

## Carcass characteristics and instrumental meat quality of suckling kids and lambs

C. Sañudo<sup>1</sup>, M. M. Campo<sup>1,\*</sup>, E. Muela<sup>1</sup>, J. L. Olleta<sup>1</sup>, R. Delfa<sup>†2</sup>, R. Jiménez-Badillo<sup>1</sup>,  
M. J. Alcalde<sup>3</sup>, A. Horcada<sup>3</sup>, I. Oliveira<sup>1</sup> and I. Cilla<sup>1</sup>

<sup>1</sup> *Departamento de Producción Animal y Ciencia de los Alimentos, Facultad de Veterinaria,  
Universidad de Zaragoza, 50013 Zaragoza, Spain*

<sup>2</sup> *Centro de Investigación y Tecnología Agroalimentaria de Aragón, Avenida de Montañana 930,  
50059 Zaragoza, Spain*

<sup>3</sup> *Area de Ciencias Agroforestales, Escuela Universitaria de Ingeniería Técnica Agrícola, Universidad de Sevilla,  
41013 Sevilla, Spain*

† Deceased

---

### Abstract

Meat from very young, milk-fed, small ruminants is an appreciated product in Mediterranean countries where milk is the main product derived from the herds. Nevertheless, many aspects of the quality of the products are virtually unknown for many goat breeds, especially among those that are reared for their meat. In this study, the quality from 50 animals from 5 local goat breeds (one dairy purpose and 4 meat purpose) and 19 lambs (from Churra, a dairy breed) was compared at commercial cold carcass weights of 4.4-6.6 kg. Carcass quality, ultimate pH and meat colour were assessed following standard procedures. Statistical differences ( $p < 0.05$ ) were found in all of the variables analysed. Some of these differences might have been due to the influence of the genotype, the dam's production potential, or differences in carcass weight and age, but most were species dependent. Lambs differed from the kids, especially from those of meat purpose breeds, due to their high proportion of bone (25.0 vs. 21.3 to 23.7%), and a more intense meat colour (higher hue: 29.2 vs. 23.4 to 28.7, and chroma: 14.6 vs. 12.1 to 14.6). Among the goat breeds, Murciano Granadina (dairy breed) and Blanca Celtibérica (meat breed) were the most different in terms of carcass morphology, fatness, and meat colour. The other three local meat-purpose goat breeds (Moncaína, Negra Serrana, and Pirenaica) differed little. To obtain a better understanding of goat species, the differences among breeds, in kids or in their most common products, require further studies.

**Additional key words:** carcass morphology; colour; goat; pH; sheep; tissue composition.

### Resumen

#### Características de la canal y calidad instrumental de la carne en cabritos y corderos lechales

La carne de lechal es muy apreciada en los países mediterráneos, en los que la leche es una producción fundamental. Además, muchos aspectos de los productos de las razas caprinas locales son prácticamente desconocidos. En este estudio se analizó la calidad de 50 animales de 5 razas caprinas (una lechera y 4 de aptitud cárnica) y de 19 corderos (raza Churra de tipo lechero), a pesos comerciales de 4,4-6,6 kg de canal fría. Se evaluaron la calidad de la canal, el pH último y el color de la carne, siguiendo metodologías estandarizadas. Se encontraron diferencias significativas ( $p < 0,05$ ) en todas las variables analizadas. Algunas de estas diferencias se podrían justificar por diferencias raciales, potencial lechero de las madres o peso canal final, pero la mayor parte fueron debidas a la especie considerada. Los corderos fueron diferentes, especialmente de los cabritos de razas con orientación predominantemente cárnica, en la proporción de hueso (25,0 vs. 21,3-23,7%) y color de carne más intenso (superiores valores de tono: 29,2 vs. 23,4-28,7 y saturación: 14,6 vs. 12,1-14,6). Entre las razas caprinas, la Murciano Granadina (raza de aptitud lechera) y la Blanca Celtibérica (raza cárnica) fueron las más diferentes en morfología de la canal, engrasamiento y color de carne. Las otras tres razas de aptitud cárnica (Moncaína, Negra Serrana y Pirenaica) fueron poco diferentes entre sí. Para conocer mejor a la especie caprina, las diferencias entre razas y la calidad de sus productos, son necesarios una mayor cantidad de estudios.

**Palabras clave adicionales:** caprino; color; composición tisular; morfología de la canal; ovino; pH.

## Introduction

On a global scale, the production of meat from small ruminants is relatively small; however, in some regions, especially dry or mountainous habitats, where other species cannot thrive, small-ruminant species are very important. Goat products such as meat, milk and dairy products are important protein sources of animal origin for local people of rural areas, especially in developing countries (Ekiz *et al.*, 2010). Also, they represent a growing market share in many developed countries (Haenlein, 2004). Thus, among sub-developing, developing, and developed countries, agricultural objectives differ, and subsistence, quantity, and quality often are their respective objectives.

In the lamb meat industry, many commercial branches, trademarks, and Geographical Protected Indications (GPI) exist, but generally this is not true in the goat meat industry, especially when we considered meat purpose breeds. Those breeds, which are not milked, are raised in agro-pastoral production systems on arid rangelands with traditional, socially tolerant, and sustainable techniques, and in harmony with the local environment (Shrestha & Fahmy, 2005). Goats are no longer synonymous with underdevelopment and poverty because they can be an important source of products in many parts of the world (Dubeuf & Boyazoglu, 2009).

Meat goats include the majority of breeds not specialised for either dairy or fibre production and their numbers are increasing (Shrestha & Fahmy, 2005). On one hand, the population of these breeds is small, and they are considered among the endangered breeds, which have a limited geographical distribution. On the other hand, in many countries, including Spain, France, and Italy, a significant proportion of the meat produced is sold in domestic markets, where it is seasonally much appreciated (Le Jaouen, 1997). Frequently, kids are sold as suckling animals, but without specific quality identification, a positive cue in many markets (Rubino *et al.*, 1999; Schnettler *et al.*, 2009). In general, kids are weaned at 2-3 months of age and goats are milked for the next 4-6 months. In this production models, kids are slaughtered immediately after weaning at 10-15 kg live weight and therefore low weight carcasses are

produced (Ekiz *et al.*, 2010). Given the need to increase the income of goat meat producers, objective information about the quality of the product (carcass and meat) is a necessary argument to get the consideration of a specific quality product for local, national, and supra-national (*i.e.*, European Union) authorities. The different species have a logical competence in the marketplace because there is a specific and maximum amount of meat *per capita* and per year consumed in developed countries. Despite the fact that the amount of goat meat consumed is small, it commands a below-average price compared to other meats such as mutton, which is attributed to the popular belief that goat meat is inferior to mutton, even though research suggests otherwise (Babiker *et al.*, 1990).

Nevertheless, some authors have indicated the small proportion of research in goats compared with other ruminants, even considering that the difference between numbers of goat and sheep manuscripts declined from 30% in 1980 to 22% in 1999 of the total of papers concerning small ruminant research. If we compared this data with the increase in goat population during the same period, the increase in number of goat papers was relatively small (Morand-Fehr & Lebbie, 2004). Therefore, more research in this species and in the area of carcass and meat quality (3% of the overall goat research during the period: 1982-2000) is needed.

Carcass traits, such as the conformation as well as fat distribution within the carcass, are therefore of great importance in meat production, including suckling kids and lambs. The proportion of high value cuts is also an important indication of the overall value of the carcass. Carcasses attributes are principally concerned with the quantity of saleable meat that can be obtained, but also have significant implications on the technological properties of the meat, such as pH, colour and tenderness (Simela *et al.*, 2011). Some studies have indicated that carcass quality can differ significantly among breeds, particularly among light lambs, but to some extent differences depend on the criteria used in comparisons (same weight, same age, or same proportion of mature weight). However, breed is much less important in lamb meat quality than other factors (Santos Sylva *et al.*, 2002; Martínez-Cerezo *et al.*, 2005; Pérez *et al.*, 2007; Miguélez *et al.*, 2006). In goats, some papers have also

---

Abbreviations used: BC (Blanca Celtibérica meat goat breed); BG (buttock perimeter); CCW (Cold Carcass Weight); Ch (Churra dairy ewe breed); EF (breastbone fat thickness); F (pelvic limb length); G (buttock width); GPI (); K (carcass external length); LD (*Longissimus dorsi* muscle); MG (Murciano Granadina dairy goat breed); Mo (Moncaína meat goat breed); NS (Negra Serrana meat goat breed); PCA (Principal Component Analysis); Pi (Pirenaica meat goat breed); Th (chest depth).

studied the importance of the breed in both carcass and meat quality. As it happens in lamb, breed is more important for carcass characteristics than for meat quality (Dhanda *et al.*, 2003; Monte *et al.*, 2007; Ekiz *et al.*, 2010). Few studies, however, have compared them with each other, or with other species (Smith *et al.*, 1974; Griffin *et al.*, 1992; Schönfeldt *et al.*, 1993; Rødbotten *et al.*, 2004), and very few have assessed meat from very young, mainly milk-fed animals, particularly in goats (Banskalieva *et al.*, 2000).

The aim of this study was to compare the carcass and instrumental meat quality, in milk-fed, very young animals, from different goat breeds, and from one labelled, GPI-EU, recognized lamb product.

## Material and methods

### Animals

The study used 50 kids from 5 goat breeds ( $n = 10$  each) and 19 animals from 1 sheep breed. Four of the goat breeds are recognised as endangered (BOE, 2008), and they could be included within the Spanish meat purpose local breeds, not milked. The adult live weights of the five goat breeds (Fuentes *et al.*, 2006; Esteban, 2009) are as follows: Blanca Celtibérica (BC), 70-85 kg (males) and 45-60 kg (females); Moncaína (Mo), 45-65 kg (males) and 30-45 kg (females); Negra Serrana (NS), 80-100 kg (males) and 50-80 kg (females); Pirenaica (Pi), 60-85 kg (males) and 50-65 kg (females); Murciano Granadina (MG), a dairy breed that has the highest census in Spain, 50-70 kg (males) and 40-55 kg (females). The lamb breed [Churra breed (Ch), with live weights of 80-90 kg (males) and 50-70 kg (females)] produces the PGI “Lechazo de Castilla y León” (Miguélez *et al.*, 2006). For more information, see Sañudo (2011).

All the animals were males reared in their respective local areas following local husbandry practices. All of them were unweaned and reared on their dam's milk. Animals were selected, to be representative, for their respective Breeder Associations, at least from two different farms.

### Slaughter and post-slaughter conditions

Animals were transported from farms in accordance with welfare specifications and slaughtered in local EU-licensed abattoirs in their respective areas of origin.

After 24 h of chilling under commercial protocols, carcasses were transported to the laboratory where carcass quality evaluations and sampling were performed at 48 h of ageing.

### Carcass quality

Cold carcass weight (CCW) and visual carcass assessment, including morphology and conformation, were evaluated using the Colomer-Rocher Scale (Ruiz de Huidobro *et al.*, 2005), and external fatness (Delfa *et al.*, 2005) and colour of the *rectus abdominis* muscle were assessed based on the European Union (EU) colour scale (Martínez-Cerezo *et al.*, 2005). Carcass linear measurements were measured based on standard protocols (Palsson & Verges, 1952; Boccard *et al.*, 1958), including carcass external length (K), buttock perimeter (BG), buttock width (G), pelvic limb length (F), chest depth (Th), and breastbone fat thickness (EF) on the 2<sup>nd</sup>, 3<sup>rd</sup> and 4<sup>th</sup> *sternbrae* (Delfa *et al.*, 1996).

The left thoracic limb was sampled (Colomer *et al.*, 1988) and dissected, to remove the muscle, subcutaneous, prescapular, intermuscular fat, bone (and cartilage), and others. Results were expressed as the proportion (%) of the dissected components.

### Sampling and instrumental meat quality

After carcass evaluation, the *Longissimus thoracis* muscle was excised from the right carcass side and its ultimate pH was measured using a portable CRISON 507 pH meter equipped with a penetrating electrode in its cranial portion. After 15 min of blooming, meat colour ( $h^*$  and  $C^*$ ) was evaluated using a portable Minolta colorimeter (CM-200), in the CIE  $L^*a^*b^*$  space, with the standard illuminant  $D_{65}$  and a 10° standard observer. Results were expressed as the average of three measurements of the same surface area (on the LD muscle between the lumbar and thoracic regions).

### Statistical analyses

A General Linear Model (GLM) in SAS 8.02 assessed the effect of breed on carcass characteristics and meat quality. Breed had a highly significant ( $p \leq 0.01$ ) effect on cold carcass weight ( $p \leq 0.001$ ); therefore, with the exception of those associated with the tho-

racic limb composition, which were expressed as percentages, carcass quality variables were reanalysed using a GLM that included cold carcass weight as a covariate. When F-tests were significant at  $p \leq 0.05$ , means were compared using Duncan's Test. All of the carcass and instrumental meat quality variables of all of the breeds were subjected to a Principal Component Analysis (PCA).

## Results

### Carcass morphology and carcass conformation

All of the carcass morphology and conformation variables differed significantly ( $p \leq 0.01$ ) among breeds (Table 1). Average carcass weights ranged from 4.38 kg (MG breed) to 6.56 kg in BC breed. In goats, all linear carcass variables were greater ( $p \leq 0.001$ ) in the BC and NS breeds than in MG breed. Nevertheless, Ch showed the highest fatness score (without significant differences with BC breed) and the lowest breastbone 4 fat thickness ( $p \leq 0.001$ ), although without significant differences with MG and Mo breeds. When data were covariates by the carcass weight, smaller differences were appreciated (Table 2). Although BC remained with the longest pelvic limb ( $p \leq 0.01$ ), only significantly different with MG and

Mo, NS showed the widest buttock ( $p \leq 0.01$ ), only significantly different with Ch and MG, and PI the deepest breast ( $p \leq 0.001$ ), only significantly different with Ch, MG and Mo. Lambs had, comparatively, an important development of the buttock perimeter (Table 2), which was associated in some extend, with their conformation score.

### Carcass fat and colour measurements

Means and covariates mean values for fatness, breastbone fat thickness, and carcass colour score, are showed in Tables 1 and 2, respectively. Results for fatness of the goat breeds did not differ significantly, even considering the lower slaughter weight of MG. Ch lambs had higher ( $p \leq 0.001$ ) fatness scores, with the exception of BC and MG in uncovariate and covariate means, respectively, and lower ( $p \leq 0.001$ ) breastbone fat thickness (4 mm), with the exception of MG and Mo and MG, Mo and BC in uncovariate and covariate means respectively, than the goat breeds did.

Carcass colour scores, in uncovariate and covariate values, were especially low ( $p \leq 0.001$ ) in the MG animals, although there were not significant differences with the rest of the compared breeds, except BC, in covariate data (see Tables 1 and 2). Ch lambs and NS kids also showed low values, although they did not differ from the other studied goat breeds.

**Table 1.** Carcass quality variables in five breeds of suckling kids and one breed of lamb (means and SED)

Quality variables	Breed <sup>1</sup>						SED <sup>2</sup>	Sig <sup>3</sup>
	Mo (n = 10)	Pi (n = 10)	BC (n = 10)	MG (n = 10)	NS (n = 10)	Ch (n = 19)		
CCW <sup>4</sup> (kg)	5.32bc	4.71ab	6.56d	4.38a	5.83cd	5.49bc	0.12	***
Conformation 1-15	2.20ab	2.30ab	3.10b	1.70a	2.00ab	2.89b	0.15	**
Pelvic limb length (cm)	23.01ab	22.97ab	24.76d	22.59a	23.68bc	24.16cd	0.14	***
Carcass external length (cm)	38.95a	39.70ab	43.10c	37.54a	42.10bc	41.75bc	0.32	***
Buttock width (cm)	12.80a	12.75a	14.05b	12.10a	13.65b	12.79a	0.11	***
Chest depth (cm)	18.05b	18.85c	19.90d	17.15a	18.95c	17.90b	0.13	***
Buttock perimeter (cm)	36.90bc	35.05ab	39.95d	34.55a	38.45cd	39.45d	0.28	***
Fatness 1-15	2.70a	2.30a	4.00ab	3.00a	3.20a	5.47b	0.26	***
Breastbone 2 fat thickness (mm)	11.01ab	14.12b	12.91b	9.58a	13.44b	11.11ab	0.43	***
Breastbone 3 fat thickness (mm)	11.61ab	14.10b	13.39ab	10.53a	14.09b	11.11ab	0.41	***
Breastbone 4 fat thickness (mm)	11.25ab	13.35bc	13.99c	10.43a	14.23c	9.45a	0.45	***
Colour 1-12	3.60b	3.60b	3.60b	1.70a	2.20ab	2.47ab	0.21	***

<sup>1</sup> Mo = Moncaína goat breed; Pi = Pirenaica goat breed; MG = Murciano Granadina goat breed; NS = Negra Serrana goat breed; BC = Blanca Celtibérica goat breed; Ch = Churra sheep breed. a-d: values in rows with different letters are significantly different ( $p \leq 0.05$ ).

<sup>2</sup> SED: standard error of the difference. <sup>3</sup> \*\*:  $p \leq 0.01$ , \*\*\*:  $p \leq 0.001$ . <sup>4</sup> CCW = cold carcass weight.

**Table 2.** Breed and species effects on carcass quality variables in suckling kids and lambs including CCW as a covariate (covariate means and SED) [see Table 1]

	Breed <sup>1</sup>						SED <sup>2</sup>	Sig <sup>3</sup>
	Mo (n = 10)	Pi (n = 10)	BC (n = 10)	MG (n = 10)	NS (n = 10)	Ch (n = 19)		
Conformation 1-15	2.25ab	2.73ab	2.38ab	2.33ab	1.73a	2.83b	0.14	*
Pelvic limb length (cm)	23.05a	23.31abc	24.18c	23.09ab	23.46abc	24.11bc	0.12	**
Carcass external length (cm)	39.11a	41.10bc	40.70abc	39.63ab	41.20bc	41.55c	0.21	***
Buttock width (cm)	12.84abc	13.14abc	13.38bc	12.68a	13.47c	12.73ab	0.08	**
Chest depth (cm)	18.11ab	19.38d	18.99cd	17.94ab	18.66bcd	17.81a	0.09	***
Buttock perimeter (cm)	37.06a	36.46a	37.56a	36.64a	37.55a	39.24b	0.13	***
Fatness 1-15	2.78a	3.00a	2.81a	4.05ab	2.75a	5.37b	0.23	***
Breastbone 2 fat thickness (mm)	11.08a	14.69b	11.93ab	10.43a	13.07ab	11.02a	0.42	**
Breastbone 3 fat thickness (mm)	11.68ab	14.72b	12.33ab	11.46a	13.69ab	11.01a	0.40	**
Breastbone 4 fat thickness (mm)	11.35ab	14.23b	12.50ab	11.74ab	13.67b	9.32a	0.42	**
Colour 1-12	3.61ab	3.73b	3.38ab	1.89a	2.12ab	2.45ab	0.21	**

<sup>1</sup> See Table 1. a-d: values in rows with different letters are significantly different ( $p \leq 0.05$ ). <sup>2</sup> SED: standard error of the difference.

<sup>3</sup> \*:  $p \leq 0.05$ , \*\*:  $p \leq 0.01$ , \*\*\*:  $p \leq 0.001$ .

### Shoulder composition

Breeds differed significantly in their shoulder tissue composition (Table 3). The lowest differences ( $p \leq 0.05$ ) were found in intermuscular fat and others percentages. The percentage of muscle was lower ( $p \leq 0.001$ ) in the Ch sheep and BC goats, without significant differences with MG and NS breeds.

BC goats had the highest percentages of the three fat depots. The proportions of fat and bone in the most muscular (higher muscle percentage) breed, Mo, were intermediate among the breeds evaluated in the current study, being the genotype a significant effect. The kids of the MG breed had the lowest subcutaneous fat ( $p \leq 0.001$ ), and the kids of the NS breed had the

lowest intermuscular fat ( $p \leq 0.05$ ) percentages, although only these differences only were significant with BC goat breed.

Ch sheep had a relatively high subcutaneous fat content, but it had the lowest percentage of prescapular fat. Intermuscular fat of Ch lambs and of the goat breeds did not differ ( $p \geq 0.05$ ) significantly.

### Instrumental meat quality

The colour variables and ultimate pH differed significantly ( $p \leq 0.01$ ) among species, being ultimate pH the lowest ( $p \leq 0.001$ ) in Ch sheep (Table 4), without significant differences ( $p \geq 0.05$ ) with Mo and Pi animals.

**Table 3.** Breed and species effects on shoulder composition (%) in suckling kids and lambs (means and SED)

	Breed <sup>1</sup>						SED <sup>2</sup>	Sig <sup>3</sup>
	Mo (n = 10)	Pi (n = 10)	BC (n = 10)	MG (n = 10)	NS (n = 10)	Ch (n = 19)		
Muscle	64.18b	63.98b	60.55a	62.24a	63.05ab	61.28a	0.12	***
Subcutaneous fat	2.94a	3.67a	5.85b	2.87a	3.78ab	4.07ab	0.28	**
Intermuscular fat	6.84ab	6.27ab	7.33b	6.65ab	5.55a	5.89ab	0.24	*
Prescapular fat	2.46ab	3.04bc	3.52c	2.35ab	2.94bc	1.91a	0.13	***
Total fat	12.23a	12.97a	16.70b	11.87a	12.27a	11.87a	0.44	***
Bone plus cartilage	21.77a	21.27a	21.44a	23.73b	23.03b	25.04c	0.20	***
Others	1.83ab	1.78ab	1.32a	2.16b	1.65ab	1.81ab	0.09	*

<sup>1</sup> See Table 1. <sup>2</sup> SED: standard error of the difference. <sup>3</sup> \*:  $p \leq 0.05$ , \*\*:  $p \leq 0.01$ , \*\*\*:  $p \leq 0.001$ .

The highest  $L^*$  value (no statistically different from Ch values) and the lowest  $a^*$  values ( $p \leq 0.001$ ) were found in the meat from MG kids, and the lowest  $L^*$ , without differences ( $p \geq 0.05$ ) with Pi, and the highest  $a^*$  ( $p \leq 0.001$ ) without differences ( $p \geq 0.05$ ) with Ch and Pi, were from BC breed. Meat yellowness ( $b^*$ ) did not differ significantly among goat breeds, but was significantly higher ( $p \leq 0.001$ ) in lamb meat. In addition, lamb had the second highest values of redness and lightness.

Ch and MG breeds had the highest ( $p \leq 0.01$ ) hue values, which were significantly higher ( $p \leq 0.01$ ) than those of the other goat breeds, which did not show differences among them. Chroma was higher ( $p \leq 0.01$ ) in the meat from Ch lambs and BC kids, but not significantly different from that of Pi kids. MG kids had the lowest ( $p \leq 0.01$ ) chroma.

### Principal component analysis

The first two principal components explained 77.54% of the variability in the model (Fig. 1). PCA 1 (49.2% of the variability) was more associated with the colour score  $a^*$ , and fat indicators in its positive scale, and PCA 2 (28.3% of the variability) was more associated with fatness scores and  $b^*$  in its positive scale and ultimate pH in the negative one.

## Discussion

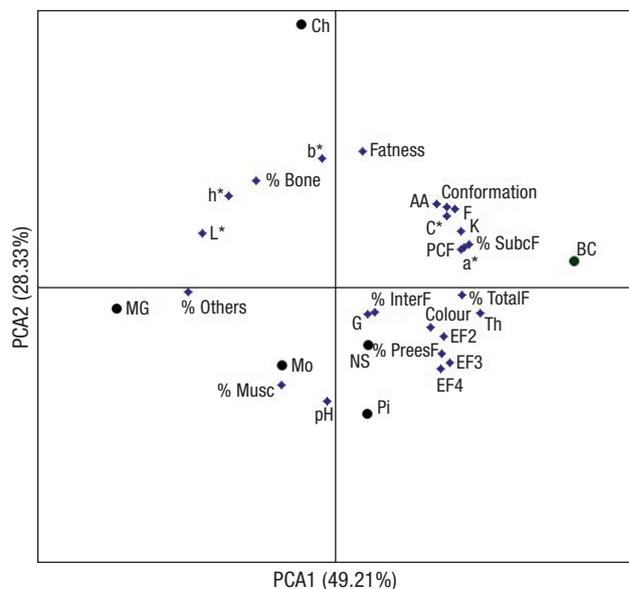
### Carcass morphology and carcass conformation

BC and NS breeds, the two with the highest carcass weights, are those that have the highest adult weight in males, which indicates later maturity and the need for higher slaughter weights to reach appropriate levels of fatness. In addition, those breeds are reared for meat (in contrast to the dairy MG), and a high slaughter weight is needed to take full advantage of their productive performance, which is unlike milk breeds in which early weaning and slaughtering are used to increase the dam's milk commercialisation. Ekiz *et al.* (2010) also justify differences among breeds considering the differences in body size and production type.

Typically, carcass weights and carcass measurements are positively correlated (Marichal *et al.*, 2003), and because of that, we covariated those variables by

weight. In the current study, the uncovariate values of the linear carcass variables were higher, between goat breeds, in BC. This agrees with Peña *et al.* (2007) who observed an increase in carcass measurements and indexes due to differences in slaughter weight. But when the comparisons were made with covariate means, only chest depth maintained that differences.

The morphology of the Ch carcasses was similar to those previously reported in the same breed and commercial type (Sañudo *et al.*, 1997), and typical of the Lechazo de Castilla y León PGI (Miguélez *et al.*, 2006). In the current study, the Ch had intermediate values for weight and most linear carcass measure-



**Figure 1.** Principal component analysis in suckling kids and lambs (Ch = Churra sheep breed and five goat breeds: MG = Murciana Granadina, Mo = Moncaína, BC = Blanca Celtibérica, Pi = Pirenaica and NS = Negra Serrana) for some carcass and instrumental meat quality variables ( $a^*$  = redness;  $b^*$  = yellowness; BG = buttock perimeter;  $C^*$  = chroma; CCW = cold carcass weight; Colour = colour score evaluated at the *rectus abdominis* level; Conformation = carcass conformation score; EF2, EF3 and EF4 = breastbone fat thickness at the 2<sup>nd</sup>, 3<sup>th</sup> and 4<sup>th</sup> *sternebrae* level, respectively; F = pelvic limb length; Fatness = fatness score; G = buttock width;  $h^*$  = hue; K = carcass external length;  $L^*$  = lightness; pH = pH on the *Longissimus dorsi* at 24 h after slaughter; Th = chest depth; % Bone = proportion of bone in the shoulder; % InterF = proportion of intermuscular fat in the shoulder; % Musc = proportion of muscle in the shoulder; % Others = proportion of other tissues in the shoulder; % PreeF = proportion of pre-carpular fat in the shoulder; % SubcF = proportion of subcutaneous fat in the shoulder; % TotalF = proportion of total fat in the shoulder.

**Table 4.** LD muscle ultimate pH and colour (15 min of blooming) in suckling kids and lambs (means and SED)

	Breed <sup>1</sup>						SED <sup>2</sup>	Sig <sup>3</sup>
	Mo (n = 10)	Pi (n = 10)	BC (n = 10)	MG (n = 10)	NS (n = 10)	Ch (n = 19)		
pH	5.76 ab	5.76 ab	5.79 bc	5.84 c	5.79 bc	5.56 a	0.02	***
L*	51.69 b	50.05 ab	49.15 a	55.14 c	51.71 b	53.69 c	0.08	***
a*	11.90 b	12.70 bc	13.39 c	10.57 a	11.80 b	12.76 bc	0.05	***
b*	5.31 a	5.70 a	5.76 a	5.79 a	5.43 a	7.07 b	0.02	***
h*	24.48 a	24.12 a	23.45 a	28.74 b	25.24 a	29.24 b	0.11	**
C*	13.13 b	13.93 bc	14.60 c	12.08 a	13.05 b	14.61 c	0.04	**

<sup>1</sup> See Table 1. <sup>2</sup>SED: standard error of the difference. <sup>3</sup>\*\*\*:  $p \leq 0.01$ , \*\*\*\*:  $p \leq 0.001$ .

ments (except those related to buttock perimeter). Typically, goats have longer limbs than sheep, and have poorer carcass morphology, even considering that Ch is a dairy sheep breed. This statement is especially evident when covariated results are compared (Table 2). In this case, Ch breed had the highest buttock perimeter ( $p \leq 0.001$ ), which differed significantly from those of the other goat breeds. In the same way, when covariated means were examined, there were fewer differences between the meat and dairy goat breeds than expected, with MG having intermediate values, which reflected the amyotrophic condition of the species, although some exception could be indicated, such as Boer breed, which has an acceptable meat conformation (Shrestha & Fahmy, 2005).

### Carcass fat and colour measurements

Fatness of the goat breeds was, in the current study, was similar. Also, Dhanda *et al.* (1999a) did not find significant differences in the fat thickness of kids from five genotypes that were slaughtered at CCW from 6.2 to 7.0 kg, having all of them had a fat thickness of only 1 mm.

On the other hand, sheep tends to deposit more subcutaneous fat than at the breast level, which might explain our results, although no significant differences existed with all the goat breeds, (higher fatness scores and lower breastbone fat thickness), because fatness score is based on the carcass surface. Thus, the breast is the site for the evaluation of body condition in goats, and in sheep the site is in the lumbar region (Delfa *et al.*, 1998; Teixeira *et al.*, 2011).

Our carcass colour scores were very low, as previously found by other authors (Martínez Cerezo *et al.*, 2005), which reflected the milk diet of the young ani-

mals since milk is not rich in iron. This was especially true for dairy specialised breeds, which have subsequently more milk nutrients disposability to young lambs and kids. Also, the relatively low values found in NS kids, although without significant differences, were probably due to that this breed has a high adult live weight, which might have led to a relatively low physiological maturity and, consequently, low iron content at the studied slaughter weights (Sañudo *et al.*, 1998).

### Shoulder composition

Shoulder tissue composition is a reasonable predictor of carcass tissue composition in kids (Argüello *et al.*, 2001). In the former study, the bone content of the Ch carcasses (25.0%) was over 2% higher ( $p \leq 0.001$ ) than in any other breed analyzed in the current study, but less than the value (26.5% in the thoracic limb) reported by Miguélez *et al.* (2006) and higher than the value (24.7% in the in the half carcass) reported by Sañudo *et al.* (1997) for the same breed and commercial type.

Probably because BC breed had the heaviest carcasses, without significant differences with NS breed, it had the highest proportions of the three fat depots, although without significant differences with some breeds depending on the fat deposit considered, showing the importance of the weight - age relationship, in the development of this later development tissue (Zygoyiannis *et al.*, 1990 for lambs; and Dhanda *et al.*, 2003, and Atti *et al.*, 2004, for goats). In some cases, slaughter weight is the main factor influencing carcass composition (Mahgoub *et al.* [2005], in Jebel Akhdar goat breed slaughtered at 4.6, 7.9 and 13.6 kg of cold carcass weight or in Pérez *et al.* [2007], in suckling lambs slaughtered at 10 or 15 kg, live weight), although

Marichal *et al.* (2003) did not find a significant relationship between composition and slaughter weight, and Todaro *et al.* (2002) only found significant differences in the proportion of muscle in the pelvic limb. Also, the genotype could have a significant effect in carcass composition because of differences in maturity, and the disposability of milk because of its energetic value and the subsequent possibility of accumulating more fat.

MG breed showed the lowest subcutaneous fat percentage, although only significantly different from BC breed, which reflected the tendency for dairy breeds to store more visceral fat than carcass adipose tissue (Dhanda *et al.*, 1999a; Marichal *et al.*, 2003), and the largest proportion of intermuscular fat. This deposit has been described as precocious, in relation to the total carcass fat (Delfa *et al.*, 1994), and it might develop quicker because of the high nutritional level of MG kids, that result from their dam's dairy production potential. In this way, in Marichal *et al.* (2003) study about the Canary Caprine Group, dairy breed, only intermuscular fat deposits varied significantly among several slaughter weights.

Generally, goats have less fat content than do sheep, although the extent of the difference can vary depending on the type of the fat deposit considered (Schönfeldt *et al.*, 1993; Sañudo *et al.*, 1997).

### Instrumental meat quality

The pH values found in the current study, in Ch breed, were similar to those found by Martínez Cerezo *et al.* (2005) in the same breed and commercial type. These results were lower, without significant differences with Moncaina and Pi breeds, than in the studied goat breeds. Possibly, kids are more sensitive than lambs to the stress of transport, handling, and lairage (Ripoll *et al.*, 2011), particularly the MG kids, the youngest animals in the study, being more susceptible to emotional stress caused by noise, transport and social disruption (weaning) than older goats (Kannan *et al.*, 2003). Also, González *et al.* (1983), Argüello *et al.* (1999), Marichal *et al.* (2003) and Ripoll *et al.* (2011) found that the smallest carcasses had the highest pH.

In the same way, differences in pH among breeds might also reflect differences in their responses to handling (Young *et al.*, 1993; Monte *et al.*, 2007). Nevertheless, differences in ultimate pH among the goat breeds other than MG were not ( $p \leq 0.001$ ) significant (range = 5.76-5.79), showing there is not effect of

breed, in goats with similar purpose. In any case, with the exception of MG, our results were similar to those of Swan *et al.* (1998) in the Cashmere breed (5.70) and crossbreed (5.78), and lower than those of Boer goat (6.04), even in electrical stimulated carcasses (King *et al.*, 2004).

Lightness in meat is associated with young animals, especially with milk fed lambs (Rubino *et al.*, 1999), which are preferred in some areas, such as Mediterranean countries. Spanish consumers associate meat from suckling kid and lamb as being tender, juicy, tasty and, especially in the case of kid meat, with a high price (Sañudo *et al.*, 1998). On the other hand, colour attributes might be the most important factor for distinguishing among species (Rødbotten *et al.*, 2004). In the current study, the  $L^*a^*b^*$  values in kids were lower than those found in the literature in heavier animals (King *et al.*, 2004), especially  $L^*$  and  $a^*$  (Monte *et al.*, 2007). Nevertheless, meat redness was higher than in Girgentana goat (Todaro *et al.*, 2002), a breed that is known to have meat with particularly low  $a^*$ .

MG kids showed the lowest  $a^*$  and highest  $L^*$  (without significant differences with Ch breed) values, probably because these animals were fed exclusively with milk, been weaned and slaughtered relatively early. Redness reflects the presence of myoglobin and the availability of iron (Sañudo *et al.*, 1997; Martínez Cerezo *et al.*, 2005; Suman *et al.*, 2009), which is virtually nil in a milk diet. Also, although  $L^*$  can be positively correlated with myofibrillar structure and negatively with pH (Marichal *et al.*, 2003), it might have been more related to their evident paleness because of the limited amount of myoglobin (Dhanda *et al.*, 1999b). The higher weight-age and, probably, the presence of some non-milk components in its diet and the subsequent increase in myoglobin might have contributed to the high redness and low lightness, without significant differences with Pi breed in both variables and with Ch lambs in redness, in the meat from BC kids (Martínez Cerezo *et al.*, 2005). In kids, it has been demonstrated that differences in slaughter weight are not significant in muscle fibre type proportions and areas (Marichal *et al.*, 2003), thus, its implication on meat colour could be of little importance.

Meat yellowness was higher in lamb meat, being similar to previous results found in the same breed by Sañudo *et al.* (1997), and in agreement with the colour consideration that a trained panel gave to the lamb colour when comparing with colour from goat and other species (Rødbotten *et al.*, 2004). Also, lamb had, comparatively,

higher values of  $a^*$  and  $L^*$ . In this case,  $L^*$  might have been related to the low pH values of the lamb meat (Webb *et al.*, 2005). Also Babiker *et al.* (1990) found higher  $L^*$  and  $b^*$  values in lamb than in goat, which had higher redness. The higher  $L^*$  and  $b^*$  values of the meat from Ch lambs might produce a more youthful aspect, as was suggested by King *et al.* (2004). Hue values did not show differences among goat breeds, except MG, coincidentally with Oman *et al.* (2000) in several Boer breed and crosses slaughtered at a similar age.

Chroma was, between goat breeds, higher in the meat from BC, without differences with Pi meat, the heaviest goat breed. It has also been suggested that a decrease in hue and an increase in chroma values are related with a carcass weight increase (Teixeira *et al.*, 2011). The NS, Mo, and Pi goats did not differ significantly among them. Muscle colour is very important in kid meat and it should be pale pink. In the current study, chroma values were even lower than the values in kids slaughtered at a cold carcass weight of < 3 kg (Marichal *et al.*, 2003). Thus, it could be expected a high meat visual acceptability in all the breeds, although some differences between our and Marichal *et al.* (2003) results might have been due to differences in methodology (*i.e.*, the latter study did not specify blooming time). Nevertheless, chroma is influenced less by the chemical state (oxidative process) of the myoglobin than hue is (Renner, 1982).

### Principal component analysis

In the PCA, Ch lambs appeared in a different quadrant (upper left) than the other goat breeds, and was more associated with  $b^*$ , the proportion of bone,  $h^*$ , and  $L^*$ . This result would show the differences in the carcass and instrumental meat quality (ultimate pH and colour) between lambs and kids. Also, Schönfeldt *et al.* (1993) observed significant differences between these two species, even using other measures of quality.

Among the goat breeds, BC, which had the heaviest carcasses, was clearly distinguished from the others because it was alone in the upper right quadrant, with positive tendencies on both axes. BC was associated with carcass weight and carcass measurements, conformation score, redness, and proportion of subcutaneous fat. All of the other goat breeds were in the negative area (two lower quadrants) of the PC2. MG was placed quite far from the central point, although in the same quadrant as Mo breed. Nevertheless, Mo breed was very

close to ultimate pH and proportion of muscle, and closest to NS and Pi, which were in the same quadrant and associated with external fat thickness, proportions of prescapular and intermuscular fat, and colour score.

In conclusion, the lamb and goat products from very young and milk-fed animals differ in carcass characteristics and some instrumental measurements of quality. Even at a young age, there are some differences in quality among the goat breeds, which are to some extent more closely associated with age at slaughter and the milk capacity of dams, given that the kids of dairy breeds have lighter meat than those from meat purpose breeds. Nevertheless, some quality labels could be justified within goat species. To obtain a better understanding of the differences among goat breeds in the quality of their carcass and meat, more comparisons among local breeds are needed and different slaughtering criteria (*i.e.* age, weight, feeding system) should be considered to get a wide and real point of view of the breed influence in the quality of goats.

### Acknowledgements

We thank the staff of the Meat Technology Group at Zaragoza University for their technical assistance. Financial support was provided by the CICYT (AGL-2005-05777-C02-01).

### References

- Argüello A, Ginés R, Capote J, López JL, 1999. Estudio de la dureza, pH y capacidad de retención de agua en la carne de cabritos de la Agrupación Caprina Canaria, sacrificados a los 6 y los 10 kg. *O Médico Veterinario* 60(30): 32-34.
- Argüello A, Capote J, Ginés R, López JL, 2001. Prediction of kid carcass composition by use of joint dissection. *Livestock Prod Sci* 67: 293-295.
- Atti A, Rouissi H, Mahouachi M, 2004. The effect of dietary crude protein level on growth, carcass and meat composition of male goat kids in Tunisia. *Small Ruminant Res* 54: 89-97.
- Babiker SA, El Khider IA, Shafie SA, 1990. Chemical composition and quality attributes of goat meat and lamb. *Meat Sci* 28: 273-277.
- Banskalieva V, Sahlu, T, Goetsch AL, 2000) Fatty acid composition of goat muscles and fat depots: a review. *Small Ruminant Res* 37: 255-268.
- Boccard DR, Dumont BL, Peyron C, 1958. Valeur significative de quelques mensurations pour apprécier la qualité des carcasses d'agneaux. *Proc 4th Meeting of the European Research Workers, Cambridge (UK)*, pp: 15-19.

- BOE, 2008. Royal decree 2129/2008, of 26 December, establishing the national Programme for the conservation, improvement and promotion of livestock breeds. *Boletín Oficial del Estado* No. 23, 27/01/2009.
- Colomer F, Morand-Fehr P, Kirton AH, Delfa R, Sierra I, 1988. Métodos normalizados para el estudio de los caracteres cuantitativos y cualitativos de las canales ovinas y caprinas. *Cuadernos del INIA* 17: 21-31.
- Delfa R, Teixeira A, Gonzalez C, 1994. Crecimiento y desarrollo de los tejidos adiposos del cuerpo de la raza Blanca celtibérica. *Revista Portuguesa de Zootecnia* 1: 131-155.
- Delfa R, Teixeira A, González C, Vijil E, 1996. Ultrasonic measurements in live goats. Prediction of weight of carcass joints and carcass quality. Proc 47<sup>th</sup> EAAP meeting. Lillehammer (Norway). pp: 272.
- Delfa R, Teixeira A, González C, 1998. Body weight and ultrasounds as predictors of carcass quality and fat partition in adult goats. *Revista Portuguesa de Zootecnia* 2: 1-16.
- Delfa R, Teixeira A, Colomer-Rocher F, 2005. Conformación, engrasamiento y sistemas de clasificación de la canal caprina. In: Estandarización de las metodologías para evaluar la calidad del producto (animal vivo, canal, carne y grasa) en los rumiantes (Cañeque V and Sañudo C, eds), Monografías INIA, Ser Gan No. 3, INIA, Madrid. pp: 181-188.
- Dhanda JS, Taylor DG, McCosker JE, Murray PJ, 1999a. The influence of goat genotype on the production of capretto and chevron carcasses. 1. Growth and carcass characteristics. *Meat Sci* 52: 355-361.
- Dhanda JS, Taylor DG, Murray PJ, McCosker JE, 1999b. The influence of goat genotype on the production of capretto and chevron carcasses. 2. Meat quality. *Meat Sci* 52: 363-367.
- Dhanda JS, Taylor DG, Murray PJ, 2003. Carcass composition and fatty acid profiles of adipose tissue of male goats: effects of genotype and live weight at slaughter, Part 2. *Small Ruminant Res* 50: 67-74.
- Dubeuf JP, Boyazoglu J, 2009. An international panorama of goat selection and breeds. *Livestock Sci* 120: 225-231.
- Ekiz B, Ozcan B, Yilmaz A, Tolu C, Savas T, 2010. Carcass quality characteristics of Hair Goat and Saanen × Hair Goat crossbred kids from intensive production system. *J Anim Feed Sci* 19: 368-378.
- Esteban C, 2009. Razas ganaderas españolas caprinas. FEAGAS, Madrid, Spain.
- Fuentes F, Sánchez JM, Gonzalo G, 2006. Tratado de Etología Animal: razas de rumiantes y monogástricos. Ed Diego Marín, Murcia, Spain.
- González R, Owen JE, Cereceres MTA, 1983. Studies on the Criollo goat of northern Mexico: 2. Physical and chemical characteristics of the musculature. *Meat Sci* 9: 305-314.
- Griffin CL, Orcutt MW, Riley RR, Smith GC, Savell JW, Shelton M, 1992. Evaluation of palatability of lamb, mutton and chevron by sensory panels of various cultural backgrounds. *Small Ruminant Res* 8: 67-74.
- Haenlein GFW, 2004. Goat milk in human nutrition. *Small Ruminant Res* 51: 155-163.
- Kannan G, Kouakou B, Terrill T H, Gelaye S, 2003. Endocrine, blood metabolite, and meat quality changes in goats as influenced by short-term, preslaughter stress. *J Anim Sci* 81: 1499-1507.
- King DA, Voges KL, Hale DS, Waldron DF, Taylor CA, Savell JW, 2004. High voltage electrical stimulation enhances muscle tenderness, increases aging response, and improves muscle color from cabrito carcasses. *Meat Sci* 68: 529-535.
- Le Jaouen JC, 1997. Goat production in Europe: the first European meeting. *Chevre* 220: 13-15.
- Mahgoub O, Kadin I., Al-Saqry NM, Al-Busaidi M, 2005. Potential of Omani Jebel Akhdar goat for meat production under feed lot conditions. *Small Ruminant Res* 56: 223-230.
- Marichal A, Castro N, Capote J, Zamorano MJ, Argüello A, 2003. Effects of live weight at slaughter (6, 10 and 25 kg) on kid carcass and meat quality. *Livestock Prod Sci* 83: 247-253.
- Martínez-Cerezo S, Sañudo C, Panea B, Medel I, Delfa R, Sierra I, Beltrán JA, Cepero R, Olleta JL, 2005. Breed, slaughter weight and ageing time effects on physico-chemical characteristics of lamb meat. *Meat Sci* 69: 325-333.
- Miguélez E, Zumalacárregui JM, Osorio MT, Beteta O, Mateo J, 2006. Carcass characteristics of suckling lambs protected by the PGI "Lechazo de Castilla y León" European quality label: effect of breed, sex and carcass weight. *Meat Sci* 73: 82-89.
- Monte AL, Selaive A., Garruti D, Zapata JF, Borges, A, 2007. Parâmetros físicos e sensoriais de qualidade da carne de cabritos mestiços de diferentes grupos genéticos. *Ciência y Tecnología de Alimentos* 27: 233-238.
- Morand-Fehr P, Lebbie SHB, 2004. Proposals for improving the research efficiency in goats. *Small Ruminant Res* 51: 145-153.
- Oman JS, Waldron DF, Griffin DB, Savell JW, 2000. Carcass traits and retail display-life of chops from different goat bred types. *J Anim Sci* 78: 1262-1266.
- Palsson H, Verges J, 1952. Effects of the plane of nutrition on growth and development of carcass quality in lambs. *J Agric Sci* 42: 1-12.
- Peña F, Perea J, García A, Acero R, 2007. Effects of weight at slaughter and sex on the carcass characteristics of Florida suckling kids. *Meat Sci* 75: 543-550.
- Pérez P, Maino M, Morales MS, Köbrich C, Bardon C, Pokniak J, 2007. Gender and slaughter weight on carcass quality traits of suckling lambs from four different genotypes. *Small Ruminant Res* 70: 124-130.
- Renerre M, 1982. La couleur de la viande et sa mesure. *Bulletin Tech CRZV, Theix, INRA* 47: 47-54.
- Ripoll G, Alcalde MJ, Horcada A, Panea B, 2011. Suckling kid breed and slaughter weight discrimination using muscle colour and visible reflectance. *Meat Sci* 87: 151-156.
- Rødbotten M, Kubberød E, Lea P, Ueland Ø, 2004. A sensory map of the meat universe. Sensory profile of meat from 15 species. *Meat Sci* 68: 137-144.

- Rubino R, Morand-Fehr M, Renieri C, Peraza C, Sarti FM, 1999. Typical products of the small ruminant sector and the factors affecting their quality. *Small Ruminant Res* 34: 289-302.
- Ruiz de Huidobro F, Miguel E, Cañeque V, Velasco S, 2005. Conformación, engrasamiento y sistemas de clasificación de la canal ovina. In: Estandarización de las metodologías para evaluar la calidad del producto (animal vivo, canal, carne y grasa) en los rumiantes (Cañeque V and Sañudo C, eds), Monografías INIA, Ser Gan No. 3, INIA, Madrid. pp: 143-169.
- Santos Sylva J, Mendes I A, Bessa RJB, 2002. The effect of genotype, feeding system and slaughter weight on the quality of light lambs. 1. Growth, carcass composition and meat quality. *Livestock Prod Sci* 76: 17-25.
- Sañudo C, Campo MM, Sierra I, María G, Olleta JL, Santolaria P, 1997. Breed effect on carcass and meat quality of suckling lambs. *Meat Sci* 46: 357-365.
- Sañudo C, Sánchez A, Alfonso M, 1998. Small ruminant production systems and factors affecting lamb meat quality. *Meat Sci* 49: 29-64.
- Sañudo C, 2011. Razas españolas de lana basta y especie caprina. In: Atlas Mundial de Etnología Zootécnica. Ed. Servet, Zaragoza. pp: 420-489.
- Schnettler B, Vidal R, Silva R, Vallejos L, Sepúlveda N, 2009. Consumer willingness to pay for beef meat in a developing country: the effect of information regarding country origin, price and animal handling before slaughter. *Food Qual Prefer* 20: 156-165.
- Schönfeldt HC, Naudé RT, Bok W, van Heerden SM, Smit R, 1993. Flavour and tenderness related quality characteristics of goat and sheep meat. *Meat Sci* 34: 363-379.
- Sherestha JNB, Fahmy MH, 2005. Breeding goats for meat production: a review 1. Genetic resources, management and breed evaluation. *Small Ruminant Res* 58: 93-106.
- Simela L, Webb EC, Bosman MJC, 2011. Live animal and carcass characteristics of South African indigenous goats. *S Afr J Anim Sci* 41: 1-15.
- Smith GC, Pike MI, Carpenter ZL, 1974. Comparison of the palatability of goat meat and meat from other animal species. *J Food Sci* 39: 1145-1146.
- Suman SP, Joseph P, Li S, Steinke L, Fontaine M, 2009. Primary structure of goat myoglobin. *Meat Sci* 82: 456-460.
- Swan JE, Esguerra CM, Farouk MM, 1998. Some physical, chemical and sensory properties of chevron products from three New Zealand goat breeds. *Small Ruminant Res* 28: 273-280.
- Teixeira A, Jimenez-Badillo MR, Rodrigues S, 2011. Effect of sex and carcass weight on carcass traits and meat quality in goat kids of Cabrito Transmontano. *Span J Agric Res* 9: 753-760.
- Todaro M, Corrao A, Barone CMA, Schinelli R, Occidente M, Giaccone P, 2002. The influence of age at slaughter and litter size on some quality traits of kid meat. *Small Ruminant Res* 44: 75-80.
- Webb EC, Casey NH, Simela L, 2005. Goat meat quality. *Small Ruminant Res* 60: 153-166.
- Young OA, Reid DH, Scales GH, 1993. Effect of breed and ultimate pH on the odour and flavour of sheep meat. *N Z J Agric Res* 36: 363-370.
- Zygoiannis D, Stamataris K, Kouimtzis S, Doney JM, 1990. Carcass composition in lambs of Greek dairy breeds of sheep. *Anim Prod* 50: 261-269.