*Manuscript

Animal performance, carcass traits and meat characteristics of Assaf and Merino × Assaf growing lambs

A.B. Rodríguez, R. Bodas*, R. Landa, Ó. López-Campos, A.R. Mantecón, F.J. Giráldez

Instituto de Ganadería de Montaña (CSIC-ULE), Finca Marzanas, 24346 Grulleros, León (Spain)

* Corresponding author: Raúl Bodas

E-mail address: raul.bodas@eae.csic.es

Tel: +34 987 317 156; Fax: +34 987 317 161

Abstract

This study was conducted to compare the growth, carcass and meat quality of light, intensively reared Assaf and crossbred Merino × Assaf lambs. Twelve Assaf and twelve Merino × Assaf lambs of both sexes were intensively reared from weaning until they reached 20 kg Live Body Weight (LBW). Crossbreeding improved both daily weight gain ($P<0.01$) and feed conversion ($P<0.001$), resulting in a reduction in accumulative dry matter consumption ($P<0.05$).

Carcass conformation was also improved by crossbreeding, although commercial cut category differences ($P>0.05$) were not observed. Carcass ($P<0.10$) and shoulder fat content ($P<0.01$) were breed dependent, with Assaf lambs yielding the highest values. Assaf lambs also displayed lower 24h pH ($P<0.01$) and greater L* values ($P<0.05$) than the Merino × Assaf crossbreeds, but other, equally important parameters, such as cooking losses or shear force, were not breed dependent.

Females showed smaller weight gains ($P<0.05$) and higher feed conversion ($P<0.01$), due to differences in gain composition. Furthermore, internal ($P<0.01$) and shoulder fat ($P<0.01$) weights were higher in females. Sex dependent differences in meat quality were also related to meat fat content, with females yielding the highest values ($P<0.01$).

Raising Merino × Assaf lambs to a weight between suckling and fattening categories could avoid the seasonality problem in current suckling lamb production, by improving productive parameters such as growth or conformation.

Keywords: Breed, sex, light intensive lambs, carcass, meat quality, Merino, Assaf.

1. Introduction

In Mediterranean countries, dairy sheep production is based on milk breeds, and lambs are normally slaughtered between 10 and 12 kg live body weight (LBW). Suckling lamb meat is a valuable commodity, which, due to its seasonal nature, can reach elevated prices during certain periods of the year.

It is well known that carcass weight is the most relevant parameter influencing the value of the carcass (Beriain et al., 2000). In fact, because of its economic importance; differences in prices between weight categories fluctuate throughout the year, and are more pronounced in certain months of the year, when lamb production is scarce. As previously reported, during these months of lamb production scarcity, it is possible to slaughter lambs heavier than 10-12 kg in order to break with seasonal lamb production, without resulting in significant economic damage (Sañudo et al., 1992).

Intensive lamb rearing after weaning is a common practice for meat breeds, but not for dairy breeds. Generally, dairy breeds mature earlier and their precocious fatness results in slaughter at lighter weights; *i.e.* as suckling lambs. Crossing meat breeds with dairy breeds and slaughtering at heavier weights would be an attractive alternative to both complement milk production and reduce the seasonality of farm income. These crossbreeds could also enhance the added value of the carcasses, by increasing their weight and reducing fat content. Moreover, in order to ensure a high water content and enhance juiciness, suckling lamb meat is traditionally oven-roasted (Cross et al., 1979). Raising lambs past the suckling age would allow for other cooking methods to be employed, while maintaining meat juiciness and tenderness; the ability to prepare lamb meat in multiple ways could broaden its marketability.

To date, studies in the literature concerning Assaf lamb feed intake, growth, carcass and meat quality have involved either suckling lambs (Landa et al., 2004; Rodríguez et al., 2008) or 25 kg fattening lambs (Rodríguez et al., 2008). To the best of our knowledge, very little information exists in the literature about carcass and meat quality in light, intensively reared Assaf lambs, or their crosses, at weights between suckling and fattening; *i.e.* the lamb weight Mediterranean area consumers prefer (Sañudo et al., 2007).

Considering these arguments, the present study was conducted to evaluate the growth, carcass and meat quality of Assaf and Merino × Assaf light lambs, when intensively reared to a weight between a suckling and fattened lamb.

2. Material and Methods

2.1. Animals and diets

Twenty four lambs (14.4 ± 0.09 kg LBW), 12 Assaf (6 intact males and 6 females) and 12 Merino × Assaf (6 intact males and 6 females) were used. Lambs were distributed according to breed and sex in a 2 x 2 factorial design. All lambs were kept with their mothers until weaning (12 kg LBW and 6 weeks of age). After weaning they were dewormed by Ivomec (Merial Labs., Spain) administration and vaccinated against enterotoxaemia (Miloxan, Merial Labs., Spain). All animal handling practices followed the recommendations of European Council Directive 86/609/EEC for the protection of animals used for experimental and other scientific purposes, and all animals were able to see and hear other sheep.

2.2. Experimental procedures

All animals were individually housed in 1.5 × 1.5 m floor pens, in a naturally ventilated animal house and remained there until slaughter. All animals received a pellet concentrate (70% barley, 22% soybean meal, 4.8% wheat and 3.2% vitamin and mineral mixture; chemical composition: 898 g DM/kg, 166 g CP/kg DM, 163 g NDF/kg DM, 99 g ash/kg DM) and barley straw (910 g DM/kg, 35 g CP/kg DM, 813 g NDF/kg DM, 47 g ash/kg DM) for consumption *ad libitum*.

All lambs received experimental feeds *ad libitum* and separately once a day at 9:00 in the morning. The amount of feed offered permitted refusal of between 15 and 20% of the previous maximum intake. The amount of feed offered and refused was weighed daily and samples were collected for chemical analyses. LBW was recorded three times per week, before morning feeding. Lambs were slaughtered when they reached 20 kg LBW. Slaughter was carried out by stunning and desanguination via the jugular vein. Lambs were then sheared, skinned and eviscerated. The body of each lamb was separated into carcass and non-carcass parts.

2.3. Carcass and non-carcass characteristics

Weights of the different parts of the non-carcasses were recorded. Red offal contained the heart, lungs, spleen, and either udder or penis in the case of females and males, respectively. White offal comprised the empty digestive tract. Non-carcass components, aside from wool and blood, were minced, mixed and homogenised in a commercial blender, and samples were taken and stored at -30 ºC, then lyophilised (FTS-Lyostar, United States) for chemical analysis.

Carcasses contained kidneys, thymus, testicles and the kidney knob and channel fat. The carcass was weighed before and after chilling at 4 ºC for 24 h. The dressing percentage was calculated as the cold carcass weight (CCW), expressed as a proportion of the slaughter weight. Linear measurements were determined following the procedure of Colomer-Rocher *et al.* (1988). The carcass compactness index was calculated by dividing the CCW by the carcass external length and the leg compactness index was calculated by dividing the buttock width by the pelvic limb length. The left sides were separated into commercial joints as described by Colomer-Rocher *et al.* (1988). Legs, ribs and fore ribs comprised the higher priced joints; shoulders comprised the medium priced joints, and the lower priced joints included breasts, necks and tails. Shoulders were dissected as described by Fisher & De Boer (1994). The right sides containing the tail were minced, mixed, and homogenised as described for the non-carcass samples for chemical analysis.

2.4. Meat characteristics

Measurements for meat characteristics were conducted on the left side of the carcass. *Longissimus thoracis* muscle pH was measured at 24 h using a pH meter equipped with a penetrating glass electrode (Metrohm® 704 pHmeter, Switzerland). Muscle colour measurements were carried out using a chromatometer (Minolta® Croma Meter 2002, Germany) equipped with a D65 illuminant and 10º observer. Muscle areas at the 13th rib were drawn on a transparent film and their surface areas were measured (AreaMeter® MK2, Holland). Muscles were then removed from the carcass, vacuum packed and stored at -30 ºC until analysis. *Longissimus thoracis* were allowed to thaw for 24 hours at 4 °C, and then placed in plastic bags in a 75 °C water bath until they reached an internal temperature of 70 °C. Cooking loss percentages were calculated according to the initial weight. From each lamb, eight 1×1×2 cm cores along the fibre direction were used for measuring the Warner Bratzler shear force (Texture Analyser® TA.XT2, Great Britain), with a crosshead speed of 5 mm/s. *Longissimus lumborum* was lyophilised, minced and homogenised for chemical analysis.

2.5. Analytical procedures

Procedures outlined by the AOAC (2003) were used to measure dry matter (DM, method ID 934.01), ash (method ID 942.05) and Kjeldahl N (CP, method ID 976.06) in experimental feed samples. Neutral detergent fibre (NDF) was determined as described in Van Soest *et al.* (1991), using sodium sulphite in the neutral detergent solution. Commercial concentrate NDF was assessed using alpha-amylase.

Non-carcass, carcass and *longissimus lumborum* samples were analysed for dry matter (DM, method ID 950.46), ash (method ID 920.153), Kjeldahl N (CP, method ID 981.10) and crude fat content (method ID 960.39).

2.6. Calculations and statistical analyses

Average daily gain was determined using the REG procedure (SAS, 2004). Data on dry matter intake and growth, as well as non-carcass, carcass and meat parameters were analysed using the GLM (General Linear Models) procedure implemented in the SAS package (SAS, 2004). Mean separation for statistical significance ($P<0.05$) was carried out using the PDIFF procedure (SAS, 2004).

3. Results

3.1. Feed intake and changes in live body weight

Cumulative feed intake was significantly affected by both sex and breed ($P<0.05$), averaging 16.8 and 14.3 kg for Assaf vs. Merino × Assaf lambs and 17.3 and 14.1 kg for females vs. males, respectively (Table 1). Nevertheless, no statistically significant breed dependence on daily feed intake was observed (P>0.10), with mean values measured to be 703 and 667 g/day for Assaf vs. Merino × Assaf lambs, respectively. However, average barley straw intake was affected by both breed (P<0.001) and the interaction between sex and breed. Specifically, male Merino × Assaf lambs had a lower average barley straw intake (12.7 g/day), whereas male Assaf lambs averaged higher values (32.7 g/day). In contrast, female lambs of both breeds displayed intermediate values (28.4 vs. 23.0 g/day for Merino × Assaf vs. Assaf, respectively).

Table 1 contains mean values for daily weight gain and feed conversion ratio Daily weight gain (P<0.001) and feed conversion ratios (P<0.01) showed significant breed dependent differences. Higher average daily weight gains (224 *vs*. 299 g/d) and lower feed conversion values (3.1 *vs*. 2.4 g DMI/g ADG) were observed in Merino × Assaf lamb breeds. Sex significantly affected both parameters, with males averaging higher daily weight gains (P>0.05) and lower feed conversion values (P>0.01) compared to females.

(insert Table 1 here)

3.2. Non-carcass characteristics

Non-carcass weight (P<0.01, Table 2) was also breed dependent. Specifically, head and hide weights (P<0.001), wool (P<0.001) and total digestive fat deposits (P<0.05) were greater in Assaf lambs. In addition, female lambs yielded significantly greater wool weight values and digestive fat content than male lambs (P<0.01). Non-carcass component crude fat and water content were also significantly different between Assaf and Merino × Assaf breeds (P<0.01); higher crude fat and lower water content was observed in the Assaf breed. Sex dependent effects were also observed for both parameters, with female lambs yielding greater crude fat and lower water content than male lambs (P<0.05).

(insert Table 2 here)

3.3. Carcass characteristics

Carcass performance, linear morphology, commercial cut category percentages, shoulder tissue composition and chemical composition are presented in Tables 3 and 4. Cold carcass weight indicates a statistically significant interaction between the main effects ($P<0.05$), with female Assaf lambs yielding the highest values. Sex significantly affected dressing percentages, and the greatest values were found in females (47.8 %) vs. males (46.4 %) ($P<0.05$). Refrigeration losses were significantly lower in the Assaf breed than in the Merino × Assaf breed ($P<0.001$).

(insert Table 3 here)

Carcass linear measures were breed dependent. Buttocks were wider ($P<0.05$) and carcasses were larger ($P<0.01$) in Assaf than in Merino × Assaf lambs. Buttocks perimeters indicate an interaction between main effects ($P<0.05$). For example, female Assaf lambs yielded higher values and Merino × Assaf lambs yielded lower values. Merino × Assaf lambs were observed to have greater compactness index values ($P<0.05$).

Although breed does not significantly affect the proportions of the three commercial cut categories ($P>0.05$), sex dependent effects appeared to be statistically significant ($P<0.10$) for the medium priced joints, with male carcasses yielding slightly higher percentages than females. However, Merino × Assaf lambs did yield more muscle ($P<0.05$) and lower subcutaneous fat proportions ($P<0.001$) than Assaf lambs. Sex affected tissue composition. For example, female shoulders contained higher fat content, consisting mainly of subcutaneous fat ($P<0.01$) and smaller bone proportions ($P<0.001$) than males. Carcass composition was found to be breed dependent. A significant trend was observed in crude fat content per kilogram of carcass fresh matter ($P<0.10$); Assaf carcasses yielded higher values. Crude protein and ash content were greater in Merino × Assaf carcasses ($P<0.05$). The effect of sex on carcass composition was only apparent with respect to water content ($P<0.10$), however, although not statistically significant, female carcass fat content was measured to be 14% higher than in male carcasses.

(insert Table 4 here)

3.4. Meat characteristics

Longissimus meat quality parameters are shown in Table 5. Significant differences between breeds were recorded for 24 hours *Longissimus thoracis* pH measurements, with Merino × Assaf muscles having higher pH values. *Longissimus lumborum* ash content was also breed dependent. Assaf meat had greater ash content (P<0.001) than Merino × Assaf lamb meat. Sex only affected muscle chemical composition, mainly crude fat (P<0.01), with the highest values measured in female lambs.

(insert Table 5 here)

4. Discussion

4.1. Feed intake and changes in live body weight

With respect to feed consumption, as expected, the proportion of concentrate intake exceeded barley straw intake, (96.4 vs. 3.6%). Consumption of concentrate and barley straw was lower than that reported in several studies on Merino (Bodas *et al.*, 2007; Manso *et al.*, 1998) and Assaf (Fernández *et al.*, 2005) lambs. These differences are fundamentally due to the young age at which the lambs in the present study were slaughtered. Although significant differences in daily dry matter intake between breeds were not observed, in terms of cumulative intake, Merino × Assaf lambs required 17% less dry matter to reach higher body weights than Assaf lambs and consequently displayed better feed conversion efficiency. Differences in feed intake, growth and efficiency can be accounted for by breed variations in gain composition.

In a growth study using an Assaf and Merino Booroola crossbreed, Gootwine *et al.* (1993) reported similar average daily gain values after weaning to those measured in the present study. Males of both breeds grew faster than females. This fact can only be explained by differences in gain composition, because female carcasses contained more fat content than intact male carcasses. Data from this study confirms this approach, because most of the adipose tissues were larger in female lambs.

4.2. Non-carcass and carcass characteristics

Breed dependent differences in fat content are associated with variations in feed efficiency (Notter et al., 1984). As mentioned above, the improved average daily body weight gain values and feed to gain ratios of Merino × Assaf lambs might be due to differences in body gain composition. In fact, Assaf lambs displayed greater digestive, carcass and non-carcass fat content than Merino × Assaf lambs and, in addition, these lambs developed proportionally more muscle than adipose tissue.

From an economic viewpoint, the carcass is the most valuable part of the animal, and at certain weights it can be largely breed dependent (Barone et al., 2007). Carcass weight, along with dressing percentages, depends on both fat and muscle content (Geay and Robelin, 1979). In this study, breed did not significantly affect cold carcass weights and dressing percentages, but numerically, Assaf female lambs tended to yield higher carcass weights. These differences might be related to adipose content and the fact that for the same average body weight, female Assaf lambs are physically bigger than the other three experimental groups, which is characteristic for this breed (Martínez et al., 1999). Moisture evaporation during chilling is responsible for carcass weight losses, and, according to Johnson *et al.* (1988), the greater carcass fat content in Assaf lambs compared to Merino × Assaf lambs could slow down moisture losses.

Carcass linear measurements underscore the generally accepted fact that Merino × Assaf carcasses have preferred conformations, because the external carcass length was lower and the carcass compactness index was higher. Despite morphological differences, the main commercial cut category percentages were not significantly breed dependent. Assaf is characterised as a fatty tailed breed, because significant quantities of fat are found in the tails (Gootwine et al., 2001). In fact, tail percentages in Assaf lamb carcasses were twice that of Merino × Assaf lambs, with values between 0.87 and 3.96 % of the cold carcass weight. In any case, Merino × Assaf crossbreeding did yield percentages greater than 1.2% of the carcass weight. Differences in tail fatness have been observed by Kashan *et al.* (2005), who found 50% lower tail and 25% lower subcutaneous fat weights in the carcass, resulting only from crossing a fat tailed and leaner tailed breed, in an attempt to reduce the energetic cost of fat deposition. However, in contrast with results observed in the present study, these authors did not report improvements in economically important traits such as feed conversion rates, average daily gain or lean meat content.

However, comparing carcass quartering results from the different procedures that have been carried out by diverse authors is complex. In contrast with results obtained by Rodríguez *et al.* (2008a), differences between sexes in carcass commercial cut categories were not observed, possibly due to the lower age of the lambs used in the present study. Other authors did not report sex related differences between commercial cuts for 15 kg LBW lambs (Pérez *et al.*, 2007). In terms of shoulder dissection, our data are similar to those obtained by Miguélez *et al.* (2006) in Castellana and Churra lambs.

Sex related differences in the dissected shoulder bone are due to physiological factors that induce males to grow faster and develop longer bones (Wylie *et al.*, 1997). In addition, adipose tissue differences were also measured, as previously discussed.

4.3. Meat characteristics

In lamb consuming countries, consumer perceptions of meat quality are associated with both lamb breed and rearing system. For consumers, meat colour is on one of the most important parameters influencing purchase decisions. Pigment accumulation and chemical status are the main factors affecting meat colour, but, in addition, meat colour depends on diet (Priolo *et al.*, 2002), animal maturity (Moon *et al.* 2006) and differences in meat pH (Mancini and Hunt, 2005). Normal pH values 24 hours postmortem are between 5.4 and 5.7 (Warriss, 1990). In our study, *Longissimus thoracis* pHs values were in the normal range, and slight differences could be accounted for by differences in breed response to stressful conditions before slaughter. The importance of pH on meat quality has been previously noted by other authors, however, in this study, pH changes only affected some colour variables (such as lightness and yellowness), whose values were within the range of those reported in the literature (Sañudo *et al.*, 1992, Hopkins and Fogarty, 1998; Martínez-Cerezo *et al.*, 2005). Remaining parameters, such as water holding capacity or shear force did not significantly affect the results and were comparable to those reported by Sañudo *et al.* (1996) for lambs reared under similar conditions. Martínez-Cerezo *et al.* (2005) also found differences in colour variables between breeds; however these and other authors (Sañudo et al., 1996) pointed out that other colour variation sources, such as feed source or the length of fattening period (which could be the case in our study) might have a larger effect on colour parameters than breed. In any case, our results are in agreement with Solomon *et al.* (1980), Sañudo *et al.* (1992) and Hopkins and Fogarty (1998), who also reported a smaller breed dependence on most lamb meat quality parameters. Sex dependent effects on meat quality parameters were also not observed, with the exception of fat content, in agreement with Rodríguez et al. (2008 a,b) in studies on suckling and 25 kg body weight Assaf lambs.

5. Conclusions

Sex dependent differences in average daily gain, feed conversion rates or dressing percentages can be explained by differences in gain composition that lead females to develop greater adipose tissue content than males. On the other hand, by crossbreeding Merino and Assaf breeds, the average daily gain, feed conversion and carcass conformation were improved, and the carcass and non-carcass fat content was reduced. Cold carcass weight was not breed dependent. However, at such low animal body weights and a fixed slaughter weight, adipose tissues might be relevant. Although economical issues should also be considered, data obtained in this study suggest that breed has a large effect on lamb performance, carcass and meat composition, which must be taken into account when planning commercial crossbreeds.

6. Acknowledgements

This work was supported by funds from FEDER (Project 1FD1997-1898) and Junta de Castilla y León (Project GR158). Raúl Bodas has a JAE-Doc contract from the CSIC under the programme “Junta para la Ampliación de Estudios”.

References

Barone, C.M.A., Colatruglio, P., Girolami, A., Matassino, D., Zullo, A., 2007. Genetic type, sex, age at slaughter and feeding system effects on carcass and cut composition in lambs. Livest. Sci. 112, 133-142.

Beriain, M.J., Horcada, A., Purroy, A., Lizaso, G., Chasco, J., Mendizábal, J.A., 2000. Characteristics of Lacha and Rasa Aragonesa lambs slaughtered at three live weights. J. Anim. Sci. 78, 3070-3077.

Bodas, R., Giráldez, F.J., López, S., Rodríguez, A.B., Mantecón, A.R., 2007. Inclusion of sugar beet pulp in cereal based diets for fattening lambs. Small Ruminant Res. 71, 250-254.

Colomer-Rocher, F., Morand-Fehr, P., Kirton, A.H., Delfa, R., Sierra Alfranca, I., 1988. Métodos normalizados para el estudio de los caracteres cuantitativos y cualitativos de las canales caprinas y ovinas. Cuadernos del INIA, 17, 19-41.

Cross, H.R., Stanfield, M.S., Elder, R.S., Smith, S., 1979. A comparison of roasting versus broiling on the sensory characteristics of beef longissimus steaks. J. Food Sci. 44, 1, 310-311.

Fernández, M., Giráldez, J., Frutos, P., Hervás, G., Mantecón, A.R., 2005. Effect of undegradable protein concentration in the post-weaning diet on body growth and reproductive development of Assaf rams. Theriogenology 63, 2206-2218.

Fisher A.V., de Boer H., 1994. The EAAP standard method of sheep carcass assessment. Carcass measurements and dissection procedures. Report of the EAAP Working Group on Carcass Evaluation, in cooperation with the CIHEAM Instituto Agronómico Mediterraneo of Zaragoza and the CEC Directorate General for Agriculture in Brussels. Livest. Prod. Sci. 38, 149-159.

Geay, Y., Robelin, J., 1979. Variation of meat production capacity in cattle due to genotype and level of feeding: genotype – nutrition interaction. Livest. Prod. Sci. 6, 263-276.

Gootwine, E., Bor, A., Braw-Tal, R., Zenou, A., 1993. Inheritance of birthweight and growth traits in crosses between the Booroola Merino and Assaf sheep breeds. Livest. Prod. Sci. 33, 119-126.

Gootwine, E., Zenu, A., Bor, A., Yossafi, S., Rosov, A., Pollott, G. E., 2001. Genetic and economic analysis of introgression the B allele of the FecB (Booroola) gene into the Awassi and Assaf dairy breeds. Livest. Prod. Sci. 71, 1, 49-58.

Johnson, R. D., Hunt, M. C., Allen, D. M., Kastner, C. L. Danler, R. J., Schrock, C. C., 1988. Moisture uptake during washing and spray chilling of holstein and beef-type steer carcasses. J. Anim. Sci. 66, 2180-2184.

Kashan, N.E.J., Manafi Azar, G.H., Afzalzadeh, A., Salehi, A., 2005. Growth performance and carcass quality of fattening lambs from fat-tailed and tailed sheep breeds. Small Ruminant Res. 60, 267-271.

Hopkins, D.L., Fogarty, N.M., 1998. Diverse lamb genotypes. 2. Meat, pH, colour and tenderness. Meat Sci. 49, 4, 477-488.

Landa, R., Lavín, P., Frutos, P., Mantecón, A.R., Giráldez, F.J., 2004. Animal performance and carcass quality of milk-fed Assaf lambs. Options Mediterranéennes, 59, 85-89.

Martínez, R.S., Mantecón, A.R., Chico, M.D., Anel, L., Alvarez, M.M., Jurado, J.J., Díaz, C., Pérez J., Aparicio, N., 1999. Antecedentes históricos y bases de un programa de mejora genética y selección de la raza Assaf española. Consejo Superior de Investigaciones Científicas, pp. 37

Martínez-Cerezo, S., Sañudo, C., Panea, B., Medel, I., Delfa, R., Sierra, I., Beltrán, J.A., Cepero, R., Olleta, J.L., 2005. Breed, slaughter weight and ageing time effects on physico-chemical characteristics of lamb meat. Meat Sci. 69, 325-333.

Mancini, R.A., Hunt, M.C., 2005. Current research in meat color. Meat Sci. 71, 1, 100-121.

Manso, T., Mantecón, A.R., Giraldez, F.J., Lavín, P., Castro, T., 1998. Animal performance and chemical body composition of lambs fed diets with different protein supplements. Small Ruminant Res. 29, 185-191.

Miguélez, E. Zumalacárregui, J.M., Osorio, M.T., 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.

Moon, S.S., Yang, H.S., Park, G.B., Joo, S.T., 2006. The relationship of physiological maturity and marbling judged according to Korean grading system to meat quality traits of Hanwoo beef females. Meat Sci. 74, 516-521.

Notter, D. R., Ferrell, C. L., Field, R. A., 1984. Effects of breed and intake level on growth and feed efficiency in ram lambs. J. Anim. Sci. 58, 560-576

Pérez, P., Maino, M., Morales, M.S., Köbrich, C., Bardon, C., Pokniak, J., 2007. Gender and slaughter weights effects on carcass quality traits of suckling lambs from four different genotypes. Small Ruminant Res. 70, 124-130.

Priolo, A., Micol, D. Agabriel, J., Prache, S., Dransfield, E., 2002. Effect of grass or concentrate feeding systems on lamb carcass and meat quality. Meat Sci. 62, 179-185.

Rodríguez, A.B., Bodas, R., Prieto, N., Landa, R., Mantecón, A.R., Giráldez, F.J., 2008a. Effect of sex and feeding system on feed intake, growth, and meat and carcass characteristics of fattening Assaf lambs. Livest. Sci. 116, 118-125.

Rodríguez, A.B., Landa, R., Bodas, R., Prieto, N., Mantecón, A.R., Giráldez, F.J., 2008b. Carcass and meat quality of Assaf milk fed lambs: effect of rearing system and sex. Meat Sci. 80, 225-230.

Sañudo, C., Delfa, R., González, C., Alcalde, M.J., Casas, M., Santolaria, P., Vigil, E., 1992. Meat quality of young light lambs. ITEA 88A, 3, 221-227.

Sañudo, C., Alfonso, M., San Julián, R., Thorkelsson, G., Valdimarsdottir, T., Zygoyiannis, D., Stamataris, C., Piasentier, E., Mills, C., Berge, P., Dransfield, E., Nute, G.R., Enser, M., Fisher, A.V., 2007. Regional variation in the hedonic evaluation of lamb meat from diverse production systems by consumers in six European countries. Meat Sci. 75, 610-621.

Sañudo, C., Santolaria, M.P., María, G., Osorio, M., Sierra, I., 1996. Influence of carcass weight on instrumental and sensory lamb meat quality in intensive production systems. Meat Sci. 42, 195-202.

SAS, 2004. SAS Institute Inc., SAS® 9.1.2 Qualification Tools User’s Guide, Cary, NC: SAS Institute Inc., 2004.

Solomon, M.B., Kemp, J.D., Moody, W.G., Ely, D.G., Fox, J.D., 1980. Effect of breed and slaughter weight on physical, chemical and organoleptic properties of lamb carcasses. J. Anim. Sci. 51, 5, 1102-1107.

Wylie, A.R.G., Chestnutt, D.M.B., Kilpatrick, D.J., 1997. Growth and carcass characteristics of heavy slaughter weight lambs: effects of sire breed and sex of lamb and relationships to serum metabolites and IGF-1. Anim. Sci. 64, 309-318.

Table

Table 1. Mean corresponding values for initial weight (kg), daily DMI (g/d), cumulative DMI (kg), daily weight gain (g/d) and feed conversion rate (g DMI/g ADG)

	Assaf		Merino × Assaf		RSD	Significance level		
	Females	Males	Females	Males		B	S	B × S
Initial weight	14.4	14.4	14.3	14.4	0.37	ns	ns	ns
Daily DMI	708	627	708	699	91.8	ns	ns	ns
Cummulative DMI	18.8	14.8	15.5	13.4	2.71	*	*	ns
Daily weight gain	207	241	272	326	42.7	***	*	ns
Feed conversion	3.42	2.68	2.65	2.16	0.408	**	**	ns

RSD = residual standard deviation.

B: effect due to breed; S: effect due to sex; B × S: effect due to interaction.

ns, P>0.10; * P<0.05; **, P<0.01; ***, P<0.001.

Table 2. Mean values for non-carcass characteristics. Non-carcass weight (kg), non-carcass components (g) and chemical composition (g/kg) in the experimental treatments.

	Assaf		Merino × Assaf		RSD	Significance level		
	Females	Males	Females	Males		B	S	B × S
Non-carcass weights								
Non-carcass weight	8.37	8.21	7.34	8.01	0.800	**	ns	t
Blood	928	918	1010	1091	93.9	**	ns	ns
Wool	547	455	395	291	81.3	***	**	ns
Head and hide	3907^{b}	3894^{b}	3443^{a}	3586^{ab}	355.0	***	ns	t
Red offals	1171	1178	1074	1143	99.5	ns	ns	ns
White offals	1415	1463	1484	1628	178.4	ns	ns	ns
Total digestive fat	406	306	328	274	61.1	*	**	ns
Non-carcass composition								
Water	646	677	683	694	21.2	**	*	ns
Crude protein	179	171	172	174	7.6	ns	ns	ns
Crude fat	129	111	104	92	16.1	**	*	ns
Ash	32.9	29.7	30.0	31.4	2.92	ns	ns	t

RSD = residual standard deviation.

B: effect due to breed; S: effect due to sex; B × S: effect due to interaction.

ns, P>0.10; t, P<0.10; * P<0.05; **, P<0.01; ***, P<0.001.

[a, b] Different letters in the same line show significant differences when P value for interaction is < 0.10.

Table 3. Mean values of carcass characteristics. Cold carcass weight (kg), dressing percentaje (%), chilling losses (%), carcass linear measurements (cm), carcass compactness index (g/cm) and leg compactness (cm/cm), in the experimental treatments.

	Assaf		Merino × Assaf		RSD	Significance level		
	Females	Males	Females	Males		B	S	B × S
Carcass characteristics								
Cold carcass weight	9.75^{b}	9.37^{a}	9.34^{a}	9.49^{a}	0.289	ns	ns	*
Dressing percentage	48.7	46.5	46.8	46.4	1.27	t	*	ns
Chilling losses	2.32	2.31	2.71	2.77	0.200	***	ns	ns
Buttock perimeter	53.9^{c}	52.4^{b}	51.0^{a}	51.3^{ab}	0.95	***	ns	*
Buttock width	19.6	19.1	18.5	18.7	0.69	*	ns	ns
Carcass ext. length	61.9^{b}	59.1^{a}	57.2^{a}	58.3^{a}	2.22	**	ns	ns
Leg internal length	32.7	32.8	33.1	33.0	1.52	ns	ns	ns
Carcass compactness	158	159	164	163	5.5	*	ns	ns
Leg compactness	0.60	0.58	0.56	0.57	0.060	ns	ns	ns

RSD = residual standard deviation.

B: effect due to breed; S: effect due to sex; B × S: effect due to interaction.

ns, P>0.10; t, P<0.10; * P<0.05; **, P<0.01; ***, P<0.001.

[a, b] Different letters in the same line show significant differences when P value for interaction is < 0.05.

Table 4. Mean corresponding percentages of the different commercial categories, shoulder tissular composition and chemical composition (g/kg) of the experimental treatments.

	Assaf		Merino × Assaf		RSD	Significance level		
	Females	Males	Females	Males		B	S	B × S
Carcass commercial categories								
Higher priced joints	58.0	58.0	58.7	58.0	1.51	ns	ns	ns
Medium priced joint	17.8	18.0	17.8	18.9	0.85	ns	t	ns
Lower priced joints	21.2	20.7	20.6	20.1	1.39	ns	ns	ns
Shoulder tissular composition								
Muscle	64.1	62.5	64.7	65.1	1.80	*	ns	t
Total fat	13.7	12.4	12.7	10.1	2.20	t	*	ns
Bone	19.1	21.0	19.4	20.8	1.56	ns	**	ns
Others	3.18	4.10	3.23	3.97	1.080	ns	t	ns
Carcass composition								
Water	622	641	635	655	23.2	ns	t	ns
Crude protein	168	167	173	173	5.5	*	ns	ns
Crude fat	161	150	145	121	29.9	t	ns	ns
Ash	41.6	39.8	38.0	37.9	2.66	*	ns	ns

RSD = residual standard deviation.

B: effect due to breed; S: effect due to sex; B × S: effect due to interaction.

ns, P>0.10; t, P<0.10; * P<0.05; **, P<0.01.

Table 5. Mean values for the *longissimus* muscle colorimetric parameters, pH, cooking losses (%), WB shear force (N), area (cm^2) and chemical composition (g/kg) of the experimental treatments.

	Assaf		Assaf x Merino		RSD	Significance level		
	Females	Males	Females	Males		B	S	B × S
Longissimus thoracis muscle								
Lightness (L*)	45.0	43.0	41.7	42.4	2.17	*	ns	ns
Redness (a*)	10.6	12.2	11.0	10.6	1.68	ns	ns	ns
Yellowness (b*)	6.25	6.78	5.36	5.66	1.380	t	ns	ns
pH 24 h	5.54	5.54	5.65	5.61	0.075	**	ns	ns
Cooking losses	12.0	13.5	12.6	13.8	2.38	ns	ns	ns
WB shear force	36.4	41.4	40.9	49.0	11.43	ns	ns	ns
Area 13th toracic	12.3	10.7	11.6	12.0	1.65	ns	ns	ns
Longissimus lumborum composition								
Water	742	754	736	755	17.6	ns	*	ns
Crude protein	210	205	216	205	9.7	ns	t	ns
Crude fat	28.0	18.9	26.1	19.1	7.30	ns	**	ns
Ash	18.0	15.4	12.9	12.8	2.41	***	ns	ns

RSD = residual standard deviation.

B: effect due to breed; S: effect due to sex; B × S: effect due to interaction.

ns, P>0.10; t, P<0.10; * P<0.05; **, P<0.01; ***, P<0.001.