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Article

Effects of genotype, litter size and sex on carcass characteristics and fatty acid profile in hair lambs

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Abstract:

The effect of the genotype (Pelibuey *vs* Katahdin), type of lambing (single *vs.* double) and sex (males *vs.* females) on the characteristics of the carcass and its cuts, in addition to the fatty acid profile of the loin were evaluated in 66 lambs slaughtered at weaning. The yield of the carcass and ribs were higher (P<0.05) in the Pelibuey breed. Slaughter weight, carcass weight and rib yield were higher (P<0.01) in single-born lambs, while the yield of shoulder and leg were lower (P<0.01) than in double-born lambs. The proportion of soft tissue of the different cuts was higher (P<0.05), but that of bone was lower (P< 0.05) in single-born lambs than in double-born lambs. Females had a higher (P<0.05) proportion of soft tissue and a lower proportion of bone (P<0.01) than males. The concentrations of C18:1n7 and C20:4n-6 were higher (P<0.05) in the Pelibuey breed than in the Katahdin breed, while the C22:5n-3 and C22:6n-3 were lower. The percentage of monounsaturated fatty acids was higher (P<0.05) in the meat of single-born lambs, while that of total polyunsaturated fatty acids and n-3 was higher (P<0.05) in double-born lambs. The characteristics of the carcass, the tissue composition of the commercial cuts and the fatty acid profile in hair sheep slaughtered at weaning varied more due to the type of lambing than due to the genotype or sex.

Keywords: Carcass characteristics, Sheep carcasses, Lambs, Primal cuts, Tissue composition, Fatty acids.

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Introduction

Sheep meat in Mexico is consumed mostly in the form of *barbacoa*, an annual per capita consumption of 600-1000 g is estimated, so fattening male and female lambs, as well as cull adult ewes and rams, are used interchangeably for the preparation of this typical dish of the center of the country[1,2,3]. However, there is currently a small sector of the Mexican population that demands gourmet dishes with high quality meat, preferably from young lambs[2,3]. One of the most desired products in Mediterranean countries, such as Spain, is lactating lamb, which comes from lactating sheep with ultra-light carcasses and is characterized by having a meat traditionally considered to be of great sensory quality and highly appreciated locally[4]. However, the commercialization of primal cuts or carcasses from young lambs, less than three months, has not been usual in Mexico[5]. Notwithstanding the above and given the emergence of this market, it is very pertinent to define the type of lambs that offers the best quality of carcass, meat and selling cuts, considering both the sex and type of lambing, as well as the genotype.

In fattening lambs, carcass characteristics and meat quality vary due to genetic factors, type of lambing and sex, as well as some management factors that affect feeding, age and slaughter weight[4-11]. These factors also influence the yield of commercial cuts and the fatty acid profile of meat from lambs[7,8]. All these differences in carcass and meat are due to the fact that these factors cause metabolic, endocrine and gene expression variations, which lead lambs to vary in their growth, as well as in the formation of muscle tissue and fat tissue in the body[3].

Several studies have documented the impact that genetic and environmental factors have on the preweaning growth of hair lambs[12-16]; however, few have focused on the study of carcass characteristics, the tissue composition of commercial cuts and the fatty acid profile of meat. Recently, some authors[5,17] reported that the characteristics and tissue composition of the carcass are influenced by the type of birth of Blackbelly × Pelibuey lambs, with the carcasses of single-born lambs being heavier and with a higher soft tissue content than the carcasses of multiple-born lambs. However, no information was found regarding the effect of genotype and sex on carcass composition in lambs slaughtered at weaning.

Hair sheep are widely distributed in the tropical and subtropical regions of Mexico and, in general, of the American continent, which is due to the fact that they do not present reproductive seasonality and adapt easily to warm climates[18], so they are used for the production of meat for slaughter, but their use is currently being promoted for the production of fine cuts aimed at a select market that demands young lamb meat[19]. Therefore, the objective of the present study was to evaluate the effects of genotype, type of lambing and sex on carcass characteristics, tissue composition of commercial cuts and fatty acid profile of meat in lactating hair lambs.

Material and methods

Location of the experiment

The study was carried out at the ranch "El Rodeo", located at 17º 84' NL and 92º 81' WL, in the municipality of Villahermosa, Tabasco, Mexico. The climate in the region is humid tropical, with an average temperature of 27 ºC and a rainfall of 2,550 mm per year[20]. All the handling of the animals was carried out in accordance with the Mexican standards that describe the guidelines for the production, care and use of laboratory animals (NOM-062-ZOO-1992), as well as their slaughter (NOM-033-ZOO-1995).

Animals and experimental management

Sixty-six lambs, born to 49 multiparous ewes (age= 2-3 yr, live weight [LW]= 45.6 ± 6.8 kg and body condition= 2.2 ± 0.7 units[21] of the Pelibuey (n= 28) and Katahdin (n= 21) breeds, were used. Of the total number of lambs, 39 were of the Pelibuey breed (21 males and 18 females) and 27 Katahdin (15 males and 12 females), 31 of single lambing and 36 of double lambing, 36 males and 30 females.

At lambing, the lambs were identified and housed in individual pens with their mothers, where they remained until d 56 when they were weaned and slaughtered. The pens were located under a shed built with galvanized sheets, without walls and with cement floor. Each pen was equipped with a drinker and a feeder designed so that the lambs did not have access to the mother's food. The feeding of the ewes consisted of a comprehensive diet formulated to provide 12 MJ of ME/kg of dry matter and 15 % of crude protein. The diet was formulated with 50 % star grass hay (*Cynodon nlemfuemsis*), 30 % ground corn, 10 % soybean meal, 5 % molasses and 5 % minerals. The ewes were weighed weekly with the aim of adjusting the amount of feed offered according to live weight (LW) to ensure a daily rejection of around 15 %. Feed was offered daily at 0800 and 1500 h in a 50:50 ratio. The availability of water was *ad libitum* and the state of health of all animals was visually checked daily. In the case of the lambs, the feeding depended only on the consumption of the milk provided by the ewe, the consumption of milk of the lambs was supervised daily, so when some ewes refused to suckle them, the mother was held so that her lamb could suckle.

Characteristics of the carcass and commercial cuts

The lambs were weaned at 56 d postpartum, weighed to obtain the live weight at slaughter (LWS) and slaughtered according to the guidelines of the Mexican standard for humanitarian slaughter (NOM-033-ZOO-1995). The lambs had their skin, head, trotters and viscera removed. The content of the gastrointestinal tract was calculated by difference between full and empty weight. The weight of the gastrointestinal content was subtracted from the LWS to obtain the empty live weight (ELW). Once the carcass was obtained, its hot weight (HCW) was recorded and after 24 h of refrigeration at approximately 2 °C, its cold weight (CCW) was recorded. Hot carcass (HCY% = HCW / LWS × 100) and cold carcass yields (CCY% = CCW / LWS × 100), as well as true yield (TY = HCW/ELW × 100), were also calculated. For the determination of the regional composition, the carcasses were cut along the dorsal midline and from the left half carcass, the following cuts were obtained: neck, shoulder, leg, loin and ribs, according to the methodology previously described[3]. The weight of the half carcass was recorded, as well as of each cut and the percentage of each of them was calculated. Finally, to obtain the meat yield (composition), each cut was dissected by separating and recording the weight of soft tissue together (muscle, fat, aponeurosis, tendons, nerves and vessels) and bone[22,23]. The weight of the soft tissue and bone of each primal cut, as well as the half carcass, were expressed as a percentage of the weight of each cut and the left half carcass, respectively.

Determination of fatty acids

In 24 selected lambs, 12 of each genotype and of which six were females and six were males, as well as six from single lambing and six from double lambing, the fatty acid composition of the *Longissimus dorsi* muscle was determined using a Perkin Elmer Auto system gas chromatograph (Perkin-Elmer, Norwalk, CT, USA), equipped with a flame ionization detector (FID). Fatty acid methyl esters (FAMEs) were prepared according to the methodology described above[24] and injected (1.0 μL) into a BPX–70 capillary column (60 m × 0.25 mm ID). The temperatures of the detector and injector were 260 °C and 240 °C, respectively. The temperature program of the column was from 140 to 240 °C with an increase of 4 °C per minute, using nitrogen (1.0 mL/min) as a carrier gas[25,26]. A mixture of FAME standards was used for the identification (by comparison of retention times) of the chromatogram peaks of the samples. The area of the peaks was determined, and the percentage of FAMEs was obtained by the percentage of area by direct normalization. The results were expressed as a percentage of the area of each normalized peak of the total FAMEs identified.

Statistical analysis

Information on the characteristics of the carcass and the fatty acid profile of the meat was subjected to an analysis of variance under a completely randomized design with a 2×2×2 factorial arrangements, where the model included the fixed effects of genotype (Pelibuey or Katahdin), type of lambing (single or double), sex (male or female) and possible interactions between factors. A mean analysis was performed with the Tukey test between levels of each main factor and a significance value of $P<0.05$ was considered. Analyses were performed with PROC GLM of SAS[27].

Results

Genotype

Significant differences ($P<0.05$) in the centesimal yields of the carcasses ($P<0.05$) were obtained between both breeds, but no differences ($P>0.05$) were found in the variables LWS, ELW, HCW and CCW. The carcasses of Pelibuey lambs had higher ($P<0.01$) HCYs (+3.82 pp), CCYs (+3.41 pp) and TYs (+4 pp) than Katahdin lambs (Table 1). Pelibuey lambs also achieved a higher ($P<0.01$) rib yield (+2.44 pp), but lower ($P<0.05$) neck yield compared to

Katahdin lambs (-1.83 pp). No significant differences were found in the shoulder and loin, and only a tendency (*P*=0.08) to an increase in leg yield in Katahdin lambs.

The meat yields of the whole carcass and primal cuts were not affected (*P*=0.11) by the genotype (Table 2). Table 3 shows the fatty acid profile of the meat, with respect to the total fatty acids identified. Significant differences (*P*<0.01) were observed between breeds in one monounsaturated fatty acid and three polyunsaturated fatty acids. The meat (*Longissimus* M.) of the Pelibuey lambs presented higher proportions of vaccenic (C18:1n-7) and arachidonic acid (C20:4n-6) and lower proportions of DPA (C22:5n-3) and DHA (C22:6n-6) than the meat of lambs of the Katahdin breed. The total proportions of saturated (TS), monounsaturated (TM) and polyunsaturated fatty acids ($PUFAs_{n-3}$, $PUFAs_{n-6}$ and $PUFAs_{total}$) were not affected (*P*>0.05) by the effect of the breed, only the total content of saturated fatty acids showed a tendency (*P*= 0.07) to increase in the meat of the Katahdin breed compared to the meat of the Pelibuey breed.

Type of lambing

Significant differences (*P*<0.01) were obtained for the type of lambing in the carcass weights, but not in their centesimal yields (CCY, TY). Single-born lambs achieved higher LWS (+2.94 kg), ELW (+2.75 kg), HCW (+1.59 kg) and CCW (+1.58 kg) compared to double-born lambs (Table 1). There was only one tendency (*P*= 0.08) to increase in HCY in single-born lambs compared to double-born lambs. Shoulder and leg yields were higher (*P*<0.01) in double-born lambs, but rib yield was higher (*P*<0.01) in single-born lambs (Table 1). The type of lambing also modified (*P*<0.01) the meat yield of the half carcass, ribs, loin and leg (Table 2). Single-born lambs obtained a higher proportion of soft tissue in the half carcass than double-born lambs (*P*<0.01). The proportions of soft tissue and bone of the ribs, loin and leg were higher (6.11 pp, +7.26 pp and +4.99 pp, respectively, *P*<0.01) in single-born lambs compared to double-born lambs. Significant differences (*P*≤0.05) were observed in the percentage of one saturated fatty acid, two monounsaturated and five polyunsaturated fatty acids (Table 3). Single-born lamb meat compared to double-born lamb meat had lower content of palmitic (C16:00) and elaidic acid (C18:1n-9), but higher content of vaccenic (C18:1n-7), linoleic (C18:2n-6), dihomo-gamma-linolenic (C20:3n-6), arachidonic (C20:4n-6) and DPA acids (C22:5n-3). The type of lambing had an effect (*P*<0.05) on the total percentage of monounsaturated fatty acids (TM), $PUFAs_{n-3}$ and $PUFAs_{Total}$. The TM ratio was higher (*P*>0.01) in the meat of single-born lambs compared to that of double-born lambs; opposite results were observed for total $PUFAs_{n-3}$ and $PUFAs_{Total}$, where the highest percentage (*P*< 0.05) occurred in meat from double-born sheep (Table 3).

Sex

Sex did not affect (*P*≥0.08) LWS, ELW, carcass characteristics and the yield of commercial cuts (Table 1), but it did affect (*P*=0.04) the composition of the ribs, with the percentage of soft tissue being higher and the percentage of bone being lower in females than in males (Table 2). The fatty acid profile was not modified (*P*>0.05) by the effect of sex (Table 3).

Discussion

Carcass characteristics and meat yield

In Mexico, only a few studies(5,17) have reported the effect of the number of lambs and type of lambing of ewes on the characteristics and composition of the carcass of recently weaned lambs, so the literature is scarce. The results of the present study confirm preliminary findings regarding the effect of the type of lambing on the HCW; even with a wider difference in weights(5,17). Additionally, the present work indicates that in hair lambs slaughtered at weaning (56 d), the genotype also influences the main variables of quantitative quality of the carcass and its cuts. Single births caused greater weights of the lambs at weaning and of the carcasses of the lambs from double births, with differences of up to +2.94 kg for the LWS and +1.58 kg for the CCW, without difference in the carcass yields. However, the breed did not cause differences in weights but in yields, where the TY of the Pelibuey was 4 points higher than in the Katahdin. A study with information taken from productive records of a Pelibuey flock(28) found no differences in weaning weight between the type of lambing but in daily weight gain. In this work, as in the present study, no significant differences were found in weaning weight between males and females(5); however, several inconsistencies are mentioned(29). Some authors have also reported that, under intensive management conditions in the Pelibuey breed, the type of birth of the lamb affects its weaning weight (WW) and daily weight gain (DWG), while the sex of the lamb affects its development from birth to 180 d(30). However, in these studies only the main effects are considered, without considering the influence of the interaction between the two factors(31). In ruminants, prenatal growth is influenced by several factors, with the level of maternal nutrition and the functional capacity of the placenta standing out(17); while postnatal growth may be limited by maternal nutrition and environmental factors(32). Other authors(33) report that animals from single births have greater growth potential than those from double births. This fact, based on what has been described in previous studies(34), would be related to competition for the mother's milk, given that lambs from double birth have a lower intake of milk. In this sense, obtaining double births allows greater efficiency in the production of sheep meat, but lambs reach the weight at slaughter at an older age than those from single birth(35).

In previous studies(17), an increase in HCW was observed in single-born lambs, with no difference in LWS or CY. These differences between the carcass weight of lambs from single and multiple births may be due to the weight of muscle mass due to an increased individual milk consumption at the lactation stage(17). In lactating lambs of the Canaria breed slaughtered between 48 and 51 d of age, the effect of the breed (Canaria of hair *vs* Canaria of wool) and sex on the characteristics of the carcass(36) was evaluated, on average, these animals weighed 9.13 kg at slaughter, they obtained carcasses of 4.5 kg and a CCY of 49.06 %, but no significant differences were observed in any variable due to breed or sex.

Regarding the yield of the cuts, double-born lambs had a higher yield of the shoulder and leg, but the ribs had a higher yield in single-born lambs. With respect to the genotype, the neck had higher yield in the Katahdin breed and the ribs in the Pelibuey breed. In both cases, it is difficult to explain. Other authors(37), who compared wool lambs *vs* hair lambs, and males *vs* females, only obtained differences for both factors in the shoulder.

In the composition of the carcass and its cuts, the most outstanding differences in meat yield for this type of product (ultra-light carcasses) originated from the type of lambing, where the lambs from single births reached higher values of soft tissue in the carcass and cuts, where the loin was the cut with the highest meat yield. In this regard, other authors(28), when assessing the meat yield in carcass lambs with similar characteristics, found differences in the kilos of soft tissue of the carcass, but not in the meat yield of the carcass itself, which was lower than in the present study. Regarding the cuts, they only found differences in the weight of the soft tissue of the leg. The physical parameters of meat quality are influenced by sex, in this regard, in previous studies(38), the amount of muscle and meat in males and females of Texel breed was evaluated, observing an increase in the proportion of muscle, being greater than that of fat for variables adjusted to the same weight of the carcass in males. It should be mentioned that the present study does not differentiate the type of tissue (muscle, fat, nerves, vessels, etc.), so the analysis of these results should be taken with caution when compared with those of other authors. The differences attributed to the type of lambing could be associated with an increase in both muscle and fat. In the case of sex, the higher meat yields of some cuts in females could be associated with a higher fat deposit; however, other authors found no differences due to sex on total fat(37).

Fatty acid composition of meat

Regarding saturated fatty acids, previous studies conducted on goats(39) found a significant effect of the breed on the concentration of the fatty acids C17:0 and C18:0, of which the latter was the one with the highest proportion, reaching values above 14.5 %. In the case of palmitic acid, it presented a behavior similar to that observed in the present study, that is, its concentration was not affected by the genotype; however, the concentration oscillated between 26.32 and 27.32 %, values that were higher than those reported for lambs in the present work. Regarding the genotype, previous studies(36) show that the concentration of this fatty acid in cuts of bucklings (12 kg of LW) was significantly affected, observing values ranging between 14.59 and 15.88 %, which were lower than those obtained in the present work. Evaluating the composition of fatty acids in hair lambs and a wool breed slaughtered at different weights (10, 16 and 25 kg), they found differences in several saturated fatty acids, mostly due to the effect of slaughter weight, which also significantly influenced the total saturated fatty acids (TS); they also found significant differences due to the effect of the sex; however, these differences were not reflected in the TS(40). In this study, the concentration of palmitic acid was higher than that of the present study, but that of stearic acid was lower in males. Only palmitic acid was significantly higher in females, so there was no effect of the genotype or weight.

Regarding the total concentration of monounsaturated fatty acids (TM), a difference of almost 5 pp was observed due to the effect of the type of lambing on the TM, being greater in the meat of lambs from single births. This difference is basically due to the high concentration of oleic acid (C18:1n-9) in the meat of single-born lambs (+4.81 pp), which would cancel out the small difference of vaccenic acid in the meat of double-born lambs (+0.32 pp). Oleic acid was the fatty acid with the highest concentration in meat (30.86-35.67 %), which is consistent with what was observed in previous studies carried out in lactating kids and lambs(36), as well as in lactating hair and wool lambs(40). In this regard, it is also pointed out that this fatty acid would decrease the content of LDL cholesterol in the blood, in addition to contributing (along with other fatty acids) to the firmness of the meat and its oxidative stability, and influencing the juiciness, flavor and color. Neither genotype nor sex influenced TM; however, the Pelibuey breed had a higher concentration of vaccenic acid than the Katahdin breed. Contrary to what was observed in the present work, other studies(36) reported an important effect of the genotype on the concentration of monounsaturated fats, recording values ranging from 30.92 to 32.45 %, which are lower than those observed in the present study. On the other hand, previous studies(41) determined that the concentration of monounsaturated fat in the *Longissimus lumborum* muscle was not affected by the genotype of the lambs. Similar results were obtained in other studies(42), where the concentration of monounsaturated fats was not affected by the sheep genotypes studied (Churra and Assaf, 39.16 *vs* 40.67 %, respectively).

The greatest differences were detected in six polyunsaturated fatty acids (PUFAs) due to the type of lambing and genotype. Only the type of lambing affected the amount of $PUFAs_{n-3}$ plus $PUFAs_{Total}$, the latter being higher than that recorded by other authors(42). No differences were detected in this type of fatty acids between males and females. Previous studies(40) showed that the effect of breed, weight, and sex influenced $PUFAs_{Total}$. In this regard, they pointed out that lean breeds (hair breeds) have a relatively higher proportion of $PUFAs_{Total}$ than other less lean breeds, and that as the slaughter weight increases, this proportion decreases. This is consistent with the findings of the present study regarding the type of lambing, since this factor determined a difference in slaughter weight, which coincides with what was pointed out by these authors, who indicate that as the slaughter weight increases (greater in single-born lambs), the proportion of $PUFAs_{Total}$ decreases. Thus, the polyunsaturated fatty acids with higher concentrations in double-born lambs were linoleic (C18:2n-6) and arachidonic (C20:4n-6), and those with the lowest concentration were DPA (C22:5n-3) and C20:3n-6. The results regarding the genotype effect are less conclusive because there was no marked difference that affected the concentration of $PUFAs_{Total}$; however, the Pelibuey breed had higher concentrations of arachidonic acid and lower concentrations of DPA and DHA than the Katahdin breed; on the other hand, it has been found that the genotype does not affect the total concentration of $PUFAs_{Total}$ in the *Longissimus* M. of ewes(41); contrary to what was reported by other authors(42), who did find an effect of the genotype on the concentration of $PUFAs_{Total}$ in intramuscular tissue of lambs of the Churra (30.75 %) and Assaf breeds (28.96 %).

The total concentration of $PUFAs_{n-6}$ in lamb meat cuts was not affected by genotype, sex or type of lambing, the same trend was observed in the concentration of $PUFAs_{n-3}$, except that for this type of fatty acids, the total concentration was affected by the type of lambing, observing a higher mean in carcasses of double-born lambs. In contrast to what was found in this research, other authors(42), when analyzing the concentration of omega-6 acids in the intramuscular fat of lambs of the Churra and Assaf breeds, reported a significant effect of the genotype on this type of fatty acids of 26.64 *vs* 24.29 %, respectively for each breed.

When the effect of the genotype, sex and type of birth of the lamb on the concentration of $PUFAs_{n-6}$ was analyzed, the arachidonic acid (20:4n-6) was affected by the genotype, with a higher proportion observed in lambs of the Pelibuey breed with respect to the Katahdin breed. On the other hand, the concentrations of linoleic (18:2n-6), dihomo-g-linolenic (20:3n-6) and arachidonic acids (20:4n-6) were affected by the type of lambing, with a higher proportion observed when the lambs were from double birth. In the particular concentration of omega-6 fatty acids, in a similar way to what was observed in the present work, in previous studies(42), a significant effect of the genotype on the values of 20:4n-6 in intramuscular fat of lambs of the Churra and Assaf breeds (5.57 *vs* 4.75 %) has been observed, additionally and contrary to what was determined in this study, a higher concentration (P<0.05) of C18:2n6 has been observed(43) in Churra lambs than in Assaf lambs (19.38 *vs* 17.97 %, respectively). When the effect of the genotype, sex and type of birth of the lamb on the concentration of $PUFAs_{n-3}$ was analyzed, only the fatty acids C22:5n-3 and C22:6n-3 were affected by the genotype, observing a higher concentration in the Katahdin lambs. Other studies(41,43) showed that rumen biohydrogenation can cause low levels in the lipid profile and the lack of difference in intramuscular fat deposition of animals fed with different energy levels.

Conclusions and implications

The characteristics of the carcass and the yield of commercial cuts in hair sheep slaughtered at weaning varied according to the genotype and type of lambing, but not due to the sex. The meat yield of the half carcass and of each commercial cut was defined, mainly, by the type of lambing, with minimal changes due to genotype or sex. In general, Pelibuey lambs had higher carcass yield than Katahdin lambs, even though they obtained similar empty live weight and carcass weight; this could be associated with higher rib yield in Pelibuey lambs. According to the type of lambing, the single-born lambs had greater slaughter and carcass weight, as well as higher rib yield, but this was not reflected in a higher carcass yield. The type of lambing was the main factor that modified the fatty acid profile, producing a healthier meat for humans in the double-born lambs, since this meat had a higher proportion of polyunsaturated acids compared to the meat of single-born lambs.

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Table 1: Slaughter weight, carcass characteristics and yield of primal cuts (means ± SE) due to the effects of genotype, type of lambing and sex in 56-day-old lactating lambs

Characteristics	Breed			Type of lambing			Sex		
	Pelibuey	**Katahdin**	***P***	**Single**	**Double**	***P***	**Males**	**Females**	***P***
LWS, kg	10.73 ± 0.35	11.11 ± 0.42	0.49	12.39 ± 0.40	9.45 ± 0.37	<0.01	11.02 ± 0.37	10.82 ± 0.41	0.73
ELW, kg	9.63 ± 0.32	9.91 ± 0.38	0.57	11.15 ± 0.36	8.40 ± 0.33	<0.01	9.82 ± 0.33	9.72 ± 0.36	0.83
HCW, kg	5.43 ± 0.19	5.22 ± 0.22	0.46	6.12 ± 0.21	4.53 ± 0.20	<0.01	5.29 ± 0.19	5.36 ± 0.21	0.83
CCW, kg	5.17 ± 0.18	4.96 ± 0.21	0.44	5.85 ± 0.20	4.27 ± 0.19	<0.01	5.10 ± 0.19	5.03 ± 0.21	0.79
HCY, %	50.58 ± 0.52	46.76 ± 0.61	<0.01	49.37 ± 0.59	47.96 ± 0.54	0.08	48.17 ± 0.54	49.16 ± 0.60	0.22
CCY, %	48.03 ± 0.78	44.62 ± 0.93	<0.01	47.20 ± 0.89	45.44 ± 0.83	0.15	46.52 ± 0.81	46.12 ± 0.90	0.74
TY, %	56.38 ± 0.49	52.38 ± 0.58	<0.01	54.88 ± 0.56	53.87 ± 0.52	0.19	53.97 ± 0.51	54.79 ± 0.56	0.29
Commercial cuts (%)									
Neck	7.01 ± 0.22	8.84 ± 0.27	<0.01	7.80 ± 0.25	8.06 ± 0.23	0.47	8.09 ± 0.23	7.77 ± 0.26	0.37
Shoulder	18.97 ± 0.27	19.34 ± 0.33	0.40	18.48 ± 0.31	19.83 ± 0.29	<0.01	19.45 ± 0.29	18.87 ± 0.32	0.19
Ribs	24.90 ± 0.40	22.46 ± 0.48	<0.01	24.80 ± 0.46	22.57 ± 0.42	<0.01	23.51 ± 0.42	23.86 ± 0.46	0.58
Loin	12.98 ± 0.32	12.69 ± 0.38	0.57	13.25 ± 0.37	12.43 ± 0.34	0.11	12.39 ± 0.33	13.29 ± 0.37	0.08
Leg	35.90 ± 0.38	36.98 ± 0.45	0.08	35.65 ± 0.43	37.22 ± 0.40	0.01	36.47 ± 0.39	36.41 ± 0.44	0.91

LWS= live weight at slaughter, ELW= empty live weight, HCW= hot carcass weight, CCW= cold carcass weight, HCY= hot carcass yield, CCY= cold carcass yield, TY= true yield.

Table 2: Meat yields of carcass and primal cuts (means ± SE) due to the effects of genotype, type of lambing and sex in 56-day-old lactating lambs

Variable (%)	Breed			Type of lambing			Sex		
	Pelibuey	**Katahdin**	***P***	**Single**	**Double**	***P***	**Males**	**Females**	***P***
Half carcass									
Soft tissues	69.99 ± 0.65	69.99 ± 0.78	0.99	72.51 ± 0.75	67.97 ± 0.69	<0.01	69.19 ± 0.68	70.79 ± 0.75	0.12
Bone	29.75 ± 0.55	29.65 ± 0.65	0.91	27.81 ± 0.62	32.00 ± 0.57	<0.01	30.20 ± 0.57	29.20 ± 0.63	0.24
Neck									
Soft tissues	62.90 ± 1.50	66.40 ± 1.79	0.14	65.37 ± 1.71	63.33 ± 1.58	0.26	65.77 ± 1.56	63.52 ± 1.73	0.34
Bone	36.07 ± 5.89	43.21 ± 7.02	0.44	34.65 ± 6.73	36.62 ± 6.22	0.38	34.35 ± 6.13	35.93 ± 6.80	0.37
Shoulder									
Soft tissues	69.46 ± 1.34	67.82 ± 1.60	0.11	69.77 ± 1.53	69.30 ± 1.42	0.82	67.54 ± 1.40	71.43 ± 1.55	0.06
Bone	30.53 ± 0.62	32.26 ± 0.74	0.74	30.14 ± 0.71	30.65 ± 0.66	0.07	32.59 ± 0.65	28.60 ± 0.72	0.11
Ribs									
Soft tissues	64.85 ± 0.94	65.82 ± 1.12	0.55	68.44 ± 1.07	62.33 ± 0.99	<0.01	63.70 ± 0.98	66.90 ± 1.08	0.04
Bone	34.88 ± 0.94	33.88 ± 1.12	0.50	31.56 ± 1.07	37.68 ± 0.99	<0.01	36.83 ± 0.97	32.94 ± 1.08	0.04
Loin									
Soft tissues	75.98 ± 1.20	77.90 ± 1.43	0.31	80.56 ± 1.37	73.30 ± 1.27	<0.01	76.06 ± 1.25	77.62 ± 1.39	0.35
Bone	23.87 ± 1.27	21.69 ± 1.52	0.28	19.45 ± 1.45	26.71 ± 1.34	<0.01	24.02 ± 1.33	22.54 ± 1.47	0.22
Leg									
Soft tissues	71.68 ± 0.87	71.16 ± 1.04	0.70	73.92 ± 1.00	68.93 ± 0.92	<0.01	72.26 ± 0.91	70.99 ± 1.01	0.22
Bone	27.75 ± 1.04	28.27 ± 1.24	0.75	25.97 ± 1.19	30.95 ± 1.10	<0.01	27.74 ± 1.09	28.98 ± 1.21	0.48

Table 3: Fatty acid profile of meat of hair lambs (means ± SE) due to the effects of genotype, type of lambing and sex in 56-day-old lactating lambs

Fatty acid	Genotype (G)			Type			Sex(s)		
	Pelibuey	**Katahdin**	***P***	**Single**	**Double**	***P***	**Males**	**Females**	***P***
10:00	0.07 ± 0.02	0.09 ± 0.01	0.39	0.09 ± 0.02	0.07 ± 0.01	0.49	0.09 ± 0.02	0.07 ± 0.02	0.46
12:00	0.42 ± 0.09	0.50 ± 0.09	0.58	0.39 ± 0.10	0.54 ± 0.09	0.27	0.51 ± 0.09	0.42 ± 0.09	0.51
14:00	3.13 ± 0.66	3.79 ± 0.63	0.47	3.40 ± 0.69	3.52 ± 0.59	0.90	3.58 ± 0.66	3.34 ± 0.62	0.80
15:00	0.383 ± 0.03	0.37 ± 0.03	0.84	0.37 ± 0.04	0.39 ± 0.03	0.65	0.38 ± 0.03	0.37 ± 0.03	0.84
16:00	21.15 ± 1.0	22.09 ± 0.95	0.51	23.11 ± 1.05	20.14 ± 0.90	0.05	20.74 ± 1.0	22.50 ± 0.95	0.22
18:00	14.03 ± 1.08	16.65 ± 1.02	0.11	14.60 ± 1.13	16.08 ± 0.97	0.34	16.87 ± 1.10	13.82 ± 1.02	0.06
20:00	0.26 ± 0.06	0.27 ± 0.06	0.94	0.19 ± 0.06	0.35 ± 0.05	0.08	0.22 ± 0.06	0.32 ± 0.06	0.23
16:1n-9	0.40 ± 0.07	0.33 ± 0.06	0.48	0.39 ± 0.07	0.34 ± 0.06	0.62	0.41 ± 0.07	0.33 ± 0.06	0.38
16:1n-7	1.05 ± 0.19	1.01 ± 0.18	0.88	1.23 ± 0.20	0.83 ± 0.17	0.16	1.03 ± 0.19	1.03 ± 0.18	0.97
18:1n-9	33.90 ± 1.03	32.63 ± 0.97	0.38	35.67 ± 1.07	30.86 ± 0.92	<0.01	32.57 ± 1.03	33.96 ± 0.97	0.34
18:1n-7	2.14 ± 0.09	1.64 ± 0.09	<0.01	1.73 ± 0.10	2.05 ± 0.08	0.03	1.84 ± 0.09	1.94 ± 0.09	0.46
18:2n-6	10.24 ± 0.81	9.20 ± 0.76	0.36	8.55 ± 0.84	10.90 ± 0.72	0.05	9.41 ± 0.81	10.04 ± 0.76	0.58
20:2n-6	1.44 ± 0.18	1.57 ± 0.17	0.62	1.30 ± 0.19	1.71 ± 0.16	0.13	1.66 ± 0.18	1.35 ± 0.17	0.25
20:3n-6	0.52 ± 0.05	0.56 ± 0.04	0.52	0.47 ± 0.05	0.62 ± 0.04	0.03	0.53 ± 0.05	0.55 ± 0.04	0.78
20:4n-6	7.79 ± 0.54	5.74 ± 0.51	0.02	5.71 ± 0.57	7.82 ± 0.49	0.01	6.63 ± 0.54	6.90 ± 0.51	0.72
16:4n-3	2.06 ± 0.18	2.09 ± 0.17	0.91	1.82 ± 0.19	2.34 ± 0.16	0.05	2.32 ± 0.18	1.83 ± 0.17	0.07
22:5n-3	0.79 ± 0.10	1.10 ± 0.09	0.04	0.75 ± 0.10	1.14 ± 0.09	0.01	0.95 ± 0.10	0.94 ± 0.09	0.98
22:6n-3	0.19 ± 0.04	0.32 ± 0.03	0.02	0.22 ± 0.04	0.28 ± 0.03	0.26	0.25 ± 0.04	0.25 ± 0.03	0.98
TS	39.46 ± 1.61	43.78 ± 1.52	0.07	42.14 ± 1.68	41.10 ± 1.44	0.64	42.39 ± 1.61	40.85 ± 1.52	0.50
TM	37.50 ± 1.10	35.62 ± 1.04	0.23	39.02 ± 1.15	34.09 ± 0.98	<0.01	35.85 ± 1.10	37.26 ± 1.04	0.37
$PUFAs_{n-6}$	20.00 ± 1.46	17.08 ± 1.38	0.17	16.03 ± 1.52	21.04 ± 1.30	0.17	18.23 ± 1.46	18.85 ± 1.38	0.76
$PUFAs_{n-3}$	3.04 ± 0.29	3.52 ± 0.27	0.25	2.79 ± 0.30	3.77 ± 0.26	0.03	3.53 ± 0.29	3.04 ± 0.27	0.24
$PUFAs_{Total}$	23.04 ± 1.73	20.60 ± 1.64	0.32	18.83 ± 1.81	24.81 ± 1.55	0.02	21.75 ± 1.73	21.89 ± 1.64	0.96

Fatty acids are shown as a percentage (%) of total fatty acids. Only fatty acids found in levels above 0.05 % are shown. TS= total saturated; TM= total monounsaturated; $PUFAs_{n-6}$= n-6 polyunsaturated fatty; $PUFAs_{n-3}$: n-3 polyunsaturated fatty acids; $PUFAs_{Total}$= total polyunsaturated fatty acids.