat is so influenced by local custom and preference that it is impossible to apply a universal standard for the quality of goat meat (Naudé & Hofmeyr, 1981).

Spain has one of the largest goat populations in the European Community. Most of the goats in Spain are milk breeds, such as Murciano-Granadina, Malageña and the Majorera breeds, however, goat meat production in Spain is high. Majorera goats are found in the Canary Islands (Spain) and have a mean production of over 500 kg of milk (210 days of lactation) (Fresno et al., 1994). Milk quality is good in comparison with other Spanish and international breeds (Jordana, Sánchez, Jansa, Mahe, & Grosclaude, 1991). This excellent productive performance is matched by the ability of the breed to adapt to a wide range of climatic conditions

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(Capote, Delgado, Fresno, Camacho, & Molina, 1998). Traditionally, in the Mediterranean and Canary Island regions, kid goats are reared with their dams. This practice decreases the availability of milk for cheese production. Therefore, goatkeepers remove the kids from their dams at a very young age (15 days, 5–6 kg live weight) and these kids are then slaughtered. If the kids are artificially reared and raised to heavier live weights, there would be a significant increase in the edible meat yield from the carcasses.

Milk replacers (markedly cheaper that goats' milk) specially formulated for kids can result in good daily weight gain (DWG); although this gain is less than that of kids reared on their mothers. Goatkeepers, are reluctant to use the milk replacer because, in their opinion, this type of rearing involves greater labour cost, results in meat of a different quality and the greater live weight at slaughter (LWS) reduces the commercial value because the meat is considered, by goatkeepers, to be tougher. There are a few published reports, which compare kid meat quality attributes according to different kinds of milk fed and LWS. Hogg, Mercer, Mortimer, Kirton, and Duganzich (1992), observed that the intramuscular fat was higher when the kids were heavier, and it is accepted that in suckling kids the percentage fat and its composition depends upon that percent and composition of the milk or milk replacer fed (Morand-Fehr, Bas, Schmidely, & Hervieu, 1986; Sanz, Muñoz, Lara, Gil, & Boza, 1987). Gaili and Ali (1985) observed that when LWS is higher, the muscle fibre area is greater too. Johnson and McGowan (1998) found no effects of high feed energy on goat meat texture, but Pisula, Slowinski, Pawlowski, Bidwel-Porebska, and Piotrowski (1994) found an effect of high protein feed on kid meat texture. The objective of present study was to determine the effects of milk diet and live weight at slaughter (LWS) on the meat characteristics of milk breed kids.

2. Materials and methods

2.1. General procedure

This experiment was conducted at the Veterinary Faculty Farm of Las Palmas de Gran Canaria University (Canary Islands, Spain). Forty male twin kids of the Majorera breed were randomly allotted to one of the four treatments. Two groups were reared with their dams (SD) and the other two were reared with milk replacer (MR). Two LWS were used for each feeding method, 6 or 10 kg. The SD animals were with their dams, 24 h/day, fed ad libitum. These animals were not given mixed feed directly but had access to their mother who was fed a mixed feed (corn, soy 66, dehydrated Lucerne pellets, dehydrated beetroot pellets, wheat straw, plane tree leaves ad libitum, and a vitamin and mineral supplement) according INRA (Jarrige, 1990). The MR animals were removed at birth from their dams and fed with fresh colostrum for two days (Argüello, Castro, Zamorano, Castroalonso, & Capote, 2004). After that, they received milk replacer (Table 1) reconstituted at 16% w/w and fed twice a day during the experiment. On the 15th day water and starter mixed feed (Table 1) was included.

2.2. Slaughtering

Slaughter was done at Experimental Slaughterhouse in the Veterinary Faculty, Las Palmas de Gran Canaria University (Spain). Kids were weighed and then fasted for 18 hs with free access to water and weighed again immediately prior to slaughter. The kids were slaughtered using captive bolt stunning followed by throat cut to sever carotid arteries and jugular veins. Kids were dressed according to Colomer-Rocher, Morand-Fehr, and Kirton (1987). After that, carcasses were chilled at 4 °C for 24 h.

2.3. Meat quality attributes

Meat quality measurements were made on the right side of each carcass. Muscle pH was determined using a Crisson 507 pH meter with a combined electrode, by insertion into the *longissimus* (LD) (at the 12/13th rib site), *semimembranosus* (SM) (central portion) and *triceps brachii* (TB) (central portion) muscles, immediately after slaughter and again after chilling (24 h). Muscle colour was measured at the same places and times, using a Minolta CR200 Chroma-meter (where L^* depicts relative lightness, a^* indicates relative redness and b^* represents relative yellowness). Hue and Chroma were calculated using a^* and b^* values according to Wyszecki and Stiles (1982). At 24 h postmortem, the three muscles were excised. Water-holding capacity was measured according to Grau and Hamm (1953). Muscles were cooked in plastic bags in a water bath at 85 °C until an internal temperature of 70 °C was achieved. Cooked muscle cores with a cross-section of 1 × 1 cm and at least 3 cm long were cut parallel to the muscle fibres and shear force values were taken using a Warner–Bratzler

Table 1
Chemical analysis of feedstuffs offered to the kids during the experimental period

	Composition, DM basis (%)	
	Milk replacer	Starting concentrate
Dry matter	95.5	87.5
Ash	8.0	7.6
Crude protein	23.6	16.4
Crude fiber	0.1	4.5
Ether extract	22.7	2.5

shear force apparatus on a INSTRON Machine. A triangular slot cutting edge was used with a crosshead speed of 50 mm/min. Proximate analysis was performed. The moisture content of the raw meat was determined by air drying (AOAC, 1984, procedure 24003) and fat by soxhlet extraction using petroleum ether (AOAC, 1984, procedure 13032). The Kjeldahl procedure (AOAC, 1984; procedure 2057) was used for nitrogen determination; the conversion factor of 6.25 was used to convert nitrogen to percentage protein. The determination of ash was done according to AOAC (1984, procedure 14066), and collagen content and solubility were determined according to the procedures of Hill (1966). Muscle fibre populations were determined according to Brook and Kaiser (1970). Stained sections were examined with an image analysis system using a computer program (KS300, Carl Zeiss Vision GmbH, Germany) for measuring muscle fibre areas.

2.4. Statistical analysis

The effects of diet and LWS were analyzed using the General Linear Model procedure of SPSS v.11 statistical package. The effect of diets × LWS interaction was also analyzed. Pearson correlation coefficients were computed between meat quality parameters.

3. Results and discussion

The results of meat quality attributes are shown in Tables 2–4 for the different muscles (*longissimus*, *triceps brachii* and *semimembranosus* muscles, respectively).

The pH values after slaughter ranged between 6.08 and 6.53 and after chilling between 5.49 and 5.82 and were in agreement with those found by other authors (Snell, 1996). The different diets used did not have any effect on the pH values. These results were in accordance with the observations of Kirton, Thorrold, and Mercer (1989) on lambs. In contrast, Solomon, Lynch, and Berry (1986) observed a pH difference caused by the greater glycogen concentrations present in animals raised on high energy diets. LWS effect was statistically significant on SM as pH values were higher in the 10-kg animals. Marichal, Castro, Capote, Zamorano, and Argüello (2003) found that pH levels fell as the LWS of goat kids fed by milk replacer increased from 6 to 25 kg. This apparent contradiction in terms of LWS

Table 2
Longissimus attributes of kids on different diets and slaughtered at different weights

	SD		MR		Effects		
	6 kg	10 kg	6 kg	10 kg	D	LWS	D × LWS
pH[a]	6.08 ± 0.24	6.28 ± 0.23	6.30 ± 0.31	6.20 ± 0.36	ns	ns	ns
pHz [b]	5.59 ± 0.18	5.68 ± 0.11	5.73 ± 0.01	5.59 ± 0.15	ns	ns	ns
L[a]	50.07 ± 3.92	46.76 ± 5.00	49.53 ± 3.00	47.91 ± 2.91	ns	*	ns
L[b]	56.57 ± 4.82	54.70 ± 6.42	56.93 ± 3.96	52.05 ± 4.43	ns	*	ns
Croma[a]	9.08 ± 1.72	11.50 ± 3.23	10.45 ± 2.43	9.74 ± 1.73	ns	ns	ns
Croma[b]	13.76 ± 3.99	11.48 ± 4.57	16.11 ± 5.69	16.25 ± 6.44	*	ns	ns
Hue [a]	26.79 ± 12.25	27.54 ± 10.27	29.75 ± 8.94	28.11 ± 10.75	ns	ns	ns
Hue [b]	43.99 ± 7.67	36.83 ± 19.03	42.08 ± 6.09	37.78 ± 9.95	ns	ns	ns
SF (N)	50.07 ± 14.93	58.40 ± 13.49	55.71 ± 13.41	59.15 ± 14.09	ns	ns	ns
WHC (g)	0.66 ± 0.11	0.59 ± 0.12	0.46 ± 0.10	0.47 ± 0.14	***	ns	ns
Moisture (%)	78.21 ± 0.38	76.63 ± 0.46	78.40 ± 1.20	77.24 ± 0.45	ns	***	ns
Protein (%)	18.67 ± 0.72	20.07 ± 0.98	19.05 ± 1.74	19.59 ± 0.91	ns	***	ns
Fat (%)	1.26 ± 0.41	1.54 ± 0.39	0.96 ± 0.44	1.64 ± 1.11	ns	ns	ns
Ash (%)	1.15 ± 0.09	1.17 ± 0.06	1.12 ± 0.05	1.15 ± 0.07	ns	ns	ns
Collagen (%)	0.60 ± 0.13	0.36 ± 0.07	0.46 ± 0.16	0.38 ± 0.09	ns	ns	0.05
Coll. Sol. (%)	70.49 ± 8.47	83.52 ± 5.74	85.62 ± 15.84	78.36 ± 9.45	ns	ns	ns
% Type I	24.00 ± 11.43	40.00 ± 10.00	32.91 ± 22.67	26.55 ± 6.64	ns	ns	ns
% Type IIA	46.00 ± 10.70	28.66 ± 11.15	35.50 ± 15.68	42.25 ± 13.26	ns	ns	ns
% Type IIB	30.00 ± 4.00	31.33 ± 9.01	31.85 ± 19.30	31.19 ± 12.93	ns	ns	ns
Type I (μ^2)	484.27 ± 151.88	681.04 ± 115.60	389.10 ± 123.79	584.06 ± 152.24	ns	*	ns
Type IIA (μ^2)	541.23 ± 224.02	582.13 ± 135.32	354.16 ± 164.43	511.69 ± 57.33	ns	*	ns
Type IIB (μ^2)	472.49 ± 166.04	596.13 ± 135.37	367.02 ± 86.79	547.01 ± 107.96	ns	*	ns

D, diet type and LWS, live weight at slaughter.
NS, no significance.
L, lightness; SF, shear force; WHC, water holding capacity and Coll. Sol., collagen solubility.
Data shown in the mean ± standard deviation.
[a] At slaughter.
[b] After chilling.
[*] Significance ($P < 0.05$).
[***] Significance ($P < 0.001$).

Table 3
Triceps brachii attributes of kids on different diets and slaughtered at different weights

	SD		MR		Effects		
	6 kg	10 kg	6 kg	10 kg	D	LWS	D × LWS
pH[a]	6.34 ± 0.21	6.45 ± 0.20	6.53 ± 0.27	6.52 ± 0.18	ns	ns	ns
pH[b]	5.82 ± 0.10	5.49 ± 0.10	5.80 ± 0.14	5.75 ± 0.08	ns	ns	ns
L[a]	53.08 ± 4.61	49.03 ± 3.58	53.60 ± 3.95	51.21 ± 3.76	ns	**	ns
L[b]	56.33 ± 3.08	50.79 ± 4.85	55.47 ± 4.98	55.24 ± 5.48	ns	*	ns
Croma[a]	12.50 ± 3.36	12.43 ± 3.54	11.03 ± 1.41	12.28 ± 3.40	ns	ns	ns
Croma[b]	13.99 ± 2.46	14.20 ± 3.45	15.26 ± 1.76	16.21 ± 2.71	*	ns	ns
Hue [a]	31.34 ± 8.93	25.31 ± 4.48	31.87 ± 6.74	29.52 ± 6.28	ns	ns	ns
Hue [b]	39.82 ± 7.83	30.84 ± 12.36	38.29 ± 10.36	40.56 ± 9.03	ns	ns	ns
SF (N)	83.18 ± 8.64	87.01 ± 8.78	88.40 ± 6.85	90.78 ± 7.48	*	*	ns
WHC (g)	0.41 ± 0.08	0.46 ± 0.16	0.33 ± 0.07	0.31 ± 0.05	*	ns	ns
Moisture (%)	78.38 ± 1.41	78.10 ± 0.62	78.55 ± 0.40	78.47 ± 0.45	ns	*	ns
Protein (%)	17.54 ± 2.07	17.94 ± 1.28	18.53 ± 0.69	18.90 ± 0.45	ns	*	ns
Fat (%)	0.84 ± 0.22	1.27 ± 0.31	1.08 ± 0.51	1.12 ± 0.45	ns	ns	ns
Ash (%)	1.08 ± 0.07	1.05 ± 0.13	1.16 ± 0.07	1.11 ± 0.05	ns	ns	ns
Collagen (%)	0.49 ± 0.06	0.42 ± 0.06	0.40 ± 0.06	0.53 ± 0.05	ns	ns	0.010
Coll. Sol. (%)	83.04 ± 3.04	87.72 ± 4.19	83.09 ± 12.14	74.70 ± 10.53	ns	ns	ns
% Type I	29.49 ± 8.63	28.32 ± 17.11	17.53 ± 12.72	22.40 ± 9.83	ns	ns	ns
% Type IIA	40.13 ± 9.90	45.61 ± 15.98	36.18 ± 19.26	32.95 ± 16.81	ns	ns	ns
% Type IIB	30.37 ± 6.51	26.07 ± 12.21	46.28 ± 11.55	44.64 ± 16.31	ns	ns	ns
Type I (μ^2)	596.22 ± 126.13	795.67 ± 216.06	570.73 ± 134.55	856.46 ± 209.15	ns	*	ns
Type IIA (μ^2)	707.24 ± 238.84	1074.86 ± 241.69	636.02 ± 123.01	801.90 ± 148.43	ns	***	ns
Type IIB (μ^2)	678.77 ± 254.48	847.82 ± 234.87	640.60 ± 142.63	843.68 ± 182.27	ns	*	ns

D, diet type; LWS, live weight at slaughter; NS, no significance; L, lightness; SF, shear force; WHC, water holding capacity and Coll. Sol., collagen solubility. Data shown in the mean ± standard deviation.
[a] At slaughter.
[b] After chilling.
* Significance ($P < 0.05$).
** Significance ($P < 0.01$).
*** Significance ($P < 0.001$).

effect could be related to the fact that animals fed with milk replacer adapt more quickly and efficiently to ruminant eating patterns, thus increasing their intake of carbohydrates and consequently displaying higher levels of muscle glycogen.

The lightness (L) values of the meats were higher than those observed by other authors using adult goats (Babiker, El Khider, & Shafie, 1990) or kids slaughtered with higher LWS (Snell, 1996). The different diets did not significantly affect lightness values. There was an association between LWS and lightness, the 10-kg animals being darker than those slaughtered at 6 kg. This difference was also observed by Marichal et al. (2003) on goats and also by Sañudo, Santolaria, María, Osorio, and Sierra (1996) on lambs. The substitution of milk by a feed richer in iron was possibly the cause of this.

Meat tenderness is one of the most important attributes in terms of consumer satisfaction. Diet significantly affected shear force values in the SM and TB; MR animals had greater shear force values in these muscles than the SD animals. A similar trend in the LD muscle was also observed. These differences could be due to the fact that the animals were older and had consumed greater amounts of starter feed, which would be agree with Pisula et al. (1994), who found statistically significant differences between kids slaughtered at 16 kg LWS and fed exclusively on milk replacer and those which had also consumed starter feed (35.7 vs. 42.6 N, respectively). The effect of LWS was statistically significant in the SM and TB muscles, shear forces being highest in the 10-kg LWS animals. Similar results have been observed by Marichal et al. (2003) in the same breed. Therefore, the fibre area increase could be the main cause of increased toughness, as has been claimed by Crouse, Koohmaraie, and Seideman (1991).

The values obtained for WHC ranged between 0.31 g (6.2%) and 0.72 g (14.4%). In the present study, the pH and the protein content may have played a fundamental role in the greater levels of expelled juice shown by the SD animals as the average pH value for the SD animals after chilling was 5.65, while MR kids had an average pH value of 5.70. LWS did not have a significant effect on the WHC.

Moisture percentage ranged between 76% and 78% and was significantly less in the heavier carcasses, whereas the protein content was greater. The protein percentages were characteristic of those of very young animals (approx. 17–20%), and low muscle fat (0.84–1.26%). Fat is a delayed deposition tissue and in goats it is visceral (Chilliard, Sauvant, Bas, Pascal, & Mor-

Table 4
Semimembranosus attributes of kids on different diets and slaughtered at different weights

	SD		MR		Effects		
	6 kg	10 kg	6 kg	10 kg	D	LWS	D × LWS
pH[a]	6.09 ± 0.27	6.40 ± 0.21	6.39 ± 0.22	6.41 ± 0.33	ns	ns	ns
pH[b]	5.58 ± 0.04	5.73 ± 0.19	5.64 ± 0.07	5.66 ± 0.07	ns	*	ns
L[a]	47.13 ± 17.32	46.17 ± 7.19	54.43 ± 3.11	52.83 ± 3.18	ns	*	ns
L[b]	53.61 ± 5.47	50.68 ± 4.69	54.49 ± 2.11	50.54 ± 4.79	ns	*	ns
Croma[a]	9.73 ± 2.34	12.40 ± 2.34	11.87 ± 2.61	10.45 ± 1.98	ns	ns	ns
Croma[b]	12.43 ± 2.24	13.35 ± 4.63	14.46 ± 3.64	16.47 ± 4.76	**	ns	0.016
Hue[a]	34.57 ± 13.71	26.18 ± 11.65	32.28 ± 7.01	32.11 ± 7.34	ns	ns	ns
Hue[b]	44.93 ± 12.01	36.35 ± 7.24	41.28 ± 6.62	41.55 ± 7.29	ns	ns	ns
SF (N)	32.64 ± 11.87	50.28 ± 8.08	43.67 ± 6.24	56.34 ± 12.65	**	*	ns
WHC (g)	0.72 ± 0.16	0.65 ± 0.13	0.60 ± 0.15	0.60 ± 0.16	*	ns	ns
Moisture (%)	78.46 ± 0.50	77.35 ± 0.81	78.51 ± 0.88	78.26 ± 1.32	ns	*	ns
Protein (%)	18.20 ± 0.99	19.09 ± 1.24	18.10 ± 1.65	18.52 ± 1.84	ns	*	ns
Fat (%)	0.91 ± 0.34	1.33 ± 0.57	1.10 ± 0.51	1.19 ± 0.47	ns	ns	ns
Ash (%)	1.18 ± 0.06	1.13 ± 0.08	1.18 ± 0.09	1.11 ± 0.08	ns	ns	ns
Collagen (%)	0.46 ± 0.05	0.32 ± 0.03	0.42 ± 0.09	0.39 ± 0.06	ns	ns	ns
Coll. Sol. (%)	81.52 ± 10.48	84.61 ± 8.46	74.69 ± 8.77	77.37 ± 11.17	ns	ns	ns
% Type I	9.75 ± 5.68	15.66 ± 5.52	31.40 ± 25.65	18.92 ± 7.39	ns	ns	ns
% Type IIA	84.25 ± 4.27	50.33 ± 29.57	13.83 ± 9.24	19.21 ± 8.27	ns	ns	ns
% Type IIB	6.00 ± 1.82	34.00 ± 20.19	54.77 ± 34.61	61.87 ± 34.56	ns	ns	ns
Type I (μ^2)	508.45 ± 93.47	804.87 ± 115.09	528.04 ± 106.56	598.74 ± 109.53	ns	*	ns
Type IIA (μ^2)	564.45 ± 198.00	884.35 ± 197.21	602.65 ± 138.86	679.38 ± 125.65	ns	*	ns
Type IIB (μ^2)	565.55 ± 146.38	735.15 ± 185.40	586.34 ± 129.95	664.18 ± 150.99	ns	*	ns

D, Diet type; LWS, live weight at slaughter; NS, no significance; L, lightness; SF, shear force; WHC, water holding capacity; and Coll. Sol., collagen solubility; Data shown in the mean ± standard deviation.
[a] At slaughter.
[b] After chilling.
[*] Significance ($P < 0.05$).
[**] Significance ($P < 0.01$).

and-Fehr, 1981). These reasons could explain the low fat contents found compared with other goat breeds. The diet did not have any effect on the chemical composition, which was in accordance with the observations of Mueller, Steinhart, and Scheper (1985) using kids of similar weights and feed types. No significant LWS effects were found for fat percentages. The muscle which presented the greatest increase in terms of type I fibre area, the LD, also experienced the greatest increase in terms of fat percentage, which was in accordance with earlier findings with lambs (Moody, Kemp, Mahyuddin, Jonhston, & Ely, 1980).

Collagen percentages were similar to those observed by Van Niekerk and Casey (1988) in Boer goats, but collagen solubility was higher in the present study. The higher degree of collagen solubility in goats vs. other species has already been described (Van Niekerk & Casey, 1988), but in this study solubility rates were very high indeed, from 70% to 87% as opposed to the 33% observed in the Boer breed, the 20% in 20-kg LWS sheep (Morbidini, Sarti, Pollidori, & Valigi, 1999). These major differences with regard to collagen solubility were probably due to the age of the animals. Neither LWS nor lactation type had any significant effect on collagen content and solubility.

Diet did not affect muscle fibre areas (Tables 2–4). The results found in the present study are in agreement with Argüello, López-Fernández, and López-Rivero (2001). LWS had a statistically significant effect on muscle fibre areas. When the LWS increase from 6 to 10 kg, the muscle fibre area increased by 28.55%, 39.00% and 40.20% for the LD, SM and TB muscles, respectively. This increase was due to the hypertrophic growth which has been previously described by Swatland (1975). As has been previously established by Yamaguchi, Horio, Sakuma, and Katsuta (1993), it is the weight of an animal rather than its age which determines its fibre areas, and this was amply demonstrated in the present study in which animals of differing ages but of the same weights displayed similar muscular fibre areas.

Table 5 shows the correlation matrix between the meat quality parameters. The ultimate pH value presented a negative correlation with the amount of juice expelled.

There was a highly significant correlation between lightness and the Hue angle 24 hours after slaughter, indicating that the lighter coloured meats had a more pinkish colour, while the darker meats had a more brownish tone. Meat toughness was highly significantly correlated with the amount of juice expelled and was significantly correlated with the percentage of collagen.

Table 5
Correlation matrix

	pH[1]	L[1]	Croma[1]	Hue[1]	SF	WHC	M	P	F	A	Colla.	Colla. Sol.	% I	% IIA	% IIB	Area I	Area IIA
L[a]	−0.003																
Croma[a]	0.021	−0.002															
Hue[a]	−0.263	0.653 ***	−0.034														
SF	0.138	0.138	0.075	0.074													
WHC	−0.278 **	−0.109	0.036	0.102	−0.433***												
M	0.009	0.248*	0.148	0.241*	0.178	−0.033											
P	−0.082	−0.085	−0.095	−0.094	−0.014	−0.002	−0.770***										
F	−0.160	−0.025	−0.060	0.013	−0.014	−0.012	−0.337***	0.096									
A	−0.241	0.025	−0.007	0.068	−0.162	0.118	−0.436***	0.477***	0.059								
Colla.	0.196	0.056	0.040	−0.146	0.301*	−0.175	0.289*	−0.271	−0.104	0.044							
Colla. Sol.	0.016	−0.077	−0.145	−0.064	0.043	0.095	−0.073	0.007	−0.199	−0.241	−0.409**						
% I	0.086	0.161	−0.077	0.019	−0.253	0.157	−0.132	−0.085	0.231	−0.230	−0.023	0.134					
% IIA	−0.094	−0.21	0.169	−0.090	0.146	0.006	0.161	−0.075	−0.112	0.086	−0.034	−0.043	−0.461**				
% IIB	0.044	0.133	−0.132	0.085	0.012	−0.111	−0.106	0.131	0.006	0.031	0.050	−0.021	−0.153	−0.806***			
Area I	0.061	−0.157	−0.098	−0.097	0.156	−.164	0.025	−0.252	0.146	−0.249	0.048	0.218	0.182	−0.173	0.071		
Area IIA	0.293	−0.282	−0.057	−0.094	0.086	−0.178	0.215	−0.367*	0.047	−0.323*	0.029	0.030	0.067	−0.018	−0.029	0.791***	
Area IIB	0.290.	−0.178	−0.068	−0.083	0.116	−0.154	0.142	−0.323*	−0.019	−0.340*	0.010	0.077	0.151	−0.226	0.151	0.862***	0.848***

SF, shear force; WHC, water holding capacity; M, moisture; P, protein; F, fat; A, ash; Colla, collagen and Sol, Solubility.
[a] After chilling.
* $P < 0.05$.
** $P < 0.01$.
*** $P < 0.001$.

Crouse et al. (1991) observed positive correlations between the diameter of the fibres and the toughness of the muscle tissue, something which was not in evidence in our tests. Finally, a negative correlation was observed between collagen content and solubility.

4. Conclusions

Results suggest that the different variables do not have important negative effects on meat quality but would result in more edible meat (pounds) be marketed.

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