The Callipyge Phenomenon: Tenderness Intervention Methods[1]

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ABSTRACT: Consumers continue to desire leaner meats. Lambs expressing the *callipyge* gene have been identified as having superior, leaner carcasses compared with normally muscled lambs. However, the longissimus muscle, a major merchandised muscle in lamb, has repeatedly been shown to be significantly less tender in callipyge lamb compared with normally muscled lambs. Preharvest factors, such as genetics, sex, and production/management practices, have thus far shown no promise at alleviating this tenderness problem. But a number of postharvest interventions have been introduced to alleviate it. Included among the strategies are postmortem aging, carcass electrical stimulation, the combination of freezing and thawing before aging, calcium chloride injection, and the Hydrodyne process. These strategies have exhibited various degrees of success. Postharvest strategies to improve callipyge longissimus tenderness are described in this article.

Key Words: Callipyge, Lamb (meat), Tenderness

Introduction

The increasing demand for leaner meats has resulted in a need for an effective method of tenderizing these meat products. Meat from leaner carcasses has often been shown to be tough, usually as a result of muscle “cold shortening” (Locker, 1985). The *callipyge* gene in lambs has been associated with muscle hypertrophy (Koohmaraie et al., 1995; Cockett et al., 1996), thus increasing the percentage of edible lean tissue protein in a carcass. One muscle in particular, the longissimus muscle (**LM**), from callipyge lambs has been found to have a significant tenderness problem compared with normal animals (Field et al., 1996; Shackelford et al., 1997). Koohmaraie et al. (1995) suggested that both reduced rate of protein degradation and a higher capacity for protein synthesis are consequences of the callipyge condition, which in turn are associated with lower meat tenderness resulting from reduced rate and extent of postmortem meat proteolysis. However, this does not explain why the LM, which exhibits this hypertrophic condition, has a tenderness problem and other muscles (e.g., leg muscles), which also exhibit this hypertrophic condition, do not.

A variety of studies have been conducted on techniques for improving meat tenderness, many of which have been designed for improving the tenderness of beef but could or have been adapted to other species. The postmortem interventions studied include carcass electrical stimulation, high-temperature conditioning, alternative carcass suspension, wet or dry aging, blade/needle tenderization, marination in salt/acid solutions, tropical plant enzyme applications, infusion with calcium chloride, pressure treatments (hydrodynamic and hydrostatic), and freezing/thawing with an aging period. A number of these techniques require additional carcass or meat holding periods and space. Furthermore, some of these methods have been criticized for their lack of consistency in improving meat tenderness.

This paper will discuss the results of studies that evaluated various postmortem intervention methods in an attempt to eliminate the tenderness problem in callipyge lamb LM.

Results of Various Intervention Technologies

Carpenter et al. (1997), Solomon et al. (1995), and Solomon et al. (1998) using muscle samples from the same carcasses evaluated the effects of four tenderness improvement methods on normal and callipyge lamb. Treatments included 1) carcass electrical stimu-

[1]Mention of specific equipment does not imply endorsement by the USDA.

Table 1. Shear force (kg) by tenderization treatment (electrical stimulation [ES] with 1 h carcass conditioning, aging, Hydrodyne, calcium chloride [$CaCl_2$]) for normal and callipyge longissimus muscle

	Normal				Callipyge			
Longissimus	No ES	(SD)	ES	(SD)	No ES	(SD)	ES	(SD)
n =	8		8		8		8	
Aged 1 d	5.7^{aw}	(1.0)	6.0^{aw}	(.9)	6.4^{ax}	(1.7)	6.0^{ax}	(1.4)
Aged 8 d	3.3^{bxy}	(.8)	4.4^{ax}	(.9)	5.1^{ay}	(1.4)	4.7^{ay}	(.9)
Aged 15 d	2.6^{cyz}	(.5)	3.8^{bcxy}	(1.0)	5.3^{ay}	(1.2)	4.8^{ay}	(1.2)
Aged 22 d	1.9^{bz}	(.5)	3.4^{axy}	(.5)	3.8^{az}	(1.1)	4.1^{ay}	(1.0)
Hydrodyne 1 d	1.9^{cz}	(.4)	2.7^{bcy}	(.4)	4.3^{ayz}	(1.0)	3.1^{bz}	(.6)
$CaCl_2$ 1 d	4.2^{cx}	(.4)	4.5^{cx}	(1.2)	7.6^{aw}	(1.4)	6.1^{bx}	(1.1)
$CaCl_2$ 8 d	2.6^{byz}	(.5)	3.2^{by}	(.9)	4.8^{ay}	(1.1)	4.3^{ay}	(1.0)
$CaCl_2$ 15 d	2.0^{cz}	(.6)	3.5^{abxy}	(.9)	4.4^{ayz}	(1.2)	3.2^{bz}	(.7)
$CaCl_2$ 22 d	2.3^{byz}	(.4)	2.9^{aby}	(.5)	3.8^{az}	(1.1)	3.0^{abz}	(.6)

[a,b,c]Within each row means with different superscripts differ ($P < .05$).
[w,x,y,z]Within each column means with different superscripts differ ($P < .05$).

lation (21 V; .25 ampere) with temperature conditioning (approximately 1 h postmortem), 2) calcium chloride ($CaCl_2$) injection (.3% injected to 10% fresh muscle wt at 24 h postmortem), 3) aging (1, 8, 15, or 22 d postmortem), and 4) Hydrodyne treatment performed on 1 d postmortem samples (100 g of explosive suspended at 41 cm from bottom of 208-L plastic containers fitted with a 2-cm-thick steel reflecting plate; yielding ~520,868 g/cm^2 pressure front) either in combination or alone on the tenderness of callipyge (n = 16) and normal (n = 16) lamb. They concluded that tenderness of callipyge LM can be improved with some of these postmortem intervention techniques (Table 1). However, even with these treatments, callipyge LM was still less tender than tenderized normal lamb LM. Carpenter et al. (1997) pointed out that the calcium chloride treatment used was only one-third of that used in most studies involving callipyge lamb (.3% compared with 2%). However, in the Carpenter et al. (1997) study, the .3% $CaCl_2$ solution was injected to 10% of the muscle fresh weight compared with 2% solutions injected to 5% muscle weight in most of the other studies.

The Hydrodyne process (Solomon et al., 1997) uses a small amount of high-energy explosive to generate a supersonic-hydrodynamic shock wave in liquid media (water). The shock wave passes through objects in the water that are an acoustical (mechanical impedance) match with the water. This shock wave lasts for a fraction of a second. Packaged meat samples are placed on a 2-cm-thick steel plate that is placed on the bottom of the container. The explosive is immersed in the water to a precise distance away from the bottom of the container. In the studies presented in their article a binary explosive consisting of two parts (ammonium nitrate and nitromethane) was used. In the study described above (Solomon et al., 1995; Solomon et al., 1998), the Hydrodyne process was effective at tenderizing the LM from callipyge, as well as normal lamb, and the tenderization effect was further enhanced in callipyge LM if it was used in conjunction with carcass electrical stimulation. Electrical stimulation in combination with aging, $CaCl_2$, or Hydrodyne treatment enhanced the tenderness improvement in callipyge LM. The combination of these treatments resulted in LM being closer to control aged normal LM shear force.

The tenderness of the semitendinosus (**ST**) muscles from these same lambs (Solomon et al., 1998) was also examined at 8 d postmortem with mean shear force of 3.6 kg. Callipyge ST control was 1 kg higher (4.1 vs 3.1 kg; n = 32) than normal ST control (Table 2). The only postmortem treatments that were used on ST muscle samples were carcass electrical stimulation and the Hydrodyne process. Both treatments reduced shear force values for callipyge ST and brought the callipyge ST shear values (3.3 kg) closer to the normal ST shear values (3.1 kg). In the instances when shear force was less than or equal to 3.6 kg, the Hydrodyne process had little additional improvement in reducing shear values.

In three separate studies, the Hydrodyne process was examined for its ability to alleviate the toughness problem in callipyge LM, and no other postmortem intervention was used. The first of these studies (not in tabular form) was performed in small plastic containers fitted with a 2-cm-thick steel reflecting plate (208 L; 150 g of explosive suspended 41 cm from

Table 2. Shear force (kg) by postmortem tenderization treatments (electrical stimulation [ES]; Hydrodyne) for normal and callipyge semitendinosus muscle

	Normal		Callipyge		
Semitendinosus	No ES	ES	No ES	ES	SEM
n =	8	8	8	8	
Control	3.1[b]	3.6[ab]	4.1[a]	3.4[ab]	.4
Hydrodyne	3.1	3.4	3.7	3.2	.3

[a,b]Means within each row with different superscripts differ ($P < .05$).

the bottom of the container; n = 18). The Hydrodyne treatment resulted in a 37% reduction in shear values (5.0 vs 3.2 kg) of callipyge LM that was frozen at 48 h postmortem and thawed before performing the Hydrodyne treatment. Shear values of 3.2 kg compare favorably to the 8- and 15-d aged normal LM shear values (Table 1) described in the Carpenter et al. (1997) and Solomon et al. (1995) studies. The second and third studies were performed in a large (1,060 L) steel commercial prototype vessel. In the second study (not in tabular form), LM (n = 6) frozen at 48 h postmortem and thawed before Hydrodyne treatment, was exposed to 350 g of explosive suspended 61 cm from the bottom of the tank. Initial shear values for callipyge LM were 4.8 kg and treatment with the Hydrodyne process resulted in a 25% reduction (3.6 kg).

In the third study (Table 3), 7- and 14-day aged callipyge LM samples (n = 20) were compared to 7-d callipyge LM treated with the Hydrodyne process. Two different Hydrodyne treatments were employed. One treatment consisted of 350 g of explosive suspended at 61 cm from the bottom of the tank, and the second treatment consisted of 350 g of explosive suspended at 46 cm from the bottom of the tank. Moving the explosive charge closer to the bottom of the tank theoretically increases the pressure front of the shock wave (Solomon, 1998). A charge of 350 g at 61 cm is calculated to generate 527,907 g/cm^2, whereas 350 g at 46 cm would generate 732,031 g/cm^2. The higher the pressure, the greater the magnitude of shear force reduction (Solomon, 1998). Results suggested that both the 7- and 14-d aged samples were tough, and aging resulted in little improvement in tenderness; however, both Hydrodyne treatments yielded tender callipyge LM. Additional improvement was observed by moving the explosive charge closer to the meat and thus, theoretically, increasing the pressure front of the charge. The Hydrodyne treatment performed at 46 cm resulted in shear values of 2.2 kg, which would be considered comparable to the shear values of the optimally tenderized normal LM samples (Table 1) in the Carpenter et al. (1997) and Solomon et al. (1995) studies.

Table 3. Shear force by postmortem tenderization treatments (aging, Hydrodyne) for callipyge longissimus muscle

Treatment	n =	Shear force, kg
Callipyge aged 7 d	10	7.21[c]
Callipyge aged 14 d	10	6.39[c]
Callipyge Hydrodyne #1[a]	10	3.77[d]
Callipyge Hydrodyne #2[b]	10	2.22[e]
SEM		0.2

[a]Hydrodyne #1 = 350 g at 61 cm from bottom, 527,907 g/cm^2.
[b]Hydrodyne #2 = 350 g at 46 cm from bottom, 732,031 g/cm^2.
[c,d,e]Within column, means with different superscripts differ ($P < .05$).

A comprehensive, multi-institutional study (Leckie et al., 1997) was designed to evaluate the effects of breed, sex, muscle phenotype (callipyge) on growth, cutability, lipid, and palatability on the efficacy of various postmortem treatments to improve the palatability of callipyge lamb. Postmortem tenderization treatments included: aging, $CaCl_2$ injection followed by aging, freezing followed by thawing with aging and the Hydrodyne process. The aging treatment consisted of storing vacuum-packaged samples at 4°C for either 7, 14, or 28 d postmortem. Calcium chloride injection (2% solution at 5% muscle wt) was followed by aging for 7, 14, or 28 d. The freezing strategy consisted of freezing samples within 60 h postmortem at –40°C for a 4-d period, after which frozen samples were thawed for 24 h at 2°C and then aged for either 7, 14, or 28 d from the time they were removed from the freezer. Hydrodyne treatment was performed on 14-d aged samples that were frozen on the 14th-d postmortem and thawed before performing the Hydrodyne treatment, after which samples were frozen until subse-

Table 4. Postmortem tenderization treatments on shear force (kg) from callipyge and normal longissimus muscle

		Aged			
Item	n	7 d	14 d	28 d	SEM
Normal	144	3.65^{z}	3.33^{z}	3.05^{z}	.1
Callipyge	221	7.60^{aw}	6.98^{ax}	5.50^{bx}	.1
Callipyge + freeze/thaw	215	6.19^{ax}	5.32^{ay}	4.39^{by}	.1
Callipyge + Hydrodyne	72		3.42^{z}		.2
Callipyge + $CaCl_2$	216	4.58^{ay}	3.51^{bz}	3.07^{bz}	.1

[a,b]Within each row, means with different superscripts differ (P <.05).
[w,x,y,z]Within each column, means with different superscripts differ (P < .05).

quent analyses were performed. Hydrodyne treatment consisted of 350 g of explosive suspended 46 cm from the bottom of the tank using the 1,060-L steel tank. Aging LM for as much as 28 d postmortem improved shear force values but did not improve shear force to the same level as for the LM from normal lamb (Table 4). Both the Hydrodyne and $CaCl_2$ injection treatments improved shear force values to make them similar to those of normal LM lamb aged for either 7, 14, or 28 d. Freeze/thaw treatment improved callipyge LM shear force but not of the magnitude achieved by the Hydrodyne or $CaCl_2$ treatments. The latter treatment achieved reduction of shear values to values exhibited by normal LM.

Carpenter et al. (1998) reported that increased shear values of callipyge LM chops were related to cooking effects (i.e., final internal temperature). Callipyge and normal LM chops cooked to 45 and 50°C had similar shear values. However, for chops cooked to 55°C and higher (80°C) callipyge chops had higher (P < .01) shear values than did normal chops. In contrast, there was no difference in shear values between biceps femoris (leg) chops from callipyge and normal lamb cooked to 70°C internal temperature. They suggested that the basal cause of toughness in LM muscle from callipyge lambs as compared with normal lambs is due, at least in part, to the toughening effect of longer cooking times on the myofibrillar proteins.

Koohmaraie et al. (1998) introduced a rapid prerigor freezing and postrigor calcium chloride injection approach for mitigating the callipyge tenderness problem. At approximately 17 min postmortem, carcasses were submersed in liquid nitrogen for 15 min and then held at –2°C for 4 d. For comparison purposes, additional carcass were chilled conventionally for 24 h at –2°C. At 1 d postmortem for carcasses chilled conventionally and at 4 d postmortem for carcasses frozen in liquid nitrogen, the LM muscles were removed. The LM from one side of each carcass were vacuum-packaged and aged (1°C) conventionally for 7 or 14 d. Remaining LM muscles from opposite carcass sides were injected with a 2.22% solution of $CaCl_2$ to 5% weight, vacuum-packaged, and aged for 7 or 14 d. Shear force values of callipyge LM were significantly higher than those from normal LM after 7 and 14 d postmortem without any additional postmortem intervention treatments. Both liquid nitrogen freezing and $CaCl_2$ injection treatments improved shear values of callipyge LM after 14 d postmortem storage. The most effective treatment for improving callipyge LM was the combination of these two treatments with 14 d postmortem storage, which resulted in tenderness similar to that of normal, untreated LM after 14 d of postmortem storage.

Duckett et al. (1998) evaluated LM from callipyge and normal lambs that were either vacuum-packaged at 24 h and aged fresh for up to 24 d postmortem (2°C) or frozen (–20°C) for 6 wk, after which frozen LM were thawed at 2°C for 18 h and aged (2°C) for up to 24 d. Postmortem aging reduced shear values of both normal and callipyge lambs; however, this reduction proceeded at a slower rate and for a longer duration (24 vs 6 d) in the callipyge LM compared with normal LM. Freezing before aging accelerated the rate of postmortem tenderization in callipyge LM, whereas no changes were observed for normal LM.

Implications

Preharvest factors, such as genetics, sex, and production/management practices have shown very little promise for eliminating the tenderness problem associated with the longissimus muscle from callipyge lamb. Several postharvest intervention strategies that have been introduced to alleviate this tenderness problem have been shown to be quite successful.

Either the Hydrodyne treatment or $CaCl_2$ injection in conjunction with an aging period seems to be a viable method for improving the tenderness of the callipyge loin. The recently introduced freezing/thawing/aging approach may also be a promising alternative for improving the tenderness of the callipyge loin.

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