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Application of tension to prerigor goat carcasses to improve cooked meat tenderness

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ABSTRACT

In two separate experiments, carcasses of intact Kiko × Boer male kids were assigned randomly to tension treatments applied 30 min postmortem: 1) suspended by the Achilles tendon (AT); 2) suspended from the pelvic bone with front and hind legs tied together (TS); or 3) suspended by the Achilles tendon, and the fore- and hindsaddle were separated at the 12th/13th thoracic intervertebral disk, external fat, accessory muscles and epimysium surrounding the *longissimus* muscle (LM) were cut (TC), and a 2.3-kg weight attached to the neck (TC + W). Warner-Bratzler shear force values for the LM were reduced ($P < 0.05$) 24.4 to 35.9 N in TS carcasses compared to AT carcasses, and WBSF values of SM from TS carcasses were 25.0 and 20.3 N less ($P < 0.05$) than those for AT and TC + W carcasses, respectively. Results indicated that cooked goat meat tenderness, particularly the LM and SM, may be improved greatly by suspending goat carcasses by the pelvic bone.

1. Introduction

Goats serve as a staple source of red meat to a considerable proportion of the world population (Webb, 2014). Moreover, consumer demand for goat meat has increased in the United States over the past 20 years (Ibrahim, 2011), largely due to increased ethnic diversity in metropolitan areas (Sande, Houston, & Epperson, 2005) and consumer leanings toward "natural" foods, like goat meat (Dubeuf, Morand-Fehr, & Rubino, 2004). McMillin and Brock (2005) indicated that goats weighing > 36 kg (e.g., chevon) are usually less valuable than lighter-weight kid goats (e.g., capretto) because of greater carcass fatness and reductions in palatability attributes, particularly cooked goat tenderness (Smith, Carpenter, & Shelton, 1978) and flavor (Dhanda, Taylor, & Murray, 2003).

Carcasses of goats slaughtered in the United States are typically light-weight, with very little subcutaneous fat, and muscles from these carcasses are susceptible to cold-shortening, and subsequent toughening, when exposed to typical chilling temperatures between 1 and 4 °C (Kannan, Lee, & Kouakou, 2014). Electrical stimulation accelerates postmortem metabolism, thereby reducing cold-shortening and improving tenderness of goat meat (McKeith, Savell, Smith, Dutson, & Shelton, 1979; Savell, Smith, Dutson, Carpenter, & Suter, 1977). Research indicated that high-voltage, electrical stimulation could reduce shear force values of goat *m. longissimus thoracis et lumborum* (LM) between 30 and 50% (Gadiyaram et al., 2008) and increase sensory tenderness scores of goat LM between 22 and 68% (Biswas, Das, Banerjee, & Sharma, 2007); yet, the vast majority of very small plants that slaughter meat goats in the United States are not equipped to employ electrical stimulation to goat carcasses prior to chilling.

Buege and Stouffer (1974) demonstrated that adding weight (4.5 to 13.5 kg) to the neck of lamb carcasses prior to chilling increased sarcomere length and decreased shear force values of *longissimus* muscle (LM) chops from the rack and loin. The tension generated by the weight of the forequarter on the LM after severing the bones, minor muscles and connective tissues surrounding the LM (Tendercut) also causes increased sarcomere lengths and improved beef tenderness (Beaty, Apple, Rakes, & Kreider, 1999; Claus, Wang, & Marriott, 1997; Ludwig, Claus, Marriott, Johnson, & Wang, 1997). In addition, suspending carcasses from the pelvis (Tenderstretch) is an easy way to increase tension on sarcomeres of the LM during chilling, resulting in improvements in cooked meat tenderness when applied to beef (Hostetler, Landmann, Link, & Fitzhugh Jr, 1970; Park et al., 2008), venison (Hutchison,

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Mulley, Wiklund, Flesch, & Sims, 2014), alpaca (Biffin, Smith, Bush, Collins, & Hopkins, 2018), and lamb carcasses (Quarrier, Carpenter, & Smith, 1972). These prerigor tension-generating treatments could be quickly and easily applied to goat carcasses, especially in very small abattoirs; therefore, the objective of this study was to determine if Tenderstretch, Tendercut, and Tendercut with added weight could improve cooked goat tenderness.

2. Materials and methods

Goat kids for these experiments were reared at the Lincoln University George Washington Carver Farm and the Alan T. Busby Farm, both located in Jefferson City, MO (USA), and all goat husbandry practices were in accordance to the Guide for the Care and Use of Agricultural Animals in Research and Teaching (FASS, 2010).

2.1. Slaughter and carcass treatment application

In two experiments, intact Kiko × Boer kids (n = 28 and 30 in Exp. 1 and 2, respectively), with an average live weight of 27 ± 2.4 and 25 ± 1.3 kg, respectively, were transported approximately 450 km (4.5 h) from Lincoln University (Jefferson City, MO, USA) to the University of Arkansas Red Meat Abattoir (Fayetteville, AR, USA). After overnight lairage with ad libitum access to water, goats were rendered unconscious via captive-bolt stunning, exsanguinated, hung by both hind legs, skinned, eviscerated, washed, and sanitized with a 2.0% lactic acid rinse before treatments were applied randomly to goat carcasses at approximately 30 min postmortem. In both experiments, control (AT) carcasses (n = 10/experiment) were suspended conventionally by the Achilles tendon, whereas Tenderstretch (**TS**) carcasses (n = 9 and 10 in Exp. 1 and 2, respectively) were suspended from the pelvic bone (*pubic symphysis*) and both front and hind legs were tensioned together (parallel to each other) with butcher's twine immediately before chilling. Additionally, in both experiments, Tendercut (**TC**) carcasses were suspended conventionally from the Achilles tendon, and a cut at the intervertebral disk between the 12th and 13th thoracic vertebrae was made and the *multifidus dorsi*, *intercostal* muscles, overlying subcutaneous fat, and epimysium were cut (care was taken not to cut into the muscle fibers), leaving the *M. longissimus thoracis et lumborum* (**LM**) being the primary attachment between the hind- and foresaddles (the cut extended approximately 20 cm from the lateral side of the LM). In Exp. 1, no weight was added to the TC (n = 9); however, in Exp. 2, a 2.3-kg weight was attached to the neck of each TC carcass with a stainless steel S-hook (**TC + W**; n = 10). Following a 48-h chilling period at 1 °C, the LM was excised from right-side loins and racks (Exp. 1 and 2) and two 2.54-cm-thick center-cut steaks were cut from right-side legs (Exp. 2), individually identified, vacuum-packaged, aged at 2 °C for seven days, and subsequently frozen at −20 °C before measurement of sarcomere length, myofibril fragmentation index, cooking loss percentage, and Warner-Bratzler shear force (**WBSF**) at a later date.

2.2. Sarcomere length determination

Sarcomere lengths were measured on thawed (24 h at 2 °C) LM (Exp. 1 and 2) and *semimembranosus* (**SM**; Exp. 2) samples by the laser diffraction method of Cross, West, and Dutson (1980–1981) using a helium-neon laser (model OEM1P, Aerotech Electronics, Pittsburgh, PA, USA). Briefly, three 1.27-cm-diameter cores were removed manually from 2.54-cm-thick slices of LM or *m. semimembranosus* (SM) from each carcass, and four to five individual fibers were teased from each core and placed on a microscope slide. Then, the slide was placed in the path of the laser beam to give an array of diffraction bands on the flat surface 10 cm below the slide. Six sarcomeres were measured from each fiber, and sarcomere lengths were calculated according to the formula of Cross et al. (1980–1981).

2.3. Myofibrillar fragmentation index (MFI)

In both experiments, LM samples were thawed overnight at 2 °C for MFI determination in accordance with the procedure of Olson, Parrish, and Stromer (1976), as modified by Culler, Parrish Jr., Smith, and Cross (1978). Briefly, two 1.27-cm-diameter cores were removed perpendicular to the cut surface of two 2.45-cm-thick LM sections, and each core was scissor-minced, with care taken to remove any readily apparent connective tissue or fat. Then, 4 g of minced LM was homogenized for 30 s with 40 mL of a cold MFI buffer (100 m*M* KCl, 20 m*M* $KHPO_4$, 1 m*M* EDTA, 1 m*M* $MgCl_2$, and 1 m*M* NaN_3, with pH adjusted to 6.9 and stored at 2 °C) using a homogenizer (model PRO250, PRO Scientific, Inc., Monroe, CT, USA). Homogenized samples were subsequently centrifuged at 1000 × *g* for 15 min at 2 °C, supernatant and fat cap were discarded, and the resulting pellet was re-suspended in 10 mL of MFI buffer, vortexed, and strained through a fine-mesh tea strainer, with the aid of a glass stir rod. The sample (0.25 mL) was mixed with 9.75 mL of MFI buffer for 10 s, and absorbance was subsequently read at 540 nm on a Spectronic-20 spectrophotometer (model no. 33-29-61-84, Bausch and Lomb, Rochester, NY, USA). Absorbance was multiplied by 200 (Culler et al., 1978) for duplicate samples/core and averaged for each LM sample for statistical analysis.

2.4. Cooking loss and WBSF determination

After thawing overnight at 2 °C, right-side LM sections (Exp. 1 and 2) and the SM from one 2.54-cm-thick center-cut leg slice (Exp. 2) were trimmed free of all subcutaneous fat and weighed before being cooked to an internal endpoint temperature of 71 °C (AMSA, 2015) on electric, countertop griddles (National Presto Industries, Inc., Eau Claire, WI, USA) set at 204 °C. The LM sections and SM slices were turned every two minutes and internal temperature was monitored with a hand-held, digital Foodcheck thermometer (Comark Instruments, Inc., Hitchin, Herefordshire, UK). At the internal endpoint temperature, muscles were removed from griddles, allowed to cool to room temperature (20 to 21 °C), and re-weighed to calculate cooking loss percentage. Then, six to eight 1.27-cm-diameter cores were mechanically removed parallel to the fiber orientation of the *m. longissimus thoracis* (LT), *m. longissimus lumborum* (LL), and SM, and each core was sheared once with a Warner-Bratzler shear device attached to an Instron Universal Testing machine (model 4466, Instron Corp., Canton, MA, USA), with a 55-kg tension/compression load-cell and a crosshead speed set at 200 mm/s. The average peak WBSF of cores from LT, LL, and SM samples were averaged for statistical analysis; however, due to a labeling error in Exp. 1, cores from the LT and LL were averaged together for statistical analysis.

2.5. Statistical analysis

In both experiments, data were analyzed as a completely randomized design, with individual carcass as the experimental unit. The analysis of variance was generated using PROC GLIMMIX of SAS (SAS Institute, Inc., Cary NC, USA), with postmortem treatment as the fixed effect in the model. Least squares means were calculated and separated statistically using pair-wise *t*-tests (PDIFF option of SAS) when the *F*-test was significant ($P \leq 0.05$).

3. Results

Body weights at slaughter ($P \geq 0.687$), hot carcasses weights ($P \geq 0.591$), and carcass yields ($P \geq 0.335$) were similar among prerigor treatments in each experiment (Table 1). Myofibrillar fragmentation index values have been shown to be an indicator of the extent of postmortem proteolytic tenderization in goat muscle (Nagaraj, Anilakumar, & Santhanam, 2006), and the extent of proteolytic degradation of LM proteins after 7 d of wet-aging was not affected by the tension-generating treatments, as evidenced by similar ($P \geq 0.088$) MFI