Effect of the Callipyge Phenotype and Cooking Method on Tenderness of Several Major Lamb Muscles[1]

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ABSTRACT: We conducted three experiments to determine the effects of the callipyge phenotype on the tenderness of several major lamb muscles and to determine the effect of method of cookery on the tenderness of callipyge lamb at 7 d postmortem. In Exp. 1, chops from normal (n = 23) and callipyge (n = 16) carcasses were open-hearth-broiled. Warner-Bratzler shear force values of longissimus, gluteus medius, semimembranosus, biceps femoris, semitendinosus, adductor, and quadriceps femoris were 123, 44, 28, 26, 19, 16, and 13% greater, respectively, for callipyge (P < .05). In Exp. 2, muscles from normal (n = 18) and callipyge (n = 18) carcasses were oven-roasted. Shear force of triceps brachii was 11% greater for callipyge (P < .001); however, phenotype did not affect shear force of supraspinatus (P = .87) or psoas major (P = .64). In Exp. 3, a trained sensory panel evaluated leg roasts and open-hearth-broiled leg chops from normal (n = 60) and callipyge lamb carcasses (n = 60). Callipyge chops were less tender than normal chops (P < .05). Regardless of callipyge phenotype, muscles were more (P < .05) tender when roasted; however, the effect of method of cookery on tenderness scores was greater for callipyge muscles than for normal muscles. Callipyge roasts and normal roasts had similar tenderness (P = .58), and callipyge roasts were more tender than normal chops (P < .05). Regardless of cooking method, callipyge samples were less juicy than normal samples (P < .05). These data demonstrate that the callipyge phenotype will likely reduce consumer satisfaction due to reduced tenderness and juiciness; however, reduced tenderness in callipyge leg muscles could be prevented by oven-roasting.

Key Words: Cookery, Lambs, Meat, Tenderness

J. Anim. Sci. 1997. 75:2100–2105

Introduction

The callipyge phenotype greatly improves lamb carcass composition (Koohmaraie et al., 1995) and thus could allow the lamb industry to more efficiently produce lean meat. Unfortunately, the callipyge phenotype greatly reduces longissimus tenderness (Koohmaraie et al., 1995, 1996). However, the effects of the callipyge phenotype on tenderness of other muscles of the carcass have not been fully investigated. Thus, the objective of these experiments was to determine the effects of the callipyge phenotype on the tenderness of several major lamb muscles and to determine the effect of method of cookery on the tenderness of callipyge lamb.

Materials and Methods

The Roman L. Hruska U.S. Meat Animal Research Center Animal Care and Use Committee approved the use of animals in this study.

Experiment 1

Animals. Dorset wether lambs (n = 39) were grain-fed and slaughtered at approximately 170 d of age. Carcasses were dressed conventionally (mean hot carcass weight = 28.7 kg) and chilled for 24 h at 1°C. On the basis of leg conformation scores, 16 of the carcasses were determined to have the callipyge phenotype. At 24 h postmortem, longissimus (**LD**), gluteus medius (**GM**), semimembranosus (**SM**), adductor (**AD**), semitendinosus (**ST**), biceps femoris (**BF**), and quadriceps femoris (**QF**) were acquired from each carcass. Although other muscles were

[1]Names are necessary to report factually on available data; however, the USDA neither guarantees nor warrants the standard of the product, and the use of the name by USDA implies no approval of the product to the exclusion of other products that may also be suitable. The authors are grateful to Kathy Mihm, Pat Tammen, and Patty Beska for their assistance in the execution of this experiment and to Marilyn Bierman for her secretarial assistance.

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Received November 12, 1996.

Accepted April 12, 1997.

considered for inclusion in this experiment, those muscles had to be excluded because chops from those muscles were too small to broil, core, and shear. All of the muscles included in this experiment are hypertrophied by the callipyge phenotype (Koohmaraie et al., 1995).

Warner-Bratzler Shear Force. Depending on muscle size, two or three chops (2.5 cm thick) were removed from each muscle, vacuum packaged, and aged until 7 d postmortem. After aging, chops were frozen and stored (−30°C) for up to 5 mo. Chops were thawed for 24 h at 4°C, broiled on Farberware (Kidde, Inc., Bronx, NY) open-hearth broilers to an internal temperature of 40°C, turned, and broiled to a final internal temperature of 75°C. Temperature endpoint was determined using copper/constantan wires placed in the geometric center of the chop (AMSA, 1995). Chops were cooled for 24 h at 4°C before removal of six cores (1.27-cm diameter) parallel to the longitudinal orientation of the muscle fibers. Each core was sheared once with a Warner-Bratzler shear force attachment using an Instron universal testing machine (Instron Corp., Canton, MA). The crosshead speed was 5 cm/min.

Statistical Analysis. For each muscle, one-way ANOVA was conducted to determine the effect of the callipyge phenotype on shear force, cooking loss, and cooking time (SAS, 1988).

Experiment 2

Animals. Crossbred (1/2 Dorset, 1/2 Romanov) wether and ewe lambs (n = 36) were grain-fed and slaughtered at approximately 250 d of age. Carcasses were dressed conventionally (mean hot carcass weight = 24.8 kg) and chilled for 24 h at 1°C. On the basis of leg conformation scores, 18 of the carcasses were determined to have the callipyge phenotype. At 24 h postmortem, supraspinatus (**SS**), triceps brachii (**TB**), and psoas major (**PM**) were acquired from normal (n = 18) and callipyge (n = 18) lamb carcasses. Because chops from these muscles were too small to broil, core, and shear, these muscles had to be excluded from Exp. 1. Supraspinatus is not hypertrophied by the callipyge phenotype; however, weights of TB and PM are approximately 20% greater for callipyge carcasses (Koohmaraie et al., 1995). The authors attempted to include infraspinatus (**IS**), a muscle that is not hypertrophied by the callipyge phenotype, in this experiment. However, IS was too thin to be cored for shear force.

Warner-Bratzler Shear Force. Muscles were aged (2°C) until 7 d postmortem, frozen, and stored (−30°C) for up to 5 mo. Whole muscles were thawed for 24 h at 4°C and oven-roasted at 93°C. A rather low oven temperature was used in this experiment to facilitate uniform cooking. As in Exp. 1, the final internal temperature was 75°C. Temperature endpoint was determined using copper/constantan wires placed in the geometric center of the muscle according to AMSA (1995). Muscles were cooled, cored, and sheared as above.

Statistical Analysis. For each muscle, ANOVA was conducted to determine the effect of the callipyge phenotype on shear force, cooking loss, and cooking time (SAS, 1988). Sex class, which was included in the model as a blocking variable, did not affect any of the traits.

Experiment 3

Animals. Crossbred (1/2 Dorset, 1/2 Romanov) wether and ewe lambs (n = 80) were grain-fed and slaughtered at approximately 250 d of age, and crossbred (3/8 Columbia, 1/4 Dorset, 3/16 Suffolk, 3/16 Hampshire) ewe lambs (n = 40) were grain-fed and slaughtered at approximately 180 d of age. Carcasses were dressed conventionally (mean hot carcass weight = 27.1 and 34.9 kg for 1/2 Dorset, 1/2 Romanov lambs and 3/8 Columbia, 1/4 Dorset, 3/16 Suffolk, 3/16 Hampshire lambs, respectively) and chilled for 24 h at 1°C. On the basis of leg conformation scores, one-half of the carcasses within each breed type-sex class subcell were determined to have the callipyge phenotype. At 24 h postmortem, the right leg was acquired from normal (n = 60) and callipyge (n = 60) lamb carcasses.

Trained Sensory Panel. No single leg muscle was big enough to yield the quantity of muscle cubes (AMSA, 1995) required for an eight-member sensory panel. Thus, SM and BF were pooled and treated as a single sample.

Short-cut, shank-off, semiboneless legs were vacuum packaged, aged (2°C) until 7 d postmortem, frozen, and stored (−30°C) for up to 7 mo. Legs were thawed for 72 h at 6°C. Thirty normal and 30 callipyge legs were oven-roasted on wire racks (fat side down) at 149°C to a final internal temperature of 75°C. The SM and BF were removed from the remaining legs, cut into chops (2.54 cm thick), and broiled as in Exp. 1. After cooking, chops and roasts were held in a warming oven at 75°C for up to 30 min before being sliced and served. Each panelist received three cubes (1.3 × 1.3 × 1.9 cm) from each sample representing a random mixture of SM and BF cubes. Sensory panelists rated cubes for tenderness, juiciness, and lamb flavor intensity on eight-point scales (1 = extremely tough, dry, and bland and 8 = extremely tender, juicy, and intense). The eight-member sensory panel was selected and trained according to the procedure of Cross et al. (1978). One sample from each treatment group (normal roast, normal chop, callipyge roast, and callipyge chop) was served per session and two sessions, were conducted per day.

Statistical Analysis. An ANOVA was conducted for a 2 (callipyge phenotype) × 2 (method of cookery)

completely randomized, factorially arranged experiment (SAS, 1988). Because breed and sex were confounded, breed and sex were simultaneously included in the model as a blocking variable by coding the following three classes: 1) 1/2 Dorset, 1/2 Romanov wethers, 2) 1/2 Dorset, 1/2 Romanov ewes and 3) 3/8 Columbia, 1/4 Dorset, 3/16 Suffolk, 3/16 Hampshire ewes. Means were separated using the PDIFF procedure (a pairwise *t*-test) of SAS (1988).

Results

Experiment 1. For all muscles investigated in this experiment, Warner-Bratzler shear force values were higher ($P < .05$) for callipyge carcasses (Table 1). However, the magnitude of the effect differed among muscles. Shear force of LD, GM, SM, BF, ST, AD, and QF were 123% (4.5 SD), 44% (2.5 SD), 28% (2.0 SD), 26% (1.5 SD), 19% (1.6 SD), 16% (.9 SD), and 13% (1.2 SD) greater, respectively, for callipyge carcasses. Although cooking time of BF, LD, SM and ST was greater for callipyge samples, cooking loss was not affected by phenotype.

Experiment 2. For oven-roasted TB, Warner-Bratzler shear force values were higher ($P < .05$) for callipyge carcasses (Table 1), but phenotype did not affect the shear force of oven-roasted SS ($P = .87$) or PM ($P = .64$). Cooking loss and cooking time were not affected by phenotype.

Experiment 3. Phenotype and method of cookery interacted to affect tenderness (Table 2). Regardless of callipyge phenotype, muscles were more ($P < .05$) tender when roasted; however, the effect of method of cookery on tenderness scores was greater for callipyge muscles than for normal muscles. Tenderness scores were lower for callipyge chops than normal chops ($P < .05$); however, phenotype did not affect tenderness scores of roasts ($P = .58$).

Regardless of method of cookery, normal samples were juicier than callipyge samples ($P < .05$). Method of cookery did not affect juiciness; however, roasts had a more intense lamb flavor than chops ($P < .05$). Lamb flavor intensity scores were not affected by phenotype ($P = .72$). Regardless of cooking method, cooking time was greater for callipyge samples ($P < .05$). Additionally, cooking loss was greater for callipyge roasts than normal roasts ($P < .05$).

Discussion

Previously, we reported that the callipyge phenotype causes extreme longissimus toughness due to a reduced rate and extent of postmortem proteolysis caused by an elevation of calpastatin activity (Koohmaraie et al., 1995, 1996). Moreover, we determined that the callipyge phenotype differentially affects hypertrophy of various muscles, and we showed that the differential effects of the callipyge phenotype on hypertrophy of various muscles are related ($r = .96$) to differential effects of the callipyge phenotype on calpastatin activity of various muscles (Koohmaraie et al., 1995). Thus, it was logical that the callipyge phenotype would affect the tenderness of some muscles to a greater extent than others. Therefore, the present experiments were conducted to determine the effects of the callipyge phenotype on the tenderness of several major lamb muscles and to determine the effect of method of cookery on the tenderness of callipyge lamb.

For all muscles investigated except SS and PM, Warner-Bratzler shear force values were higher for callipyge carcasses. The callipyge phenotype had a greater effect on shear force of LD than any other muscle. Considering that the callipyge phenotype increased calpastatin activity of BF and SM to a greater extent than LD (Koohmaraie et al., 1995), it is not clear why the callipyge phenotype had a greater effect on shear force of LD than BF or SM. However, this result is consistent with our (Shackelford et al., 1995) finding that *Bos indicus* affected tenderness of LD to a greater extent than any other major beef muscle. We have ascribed the decreased tenderness in *Bos indicus* cattle (Whipple et al., 1990; Shackelford et al., 1991) and callipyge lambs (Koohmaraie et al., 1995) to decreased postmortem proteolysis caused by increased calpastatin activity. That the effect of the callipyge phenotype and *Bos indicus* inheritance on shear force is greater for longissimus than hind limb muscles suggests that the effect of postmortem proteolysis on tenderness is diminished in muscles with a high connective tissue content.

The increased calpastatin activity of callipyge lamb is apparently caused by a different mechanism than the increased calpastatin activity of *Bos indicus* cattle. Whereas calpastatin activity is elevated in at-death muscle from callipyge lamb as compared with muscle from normal lamb, calpastatin activity does not differ in at-death muscle from *Bos indicus* and *Bos taurus* cattle. During the first 24 h postmortem, longissimus calpastatin is degraded more slowly for *Bos indicus* than for *Bos taurus*. Consequently, postrigor *Bos indicus* muscle has higher calpastatin activity than postrigor *Bos taurus* muscle. This apparent difference in mechanism of increased calpastatin activity may explain the peculiar result that *Bos indicus* inheritance increased SS shear force (Shackelford et al., 1995), whereas the callipyge phenotype did not affect SS shear force. Neither *Bos indicus* inheritance nor the callipyge phenotype affected shear force of PM. Wheeler and Koohmaraie (1996) studied the interaction of proteolysis and sarcomere length on tenderness

Table 1. Effect of phenotype on shear force, cooking loss, and cooking time of lamb

Muscle	Normal	Callipyge	SEM	Change, %	*P*-value
	Shear force, kg[c]				
Exp. 1[a]	(n = 23)	(n = 16)			
Longissimus	4.5[d]	10.1	.28	123.4	.001
Gluteus medius	3.3	4.8	.13	44.3	.001
Semimembranosus	4.7	6.1	.15	28.1	.001
Biceps femoris	4.2	5.3	.16	26.4	.001
Semitendinosus	3.5	4.2	.10	18.7	.001
Adductor	6.7	7.8	.29	15.8	.013
Quadriceps femoris	3.6	4.0	.09	12.7	.001
Exp. 2[b]	(n = 18)	(n = 18)			
Triceps brachii	2.9	3.3	.06	11.4	.001
Supraspinatus	3.3	3.3	.09	–.6	.88
Psoas major	3.0	3.0	.11	–2.5	.64
	Cooking loss, %				
Exp. 1[a]	(n = 23)	(n = 16)			
Longissimus	29.8	31.2	.6	4.7	.11
Gluteus medius	34.4	34.3	.7	–.3	.96
Semimembranosus	36.3	38.0	.9	4.7	.20
Biceps femoris	33.1	33.1	.9	.0	.97
Semitendinosus	34.3	35.6	.6	3.8	.10
Adductor	35.6	34.9	.7	–2.0	.54
Quadriceps femoris	36.2	37.0	1.1	2.2	.57
Exp. 2[b]	(n = 18)	(n = 18)			
Triceps brachii	21.4	22.7	1.0	5.8	.37
Supraspinatus	29.8	30.2	1.0	1.3	.73
Psoas major	24.4	24.8	1.2	1.7	.81
	Cooking time, min				
Exp. 1[a]	(n = 23)	(n = 16)			
Longissimus	22.1	28.1	1.2	27.1	.001
Gluteus medius	29.0	30.2	.9	4.1	.37
Semimembranosus	29.4	33.7	1.3	14.6	.03
Biceps femoris	26.7	31.2	1.1	16.9	.009
Semitendinosus	24.4	27.3	.7	11.9	.004
Adductor	28.3	30.9	1.2	9.2	.14
Quadriceps femoris	41.4	44.0	1.8	6.3	.32
Exp. 2[b]	(n = 18)	(n = 18)			
Triceps brachii	77.0	83.6	3.6	8.6	.21
Supraspinatus	86.1	88.5	3.8	2.8	.66
Psoas major	54.7	59.3	5.7	8.4	.58

[a]2.54-cm-thick chops were open-hearth-broiled.
[b]Individual muscles were oven-roasted.
[c]1.27-cm diameter core.
[d]The reader is cautioned to avoid using Warner-Bratzler shear force values to compare tenderness differences among muscles because Shackelford et al. (1995) reported that Warner-Bratzler shear force does not accurately detect tenderness differences among muscles. Warner-Bratzler shear force values should only be used to compare tenderness differences within a given muscle.

using lamb LD and PM. They concluded that proteolysis had little effect on the tenderness of normal PM because it was already tender due to long sarcomeres. However, if PM was excised from the prerigor carcass and allowed to shorten, proteolysis had a large effect on PM tenderness.

Field et al. (1996) reported that longissimus collagen concentration tended to be reduced ($P < .09$; 12.5%) and longissimus hydroxylysylpyridinoline concentration was reduced ($P < .04$; 28%) by the callipyge condition. It is possible that the positive effect of callipyge on the connective tissue component of tenderness is great enough in high connective tissue muscles to partially negate the negative effect of reduced proteolysis.

Each of the muscles that was toughened by the callipyge phenotype has been reported to be hypertrophied by the callipyge phenotype (Koohmaraie et al., 1995). Of the two muscles (SS and PM) that were not toughened by the callipyge phenotype, Koohmaraie et al. (1995) reported that SS was not hypertrophied by the callipyge phenotype and that the level of callipyge-induced hypertrophy was small for PM relative to other muscles. Moreover, calpastatin activities of SS and PM were not affected by callipyge phenotype (Koohmaraie et al., 1995).

Table 2. Interaction of phenotype and method of cookery on trained sensory panel ratings of lamb leg muscles (Exp. 3)

	Chop		Roast		
Trait[a]	Callipyge (n = 30)	Normal (n = 30)	Callipyge (n = 30)	Normal (n = 30)	SEM
Tenderness	5.7^{y}	6.6^{x}	7.1^{w}	7.0^{w}	.2
Juiciness	4.5^{x}	5.1^{w}	4.4^{x}	5.2^{w}	.1
Lamb flavor intensity	4.8^{x}	4.7^{x}	5.0^{w}	5.1^{w}	.1
Cooking loss, %	35.0^{w}	34.0^{w}	30.7^{x}	28.7^{y}	.9
Cooking time, min	33.2^{y}	26.4^{z}	172.1^{w}	151.1^{x}	3.2

[a]Sensory panelists rated samples for juiciness, tenderness, and lamb flavor intensity on eight-point scales (1 = extremely dry, tough, and bland, and 8 = extremely juicy, tender, and intense).
[wxyz]Means within a row that do not share a common superscript differ ($P < .05$).

In agreement with shear force comparisons in Exp. 1, the trained sensory panel indicated that callipyge leg (BF and SM) chops were tougher than normal leg chops. Roasting dramatically increased tenderness scores of callipyge muscles such that callipyge roasts and normal roasts had similar tenderness scores, and callipyge roasts had higher tenderness scores than normal chops. However, callipyge muscles were less juicy than normal muscles, regardless of cooking method. Thus, even if roasting or another tenderizing treatment were used to overcome the tenderness concerns with callipyge, palatability problems may still exist.

It is not clear how roasting tenderized callipyge muscles. It is possible that roasting improved callipyge tenderness by directly affecting the proteolytic component of tenderness responsible for decreased tenderness of callipyge. However, roasting may have improved the background component of tenderness and thus minimized the importance of proteolysis to meat tenderness.

Roasts and chops were cooked with dry heat to the same internal endpoint temperature (75°C). Although the method of dry heat differed between roasts (convection) and chops (radiant), the biggest difference between cooking methods was cooking time. Thus, it seems that tenderness was affected by the time-temperature relationship. It is generally believed that heat-induced changes that result in coagulation and hardening of myofibrillar protein reduce tenderness and that heat-induced changes that result in greater solubilization of connective tissue increase tenderness (Forrest et al., 1975). Cheng and Parrish (1976) demonstrated that degradation of collagen fibers in the perimysium of broiled beef longissimus steaks was initiated at 70°C and that intense disintegration was observed at 80°C. It is likely that some level of degradation of perimysial collagen fibers occurred in chops and roasts in this study, because we cooked our samples to 75°C; however, the level of degradation was likely greater in roasts due to greater cooking time. It is not known what effect the time-temperature relationship may have had on the myofibrillar component of tenderness. Further investigation of this subject is warranted.

In conclusion, the callipyge phenotype decreased tenderness of most lamb muscles. Moreover, the callipyge phenotype decreased juiciness of broiled leg chops and oven-roasted leg roasts. However, callipyge leg roasts and normal leg roasts received similar tenderness ratings.

Implications

These data demonstrate that callipyge lamb will likely reduce consumer satisfaction due to reduced tenderness and juiciness. However, under certain cooking conditions, callipyge leg muscles can be very tender.

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