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Carcass Quality of Romanov Crossbred Lambs Expressing the Callipyge Phenotype

M. H. Fahmy

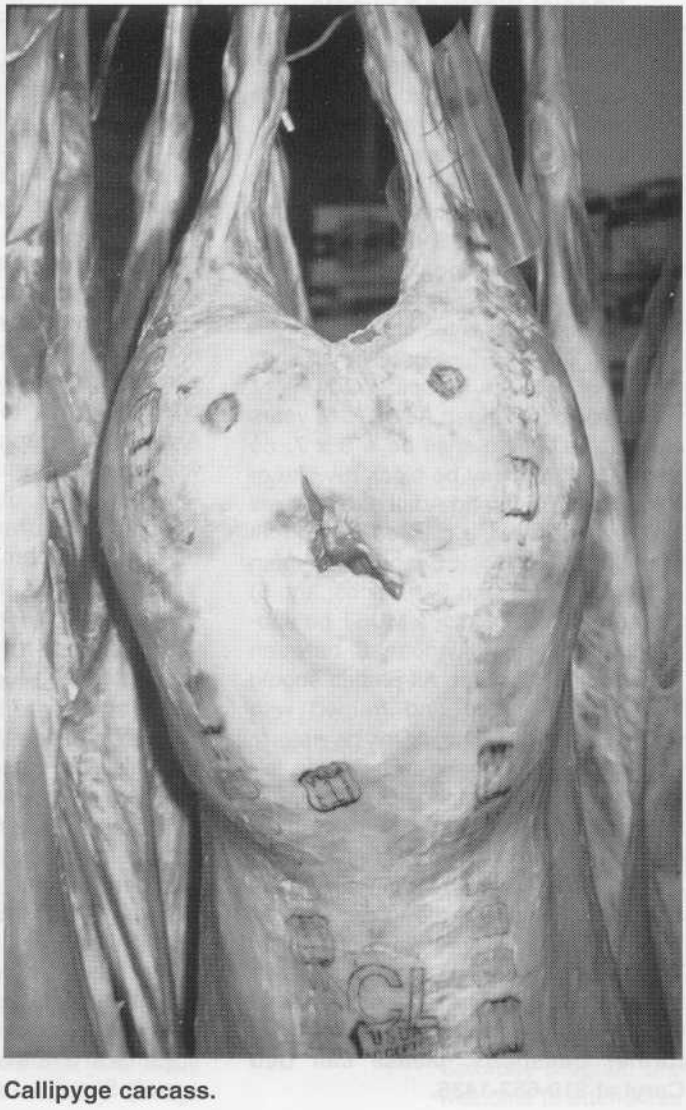
Agriculture and Agri-Food Canada. Dairy and Swine Research and Development Centre, P.O. Box 90, Lennoxville, Quebec, Canada J1M 1Z3

The superior prolificacy of Romanov and Romanov crosses has made them popular in commercial enterprises that produce market lambs. Surprisingly, however, few research studies have investigated the causes for the relatively inferior quality of Romanov (and to a lesser extent Romanov crossbred) lamb carcasses, especially intact males, resulting from the greater proportion of carcass weight in the forequarter and none has suggested remedies. In France researchers working on Romanov sheep referred to the inferior quality of the Romanov carcasses but reported no work in France designed to improve the situation.

The mutant allele of the *callipyge* gene affects carcass composition favourably through an exceptional effect on the degree of muscling and particularly on specific muscles in the loin and leg, thus improving the most valuable retail cuts of lamb. According to the American scientist Dr. Gerry Snowder the *callipyge* gene caused a significant increase (9 to 16%) in the weight of leg and loin muscles. Area of the longissimus muscle increased by 22 to 34% in the presence of the mutant allele. Moreover, measures of subcutaneous and intermuscular fat suggest that total fat decreases significantly and muscle mass increases. Therefore, the *callipyge* gene can potentially have a large economic impact on the value of lamb carcasses and particularly those with Romanov ancestry which are characterized by deficient leg muscling.

The disadvantage of carcasses showing the *callipyge* phenotype is the toughness of the loin-eye muscle presumably caused by hypertophy, reduced myofibrillar fragmentation and reduced intramuscular fat (marbling). Several approaches to solve this problem have been investigated, individually or in combination. These include different freezing times, calcium chloride injection, hydrodyne process, and electrical stimulation of carcass. A simple method to

Lamb showing callipyge phenotype.



Callipyge carcass.

increase the tenderness of a muscle is to prolong the postmortem aging process either for a long term or for shorter periods.

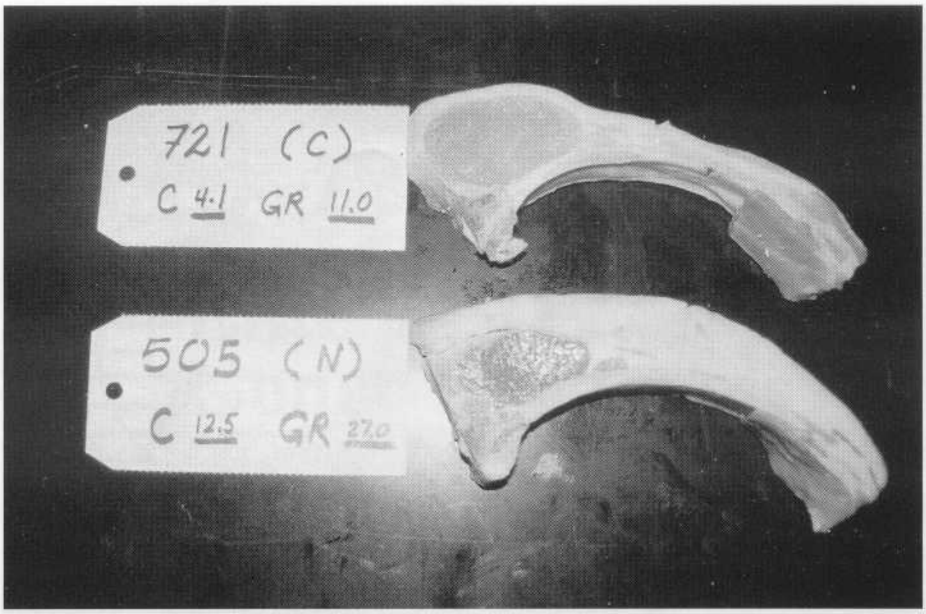
We conducted a study in Canada to investigate the effect of the *callipyge* phenotype on carcass composition of lambs particularly those characterised by poor leg muscling such as the Romanov breed and its crosses. Also, the effect of postmortem aging for 3, 9, or 15 days on loin-eye muscle tenderness was investigated.

We used 35 intact male and 41 female lambs. Forty lambs were born to Romanov and 36 lambs born to Suffolk x Romanov ewes bred by two 7/8 Columbia-1/8 Dorset rams heterozygous for the *callipyge* locus that were imported from the United States Sheep Experiment Station in Dubois, Idaho. The lambs were selected from those available on a private sheep farm about 30 km east of the Lennoxville Research Centre in Quebec.

The lambs were born from mid-January through the end of March, in a heated barn. They nursed their mothers and were provided with creep feed (19% crude protein) free choice until weaning at 50 days of age. After weaning, they were moved to unheated quarters and were allowed free access to hay and a commercial grain mixture

Of the lambs available on the farm progeny of the imported rams, 38 assumed according to phenotype to be heterozygous for the *callipyge* allele were selected and an equal number of lambs not showing the *callipyge* phenotype were used as a control. The decision on whether a lamb showed the *callipyge* phenotype or not was based on a visual appraisal of the hind-quarters during the growth period and this was later corroborated by carcass analysis of the leg and loin cuts. The phenotypic appearance of the *callipyge* lambs was similar to that described by the American Scientists Jackson and coworkers (1997a). It should be borne in mind that since the distinction between *callipyge* and wild-type phenotypes was based solely on visual appraisal, and not geneticly by markers, errors may have occurred. These errors, if any, are believed to be minor. Lambs identified as having the *callipyge* phenotype will be referred to as *callipyge* lambs and those showing the normal phenotype as controls.

When lambs reached approximately 44 kg fasted live weight, they were slaughtered at a commercial abattoir. After removing the skin and head, carcasses were opened, emptied of internal organs, chilled for 24 h then weighed to calculate the dressing percentage. Carcass weight averaged 22.8 kg, however a few carcasses were heavy, reaching 29.8 kg. Carcass weight was 23.6 kg for *callipyge* vs 21.9 kg for control, 22.0 kg for males vs 23.3 kg for females and 22.2 kg from Romanov ewes vs 23.3 kg from Romanov cross. Chilled carcasses were cut in halves through the center of the vertebral column. The left side was weighed and cut into three wholesale cuts, shoulder (between the 5th and 6th vertebrae); loin-rack (from the 6th to the last lumbar vertebrae) and leg. The three cuts from the left side and the loin from the right side were identified, put into plastic bags, placed in a cooler filled with dry ice, and transferred to the laboratories of the Lennoxville Centre for carcass evaluation.



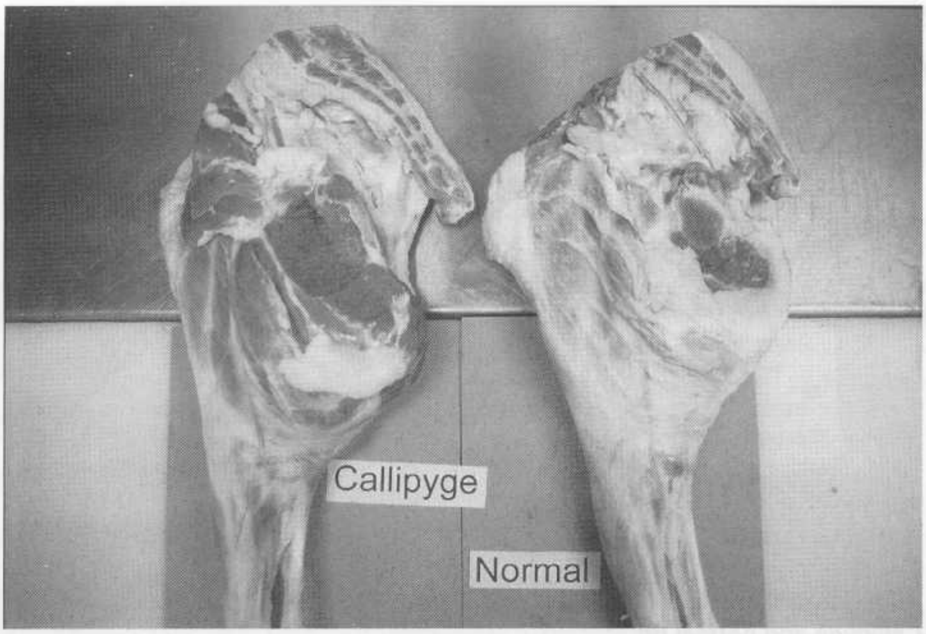
Callipyge and normal rib.

Upon arrival at the laboratory, shoulder, loin and leg cuts were weighed and dissected into lean (which also included epimysial and lymphatic tissues), fat, and bone, each component tissue was weighed and expressed as a percentage of the whole cut. Before dissecting the loin cut, the 12th rib was separated from the rest of the cut for color readings of the loin-eye muscle. Three color measurements were taken by a LabScan, Hunter L*, a*, and b* measuring respectively, the color between black and white, red and green, and yellow and blue.

The following measures were taken on the 12th rib: backfat at the C location (over the center of the loin-eye muscle), total fat and lean depth at the GR location (11 cm from the carcass midline), and area of loin-eye muscle measured on a tracing of acetate paper using a planimeter . The 12th rib was then dissected into lean, fat and bone tissues. The weights of these tissues were later added to the weight of dissected tissues of the rest of the loin cut.

Separable kidney fat in the loin cut (excluding kidney weight) was weighed separately and then added to loin fat (internal fat from the leg cut was not included in this weight). The loin-eye muscle, from both sides of the carcass, was separated from the other tissues and divided into four parts, three of which were placed in plastic bags and sealed under vacuum then refrigerated at 4° C for 3, 9, or 15 d then frozen at -20° C until analyzed for tenderness. The fourth part was used for the following determinations. A sample was separated from connective tissues surrounding it and then ground. Dry matter content of the loin-eye muscle was determined by freeze drying the entire sample. A subsample was used to determine the intramuscular fat content.

Meat tenderness was evaluated at the Food Research and Development Centre in Saint Hyacinthe, Quebec. For each animal, the three loin-eye cuts aged for different periods were thawed on the same day at 4° C for 16 hours. Each sample was placed on absorbent paper for 30 seconds, weighed, then placed in aluminum dishes. The sample was cooked at 163° C to an internal temperature of 72° C using a conventional oven. The cooked sample was weighed again to calculate weight loss during cooking. Tenderness was evaluated by shear force using the Warner Bratzler method on about ten 1 cm^2 cross sectional sticks of meat cut parallel to meat fibers.



Callipyge and normal leg.

We obtained the following results:

The effect of breed type was non-significant except for age at slaughter in which lambs born to Suffolk x Romanov ewes were 14 days younger than those born to pure Romanov. The breed type x sex interaction was significant only for dressing percentage and that of sex x phenotype for backfat at the C location.

Age at slaughter

Age at slaughter adjusted for carcass weight was 163 days for *callipyge* vs 176 days for control lambs. Male lambs were 14 days younger than females. The significantly younger age of *callipyge* lambs at a fixed carcass weight in the present study indicated a difference in growth rate. This contradicts the findings of several American studies which reported similar age and weight at slaughter of *callipyge* and control lambs indicating similar growth rate.

Dressing percentage

Effects of sex and phenotype as well as that of sex x breed type were significant for dressing percentage. Females dressed 52%, 3 percentage points higher than males, and *callipyge* lambs dressed 52%, 3 percentage points higher than controls. The difference between sexes was higher in lambs from Suffolk x Romanov ewes (4 percentage points) than between lambs from pure Romanov ewes (2 percentage points).

This study confirmed previous reports of higher dressing proportion of lambs showing the *callipyge* phenotype. Snowder *et al.*, (1994) crossing Dorset rams heterozygous for the *callipyge* locus with Rambouillet, Columbia and Suffolk ewes reported, 4.3, 2.5, and 4.2 percentage points higher dressing for *callipyge* lambs slaughtered at 54.5 kg, respectively. Similarly, other American studies reported 2.3 and 3.4 percentage points higher dressing for *callipyge* lambs. In another American study scientists reported that hot carcass weight of both Dorset x Suffolk *callipyge* and control lambs was similar, even though the weight of *callipyge* lambs was 4.4 kg lighter at slaughter. These studies are in agreement with the present findings on the higher dressing percentage of *callipyge* lambs.

Table 1. Means of proportion of wholesale cuts in *callipyge* and control lambs

Genotype	Leg (%)	Loin (%)	Shoulder (%)
Callipyge	34.1	31.5	33.8
Control	30.8	32.8	36.2
Callipyge-control	3.2***	-1.3***	-2.4***

***The difference is highly significant

Proportion of carcass wholesale cuts

The effects of sex and phenotype were significant on proportions of carcass wholesale cuts. The proportion of leg, loin, and shoulder in males were 32.9, 30.2, and 36.4%, compared to 32.0, 34.1 and 33.6% for females. *Callipyge* lambs had higher leg, lower loin and lower shoulder proportions (3.2, -1.3, and -2.4 percentage points, respectively) than controls (Table 1). The lower proportion of the loin cut in *callipyge* lambs despite the large increase in the loin-eye muscle can be explained by the considerably greater increase in the leg proportion. In fact, the weight of loin cut was heavier in *callipyge* than in control lambs (7.434 vs 7.183 kg, unadjusted for carcass weight difference).

In an American study total closely trimmed, saw-ready cuts as a proportion of carcass weight was 73.2 % in *callipyge* lambs, 2.5 percentage points greater than in control lambs. Also, the higher priced cuts were 3.1 percentage points higher in *callipyge* lambs. Snowder *et al.*, (1994) showed that Dorset x Rambouillet and Dorset x Columbia lambs showing the *callipyge* phenotype had significantly greater total cutability (71.8 vs 68.6 %), major cuts (62.4 vs 58.7 %), and proportion of leg, sirloin, and loin in the carcass (36.6 vs 33.2 %) than controls. Koohmaraie *et al.*, (1995) showed that the weight of loin-eye muscle was 32.0 % heavier in *callipyge* lambs. The present findings agree with these studies and indicate that *callipyge* lambs produce a higher proportion of the more valuable cuts.

The reason for initiating this study was to investigate the benefit of using

Table 2. Means for proportion of lean, fat and bone in wholesale cuts and half carcass of *callipyge* and control lambs

	Leg			Loin			Shoulder		
	Lean %	Fat %	Bone %	Lean %	Fat %	Bone %	Lean %	Fat %	Bone %
Callipyge	65.2	18.0	16.4	56.9	27.4	13.3	53.3	26.0	20.3
Control	57.1	23.2	19.3	45.6	37.2	14.3	45.6	31.9	21.7
Callipyge-control	8.1***	-5.2***	-2.9***	11.3***	-9.8***	-1.0*	7.7***	-5.9***	-1.4**

*, **, ***The difference is significant, moderately significant or highly significant, respectively

the mutant allele to improve conformation and carcass characteristics of lambs with Romanov ancestry. The results indicate a significant decrease in the proportion of shoulder and an increase in the proportion of leg in the carcass to values comparable to carcasses from meat-type breeds.

Proportion of lean, fat and bone in wholesale cuts and half carcass

Sex and *callipyge* phenotype had significant effects on lean, fat, and bone of the three wholesale cuts and the half carcass, except for the effect of sex on lean proportion of the leg. In general, males had more lean and bone and less fat than females. Wholesale cuts of *callipyge* lambs were generally superior to those of controls since they had more lean and less fat and bone. Overall, *callipyge* lambs had more lean (58.3 vs 49.1 %), less fat (23.8 vs 31.0 %), and less bone (16.8 vs 18.7 %) than controls (Table 2).

Very few studies have reported on proportions of carcass tissues in *callipyge* and normal sheep. An American investigation reported 11.5 % more lean, 9.3 % less fat and 1.4 % less bone in *callipyge* compared to control lambs, indicating even more leaner lambs than those in the present study. The study also showed that five muscles affected by the *callipyge* mutant allele were significantly heavier individually and accounted for 19.2 % of the total weight compared to 14.5 % for the controls.

Internal and kidney fat

Carcass weight, sex, and presence of the *callipyge* phenotype had highly significant effects on internal and kidney fat. The mean for females (337 g) was 65% higher than in males. Similarly, in control lambs internal fat deposition (339 g) was 68% higher than in *callipyge* lambs (202 g).

The 6% reduction in kidney fat of *callipyge* lambs relative to carcass weight in the present study is similar to those reported in American studies (11 vs 17%) and (36 vs 42 %). The corresponding estimate in the study of Jackson *et al.*, (1997b) was 10 % (19 vs 29). Prolific Romanov and Finnsheep and their crosses have the tendency to deposit a relatively higher proportion of their body fat internally in body cavity. The effect of the *callipyge* allele in reducing internal fat seems to be similar in prolific and non-prolific genotypes.

12th rib characteristics

Proportion of lean, fat, and bone in 12th rib. Effects of sex and phenotype were significant on proportion of the three tissues in the 12th rib except that of phenotype on the proportion of bone. The interaction sex x phenotype was significant on fat proportion, with the difference in favour of *callipyge* lambs in males (23.6 vs 30.5 %) being smaller than in females (29.5 vs 41.2 %). The proportions of lean (53.6 vs 50.0 %) and bone (17.4 vs 14.5 %) were higher in males than in females. The 12th rib of *callipyge* lambs had more lean, less fat, and less bone than control lambs (Table 3).

Table 3. Means of proportion of lean fat and bone in the 12th rib of *callipyge* and control lambs

	Lean (%)	Fat (%)	Bone (%)
Callipyge	57.4	26.6	15.5
Control	46.2	35.8	16.5
Callipyge-control	11.2***	-9.2***	-1.0

***The difference is highly significant

Area of loin-eye muscle at 12th rib. Area of loin-eye muscle at the 12th rib of *callipyge* lambs averaged 18.5 cm^2 compared to 13.1 cm^2 for controls. This difference of over 41% was highly significant. The interaction sex x phenotype was significant with the difference between *callipyge* and controls being larger in females (19.3 vs 12.8 cm^2, 50%) than in males (17.7 vs 13.3 cm^2, 33%).

Busboom *et al.*, (1994) reported that loin-eye area of *callipyge* lambs (21.2 cm^2) was 50% larger than in controls. Likewise, Fernandez *et al.*, (1996) indicated that loin-eye area in Rambouillet x Gulf Coast Native with *callipyge* phenotype was 20.9 cm^2 in carcasses weighing 26.3 kg, compared to 10.7 cm^2 in carcasses of controls weighing 22.6 kg. This represented a 95% increase, but for a more proper comparison the difference in carcass weight should be considered. Snowder *et al.*, (1994) working with three breed types reported increases of 66, 68, and 78% in *callipyge* lambs over controls. Similar results were reported in other breeds: in White-face (48%), in Rambouillet (71%), in Dorset x Suffolk (47%). Although the 41% increase in loin-eye area in the present study is impressive, it is still lower than those reported in the American studies and may be attributed to the about 10 kg lighter weight at slaughter of lambs in the present study. It was reported that in Dorset x Romanov crosses, as body weight increased, loin-eye muscle increased at a faster rate in *callipyge* lambs (19 vs 16 g per Kg body weight) than in controls.

Backfat thickness. Females had significantly thicker fat at both the C and GR locations (5.8 and 15.2 mm) than males (4.4 and 11.0 mm, respectively). *Callipyge* lambs had significantly less fat deposition at the C location (4.1 vs 6.1 mm), and at the GR location (11.0 vs 15. mm) than controls. These estimates represented 33% and 28% reduction in fat thickness in *callipyge* lambs, respectively.

Table 4. Means for color measurements on the loin-eye muscle at the 12th rib of *callipyge* and control lambs

Genotype	a*	b*	L*
Callipyge	4.51	8.62	33.38
Control	7.74	10.06	32.82

Three three color measurements Hunter, a*, b* and L* (CIE, 1976) measure respectively, the color between red (+) and green (-), yellow (+) and blue (-) and black (+) and white (-). Difference between *callipyge* and control lambs was significant ($p < 0.0001$) for color a* and b*

Table 5. For shear force (in Newton) of loin-eye muscle of *callipyge* and control lambs aged for 3, 9 or 15 days

	Day 3	Day 9	Day 15
Callipyge	113.2	97.8	98.8
Control	64.1	51.5	50.5

Differences between *callipyge* and control lambs were highly significant

Similar findings on meat-type genotypes were reported in American studies, backfat thickness over the 12th rib was 4.4 vs 7.1 mm , in *callipyge* vs control carcasses, a 38% reduction. Similarly, Snowder *et al.*, (1994) working with two breed combinations reported decreases in backfat depth of 47% and 33%. The relatively smaller decrease in backfat thickness observed in the present study compared to values in American studies is probably due to the breeds investigated, Romanov and its crosses are genotypes with low fat cover on the back. Also the lambs in the present study were slaughtered at a lighter average body weight than most other published studies.

Color of longissimus dorsi muscle at the12th rib. Carcass weight had no significant effect on the three color measurements studied. Presence of the *callipyge* phenotype affected the color measurement b*, sex affected the color measurement L*, whereas both sex and phenotype affected the color measurement a* significantly (Table 4). The muscle from *callipyge* lambs was generally lighter in color than controls, and resembled to a great extent the color of veal chops.

The present color results agree with Clare *et al.*, (1997) who found the muscle color of non-*callipyge* lambs to be of a "brighter cherry red" but contradicts Koohmaraie *et al.*, (1995) who reported that color score of lean from normal lambs was slightly paler than in *callipyge* lambs, finding that was later confirmed by Jackson *et al.*, (1997b) but the difference was not significant.

Intramuscular fat in longissimus dorsi muscle. *Callipyge* lambs had 5.0% intramuscular fat while controls had 12.0%. The effects of sex and breed type were nonsignificant.

Results from several American studies indicated that muscle from control lambs had higher fat proportions than that from *callipyge* lambs. Also it was found in two studies that marbling score was 41 and 31% higher for control lambs indicating higher fat content. The present findings are in agreement with these studies and may partially explain the relatively tougher loin-eye muscle of *callipyge* lambs. Fattening *callipyge* lambs to heavier weights in order to increase marbling and improve longissimus muscle tenderness has not been effective. Field *et al.*, (1997) compared loin-eye muscle fat content in heavy (46 kg) and normal (33 kg) carcasses of *callipyge* lambs with that in normal lambs. Fat proportion was similar in *callipyge* lamb carcasses weighing 33 and 46 kg and significantly lower than in 33 kg normal lamb carcasses.

Dry matter content of longissimus dorsi muscle. Sex and phenotype affected dry matter content of loin-eye muscle significantly. Dry matter content of muscles from males (24.4 %) and *callipyge* (24.7 %) lambs were lower than those from females (25.5 %) and controls (25.3 %). The difference between the two genetic types was negligible.

Effect of postmortem aging on cooking loss and longissimus muscle tenderness. Longissimus muscle of *callipyge* and control lambs aged for 3 and 9 days lost about a quarter of its weight during cooking, while those aged for 15 days lost slightly, though significantly, less (23% and 22%, respectively).

Table 5 shows that postmortem aging of the longissimus muscle for 9 days before freezing improved the tenderness (shear force) in both *callipyge* and control lambs, the improvement being greater in *callipyge* lambs. Aging the muscle for a longer period (15 days) did not change its tenderness in both *callipyge* and control lambs. Even with aging the muscle for a longer period, the muscle of *callipyge* lambs was still significantly less tender than in control lambs aged for only 3 days. These results agree with Duckett (1996) who reported that 70% of the increase in tenderness observed at day 24 was completed by day 6 in control lambs in contrast to only 40% in *callipyge* lambs. Busboom *et al.*, (1997) reported that aging the loin-eye muscle for 80 days decreased the shear force from 7.2 to 5.0 kg in *callipyge* and to a lesser extent in controls (3.8 to 3.2 kg).

What we concluded from the study is that even though the effects of the *callipyge* gene have recently been under intensive investigation at various institutions and with various breeds, the Romanov breed stands to gain the most from this mutant allele since it compensates for a marked conformation deficiency in Romanov carcasses and especially those from intact males. Previous studies have indicated heavier forequarter cuts from individuals with Romanov breeding compared to improved meat-type breeds. It is evident that presence of the *callipyge* allele increases leg weight, and such a fact makes Romanov carcasses of male lambs expressing the *callipyge* phenotype approach the composition of those from meat-type breeds not expressing the *callipyge* phenotype. The *callipyge* allele can also improve carcasses of other breeds with relatively poor carcass conformation and excessive fattness.

The carcasses of *callipyge* lambs had significantly less external, internal, and intramuscular fat than those of controls. Busboom *et al.*, (1994) indicated that *callipyge* lambs also had less monounsaturated and more polyunsaturated fatty acids than controls. With the consumers' increased nutritional consciousness and preference for lean meat with less fat, carcasses of *callipyge* lambs can be readily preferred.

The disadvantage of these carcasses, however, is the toughness of the longissimus dorsi muscle. Several studies have been conducted to find solutions to that. One such solution is to refrigerate the meat for a longer period before freezing or consumption. The effect of postmortem aging on loins of lambs from Romanov and Romanov-crossed ewes indicated that even though aging the longissimus muscle for 9 or 15 days caused a significant reduction in muscle toughness in *callipyge* lambs, the muscle in control lambs were still significantly more tender even at the shortest aging period. Means other than aging the muscle alone, or combination of procedures, may solve the problem of longissimus muscle toughness.

In economic terms, Busboom *et al.*, (1996) indicated that the overall advantage for *callipyge* boxed lamb cuts in USA was US$12 per lamb, $8 resulting from heavier carcasses ($114 vs 106) and $4 from better conformation (heavier more valuable leg and loin cuts). This is of considerable importance for producers and packers.

Since carcasses of lambs with Romanov ancestry showing the *callipyge* phenotype proved to be superior in conformation, composition, leanness and economic returns to those of normal lambs, use of rams with the *callipyge* mutant allele can be considered as an important tool to increase meat production output from prolific sheep flocks. A limiting disadvantage at the present time is the reported toughness of the longissimus muscle in *callipyge* lambs. Intensive research is being conducted to find a solution to that toughness problem. When this problem is solved the use of the *callipyge* phenotype can be expanded in order to produce better, healthier, and more acceptable carcasses.

References

Busboom, J.R., Hendrix, W.F., Gaskins, C.T., Cronrath, J.D., Jeremiah, L.E. and Gibson, L.L. 1994. Cutability, fatty acid profiles and palatability of *callipyge* and normal lambs. *Journal of Animal Science* 72 (Suppl. 1) :60 (Abstr).

Busboom, J. R., Snowder, G. D. and Cockett, N. E. 1996. Synopsis of the heavy muscled (*callipyge*) lamb symposium. Feb 15-16, 1996 Salt Lake City, Utah, pp 12, Mimeograph.

Busboom, J.R., Leckie, R.K., Silvestri, A.O., Rathje, N.M., Kuber, P.S., Meyer, H.H., Duckett, S.K. and Snowder, G.D. 1997. Effect of long term postmortem aging on tenderness of *callipyge* and normal lamb. *Journal of Animal Science* 75 (Suppl.1): 177 (Abstr.)

Clare, T.L., Jackson, S. P., Miller, M.F., Elliott C.T. and Ramsey, C. B. 1997. Improving tenderness of normal and *callipyge* lambs with calcium chloride. *Journal of Animal Science* 75:377-385.

Fernandez, J.M., King, K.S., White, T.W., Bidner, T.D., Franke, D.E., Hoover, D.T., Gentry, L.R, Higbie, A.D. and Lupton, C.J. 1996. Performance of F1 Rambouillet x Gulf Coast Native lambs with and without the *Callipyge* gene: feedlot phase. *J. Anim. Sci.* 74 (suppl. 1): 260. (Abstr.)

Field, R.A., Kucuk, O., Hinds, F.C., Riley, M. L., Russell, W.C. and Snowder, G.D. 1997. Carcass characteristics of extremely heavy lambs expressing the *callipyge* gene. *J. Anim. Sci.* 75 (suppl. 1) :112. (Abstr.)

Jackson, S.P., Green, R.D. and Miller, M.F. 1997a. Phenotypic characterization of Rambouillet sheep expressing the *callipyge* gene: I. Inheritance of the condition and production characteristics. *J. Anim. Sci.* 75: 14-18.

Jackson, S.P., Miller, M.F. and Green, R.D. 1997b. Phenotypic characterization of Rambouillet sheep expressing the *callipyge* gene: II Carcass characteristics and retail yield *J. Anim. Sci.* 75: 125-132

Koohmaraie, M., Shackelford, S.D., Wheeler, T.L., Lorengan, S.M. and Doumit, M.E. 1995. A muscle hypertrophy condition in lamb (*callipyge*): characterization of effects on muscle growth and meat quality traits. *J. Anim. Sci.* 73: 3596-3607.

Snowder, G.D., Busboom, J.R., Cockett, N.E., Hendrix, F. and Mendenhall, V.T. 1994. Effect of the *callipyge* gene on lamb growth and carcass characteristics. *Proc. 5th Wld Congr. Genetics Appl. Livest. Prod.* 18:51-54.