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Phenotypic Characterization of Rambouillet Sheep Expressing the *Callipyge* Gene: II. Carcass Characteristics and Retail Yield¹

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ABSTRACT: Paternal half-sibling Rambouillet ram lambs (n = 18) representing two muscle phenotypes were slaughtered at 54.5 kg to evaluate carcass characteristics and composition. Lambs were produced from a sire that was heterozygous for the *callipyge* gene. Carcasses were broken into wholesale and retail cuts to evaluate percentage bone-in retail yield of carcasses at various fat trim levels and percentage of boneless retail cuts. Retail cuts were trimmed to .6 and then to 0 cm fat trim and bones were removed to determine boneless, closely trimmed retail cut yield. Chemical composition was determined using proximate analysis. Lambs expressing the *callipyge* gene had higher dressing percentages (57.3 vs 53.9), leg (14.4 vs 11.0) and conformation (14.4 vs 11.0) scores, and larger longissimus muscle (LM) areas (17.6 cm²

vs 10.3 cm²). All other carcass measurements were similar between phenotypes except marbling score, which was higher (417.8 vs 325.6) for controls. Lambs expressing the *callipyge* gene had a higher (40.2 vs 32.9) percentage boneless retail yield than controls. Retail yield of the boneless shoulder did not differ between phenotypes (8.9 vs 8.0). All other percentages of boneless retail cuts were higher ($P < .02$) for lambs expressing the *callipyge* gene. Carcasses from lambs with the *callipyge* gene had higher protein (16.6 vs 15.2), moisture (63.6 vs 58.6) and ash (.85 vs .77) percentages and lower fat (18.9 vs 25.4) percentages than controls. These data suggest that ram lambs expressing the *callipyge* gene have an advantage in retail yield and carcass conformation when compared to normal-muscled half-siblings.

Key Words: Sheep, Carcass Yield, Meat, Muscles, Callipyge

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Introduction

Consumers of lamb in the United States prefer large loin chops that have little external fat (Shelley et al., 1970; Robinson, 1989). The current U. S. commercial lamb production system produces too many lambs that are excessively fat and lightly muscled. Sheep with the *callipyge* phenotype have the potential to eliminate this industry problem. The *callipyge* gene mutation has been in the commercial sheep population at a low frequency for approximately 10 yr. However, this germplasm has not been widely accepted or used in commercial breeding programs. The common perception in the sheep industry is that animals with this phenotype possess the negative characteristics associated with double-muscled cattle.

However, no evidence exists in the scientific literature to support this assumption. This experiment was conducted due to the lack of knowledge concerning sheep with this phenotype coupled with the industry's need for lean, heavily muscled market lambs. The objectives of this study were to evaluate dressing percentage, carcass characteristics, and percentage retail yield of ram lambs expressing the *callipyge* gene compared to their normal-muscled paternal half-siblings.

Materials and Methods

Slaughter and Dressing Procedures. All procedures were conducted under protocols approved by the Texas Tech University Animal Care and Use Committee. Lambs (n = 9) representing each muscle phenotype were slaughtered at 54.5 kg at the Texas Tech Meat Laboratory using approved USDA procedures after a 24-h fast. Live weight and linear measures were recorded immediately before slaughter. Internal organ weights were obtained immediately after evisceration. The heart, liver, lungs, kidneys, rumen, reticulum, omasum, abomasum, small intestine, large intestine,

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spleen, and testicles were opened, contents were removed, and each organ was rinsed and allowed to drip dry for 3 min before it was weighed. Fat was removed from the heart and testicles and was rinsed and allowed to drip dry for 3 min before weighing. The trachea, glands, and other tissues were trimmed from the lungs before rinsing, drying, and weighing. Mesenteric fat was stripped from each organ and was allowed to drip dry for 3 min before weighing. Kidney and pelvic fat remained on the carcass during evisceration.

Live and Carcass Measurements and scoring. Linear measurements were obtained from lambs immediately before slaughter and from their carcasses 24 h postmortem. These measurements included height at the withers, body length (base of neck to the dock), neck length (atlas joint to the base of the neck), hindsaddle length (posterior edge of the last rib to the posterior edge of the pin bone), foresaddle length (base of the neck to the posterior edge of the last rib), and scrotal circumference. Linear carcass measures of carcass length, foresaddle length, and hindsaddle length were made on the right side of each carcass. Carcass length was determined by measuring from the anterior edge of the first rib to the anterior edge of the aitch bone. Foresaddle length was determined by measuring from the anterior edge of the first rib to the posterior edge of the 12th thoracic vertebra. Hindsaddle length was determined by measuring from the anterior edge of the 13th thoracic vertebra to the anterior edge of the aitch bone. Actual 12th rib fat thickness, adjusted fat thickness, and longissimus muscle (LM) area for the right side were measured and recorded. Leg score, carcass conformation score, marbling score, LM lean color, lean firmness, texture, primary flank streakings, and USDA quality grade were evaluated. The scoring system used for LM lean color, LM lean firmness, and LM lean texture was an 8-point scale (8 = bright red, firm, or fine, respectively, and 1 = dark, soft, or coarse, respectively).

Carcass Fabrication. Chilled carcasses were weighed and split down the midline and the right and left sides were weighed. The fore- and hindsaddles were separated and weighed, and the kidney-pelvic fat was removed from the hindsaddle and weighed. The left side of each carcass was broken into wholesale cuts (leg, loin, rack, and shoulder). These cuts were individually weighed before they were fabricated into retail cuts. Bone-in retail cuts were weighed, trimmed to .6 cm of fat thickness, and reweighed. The trimmed retail cuts then were trimmed to 0 cm of fat thickness and reweighed. The bone then was removed and the boneless, closely trimmed retail cuts were weighed.

The primal leg (French leg) was separated from the primal loin by making a straight cut perpendicular to the midline between the last two lumbar vertebra. The flank was removed from the leg by cutting along the natural seam between the flank and the sirloin

tip. The tibia was removed from the leg by breaking through the epiphyseal plate and the Achilles' tendon was removed flush with the muscle surface. The short cut leg (American leg) was made by cutting through the stifle joint and removing the shank from the primal leg.

The flank was removed from the loin by a straight cut from a point 2.5 cm from the lateral end of the LM on the eye end to a point 2.5 cm from the LM on the sirloin end. The breast and shank were removed from the foresaddle by a straight cut perpendicular to the rib side and through the cartilaginous juncture of the first rib and the sternum.

The shoulder was separated from the rib between the 4th and 5th ribs by a straight cut perpendicular to the backbone. Rib ends were removed from the rack by a straight cut from a point 2.5 cm from the lateral end of the LM on the eye end to a point 2.5 cm from the lateral end of the LM on the blade end. The neck was removed from the shoulder by a straight cut perpendicular to the length of the neck.

Carcasses were separated into muscle, fat, and bone to determine carcass composition. Muscle and fat tissues were ground twice and then homogenized using a commercial meat homogenizer (Robot-Coupe, Jackson, MS). Muscle and fat samples were collected and analyzed for protein, moisture, fat, and ash using proximate analysis procedures (AOAC, 1990). Total fat percentage (Table 5) was determined by summing seam, subcutaneous, kidney-pelvic, mesenteric, and all other separable internal fat and dividing by live weight. Live weight was used as the denominator rather than carcass weight in order to show differences in both carcass and non-carcass (mesenteric and other internal organ fat) fat between phenotypes.

Statistical Analysis. Data were analyzed as a completely randomized design using the GLM procedure of SAS (1990). Type III sums of squares were used for statistical evaluation. A model using muscle phenotype as the only source of variation was used to examine differences in all independent variables.

Results

The live weights of *callipyge* lambs did not differ ($P < .41$) from the live weights of normal half-siblings. However, hot and cold, right and left side carcass weights of *callipyge* lambs were significantly heavier than those of controls (Table 1). Lambs with normal muscling had heavier large intestines ($P < .03$) than lambs expressing the *callipyge* gene. The mean weights for liver, lungs, kidneys, rumen, reticulum, omasum, abomasum, small intestine, spleen, testicles, and mesentery fat did not differ between phenotypes (Table 2). None of the linear measurements taken on the live lambs and their carcasses were different ($P > .05$) between phenotypes (Table 3). Lambs expressing

Table 1. Mean weights for Rambouillet ram lambs and carcasses expressing different muscle phenotypes^a

Weight, kg	Phenotype		Range within phenotype		SEM	P-value
	<i>Callipyge</i>	Normal	<i>Callipyge</i>	Normal		
Live	52.8	52.2	50.5–55.4	49.9–54.4	.49	.41
Hot carcass	30.2	28.1	28.8–31.4	26.8–30.6	.39	.001
Cold carcass	29.2	26.6	28.0–30.5	24.2–29.0	.34	.001
Left side	15.0	13.4	14.1–16.2	12.4–14.3	.21	.001
Right side	14.2	13.1	13.3–15.4	11.7–14.6	.27	.01

^an = 9 carcasses of each phenotype.

the *callipyge* muscle phenotype had higher ($P < .001$) dressing percentages than half-siblings with normal muscling (Table 4). No difference was detected in 12th rib or adjusted backfat thickness between the two muscle phenotypes (Table 4). Leg score and conformation score were higher ($P < .001$) for lambs with the *callipyge* phenotype. Longissimus muscle area was 71% larger ($P < .001$) in lambs expressing the *callipyge* gene than in half-siblings (Table 4). Means for LM color, LM texture, and LM firmness were not significantly different between the muscle phenotypes. Flank streakings and kidney and pelvic fat did not differ significantly between phenotypes.

Means for total carcass fat were 5.2 percentage units lower ($P < .004$) and for subcutaneous fat trim were 2.2 percentage units lower ($P < .009$) for lambs with the *callipyge* phenotype than for lambs with a normal muscle phenotype (Table 5). The .8 percentage unit seam fat difference between muscle phenotypes approached statistical significance ($P < .09$). Lambs with the *callipyge* muscle phenotype had a 3.5 percentage units lower ($P < .007$) percentage of bone in their carcasses than half-siblings with normal muscling.

At the 5% significance level, retail yield percentage did not differ for any fat trim level between lambs of different phenotypes (Table 6). However, a trend favored lambs with the *callipyge* phenotype. When boneless retail cuts were trimmed to 0 cm of fat

thickness, lambs expressing the *callipyge* gene yielded 7.3 percentage units more ($P < .001$) lean product than half-sibling controls.

Means for percentage of carcass weight in retail cuts from the shoulder were not significantly different between lambs of the two muscle phenotypes at any fat trim level or when made boneless (Table 7). Lambs with a *callipyge* phenotype had a significantly higher percentage of their carcass weight in retail cuts from the rack at all levels of fat trim (Table 8). Retail cuts yield percentage from the rack of lambs expressing the *callipyge* gene also was higher ($P < .02$) when the bone and 2.5-cm tails (fat and muscle ventral to the longissimus) were removed from the trimmed cuts. Retail yield of the loin did not differ significantly between phenotypes at any level of fat trim for the bone-in cuts (Table 9). When the bone and 2.5-cm tails were removed, carcasses from lambs with the *callipyge* gene yielded a higher ($P < .01$) percentage of boneless, retail loineye than control carcasses. The bone-in and boneless retail leg cuts from lambs with the *callipyge* phenotype represented a significantly higher percentage of carcass weight at all levels of fat trim than the leg from half-siblings (Table 10). Lambs with the *callipyge* muscle phenotype had 4.4 percentage units more ($P < .001$) yield of short-cut boneless leg than control half-siblings.

Lambs expressing the *callipyge* gene had higher percentages ($P < .001$) of protein, moisture, and ash

Table 2. Mean organ weights for Rambouillet ram lambs representing two muscle phenotypes^a

Organ, g	Phenotype		SEM	P-value
	<i>Callipyge</i>	Normal		
Heart	208.4	228.7	22.7	.678
Liver	868.6	898.3	50.8	.684
Lung	532.6	535.7	13.0	.867
Kidney	64.6	69.5	2.5	.188
Rumen, reticulum, omasum, abomasum	1,227.2	1,292.1	39.6	.263
Large intestine	422.4	470.4	14.4	.031
Small intestine	899.3	886.3	45.2	.841
Spleen	94.8	97.2	6.9	.809
Testicles	259.3	272.8	22.7	.678

^an = 9 lambs of each phenotype.

Table 3. Linear measurements of Rambouillet ram lambs representing two muscle phenotypes^a

Trait, cm	Phenotype		SEM	P-value
	<i>Callipyge</i>	Normal		
Height	69.4	69.5	1.0	.926
Body length	66.7	66.6	.86	.921
Neck length	21.8	22.8	.83	.418
Hindsaddle length	40.7	40.3	.89	.743
Foresaddle length	25.8	26.2	.74	.708
Carcass length	72.9	73.8	.76	.433
Carcass hindsaddle	43.3	44.3	.73	.351
Carcass foresaddle	28.7	29.0	.72	.764
Scrotal circumference	29.9	29.0	1.0	.574

^an = 9 lambs of each phenotype.

Table 4. Carcass characteristics of Rambouillet ram lambs representing two muscle phenotypes^a

Trait	Phenotype		SEM	P-value
	<i>Callipyge</i>	Normal		
Actual 12th rib fat thickness, mm	5.1	5.9	.2	.613
Adjusted fat thickness, mm	5.9	7.5	.2	.235
Longissimus muscle area, cm ²	17.6	10.3	.82	.001
Leg score ^b	14.4	11.0	.24	.001
Dressing percentage	57.3	53.9	.56	.001
USDA yield grade	2.7	3.1	.18	.187
Conformation ^b	14.4	11.0	.24	.001
Marbling score ^c	325.6	417.8	21.5	.007
Longissimus muscle lean color ^d	6.1	6.3	.22	.482
Longissimus muscle lean firmness ^e	5.8	6.3	.46	.507
Longissimus muscle texture ^f	6.0	6.8	.47	.257
Kidney and pelvic fat, %	1.9	2.6	.38	.213
Primary flank streakings ^c	211.1	211.1	25.4	1.00

^an = 9 carcasses of each phenotype.

^b10 = Choice⁻, 11 = Choice⁰, 12 = Choice⁺, 13 = Prime⁻, 14 = Prime⁰, 15 = Prime⁺.

^c100 = traces⁰, 200 = slight⁰, 300 = small⁰, 400 = modest⁰.

^dScored on an 8-point scale (1 = dark red, 8 = pale pink).

^eScored on an 8-point scale (1 = very soft, 8 = very firm).

^fScored on an 8-point scale (1 = very coarse, 8 = very fine).

Table 5. Effect of muscle phenotype on the percentage of total fat, fat trim, seam fat, and bone of ram lambs^a

Trait, %	Phenotype		SEM	P-value
	<i>Callipyge</i>	Normal		
Total fat ^b	18.4	23.6	.10	.004
Subcutaneous fat trim ^c	7.4	9.6	.52	.008
Seam fat ^c	3.0	3.8	.29	.091
Bone ^c	19.3	22.8	.79	.006

^an = 9 carcasses of each phenotype.

^bTotal fat was calculated by summing subcutaneous, seam, kidney-pelvic, mesenteric fat, and all other separable fat removed from the internal organs and dividing by live weight.

^cCalculated as pounds of dissectable tissue divided by left side carcass weight.

Table 6. Effect of muscle phenotype on carcass yields of bone-in and boneless retail cuts from the leg, loin, rack, and shoulder at three fat trim levels^a

Trait	Phenotype		SEM	P-value
	<i>Callipyge</i>	Normal		
Yield of bone-in cuts, %				
Untrimmed	61.9	57.5	1.8	.105
.6 cm of fat trim level	59.9	54.4	1.9	.062
0 cm of fat trim level	55.7	50.3	1.9	.072
Yield of boneless cuts, %				
0 cm of fat trim level	40.2	32.9	1.01	.001

^an = 9 carcasses of each phenotype.

in their carcasses than control half-sibling lambs (Table 11). Lambs with a *callipyge* muscle phenotype also had a lower ($P < .001$) percentage of fat than their normal-muscled half-siblings.

Discussion

Lambs expressing the *callipyge* gene had higher dressing percentages than lambs with a normal muscle phenotype. Dressing percentage is influenced by the amount of muscle, fat, gut-fill, and wool on the lamb. To more clearly evaluate the effect of muscle hypertrophy on carcass yield, the digestive tract was evaluated as a possible explanation for the differences in dressing percentage between the muscle phenotypes. In this experiment, the only internal organ that differed significantly in weight between the phenotypes was the large intestine. The large intestine was 11% heavier ($P < .03$) in control lambs than in lambs with the *callipyge* phenotype. Because the internal organ weights were similar between the phenotypes, it is logical to conclude that dressing percentage differences between phenotypes were not affected by internal organ weight. This result is not in agreement with the literature on double-muscled cattle, which have lighter digestive tracts (Vissac, 1962; Charlet and Poly, 1965) and less intake capacity (Geay et al., 1982) than normal-muscled cattle.

Scrotal circumference and testicular weight did not differ significantly between lambs of the two phenotypes. In contrast, double-muscled bulls have lighter testicles and less scrotal circumference (Kidwell et al., 1952) than normal-muscled bulls.

Linear measurements of lambs with the *callipyge* gene did not differ significantly from half-sibling measurements. The common perception in the sheep industry is that lambs expressing the *callipyge* gene are "short bodied" and have a lower percentage of their body length in the hindsaddle than normal sheep. The percentage of hindsaddle by length did not differ between phenotypes. However, because of the additional muscle mass in the leg and loin, a significantly higher percentage of trimmed hindsaddle (by weight) was found in carcasses of lambs with the *callipyge* phenotype. These data show that lambs expressing the *callipyge* gene actually have an advantage in percentage of hindsaddle rather than the deficiency of hindsaddle that has been incorrectly hypothesized.

External fat at the 12th rib and kidney and pelvic fat were not different between phenotypes. The lambs in this study were all intact males and were slaughtered at an approximate live weight of 54.5 kg (Table 1). If wether lambs were fed and allowed to grow to a heavier weight, it is likely that larger differences would be seen between phenotypes. In spite of the similar amount of external fat for lambs of each

Table 7. Effect of muscle phenotype on carcass yields of bone-in and boneless retail cuts from the shoulder at three fat trim levels^a

Trait	Phenotype		SEM	P-value
	<i>Callipyge</i>	Normal		
Yield of bone-in shoulder, %				
Untrimmed	15.9	15.1	1.04	.593
.6 cm of fat trim level	15.7	14.9	1.05	.593
0 cm of fat trim level	14.9	14.3	1.10	.680
Yield of boneless shoulder, %				
0 cm of fat trim level	8.9	8.0	.66	.344

^an = 9 carcasses of each phenotype.

Table 8. Effect of muscle phenotype on carcass yields of bone-in and boneless retail cuts from the rack at three fat trim levels and tail lengths^a

Trait	Phenotype		SEM	P-value
	<i>Callipyge</i>	Normal		
Yield of bone-in rack with 2.5 cm tail, %				
Untrimmed	8.2	6.9	.35	.023
.6 cm of fat trim level	8.1	6.8	.34	.014
0 cm of fat trim level	7.2	6.2	.34	.052
Yield of boneless loin eye, %				
2.5-cm tail	4.6	3.6	.19	.003
No tail	3.4	2.9	.16	.020

^an = 9 carcasses of each phenotype.

phenotype, the two phenotypes of lambs still differed in total fat percentage. The difference was in the amount of intermuscular, intramuscular, and internal fat in the carcasses. Seam fat deposition in lambs with the *callipyge* phenotype was reduced ($P < .09$). The large variation (SEM = .29) in seam fat from this sample of lambs was responsible for the low probability value.

The leg score and subsequently the conformation score of lambs with the *callipyge* phenotype were higher than for lambs with a normal muscle phenotype. In the leg of lambs expressing the *callipyge* gene, the sirloin and lower leg obviously were enlarged and contributed to higher scores for both the leg and overall conformation (Table 3). The USDA numerical yield grade (calculated with the formula used before 1993) was lower ($P = .18$) for lambs with the *callipyge* phenotype. When the new grading formula was used, the phenotypes did not differ in yield grade. The current yield grade formula does not accurately assess the yield of retail cuts for lambs with extreme muscling.

Muscle quality as measured by LM color, firmness, and texture did not differ significantly between muscle phenotypes. However, more variation in muscle texture was evident in lambs with a *callipyge* muscle phenotype than within the normal phenotype. Kidwell

et al. (1952) reported that meat from double-muscled cattle was coarser in texture than meat from normal cattle. The amount of marbling within the LM differed ($P < .007$) between phenotypes. This result is consistent with the seam fat and external fat deposition patterns discussed earlier. The deposition of marbling and external fat in lambs with the *callipyge* gene seems to be similar to fat deposition patterns of double-muscled cattle (Kidwell et al., 1952; Menissier, 1982). Lambs expressing the *callipyge* gene do not deposit as much fat as their normal-muscled half-siblings. Energy seems to be partitioned differently for the two muscle phenotypes. Lambs expressing the *callipyge* gene may have a systemic mechanism that favors the utilization of energy for the accretion of protein rather than fat. This result may also help explain the superior feed efficiency of lambs with the *callipyge* gene discussed in the preceding companion paper (Jackson et al., 1996a). This partitioning of energy toward muscle growth rather than fat deposition is similar to the tissue growth patterns of lambs fed β -adrenergic agonists such as clenbuterol and cimaterol (Yang and McElligott, 1989).

Lambs with the *callipyge* phenotype had a lower percentage of total carcass fat and fat trim than their half-siblings. The difference in the percentage of seam fat between the phenotypes approached statistical

Table 9. Effect of muscle phenotype on carcass yields of bone-in and boneless retail cuts from the loin at three fat trim levels and tail lengths^a

Trait	Phenotype		SEM	P-value
	<i>Callipyge</i>	Normal		
Yield of bone-in loin with 2.5 cm tail, %				
Untrimmed	8.6	8.1	.65	.560
.6 cm of fat trim level	8.6	8.1	.65	.560
0 cm of fat trim level	7.8	7.1	.54	.414
Yield of boneless loin eye, %				
2.5-cm tail	6.0	5.2	.49	.270
No tail	5.2	3.9	.31	.010

^an = 9 carcasses of each phenotype.

Table 10. Effect of muscle phenotype on carcass yields of bone-in and boneless retail cuts from the leg at three fat trim levels^a

Trait	Phenotype		SEM	P-value
	<i>Callipyge</i>	Normal		
Yield of bone-in leg, %				
Untrimmed	27.8	25.4	.89	.073
.6 cm of fat trim level	26.3	23.4	.92	.040
0 cm of fat trim level	23.7	20.1	1.14	.042
Yield of boneless sirloin, %				
0 cm of fat trim level	4.7	3.5	.31	.013
Yield of short-cut boneless leg, %				
0 cm of fat trim level	22.6	18.2	.51	.001

^an = 9 carcasses of each phenotype.

significance ($P = .09$). This reduction of carcass fat in lambs expressing the *callipyge* gene is similar to reports on double-muscled cattle that have shown less external fat, seam fat, and marbling compared with normal cattle (Menissier, 1982). The reduction of carcass fat in lambs with the *callipyge* phenotype is beneficial to the packer because it reduces the amount of fat that must be trimmed from carcasses and should increase the value of carcasses because of the reduction in fat trim.

The yield of untrimmed retail cuts was 4.4 percentage units higher for lambs expressing the *callipyge* gene than for controls. This difference was not statistically different because of the variation within the phenotypes and the small number of lambs evaluated. At the .6 and 0 cm of fat trim levels, the percentage of retail product in carcasses from lambs with the *callipyge* phenotype increased to 5.5 percentage units more than half-siblings. The only significant difference in total retail yield between the phenotypes was at the 0 cm of fat trim level with bones removed. At this fat trim level, lambs with the *callipyge* phenotype yielded 7.3 percentage units more boneless, trimmed product than their half-siblings. These retail yield differences are higher than values from a study that involved feeding β -adrenergic agonists to lambs (Shackelford et al., 1992). If the lamb packing industry moves toward a marketing scheme that sells boxed, trimmed and boneless product, lambs expressing the *callipyge* gene should have an economic advantage over normal-muscled lambs.

Retail yield of the shoulder was not significantly different for carcasses of either phenotype. This result is consistent with other data from this study that suggest little enlargement of the muscles of the shoulder. The reduction of shoulder as a percentage of carcass weight is advantageous because the shoulder is the least valuable retail cut from a lamb carcass. It is, therefore, beneficial for the shoulder to represent a smaller percentage of carcass weight. Interestingly, no increase in the retail yield of the shoulder was found from lambs fed the β -adrenergic agonist L_{644,969}

(Shackelford et al., 1992) even though percentage of retail yield increased in the leg, loin, and rack.

Retail yield from the rack was higher for lambs with the *callipyge* phenotype. The yield of total retail cuts from the rack was 1 percentage unit higher for *callipyge* lambs. The loins from lambs with the *callipyge* gene yielded approximately .7 percentage units more retail product than the loin from lambs with normal muscling. This difference was not statistically significant until the tail and bone were removed from the loin. After fat and bone removal, there was a 1.3 percentage unit advantage in boneless retail yield for lambs expressing the *callipyge* gene.

The largest difference in retail yield was found in the leg. Lambs expressing the *callipyge* gene had more than a 2 percentage unit advantage in the retail yield of the leg. When the bone was removed, *callipyge* lambs yielded approximately 4 percentage units more retail product than controls. The leg is the largest retail cut from a lamb carcass and has the highest retail value. This large difference in the retail yield of the leg between the muscle phenotypes is not surprising considering the muscle weight distribution data presented in the following companion paper (Jackson et al., 1996b).

Lambs expressing the *callipyge* gene have a clear advantage in dressing percentage and retail yield of the leg and rack. *callipyge* lambs also have leaner

Table 11. Effect of muscle phenotype on carcass soft tissue composition of Rambouillet ram lambs^a

Component, %	Phenotype		P-value
	<i>Callipyge</i>	Normal	
Protein	16.6	15.2	.001
Moisture	63.6	58.6	.001
Fat	18.9	25.4	.001
Ash	.85	.77	.001

^an = 9 carcasses of each phenotype.

carcasses with less percentage bone than their half-siblings with normal muscling. This unique combination of muscling, leanness, and dressing percentage should allow lambs with this phenotype to excel in a value-based marketing system.

Total body composition analyzed by proximate analysis also differed between the phenotypes. Proximate analysis of carcasses indicated that lambs expressing the *callipyge* gene had more protein and less fat in their carcasses than half-siblings with a normal muscle phenotype.

Implications

This study is the first to evaluate the carcass composition and cutability of sheep with the *callipyge* phenotype. Sheep expressing the *callipyge* gene have the leanness, muscling, and dressing percentage advantages needed to receive premiums in value-based marketing systems. Additional research is needed to better understand the biology of sheep expressing the *callipyge* gene. Many questions remain unanswered in the areas of muscle biology, growth physiology, and palatability of sheep with the *callipyge* gene. Knowledge of metabolic pathways involved in fat and muscle tissue growth of sheep with the *callipyge* gene could greatly enhance our understanding of animal growth.

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