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Age End-Point Effects on Performance, Carcass Measurements, and Tenderness in Goats

Kelsey Lynn Basinger
University of Arkansas, Fayetteville

Age End-Point Effects on Performance, Carcass Measurements, and Tenderness in Goats

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Kelsey Lynn Basinger
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Dr. Jason K. Apple
Thesis Director

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Dr. Bruce C. Shanks
Committee Member

____

Dr. Michael L. Looper
Committee Member

____

Dr. James D. Caldwell
Committee Member

Abstract

Goat meat is consumed all across the world, especially in developing countries. Moreover, the meat goat industry is growing in popularity in the United States due to ethnic demand of an increasing immigrant population. The objective of this study was to measure age end-point effects on performance, carcass measurements, and tenderness in goats. Intact Kiko × Boer F_1 male (n = 46) kids were born on pasture in the spring of 2014 and 2015, weaned at approximately 100 d of age, and weighed monthly. Creep feed was offered to kids from birth to weaning and a high concentrate diet was offered after weaning in a dry lot. Animals were allocated by birth weight, date of birth, and previous treatments (high vs. low parasite resistance) and assigned randomly to slaughter age end-points (135, 180, 225, 270, 315, 360, 405, or 450 d of age). At slaughter, animals were transported 450 km (4.5 h) from Lincoln University's Carver Farm to the University of Arkansas Red Meat Abattoir. After overnight lairage with water, animals were humanely slaughtered at 0900. Kids grew at a linear ($P < 0.001$) rate as d of age increased. As expected, hot carcass weight, cold carcass weight, and individual muscle weights increased ($P \leq 0.05$) as chronological age advanced. Range of dressing percentage (DP) was 40 to 50 % with 315 d old kids having the highest ($P \leq 0.001$) DP. Kids from 315 and older slaughter age groups had a more desirable ($P = 0.003$) carcass conformation compared with younger slaughter age groups. Longissimus (LM), semimembranosus (SM), biceps femoris (BF), and rectus femoris (RF) muscle $L*$ values decreased ($P \leq 0.004$) with increasing age at slaughter. Warner-Bratzler shear force values increased ($P \leq 0.001$) in the SM and BF as d of age increased. Longissimus muscle sarcomere lengths were longer ($P \leq 0.05$) at 270 d of age, whereas BF sarcomere length increased ($P \leq 0.05$) as d of age advanced; SM sarcomeres were not different ($P = 0.588$) across slaughter age groups. Therefore, goat producers can efficiently

raise goats to slaughter from approximately 225 to 360 d of age to produce larger carcasses to provide more meat for increased demand in the market without detrimentally effecting meat tenderness.

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Dedication

I would like to dedicate my M. S. thesis to the love of my life, Lucas Luebbering. You have always been the listening ear when I needed to talk to someone, the shoulder to cry on when things were not going right, and my biggest supporter to encourage me to keep going when things were going right. Your love and dedication has helped me to prove not only to myself but to everyone around me that if you put your mind to it, you can do anything. Your love of agriculture has been an influential part of our relationship and continues to grow, as I participated in earning this M. S. degree for *our* future together. Thank you for your love, patience, and sacrifice during my time in Arkansas to pursue my M. S. degree.

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Chapter 1

Review of Literature

Introduction

Meat goats can be found across the world, especially in developing countries (Barkley et al., 2012; USDA-FSIS, 2013; Webb, 2014) with growing popularity in the United States (Oman et al., 1999). There are many different meat goat breeds and production systems, thus there are variations in growth rates (Sahlu et al., 2009) and age at slaughter (Warmington and Kirton, 1990). Age at slaughter can greatly affect meat quality, including tenderness of goat kids (Webb et al., 2005). Therefore, the objective of this literature review was to examine meat goat production, summarize research on goat performance, carcass characteristics and tenderness, and review the effects of slaughter age on these traits.

Meat goat production

Nearly three-quarters of all the goats in the world are in developing countries (USDA-FSIS, 2013), where goat meat is readily consumed (Barkley et al., 2012; USDA-FSIS, 2013; Webb, 2014). In fact, goat meat has been a source of human nutrition since the beginning of human civilization (Webb et al., 2005). Two main types of goat meat that are popular are cabrito (capretto), typically milk-fed young goat kids, or chevon, which is goat meat from older weaned kids or adults (Barkley et al., 2012). Ethnicity has a major impact on overall acceptability and how goat meat is perceived (Barkley et al., 2012).

In the United States, goat meat is not a common choice in every venue; however, goat meat is available in specialty markets and is growing in popularity (Webb, 2014). In the United States, the goat industry represents a non-traditional agricultural enterprise that offers farmers an option for on-farm income (Browning et al., 2004). According to the most recent United States Agriculture Census (2012), there were 2.6 million head of goats, with 2.0 million being considered meat and other types besides milk. Goats have been traditionally raised in the United States with intentions of brush control or for the production of milk or fiber, with meat being a by-product (USDA-FSIS, 2013; Browning et al., 2004). Opportunities exist for the future of goat meat because of the many quality attributes it contains, such as its ecological image, its desired health qualities, its association with religious holidays, and goat meat fits into the newest trend of being a natural food (McMillin and Brock, 2005). As such, marketing options include direct to specific ethnic groups, health-conscious consumers, or even restaurant service marketing gourmet foods featuring goat meat (Barkley et al., 2012).

Animal performance

It was suggested by Butterfield and Berg (1966) that muscles in an animal change more within the first 3 mo of life, and growth is most affected by nutrition the animal receives during this time frame. However, there is a lack of information in the scientific world for pre- and post-weaning performance for meat-type goat kids (Sahlu et al., 2009). Furthermore, there are a variety of meat goat breeds and thus are large variations in growth rates (Warmington and Kirton, 1990). According to Maiorano et al. (2001), goats were designed to survive and produce in harsh environmental surroundings, transforming low-quality resources into high-quality protein. Therefore, comparison of different goat breeds and their performance can also be confounded because of the vast range of environmental factors which goats are typically raised (Warmington and Kirton, 1990). Poor environmental adaptation could cause undesirable effects on animal performance (Browning et al., 2004).

It has been suggested that the Boer breed may have more muscle compared with other breeds (Warmington and Kirton, 1990; Browning and Leite-Browning, 2011; Browning et al., 2012) and tends to grow more rapidly and efficiently under high-input systems (Solaiman et al., 2012). This is a primary reason why Boer goats have been used extensively in the United States for the goal of enhancing growth and conformation of market kids (Browning et al., 2004). Another popular meat goat breed in the United States is Kiko (Solaiman et al., 2012). The Kiko breed of goat was developed in New Zealand by crossing feral goats with other breeds such as Nubian, Toggenberg, and Saanen. Kikos have been touted as having increased parasite-resistance capabilities and an increased rate of pounds of kid weaned per doe (Gipson et al., 2005). During a feeding trial with Boer and Kiko intact male goat kids age ranging from 141 to 225 d of age, Solaiman et al. (2012) found the range of average daily gain (ADG) to be between 0.11 and 0.14 kg/d, when animals were individually penned and offered a high concentrate diet over a 12 wk period. A project focused on reproductive and maternal capabilities of Boer and Kiko does under subtropical climatic environments observed pre-weaning growth rates of meat-type goat kids to range between 0.13 and 0.14 kg/d when kids were reared with their mothers on pasture without creep feed supplementation (Browning et al., 2004). Those same kids at weaning weighed between 15.29 and 16.81 kg at approximately 14 wk old (Browning et al., 2004). In a similar study by Browning and Leite-Browning (2011), they found pre-weaning ADG in meat-type goat kids to have a larger range from 0.11 to 0.14 kg/d when kids were weaned at approximately 90 d old and reared with their mothers on pasture without creep feed supplementation. Those same kids at weaning weighed 13.19 to 15.58 kg (Browning and Leite-Browning, 2011), also having a larger range in end weights compared with Browning et al. (2004).

A major factor in the growth rate of goat kids is mature size of the sire and dam (Dhanda et al., 2003). In general, a larger breed of goat grows faster than a smaller breed (McGregor, 1984). Crossbred bucklings of different meat breeds (Boer, Angora, Feral, and Saanen) were compared as two groups, one group slaughtered at 93 d of age had an ADG of 0.17 kg/d, whereas the older slaughter group (254 d of age) had a significantly lower ADG of 0.12 kg/d (Dhanda et al., 2003). Crossbred male goats raised on different diets containing medium quality hay and a concentrate supplement slaughtered at an average 188 d of age had weaning weights ranging from 14.5 to 16.1 kg at 75 d of age and ADG range of 0.15 to 0.17 kg/d (Poore et al., 2013). A study done in Italy to study variations in growth traits of goat kids examined ADG of male goat kids from birth to 60 d of age and reported ranges from 0.096 to 0.099 kg/d (Portolano et al., 2002).

Pre-weaning growth of goat kids is normally at a faster pace than post-weaning growth, even when high-quality supplements are offered to kids during the post-weaning period (Warmington and Kirton, 1990; Palma and Galina, 1995). Growth rate during the pre-weaning period for goat kids is highly dependent on milk provided by the mother and rate of intake (Warmington and Kirton, 1990). An increase in nutritional value of the dam's diet during lactation can in turn increase nutritional value of milk provided to suckling kids (Warmington and Kirton, 1990). Also, a decrease in male goat kid growth rate during the fall could possibly be from onset of sexual maturity of spring-born intact male kids (Warmington and Kirton, 1990). After weaning, growth of kids can remain linear up to about 1 yr of age, if their environment and diet remain similar (Warmington and Kirton, 1990). According to Dhanda et al. (1999), when looking at multiple genotypes of crossbred goats, with two slaughter age groups averaging 90 and 270 d of age, ADG decreased for all goats as age increased. In a similar study by Limea et al. (2009), goat kids in three different slaughter age groups (7, 11, and 15 mo of age) had similar pre-weaning ADG (84, 85, and 84 grams per d for 7, 11, and 15 mo groups, respectively) but differed in post-weaning ADG (60.9, 61.4, and 51.3 g/d for 7, 11, and 15 mo groups, respectively). In a study by Solaiman et al. (2012), final weight and ADG of kids slaughtered at approximately 140 d of age were 23.1 to 24.7 kg and 117.6 to 141.1 g/d, respectively. Goat kids slaughtered at approximately 170 d of age had a final weight of 25.5 to 27.0 kg with an ADG of 108.8 to 122.7 g/d. The slaughter age group at approximately 196 d had an ADG of 103.8 to 147.1 g/d with a final body weight 28.8 to 31.6 kg. The final slaughter age group (at approximately 225 d of age) had final body weights ranging from 31.3 to 37.4 kg with ADG from 110.0 to 136.9 g/d. (Solaiman et al., 2012). In general, ADG of goats decreased as age of the animal increased.

When looking at increasing amounts of concentrate feed offered to goat kids slaughtered at a similar weight, kids offered the most feed reached their goal end weight faster (275 d of age) than those goats not offered any supplemental concentrate feed (400 d of age; Limea et al., 2012). Goat feedlot growth rates have not been extensively looked at, but Oman et al. (1999) collected data from crossbred goat kids (averaged 124 d old at feedlot entry) on a feedlot system for 130 d and reported end live weights (averaged 254 d old) ranging from 33.5 to 38.2 kg.

Amount of intake and configuration of the diet can increase fat deposition within an animal, but there is limited knowledge about this topic in goats (Warmington and Kirton, 1990). Diet is the main source for fatty acid deposition in the adipose tissue of young animals, especially before weaning when the diet consists mainly of milk, but declines as the ruminant digestive system develops and the diet becomes more complex with forages and feedstuffs (Dhanda et al., 2003b).

Carcass characteristics of meat goats

Goat meat consumption has increased in the United States due to an increase in ethnic populations that readily consume goat meat especially on holidays and special occasions. Different ethnicities prefer different ages of goats at slaughter (Barkley et al., 2012; Gipson et al., 2005; McMillin and Brock, 2005; Webb et al., 2005; Webb, 2014). However, goats are slaughtered at a particular time of year regardless of a standard age or target weight because of demand during holiday seasons (Cameron et al., 2001). Goats harvested at a larger live weight could be beneficial for producers by providing increased revenue, and beneficial for consumers with more product purchased, as long as quality is not compromised with increasing age of animals (Ruvuna et al., 1992). Slaughter age end-points need to be defined to ensure the quality of goat meat that consumers' desire.

Grades

The amount of information about goat meat quality and yield are restricted compared with sheep and cattle (Warmington and Kirton, 1990). Currently, there are no United States Department of Agriculture (USDA) quality or yield grades established for meat goats (USDA-FSIS, 2013), but according to USDA Agricultural Marketing Service, goat grades are currently under development (USDA-AMS, 2016). Although there is not a grading system established for fresh goat they are still covered under the United States Federal Meat Inspection Act of 1906; thus they must be slaughtered under Federal or State inspection if the meat is intended to be sold for consumption (USDA-FSIS, 2013). In 2010, there were 779,000 head of goats slaughtered under Federal inspection (USDA-FSIS, 2013). Louisiana State University Ag Center in Baton Rouge, LA, developed a Meat Goat Selection, Carcass Evaluation, and Fabrication Guide (McMillin and Pinkerton, 2008) based on terminology from USDA-AMS Institutional Meat

Purchase Specifications (IMPS) for Fresh Goat Series 11, including goat carcass evaluation for muscle conformation, flank lean color, kidney, pelvic, and heart fat, and subcutaneous fat coverage.

Carcass measurements

Based on lamb and beef carcasses, it can be assumed that carcass characteristics (carcass weights, DP, loin eye area (LEA), and fat thickness (FT) will increase in goats as they progress in chronological age (Dhanda et al., 1999). Hot carcass weight (HCW), or un-chilled weight of the carcass after slaughter with the head, hide, and viscera removed, is one measurement used in the determination of yield and dressing percentage for the carcass. Cold carcass weight (CCW) is the weight of the carcass after a chill period, normally 24 h.

Average HCW from kids with multiple genotypes slaughtered at approximately 90 d of age were 6.7 kg, whereas kids slaughtered at approximately 270 d of age weighed 15.1 kg (Dhanda et al., 1999). Accordingly, CCW of those same two age groups were 6.5 kg and 14.7 kg, respectively (Dhanda et al., 1999). Bucklings of several different genotypes averaging 93 and 254 d of age had an average HCW of 8.2 kg and 14.9 kg, respectively (Dhanda et al., 2003). Browning et al. (2012) used crossbred buck kids on a terminal performance trial resulting in kids slaughtered at an average age of 231 d, with an average HCW of 11.0 kg and average CCW of 10.1 kg. Boer × Spanish crossbred goat kids slaughtered at 5 different age end-points beginning with 116 d of age, with 56 d intervals in between, ending with 340 d of age, had HCW starting at 6.8 kg and increasing with d of age to 22.6 kg (Cameron et al., 2001). Oman et al. (1999) slaughtered Boer × Spanish crossbred goats at an average age of 254 d after a 130-d post-weaning growth period in a feedlot, and offered concentrate feed at either 12.5 or 15% CP; those carcasses yielded an average HCW of 21.7 kg. Boer-cross males, either intact or castrates, were slaughtered at an average age of 188 d, with bucks having heavier HCW (15.67 kg) compared with wethers (13.0 kg; Poore et al., 2013). Boer kids of mixed sex, reared with their mothers on pasture with access to a commercial creep feed (18% CP) yielded HCW of 9.2 kg for kids slaughtered at approximately 85 d of age and 13.8 kg for kids slaughtered at approximately 139 d of age (Kaic et al., 2012). Creole goats from the French West Indies were used in a growth performance trial ending with 3 different slaughter age end-points of 7, 11, and 15 mo and produced HWC of 6.6, 10.2, and 12.3 kg, respectively (Limea et al., 2009). Gargancia intact male kids from the Mediterranean slaughtered at 75 d of age produced HCW of 6.6 kg and CCW of 6.4 kg (Maiorano et al., 2001).

Dressing percentage is an easily calculated (final live weight divided by HCW multiplied by 100) and important trait when considering carcass yield characteristics. Kids slaughtered at 25 to 35 d of age dressed between 51 to 54 %, based on an empty body weight (Dhanda et al., 2003a). Todaro et al. (2002) also compared goat kids slaughtered at 25 and 35 d old; however, DP was reported to range from 70.1 to 70.6 %, substantially higher than that found by Dhanda et al. (2003a). However, in that study DP was calculated using HCW and empty body weight. In another study, Dhanda et al. (1999) compared multiple genotypes of meat-type goat breeds with goat kids slaughtered at 2 different ages and reported DP based on live weight or empty body weight. Average DP based on live weight was 43.1 % at 90 d of age and 44.7 % at 270 d of age, whereas DP based on EBW was 50.4 % (90 d of age) and 52.5 % (270 d of age). Other research found that DP for commercial New Zealand breeds of goat kids ranging from newborns to mature animals was approximately 46 to 48 % (Colomer-Rocher et al., 1992; Hogg et al., 1992). Crossbred goat kids, both male and female, slaughtered at 5 different age end-points beginning with 116 d of age, with 56 d intervals, and ending with 340 d of age, had DP ranging from 41.7

to 51.3 % (Cameron et al., 2001). Native French West Indies goats were used in a growth performance trial ending with 3 different slaughter age end-points of 7, 11, and 15 mo, produced DP ranging from 53.0 to 59.0 %, with increasing DP as age increased (Limea et al., 2009). Crossbred male goat kids, either intact or castrates, were slaughtered at an average 188 d of age and both groups had similar DP of 49.0 and 49.1 %, respectively (Poore et al., 2013).

Longissimus muscle area is another carcass measurement to help predict yield from carcasses. Dhanda et al. (1999) compared multiple genotypes of meat-type goat breeds at 2 different age groups, and found that 90 d old kids had a 7.5 cm^2 loin eye area and kids slaughtered at 270 d had a 12.3 cm^2 loin eye area. In another study, bucklings from several different genotypic backgrounds were slaughtered after a performance trial producing an average 9.0 and 12.1 cm^2 loin eye area for kids averaging 93 and 254 d of age, respectively (Dhanda et al., 2003). Mixed sex crossbred goat kids slaughtered at 5 different age end-points beginning with 116 d of age, with 56 d intervals, and ending with 340 d of age, had loin eye areas ranging from 7.3 to 13.7 cm^2 that increased as chronological age advanced (Cameron et al., 2001). Oman et al. (1999) examined crossbred goats at an average 254 d of age after a 130-d post-weaning growth period in a feedlot with *ad libitum* access to an 80 % concentrate feed, and carcasses had a 12.51 cm^2 loin eye area. Intact male crossbred goat kids (188 d of age) had a larger (9.42 cm^2) loin eye area compared with castrated males (8.15 cm^2) of the same age in a study by Poore et al. (2013).

Goats deposit a considerable amount of internal fat when offered a high concentrate diet (Warmington and Kirton, 1990; Ngwa et al., 2007) indicating that omental and mesenteric fat tissues grow more quickly than lean tissues in goats (Warmington and Kirton, 1990; Webb et al., 2005). Conversely, subcutaneous back fat cover is slow to develop in goats (Dhanda et al., 2003b; Webb et al., 2005) when compared with sheep (Warmington and Kirton, 1990). However, during a study conducted in Australia, crossbred goats were raised for slaughter and ultrasonically measured for backfat thickness and they found as age increased subcutaneous fat coverage also increased (Dhanda et al., 1999). In another study, Cameron et al. (2001) used crossbred goats to measure effects of age on back fat thickness and reported an unmeasurable amount of back fat for goats approximately 116 d of age with similar back fat thicknesses (0.10 to 0.16 cm) from 172 to 284 d of age, and the most (0.34 cm) subcutaneous fat coverage observed in 340 d old goats. Goats tend to deposit subcutaneous fat differently compared with other red meat species; they deposit fat behind their front shoulders and then over the rib cage (McMillin and Pinkerton, 2008). Even though subcutaneous fat coverage increased with age in previously mentioned studies, the amount might still be inadequate for proper insulation of muscles during postmortem chilling thus, leading to meat quality issues such as cold shortening (Warmington and Kirton, 1990). Dikeman (1996) suggested a minimum of 4 mm of fat coverage was needed to help mitigate the effects of cold shortening on muscles during chilling. The relatively low amount of back fat on a goat carcass can also present an issue when trying to estimate carcass yield. Lamb and beef carcasses rely on the amount of subcutaneous fat as a predictor of grade for those species but goats cannot use this estimate in a reliable manner (Webb et al., 2005).

Cooler shrink is the amount of weight lost, as moisture, during the chill period for a carcass. The difference from HCW and CCW is calculated as cooler shrink. Poor subcutaneous fat coverage leaves goat carcasses susceptible to high moisture loss during chilling (Webb et al., 2005). Dhanda et al. (2003a) calculated more moisture loss from young goat kids compared with older goats, which is in agreement with Webb et al. (2005) that suggested higher moisture losses result from smaller goat carcasses compared with larger carcasses.

Meat color

Consumers use color to visually determine quality characteristics of fresh meat. Instrumental surface color measurement of fresh meat is a method most closely related to what a consumer would see and is a universal tool that is easily applicable for comparison of results between multiple studies (Kerth, 2013). The most common variables measured are lightness (L^*), redness (a^*), and yellowness (b^*). Lightness is measured on a scale of 0 (black) to 100 (white), whereas a^* and b^* are measured by numerical values and increasing values indicate more color (red or yellow) present in the muscle (Kerth, 2013). Color of muscle is indicated by content of myoglobin, which makes up 80 to 90 % of total pigments within a muscle. Quantity of myoglobin varies with species, age, sex, muscle, and physical activity, which accounts for the wide variability in meat color (Aberle et al., 2012). Myoglobin concentration within a muscle is also reported to increase as chronological age advances, resulting in an increased muscle color intensity (Dhanda et al., 2003a). The color of lean muscle in goat kids is normally pale and pink, which is most acceptable to consumers preferring cabrito (Todaro et al., 2002).

Todaro et al. (2002) looked at the color of longissimus muscle in kids slaughtered at either 25 or 35 d of age and found no significant differences in L^* values (47.76 and 46.21, respectively) and a^* values (1.57 and 2.30, respectively). For longissimus muscle of goat kid carcasses harvested at 93 or 254 d of age, Dhanda et al. (2003a) reported L^* values of 38.5 and 40.7, a^* values of 11.0 and 12.3, and b^* values of 5.4 and 9.7, respectively. Harvest age also influenced muscle color in an experiment by Solaiman et al. (2012), where younger Boer and

Kiko kids (141 d of age) had higher *L**, *a**, and *b** values (44.6, 12.4, and 4.6, respectively) compared with older kids (225 d of age; *L** = 42.4, *a** = 9.3, *b** = 2.4).

Babiker et al. (1990) found that goat LM had lower *L** value (34.8) compared with lamb (36.2), with *a** values higher in goats (13.1) compared with lamb (11.96). Santos et al. (2008) compared young goat kids (up to 3 mo of age) with young lambs (4 to 6 wk of age) meat color from goats were significantly lighter (47.3 vs. 46.0) and less yellow (5.2 vs. 11.1) than lamb when measured on the surface of the longissimus muscle. Sheridan et al. (2003) also compared goats and lambs, but measured color on the semimembranosus muscle and found *L** values of 38.3 and 38.0 for 163 and 191 d old kids and 34.6 and 36.7 for 118 and 146 d old lambs, respectively; thus, goat meat seems to be lighter compared with lamb.

Tenderness

Tenderness can be described as the amount of force it takes to bite through a piece of meat (Kerth, 2013). Tenderness is an important attribute that consumers demand, according to National Beef Tenderness Surveys that was conducted over the past 3 decades (Guelker et al., 2013; Voges et al., 2007; Brooks et al., 2000; Morgan et al., 1991). There are a number of different factors that can alter tenderness such as breed, age, sarcomere length, protein, fat, moisture, and a few postmortem factors that also contribute to tenderness of a muscle, such as pH, temperature, and postmortem muscle metabolism. Reported tenderness values can also vary depending on the treatment of the animal pre-slaughter, postmortem treatment of carcasses, muscles being sampled, and methods of preparation of sampled cuts (Webb et al., 2005).

How to measure tenderness

Tenderness can be a subjective trait determined by individuals or can be measured by an instrument to give a universal measurement of meat tenderness (Kerth, 2013). The most widely accepted objective measure of tenderness is shear force (Kerth, 2013). Shear force is a general, easy determination of tenderness of a cooked product. All variations of shearing methods allow cooked meat samples to cool to room temperature before being sheared. Warner-Bratzler shear force determination requires core samples, usually 1.27 cm diameter, removed parallel to the muscle fiber orientation from multiple locations (6 to 8) within the muscle (Kerth, 2013). These cores are then sheared once under a V-shaped blade and force is measured by a computerized device with a load cell attached. Shear force measurements are a good indication of protein tenderness within a muscle. There are multiple types of proteins found in the muscles of animals, which all come together and play a role in structure of the muscle. Sarcoplasmic, myofibrillar, and stromal proteins are just a few examples of the types of proteins in muscle. Sarcoplasmic proteins are microscopic proteins found in the sarcoplasm. Myofibrillar proteins are muscle contraction proteins, whereas stromal proteins are connective tissue proteins.

Australian and New Zealand consumers accept lamb tenderness at about 3 kgf (Warner-Bratzler shear force) but if the value is ≥ 6 kgf then it is considered unacceptable (Webb et al., 2005). Beef tenderness is very similar to lamb tenderness acceptability, tender is closer to 2 kgf and unacceptable would be > 6 kgf according to Webb et al. (2005). Shear force of goat meat from male kids was reported to range from 3.7 to 4.6 kgf (Dhanda et al., 2003a), whereas more recently, Basinger et al. (2013; 2014) found goat longissimus muscle Warner-Bratzler shear force values to range from 1.8 to 7.29 kgf. Consumer and sensory panels have not been extensively utilized to evaluate the tenderness of goat meat, therefore information is limited. Sensory panel discrimination of goat meat was determined to be from lack of tenderness in a study conducted in New Zealand by Kirton (1970). A study conducted by Babiker et al. (1990) compared goat with lamb and consumers rated the species both as average acceptability.

Age effects on tenderness

In general, young goats produce more tender meat than older goats but conformation and breed may influence effects of age on meat properties (McMillin and Brock, 2005; Webb et al., 2005; Sahlu et al., 2009). Tenderness is reduced with increased age due to toughening of myofibrillar proteins and cross bridge formations occurring in muscles (Madruga et al., 2000). Factors to take into account when looking at how tenderness is changed as an animal ages would be carcass weight, which can be affected by physical size of the muscles themselves, connective tissue content, chilling rate, which can be altered by fat coverage, and treatment of carcasses post-mortem (Shorthose and Harris, 1990).

According to Warmington and Kirton (1990), tenderness and juiciness appear to decrease with increasing age in goats, whereas other species report a decline in tenderness, but not juiciness. A study done in Brazil, looking at consumer acceptance of goats slaughtered at different ages showed tenderness and overall palatability to be highest for kids slaughtered at 175 d compared with kids slaughtered at 220, 265, and 310 d of age (Madruga et al., 2000). In a similar study, Mandakmale et al. (2007) observed goat kids slaughtered from 6 to 12 mo of age and found that across age groups were of equal quality according to a consumer panel.

Proximate analysis and tenderness

Goat meat is generally lean and contains higher moisture content than other red meats which can affect tenderness (USDA-FSIS, 2013). Moisture and intramuscular lipid content also directly effects juiciness of the meat (Webb et al., 2005). Castrated male goats from the northeastern region of Brazil, slaughtered at 2 different age groups (average 5 and 9 mo of age), were utilized to examine effects of age at slaughter on chemical composition of muscles in a study by Beserra et al. (2004). Composited muscle samples were analyzed for moisture, protein, and fat with younger groups having slightly more moisture (77.2 g/ 100 g = 5 mo; 76.5 g/ 100 g = 9 mo), very similar results for protein between age groups (21.0 g/ 100 g = 5 mo; 21.1 g/ 100 g = 9 mo), with older goats having higher amounts of fat (2.1 g/ 100 g) than younger goats (0.7 g/ 100 g). In another study by Madruga et al. (1999), crossbred male goats were utilized to examine effects of 4 different slaughter ages (175, 220, 265, and 310 d of age) on proximate composition of muscles. Moisture content ranged from 75.0 to 78.0 %, fat content ranged from 1.8 to 4.1 %, and protein ranged from 18.7 to 23.1 %. Amount of protein increased as d of age increased, whereas moisture and fat contents varied among the 4 slaughter ages (Madruga et al., 1999). Conversely, Todaro et al. (2002) compared meat from 25 and 35 d old goat kids and found no difference in protein content (89.9 and 89.6 % of DM, respectively).

pH and tenderness

Postmortem muscle metabolism can be described as chemical changes that occur in the transition from muscle to meat, or more commonly referred to as rigor mortis. This normally happens within 24 h after slaughter. Goats have been known for their flighty responses, which are apparent in stressful situations; stress can play a role in postmortem glycogen metabolism, causing a higher-than-normal pH (Dhanda et al., 2003a; Webb et al., 2005). Ultimate pH plays a feature role in meat quality and is associated with frequency of glycogen breakdown and depletion of lactate during pre- and post-slaughter periods (Kadim et al., 2006). Goat carcasses with a lower pH have longer sarcomeres after chilling, lower shear force values, and better colorimetric values compared with goats that have higher pH according to Webb et al. (2005) and Kadim et al. (2006). In a study by Dhanda et al. (2003a), researchers looked at effects of genotype and live weight at slaughter and effects on meat quality of goats. They reported pH ranges from 5.7 to 5.9 (Dhanda et al., 2003a). In a study conducted by Madruga et al. (1999)

using crossbred male goats slaughtered at 4 different age end-points (175, 220, 265, and 310 d of age), pH for a composited lean sample ranged from 6.1 to 6.6.

Sarcomere length and tenderness

Length of a sarcomere can be defined as the distance from Z-line to Z-line within a myofibril (Aberle et al., 2012). Sarcomere length is directly affected during rigor mortis when permanent cross-bridges are being formed between actin and myosin. These bonds are normally broken with presence of ATP (energy), but postmortem, these energy stores are depleted resulting in inability of muscle to return to a relaxed state. Calcium triggers formation of the actomyosin bond, and is released quickly when the sarcoplasmic reticulum is unable to maintain stored calcium because muscles on the carcass are chilled too rapidly (Kerth, 2013). This condition is referred to as cold shortening. A study conducted by Weaver et al. (2008) showed that it takes more force to shear muscles with short sarcomeres, due to overlap of filaments causing muscles to become denser. Small ruminants, such as goats are susceptible to cold shortening because of their lack of insulation, or fat covering on the carcass. Unless chill period temperatures are strictly controlled, goats will always be susceptible to cold shortening according to Dhanda et al. (2003a).

There are ways to mitigate and reduce toughening effects of cold shortening on carcasses without adequate back fat coverage. A shorter chilling period may be necessary to account for rapid change in temperature of carcasses. Ways to mitigate unwarranted tenderness issues from lighter carcasses, such as those commonly found for light weight goats, are alternative suspension methods or electrical stimulation. Both methods help to minimize prerigor myofibrillar shortening and allows rigor mortis to complete, so that permanent cross-bridges can be made with the sarcomeres in a stretched or elongated position (Kerth, 2013).

Published scientific data about age and sarcomere length is virtually nonexistent for goats. Basinger et al. (2012; 2013) recently examined 8 mo old goats slaughtered and suspended in a conventional versus non-conventional manner and reported sarcomere lengths ranging from 0.093 to 0.160 µm. Boer-cross kids (150 d of age) that were examined for effects of electrical stimulation on the carcass before chilling showed that stimulated groups had similar sarcomere lengths (1.68 and 1.70 µm) compared with control groups (1.62 µm) in a study by King et al. (2004). Lack of consistent findings in previously mentioned studies could be due to differences in age, treatment of carcasses postmortem, or insufficient fat coverage on the carcasses during the chill period.

Conclusion

Due to an increase in demand of goat meat in the market and ability to add on-farm income for producers, meat goat production is rapidly growing in popularity in the United States. Animal performance is an important aspect that can be influenced by age, especially during critical growing periods, such as the first few months of life. Goat growth rates have been researched to some extent during both pre- and post-weaning growth periods, but findings are not consistent. Currently there are no USDA quality or yield grades for goats, but they are still under inspection during slaughter when the meat is intended for public consumption. Carcass measurements (weights, DP, LEA, etc.) are influenced by age of the animal and increase as chronological age increases, but have not been extensively observed in goats. Consumers in the market use visual color to determine the value of meat they purchase and lean color of goat meat can be influenced by age, such as young kids (cabrito) having a lighter color compared with older animals. Tenderness is an influential factor for consumers and influenced by age of the animal at time of slaughter, normally with younger animals having more tender meat. Meat quality characteristics, such as sarcomere length are virtually nonexistent in the literature for goat meat. Most goat meat in the United States is consumed during the holidays, suggesting goats are slaughtered at a particular time of year instead of a particular age. Slaughter age end-points need to be further defined to help producers raise quality goat meat desired by consumers.

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Chapter 2

Age End-Point Effects on Performance, Carcass Measurements, and Tenderness in Goats

Abstract

Goat meat is consumed all across the world, especially in developing countries. Moreover, the meat goat industry is growing in popularity in the United States due to ethnic demand of an increasing immigrant population. The objective of this study was to measure age end-point effects on performance, carcass measurements, and tenderness in goats. Intact Kiko × Boer F_1 male (n = 46) kids were born on pasture in the spring of 2014 and 2015, weaned at approximately 100 d of age, and weighed monthly. Creep feed was offered to kids from birth to weaning and a high concentrate diet was offered after weaning in a dry lot. Animals were allocated by birth weight, date of birth, and previous treatments (high vs. low parasite resistance) and assigned randomly to slaughter age end-points (135, 180, 225, 270, 315, 360, 405, and 450 d of age). At slaughter, animals were transported 450 km (4.5 h) from Lincoln University's Carver Farm to the University of Arkansas Red Meat Abattoir. After overnight lairage with water, animals were humanely slaughtered at 0900. As expected, live weight, ADG, HCW, CCW, and individual muscle weights increased ($P \leq 0.05$) as chronological age advanced. Dressing percentage ranged from 40 to 50 % with 315 d old kids having the highest ($P \leq 0.001$) compared with all slaughter age end-points. Kids from 315 and older had the best ($P = 0.003$) carcass conformation compared with younger slaughter age groups. Moderate subcutaneous fat was observed on all slaughter d except 135 and 180 d having the least ($P \leq 0.001$). Lightness (L^*) values of the LM, SM, BF, and RF decreased ($P \leq 0.004$) with increasing age at slaughter. Warner-Bratzler shear force values for LM peaked ($P \leq 0.05$) at 180, 270, and 450 d of age with all other d being more tender. Whereas SM and BF shear force values increased ($P \leq 0.001$) as d

of age increased. Sarcomere length for LM were longest ($P \leq 0.05$) at 270 d of age, with all other slaughter age end-points having similar lengths. However, BF sarcomere length increased ($P \leq 0.05$) as d of age advanced, whereas SM sarcomeres were not different ($P = 0.588$) for all ages.

Introduction

Meat goat production has become increasingly popular over the past few years, especially as a complement to other livestock species or for control of weeds and brush in a grazing-based system (USDA-FSIS, 2013; Browning et al., 2004). There is also increased demand for goat meat in the United States, due to an increase in ethnic populations (Barkley et al., 2012; Gipson et al., 2005; McMillin and Brock, 2005; Webb et al., 2005; Webb, 2014). Goat meat tends to be known for its low fat content which could be an incentive for people looking for a healthy protein alternative than other red meats (Maiorano et al., 2001; Dhanda et al., 2003b). However, an important consideration is perception of goat meat, particularly for consumers who have not tried or do not eat goat on a regular basis (Sahlu et al., 2009). Once consumers become more familiar with goat meat, they may be more inclined to accept it as a staple red meat in the United States. In the least, consumer bias may lessen for goat meat after exposure to quality products and having a satisfactory eating experience (Webb et al., 2005).

Tenderness, a main driver of consumer satisfaction, is generally accepted to be reduced with increased age due to toughening of myofibrillar proteins and cross bridge formation in muscles (Madruga et al., 2000). As such, effects of animal age on tenderness have been examined in sheep (Weller et al., 1962; Paul et al., 1964; Jeremiah et al., 1971; Cross et al., 1972; Bouton et al., 1978a; Ho et al., 1989; Jeremiah et al., 1997; Jeremiah et al., 1998a; Jeremiah et al., 1998b) and classical research examining age and effects on tenderness in beef have been extensively researched since the early 1950s (Hiner and Hankins, 1950; Simone et al., 1959; Blackman, 1960; Tuma et al., 1962; Tuma et al., 1963; Ritchey and Hostetler, 1964; Henrickson and Moore, 1965; Romans et al., 1965; Field et al., 1966; McBee et al., 1968; Zinn et al., 1970; Cormier et al., 1971; Hunsley et al., 1971; Brekke and Wellington, 1972; Reagan et al., 1976; Bouton et al., 1978b; Boccard et al., 1979; Cross et al., 1984a; Cross et al., 1984b; Dikeman et al., 1986; Shorthose and Harris, 1990; Shackelford et al., 1995).

However, there is little scientifically published information on slaughter age and effects on carcass characteristics and meat quality in goats (Warmington and Kirton, 1990; Solaiman et al., 2012). Therefore, the objective of this study was to measure performance, carcass characteristics, and tenderness of intact male goat kids slaughtered at 8 different age end-points.

Materials and methods

Animals for this project were provided by Lincoln University and humanely harvested at the University of Arkansas. Before beginning this research trial, experimental protocols were approved in accordance with the guidelines for the Care and Use of Agricultural Animals in Agricultural Research and Teaching (FASS, 2010) by the Lincoln University Animal Care and Use Committee (#14-14) and the University of Arkansas Institutional Animal Care and Use Committee (#15032)

Pre-weaning animal management

Intact F_1 Kiko × Boer male goat kids (n = 46) born at the Lincoln University George Washington Carver Farm in Jefferson City, MO during the spring of 2014 and 2015 were utilized for this project. Kids were born on pasture and immediately weighed, individually identified with ear tags, and were given 1 mL vitamin E (BO-SE, Merck Animal Health, Summit, NJ) subcutaneously. Yearly, after all kids were born, male kids were stratified by date of birth, birth weight, kids per litter, and previous treatment assignment (genetic selection for high resistance or low resistance to parasites) and were allocated randomly to 8 different slaughter age end-point groups. Kids born in 2014 were assigned to d 270, 315, 360, 405, and 450 slaughter age end-points, whereas kids from the 2015 kidding season were assigned to d 135, 180, and 225 slaughter age end-points. Goat kids were reared with their mothers on a rotational grazing system on fescue-based pastures and corn-soybean meal based creep feed (Table 2.1) was available to kids at birth until weaning.

Weaning and post-weaning animal management

Kids were weaned at approximately 100 d of age and were placed in a 0.03 ha dry lot for the first 110 d post-weaning, at which time dry lot size was increased to 0.65 ha. At all times, kids had *ad libitum* access to fresh water, goat mineral (Goat Mineral, Kent Nutrition Group, Muscatine, IA), free choice lime (Calcium Carbonate Fre-Flo, ILC Resources, Urbandale, IA; 2014 kids only), and the same corn-soybean-meal based feed (Table 2.1) offered prior to weaning. For 2015 kids, calcium was mixed in the feed ration, so free choice lime was excluded. Kids were also offered fescue hay at approximately 0.15 kg/hd/d. All feed was mixed and bagged at a local feed mill (MFA Lohman Producers Exchange, Lohman, MO) and samples were taken every 3rd bag per batch of feed and every 3rd square hay bale for chemical and analytical analyses. Kids were weighed once a mo to develop a growth curve and to determine ADG.

Slaughter

Kids were transported approximately 450 km (4.5 h) from Lincoln University's Carver Farm (Jefferson City, MO, USA) to the University of Arkansas' red meat abattoir (Fayetteville, AR, USA) one d prior to their assigned slaughter date. Kids were weighed prior to transportation and upon arrival for calculation of shrink (end weight – start weight = shrink).

After overnight lairage with water, goats were humanely slaughtered according to industry procedures. Whole carcasses were hung conventionally, and just before entering the cooler, were weighed to obtain hot carcass weight (HCW) and dressing percentage (DP = [HCW/ live weight]*100).

Sample collection

6 h postmortem samples

Carcasses were chilled in a cooler (0°C) for 6 h at which time pH (Meat pH Portable Meter, Hanna Instruments, Inc., Model HI99163 with a pre-amplified pH probe, Woonsocket, RI) and carcass temperature (Internal temperature sensor electrode, Hanna Instruments, Inc., Model FC232D, Woonsocket, RI) were measured on right sides of carcasses between the 12^{th} and 13^{th} ribs in the *longissimus thoracis* (LM).

24 h postmortem samples

Once carcasses were chilled (0°C) for 24 h, they were weighed to obtain cold carcass weight (CCW) and calculate cooler shrink (cooler shrink = (CCW – HCW)*100; moisture lost during chill period), pH and temperature were recorded (12^{th} rib), and subjective carcass grading was evaluated by a trained individual. The grading scale used was developed by McMillin and Pinkerton (2008) and consisted of carcass conformation (1.00 to 3.99), flank lean color (A00 to B99), kidney, pelvic, and heart fat (percentage of carcass weight), and subcutaneous fat cover (1 to 3). After subjective grading was complete, LM, *semimembranosus* (SM), *rectus femoris* (RF), and *biceps femoris* (BF) muscles were fabricated from left sides of carcasses, were weighed, and utilized for instrumental color and LM, SM, and BF were further utilized for shear force. The LM, SM, and BF muscles were extracted from right sides of carcasses for loin eye area measurement, sarcomere length determination, and proximate analysis. All muscle samples were stored in individual bags and frozen (-20°C) for further analyses, except muscles that were used for shear force determination; those samples were sealed in vacuum package bags, stored at 0°C for 10 d, and then frozen (-20°C) until analysis was conducted.

Sample analyses

Instrumental muscle color measurements

Color was measured by a handheld spectrophotometer (MiniScan EZ 4500L, Hunter Lab, Reston, VA) recording *L** (lightness), *a** (redness), and *b** (yellowness) for each muscle after they were extracted from carcasses and allowed to bloom for 30 min. Three readings were recorded per muscle and averaged together for *L**, *a**, and *b** values.

Proximate analysis

Frozen muscle samples for proximate analysis were thawed at room temperature (20°C) for approximately 30 min. Duplicate samples were weighed, placed in individual beakers, and refrozen to prepare for freeze drying. Samples were placed in a freeze dryer (Freeze Dryer 8 Labconco, Kansas City, MO) for approximately 120 to 144 h until samples were completely dry. Once samples were dry, they were reweighed to measure moisture content (start weight – end weight = moisture content) and then pulverized in a countertop coffee grinder (Fresh Grind™ coffee grinder, Hamilton Beach Brands Inc., Richmond, VA). Ground meat samples were placed in pre-labeled 50 ml centrifuge tubes and stored frozen (-20°C) until further analyses.

Protein content of the muscle samples were determined by the Dumas total combustion method (Elementar, Rapid N III, Mt. Laurel, NJ; Method 990.03, AOAC, 2000). Crude fat content of the muscle samples were determined using the ether extract direct method (Method 920.39C, AOAC, 2000).

Sarcomere length determination

The procedure for sarcomere length determination followed a modified version of Cross et al. (1981) and Koolmees et al. (1986). Frozen muscle samples assigned for sarcomere length determination were removed from the freezer and allowed to thaw at room temperature (20°C) for approximately 30 min. Core samples (1.27-cm-diameter) were extracted with muscle fibers running longitudinally in triplicate using a coring device attached to an electric drill (Model 6405, Makita, Inc., Buford, GA) and were placed in individual pre-labeled scintillation vials. A 5 % glutaraldehyde solution (10 to 15 ml) was added to vials to submerge core samples and was allowed to fix for 4 h at 4°C. Then, glutaraldehyde solution was poured off, 0.2 *M* sucrose solution (10 to 15 ml) was added, and vials were stored overnight at 4°C.

Samples were then gently homogenized for 10 to 15 sec to release muscle fibers into solution. Using a disposable transfer pipette, muscle fibers were then placed onto a clean microscope slide (1 to 2 drops) and smeared with a pipette tip across the slide to make a single layer of muscle fibers on the surface of the slide. Slides were then placed in the path of a He-Ne laser (Aerotech Electronics, Pittsburg, PA) which was used to measure diffraction patterns displayed on a solid white stage exactly 10 cm below slides. The entire length between two parallel diffraction bands was measured. Six sarcomeres were measured from each sample and sarcomere lengths were calculated based on the formula of Cross et al. (1981).

Cooking loss and Warner-Bratzler shear force

Frozen samples were thawed in a refrigerator (0°C) overnight. Samples were then weighed (Taylor TE10C 6.06 digital scale, Taylor Precision Products, Las Cruces, NM), placed on pre-labeled paper plates, and grilled on counter top griddles (Presto Electric Griddle, National Presto Industries Inc., Eau Claire, WI) until an internal temperature of 70°C (Foodcheck

Thermometer KM28, Comark Instruments Inc., Beaverton, OR) was reached. Once samples were cooked, they were placed on pre-labeled paper plates and allowed to cool to room temperature (20°C). Samples were then reweighed and cooking loss percentage was calculated by subtracting final weight from beginning weight and multiplying by 100. Then, 4 to 9 cores (1.27-cm-diameter) were extracted with muscle fibers running longitudinally using a coring device attached to an electric drill. Sample cores were sheared once using an Instron machine (Model 4466 Instron Corporation, Canton, MA) with a Warner-Bratzler shearing attachment on a 50 kg load cell with a crosshead speed of 250 mm/min. Maximum force (kgf) was recorded for each core and samples were averaged for each individual muscle from each animal.

Statistical analyses

Data were analyzed using mixed-effects model of SAS (PROC MIXED; SAS Inst., Inc., Cary, NC). The experimental unit was individual animal or carcass. For performance data, d of age at slaughter was used as a repeated measure for weigh periods. Year was included as a random effect and d of age at slaughter was the main fixed effect. Least squares means were computed for the main effect and were separated statistically using the probability of difference (PDIFF) option (SAS Inst., Inc., Cary, NC). Statistically significant differences among treatment groups were identified at a P-value of less than 0.05. The model was tested for linear, quadratic, cubic, and quartic effects of slaughter age and their interactions with all parameters measured; live weights, ADG, carcass measurements, fresh lean instrumental color, proximate analysis, cooking loss, Warner-Bratzler shear force, and sarcomere length.

Results and discussion

Effect of age at slaughter on live weight and ADG can be found in Figures 2.1 and 2.2. Kids grew at a linear rate ($P < 0.001$) as d of age increased over the duration of the project.

Average daily gain for goat kids from 225 to 270 d of age grew at a rate of 198.3 g/d, from 315 to 360 also seeing rapid growth with 249.1 g/d, whereas all other weigh periods had less (P < 0.001) gains. In studies by Browning et al. (2004) and Browning and Leite-Browning (2011), meat-type goat kids that were raised on pasture with their mothers had a range of 0.11 and 0.14 kg/d ADG. In agreement, Portolano et al. (2002) reported ADG of goat kids from birth to 60 d of age to be 0.10 kg/d ADG. In a study by Solaiman et al. (2012) using Boer and Kiko intact males of a similar ages (141 to 225 d old) in a feeding trial reported ADG to range from 0.11 to 0.14 kg/d. Also in agreement with the current study, Poore et al. (2013) found ADG to range from 0.15 to 0.17 kg/d for crossbred male goats slaughtered at an average age of 188 d.

Data for carcass characteristics from kids slaughtered at 8 different age end-points is displayed in Tables 2.2 and 2.3. Kids slaughtered at 225, 360, 405, and 450 d of age had significantly less (linear, P = 0.006) shrink (-0.05 to 0.12 % vs. 3.2 to 5.0 %) from transportation compared to kids from 135, 180, 270, and 315 d of age slaughter end-points. In agreement with our study, Solaiman et al. (2012) reported shrink ranging from 4.0 to 7.0 %, with younger animals having more body weight lost compared to older animals. Kadim et al. (2006) also reported shrink loss of 3.7 to 7.0 % for goats transported 2 h prior to slaughter.

As expected, HCW and CCW increased (linear, P < 0.001) as age increased for kids. In agreement with the current study, Cameron et al. (2001) reported that crossbred, mixed sex goats slaughtered at 5 different ages (116, 172, 228, 284, and 340 d of age) had heavier HWC as d of age increased. Also, Solaiman et al. (2012) reported HCW and CCW to be heavier as age increased over 4 slaughter ages of 141, 169, 196, and 225 d of age.

Carcass cooler shrink was least (quadratic, P = 0.017) for the youngest slaughter age group (135 d) and the 270 d end-point group had the most (quadratic, P = 0.017) shrink in carcass weight after a 24-h chill period. In another study, Boer and Kiko goat kids slaughtered at 4 different age end-points (141, 169, 196, and 225 d of age) had carcass shrink values between 3.1 and 5.0 %, with age at slaughter not having any effects (Solaiman et al., 2012).

In our study, range of DP was 40 to 50%, with 315 d having the highest (quadratic, $P < 0.001$) and 135 d having the lowest (quadratic, $P < 0.001$) DP. In a similar study by Cameron et al. (2001) crossbred, mixed sex goats slaughtered at 5 different ages (116, 172, 228, 284, and 340 d of age) had a range in DP of 42 to 51 %, with increasing DP as d of age increased. Kids slaughtered at younger ages of 25 or 35 d of age dressed between 51 and 54 % in a study by Dhanda et al. (2003a) and 70 to 71 % for kids of the same ages (25 or 35 d) in a study by Todaro et al. (2002; which the equation used could be the explanation, they used EBW rather than a HCW for the calculation). Dhanda et al. (1999) compared two methods of calculation of DP in goat kids with 43 and 50 % DP based on live weight and EBW, respectively for kids slaughtered at 90 d of age and, 45 and 53 % DP based on live weight and EBW, respectively for kids slaughtered at 270 d of age.

For subjective scoring of carcass muscling, rated on a scale from 1.00 to 3.99, the 315 d slaughter age group had the highest (linear, $P = 0.003$) conformation compared to all other slaughter age groups, whereas, 135 slaughter age group had the lowest (linear, $P = 0.003$). Our observations for subcutaneous fat covering indicated 135 and 180 d slaughter end points had the least (linear, $P < 0.001$) amount compared to all other age slaughter groups. McMillin and Brock (2005) summarizing modern information for Australia and New Zealand observed conformation scores ranging from 1.08 to 2.56 for domestic and imported goats on pasture only or supplemented on pasture and subcutaneous fat scores ranging from 1.07 to 1.59.

Goats deposit a considerable amount of internal fat when offered a high concentrate diet according to Warmington and Kirton (1990) and Ngwa et al. (2007). In the current study, kids slaughtered at 225 and 450 d of age had the most (linear, $P = 0.040$) amount of KPH (4.1 and 4.2 %, respectively) with all other slaughter end-points having a range in KPH from 2.4 to 3.7 %. Solaiman et al. (2012) reported no differences in internal fat content of goats slaughtered at 4 different ages (141, 169, 196, and 225 d of age). In another study by Todaro et al. (2002), they observed goat kids slaughtered at either 25 or 35 d of age to have KPH of 2.0 to 3.2 %, respectively, which is similar to KPH of younger slaughter age groups in the current study.

Slaughter age end-point impacted pH recorded at 24 h postmortem with gradual fluxes slightly above and below a pH of 6 (range 5.5 to 6.2). The highest (quadratic, $P = 0.001$) pH was observed for kids at 135 d old, whereas the lowest (quadratic, $P = 0.001$) was observed in the 180 and 225 slaughter age groups. In agreement with the current study, Madruga et al. (1999) slaughtered crossbred male goats at 4 different ages (175, 220, 265, and 310 d of age) and observed 24 h pH to range from 6.1 to 6.6. In another study, Dhanda et al. (2003a) slaughtered kids at 93 and 254 d of age and reported a 24 h pH of 6.0 and 5.6, respectively.

In the current study, kids slaughtered at 270, 360, 405, and 450 had larger (linear, $P < 0.001$) LEA (5.97 to 6.95 cm^2) compared to d-135, -180, -225, and -315 slaughter age groups (3.49 to 4.68 cm^2). In a study by Solaiman et al. (2012) with Boer and Kiko goats, LEA ranged from 7.77 to 9.81 cm^2 across 4 different slaughter ages (141, 169, 196, and 225 d of age), which was larger than the current study. Accordingly, Cameron et al. (2001) reported an increase in LEA as d of age increased in crossbred goats slaughtered at 5 different ages (116, 172, 228, 284, and 340 d of age). Dhanda et al. (1999; 2003a) slaughtered kids at 90 d of age and LEA ranged from 6.5 to 8.7 cm^2; kids slaughtered at an average age of 254 d old had a LEA of 12.1 cm^2. As expected, individual muscles (LM, SM, and BF) also grew linearly ($P < 0.001$) as kids advanced in age from 135 to 450 d of age in the current study.

The effect of age at slaughter on LM, SM, and BF proximate analysis is reported in Table 2.4. Fat content of the LM, SM, and BF increased (linear, $P < 0.001$) and moisture content decreased (linear, $P < 0.001$) as d of age at slaughter increased. Beserra et al. (2004) observed a similar pattern of fat increasing and moisture decreasing with advancing ages for goats. For LM samples in the current study, kids slaughtered at 135 d of age had more ($P < 0.05$) moisture than LM samples of kids slaughtered at 270 d or older, whereas LM moisture was the least ($P < 0.05$) in kids slaughtered at 360 d of age. Fat content of LM samples was greatest ($P < 0.05$) at 360 d, whereas the least ($P < 0.05$) amount of fat was observed at younger slaughter ages of 135-, 180-, and 270-d. Moisture content of BF decreased (linear, $P < 0.05$) as slaughter age of kids increased from 135 d of age to 450 d. Fat content percentage of the BF increased ($P < 0.05$) from 135 to 360 d of age, with peak fat content observed at 360 d of age. Madruga et al. (1999), slaughtered crossbred male goats at 4 different ages (175, 220, 265, and 310 d of age) and reported moisture content to range from 75.0 to 78.0 %, fat content to range from 1.8 to 4.1 %, and protein to range from 18.7 to 23.1 %. In the current study, even though LM protein content decreased (linear, $P = 0.038$) as slaughter age of kids increased from 135 to 450 d, slaughter age did not ($P \geq 0.085$) affect protein content of SM and BF muscles.

Effect of age at slaughter on instrumental color of goat LM, SM, BF, and RF is found in Table 2.5. L* values of LM, BF, RF, and SM decreased (linear, $P \leq 0.004$) with increasing age at slaughter. Furthermore, LM and BF became redder (linear, $P \leq 0.026$) as slaughter age increased from 135 to 450 d; however, age at slaughter had no effect on a* values of the RF ($P \geq 0.102$) or SM ($P \geq 0.113$). With the exception of kids slaughtered at 225 d, LM from goats slaughtered at 405 d was more ($P < 0.05$) yellow (higher b+ value) than all other slaughter age end-points. In an experiment by Solaiman et al. (2012), harvest age influenced muscle color with younger Boer and Kiko kids (141 d of age) having higher L^*, a^*, and b^* values (44.6, 12.4, and 4.6, respectively) compared to older kids (225 d of age; $L^* = 42.4$, $a^* = 9.3$, $b^* = 2.4$). Also, in contrast with the current study, L^* values increased as age increased in a study by Dhanda et al. (2003a), whereas a^* and b^* were similar as values increased as age advanced.

The results for sarcomere length, cooking loss, and Warner-Bratzler shear force from kids slaughtered at different age end-points are reported in Table 2.6. Sarcomere length of the LM peaked (quadratic, $P = 0.054$) at 270 d of age with all other d of age being similar. However, BF sarcomere lengths increased (linear, $P = 0.010$) as age increased, whereas SM sarcomere lengths were not different ($P = 0.588$) across all 8 slaughter age end-points. There is limited scientific data for sarcomere length in goats; however, Basinger et al (2012; 2013) observed goats slaughtered at approximately 8 mo of age to have sarcomere lengths ranging from 0.093 to 0.160 µm. Conversely, in another study, Boer-cross kids slaughtered at approximately 150 d of age had a sarcomere length averaging 1.62 µm (King et al., 2004). In the current study, cooking loss for LM samples increased (linear, $P = 0.044$) as d of age at slaughter increased, with the highest amount of LM cooking loss being at 315 d of age. Cooking loss of the SM increased (quadratic, $P = 0.033$) with peak losses at 405 and 450 d of age at slaughter. Warner-Bratzler shear force values for LM were not different ($P > 0.05$) across slaughter age groups; however, for SM and BF shear force values increased (linear, $P < 0.001$) from 135 to 450 d of age, with lowest values being at 180 d and peak values at 450 d of age at slaughter. Basinger et al. (2012; 2013) reported LM shear force values from kids slaughtered at approximately 8 mo of age to range from 1.8 to

7.29 kgf. In another study, Johnson et al. (1995) reported shear force values of goats slaughtered at 6 to 8 mo of age (6.5, 6.6, and 8.2 kgf, respectively) for LM, BF, and SM.

Conclusion

Goat kids grew at a linear rate as d of age increased over the duration of the project. There were two major growth periods from 225 to 270 and 315 to 360 d of age observed by goats slaughtered at 8 different age end-points. Age at slaughter had a significant influence on hot carcass weight, cold carcass weight, dressing percentage, and loin eye area, having increased with increasing d of age. Fat content increased and moisture content decreased as d of age increased in all muscles sampled. Protein content of the LM decreased as age increased, but age did not affect protein content in SM and BF muscles. Muscles became darker as age at slaughter increased. Increasing *a** values were observed in the LM and BF as age increased, whereas older goats had higher LM *b** compared to younger kids. Sarcomere length increased in the BF as age at slaughter increased, whereas LM lengths increased only until about 270 d of age, and SM sarcomere lengths were not affected by age at slaughter. Cooking loss increased as d of age increased for the LM and SM, but age did not affect BF cook loss. Longissimus muscle Warner-Bratzler shear force was not affected by age at slaughter, whereas SM and BF shear force values increased with increasing age. Therefore, goat producers can efficiently raise goats to slaughter up to 270 d of age to produce larger carcasses to provide more meat for increased demand in the market without detrimentally effecting meat tenderness.

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Table 2.1. Diets offered to goat kids throughout pre- and post-weaning periods.

	Diets[a]	
Item[b]	CF	FF
Corn, %	73.99	82.50
SBM, %	26.01	17.50
CP, %	17.9	14.1
NDF, %	28.19	24.51
ADF, %	3.29	2.72

[a] CF = Creep feed (d 0 to 99); FF = Full feed (d 99 to slaughter).
[b] SBM = Soybean meal, 47%; CP = Crude protein; NDF = Neutral detergent fiber; ADF = Acid detergent fiber.

Table 2.2. Effect of age at slaughter on live animal shrink, carcass weights and dressing percentage of goat kids.

Item[2]	Age at slaughter, d								SEM	*P*-value[1]	
	135	180	225	270	315	360	405	450		LIN	QUAD
Pre-weight, kg	17.77^{d}	24.04^{cd}	31.30^{c}	31.19^{c}	34.60^{c}	45.96^{b}	49.05^{ab}	56.15^{a}	3.344	<0.001	0.497
Post-weight, kg	17.16^{d}	23.13^{cd}	31.53^{c}	30.16^{c}	32.92^{c}	46.19^{b}	49.18^{ab}	56.16^{a}	3.393	<0.001	0.407
Shrink, %	3.75^{a}	3.99^{a}	-0.66^{b}	3.15^{a}	5.03^{a}	-0.27^{b}	-0.05^{b}	0.12^{b}	1.048	0.006	0.602
HCW, kg	6.62^{d}	10.51^{d}	15.14^{cd}	14.83^{cd}	16.59^{c}	22.19^{b}	24.53^{ab}	27.94^{a}	1.846	<0.001	0.747
CCW, kg	6.96^{d}	9.98^{ab}	14.74^{cd}	14.03^{cd}	15.94^{c}	21.20^{b}	23.75^{ab}	26.72^{a}	1.765	<0.001	0.612
CS, %	1.27^{c}	5.35^{ab}	2.92^{bc}	5.55^{a}	4.29^{ab}	4.60^{ab}	3.32^{b}	4.41^{ab}	0.706	0.129	0.017
DP, %	40.90^{c}	45.51^{b}	47.69^{b}	48.95^{ab}	50.27^{a}	48.08^{b}	49.62^{ab}	49.55^{ab}	0.834	<0.001	<0.001

$^{a-d}$Within a row, least squares means lacking common superscript letters differ, $P < 0.05$.
[1]Probability values for linear (LIN) and quadratic (QUAD) effects of slaughter age.
[2]Pre-weight = live weight before transportation; Post-weight = live weight after transportation; Shrink = percentage of live weight difference from pre- and post-transportation weight; HCW = Hot carcass weight; CCW = Cold carcass weight; CS = Cooler shrink (percentage of carcass weight difference from pre- and post-chill period); DP = Dressing percentage.

Table 2.3. Effect of age at slaughter on carcass measurements of goat kids.

Item[2]	Age at slaughter, d								SEM	*P*-value[1]	
	135	180	225	270	315	360	405	450		LIN	QUAD
Conformation	3.13^{a}	2.42^{ab}	2.94^{ab}	2.49^{ab}	2.32^{b}	2.03^{b}	1.86^{b}	1.65^{b}	0.287	0.003	0.738
Fat	1.17^{b}	1.00^{b}	1.88^{a}	1.94^{a}	.	2.08^{a}	2.29^{a}	1.90^{a}	0.211	<0.001	.
KPH, %	2.39^{b}	2.71^{b}	4.24^{a}	2.78^{b}	2.35^{b}	3.67^{ab}	3.44^{ab}	4.11^{a}	0.449	0.040	0.693
LEA, cm^2	3.49^{b}	4.62^{b}	4.48^{b}	5.97^{a}	4.68^{b}	6.94^{a}	6.95^{a}	6.53^{a}	0.496	<0.001	0.375
6 h pH	6.14	5.47	6.51	6.45	5.83	6.16	5.64	6.76	0.200	0.216	0.450
24 h pH	6.13^{a}	5.53^{c}	5.57^{c}	5.94^{b}	5.91^{b}	5.96^{b}	5.85^{b}	6.04^{ab}	0.062	0.022	0.001
6 h Temp, ºC	7.60^{bc}	6.67^{c}	7.78^{bc}	8.59^{b}	6.63^{c}	10.15^{a}	7.46^{bc}	2.30^{d}	0.538	0.007	<0.001
24 h Temp, ºC	4.83^{ab}	5.90^{a}	3.00^{bc}	6.06^{a}	1.30^{c}	2.98^{bc}	5.50^{a}	3.44^{b}	0.645	0.076	0.091

[a – d]Within a row, least squares means lacking common superscript letters differ, $P < 0.05$.
[1]Probability values for linear (LIN) and quadratic (QUAD) effects of slaughter age.
[2]Conformation subjective scoring (1.00 to 3.99) according to McMillin and Pinkerton (2008); Subcutaneous fat covering subjective scoring (1 to 3) according to McMillin and Pinkerton (2008); KPH = Kidney, pelvic, heart fat; LEA = Loin eye area; Temp 6 = temperature recorded 6 h postmortem; Temp 24 = temperature recorded at 24 h postmortem.

Table 2.4. Effect of age at slaughter on proximate analysis and individual muscle weights of goat kids.

Item	Age at slaughter, d								SEM	*P*-value[1]	
	135	180	225	270	315	360	405	450		LIN	QUAD
Longissimus thoracis											
Weight, g	144.33[c]	224.00[c]	315.50[bc]	369.50[b]	374.29[b]	502.00[a]	512.29[a]	523.20[a]	42.156	<0.001	0.173
Moisture, %	76.67[a]	75.36[ab]	75.33[ab]	74.08[bc]	73.54[c]	71.49[d]	73.01[c]	73.18[c]	0.483	<0.001	0.005
Fat, %	6.18[c]	6.71[c]	8.75[bc]	7.99[c]	9.54[bc]	17.34[a]	13.36[ab]	14.82[ab]	2.091	<0.001	0.965
Protein, %	15.34[ab]	13.92[bc]	14.31[bc]	13.64[c]	17.21[a]	13.66[bc]	13.66[c]	12.79[c]	0.655	0.038	0.126
Semimembranosus											
Weight, g	80.67[c]	122.67[bc]	148.00[bc]	185.00[b]	190.86[b]	206.33[ab]	208.86[ab]	264.00[a]	25.597	<0.001	0.555
Moisture, %	77.19[a]	75.32[bc]	76.05[b]	74.51[c]	74.55[c]	73.63[d]	75.02[c]	75.16[bc]	0.292	<0.001	<0.001
Fat, %	6.72	6.42	7.38	7.38	8.16	9.73	8.4	9.91	1.215	0.025	0.892
Protein, %	13.87	13.92	14.45	13.75	14.64	13.44	14.13	13.21	0.346	0.231	0.085
Biceps femoris											
Weight, g	85.00[c]	137.33[c]	194.00[bc]	187.00[bc]	237.71[b]	254.67[ab]	294.00[ab]	316.80[a]	26.929	<0.001	0.523
Moisture, %	76.80[a]	74.77[bc]	75.59[ab]	74.17[c]	74.08[c]	72.48[d]	74.61[bc]	74.49[bc]	0.456	<0.001	<0.001
Fat, %	8.08[c]	10.41[bc]	9.61[bc]	9.76[bc]	11.35[bc]	15.72[a]	12.14[ab]	13.19[ab]	1.463	0.003	0.600
Protein, %	14.13	13.54	13.98	13.49	17.70	14.15	13.16	12.78	1.093	0.652	0.091

[a – d]Within a row, least squares means lacking common superscript letters differ, $P < 0.05$.
[1]Probability values for linear (LIN) and quadratic (QUAD) effects of slaughter age.

Table 2.5. Effect of age at slaughter on instrumental color of goat muscles.

	Age at slaughter, d									*P*-value[1]	
Item[2]	135	180	225	270	315	360	405	450	SEM	LIN	QUAD
Longissimus thoracis											
L*	44.24^{a}	45.53^{a}	39.20^{b}	41.29^{ab}	39.22^{b}	39.80^{b}	40.79^{ab}	38.44^{b}	1.421	0.004	0.170
a*	20.12^{d}	19.37^{d}	22.65^{bc}	21.22^{cd}	21.21^{cd}	21.87^{bc}	24.38^{a}	22.90^{ab}	0.578	<0.001	0.919
b*	13.26	14.23	15.45	13.74	12.86	13.23	16.18	14.39	0.637	0.236	0.557
Semimembranosus											
L*	46.56^{a}	43.07^{ab}	40.08^{b}	41.74^{b}	40.99^{b}	38.11^{b}	38.15^{b}	39.68^{b}	1.234	<0.001	0.021
a*	17.58	17.77	19.52	18.88	18.51	19.83	20.56	18.58	0.828	0.113	0.194
b*	10.47	8.51	9.62	9.72	8.75	9.88	10.78	8.66	0.931	0.922	0.841
Biceps femoris											
L*	46.65^{a}	47.72^{a}	43.05^{bc}	45.86^{ab}	42.95^{c}	41.64^{c}	40.52^{c}	42.87^{c}	1.022	<0.001	0.207
a*	17.85	18.87	19.66	19.65	19.00	19.47	21.40	19.82	0.746	0.026	0.485
b*	9.97	11.18	9.53	11.06	9.48	9.06	11.85	10.15	0.768	0.887	0.592
Rectus femoris											
L*	51.73^{a}	47.75^{ab}	46.56^{b}	45.20^{b}	44.07^{bc}	41.44^{bc}	43.33^{bc}	41.13^{c}	1.353	<0.001	0.074
a*	18.85	18.82	22.29	22.09	20.71	20.00	21.18	21.94	0.936	0.102	0.192
b*	10.36	10.37	13.78	12.86	9.19	9.44	10.01	11.73	1.108	0.619	0.724

$^{a-d}$Within a row, least squares means lacking common superscript letters differ, $P \leq 0.05$.

[1]Probability values for the linear (LIN) and quadratic (QUAD) effects of age at slaughter.

[2]L* values are a measure of darkness to lightness (a greater L* value indicates a lighter color); a* values are a measure of redness (a greater a* value indicates a redder color); and b* values are a measure of yellowness (a greater b* value indicates a more yellow color).

Table 2.6. Effect of age at slaughter on goat meat sarcomere length, cooking loss, and Warner-Bratzler shear force values.

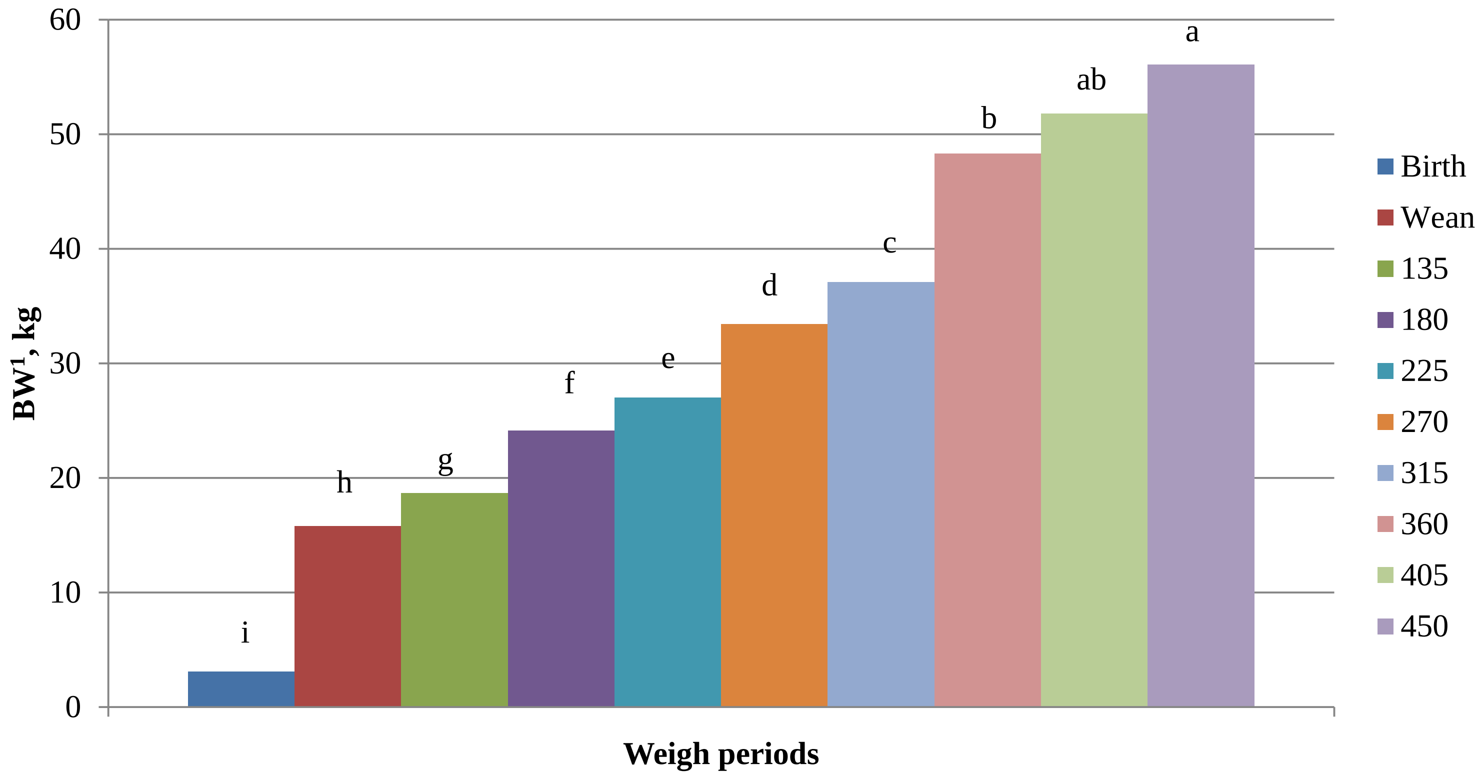
Item[2]	Age at slaughter, d								SEM	*P*-value[1]	
	135	180	225	270	315	360	405	450		LIN	QUAD
Longissimus thoracis											
Sarc, µm	1.43^{b}	1.32^{b}	1.33^{b}	1.69^{a}	1.40^{b}	1.44^{b}	1.42^{b}	1.33^{b}	0.066	0.806	0.054
CL, %	21.88^{b}	24.73^{ab}	23.01^{ab}	21.18^{b}	25.58^{a}	23.24^{ab}	24.07^{ab}	27.28^{a}	1.356	0.044	0.252
WBSF, kg	3.74	5.97	4.40	5.34	4.942	3.76^{b}	2.97	5.43	0.500	0.440	0.685
Semimembranosus											
Sarc, µm	1.44	1.35	1.37	1.50	1.43	1.39	1.45	1.30	0.055	0.588	0.188
CL, %	30.07^{b}	32.48^{ab}	31.80^{ab}	29.99^{b}	30.24^{b}	30.31^{b}	33.53^{a}	34.87^{a}	1.150	0.039	0.033
WBSF, kg	4.53^{bc}	3.95^{c}	5.07^{b}	4.76^{b}	4.50^{bc}	5.04^{b}	4.63^{bc}	6.00^{a}	0.237	<0.001	0.074
Biceps femoris											
Sarc, µm	1.37^{ab}	1.23^{b}	1.39^{ab}	1.47^{ab}	1.36^{b}	1.56^{a}	1.40^{ab}	1.56^{a}	0.068	0.010	0.881
CL, %	22.74^{b}	24.91^{ab}	28.38^{a}	25.97^{ab}	27.26^{a}	27.64^{a}	26.01^{ab}	26.85^{a}	1.279	0.072	0.036
WBSF, kg	3.55^{d}	3.52^{d}	4.58^{bc}	4.65^{bc}	4.30^{c}	5.20^{b}	4.54^{bc}	6.76^{a}	0.252	<0.001	0.069

$^{a-d}$Within a row, least squares means lacking common superscript letters differ, $P < 0.05$.

[1]Probability values for linear (LIN) and quadratic (QUAD) effects of slaughter age.

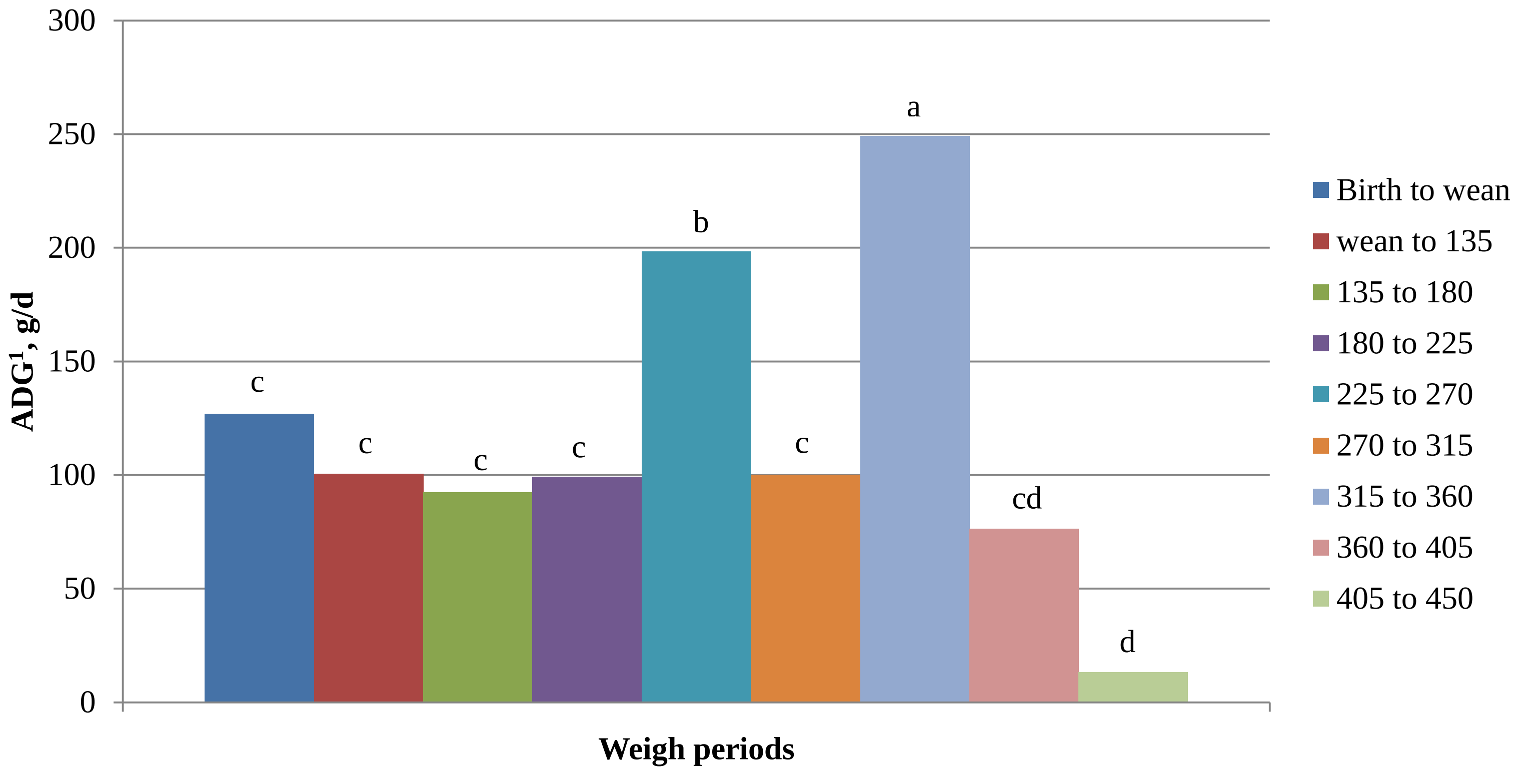
[2]Sarc = Sarcomere length; CL = Cooking loss; WBSF = Warner-Bratzler shear force.

Figure 2.1. Effect of age at slaughter on live weight of goat kids.



[a – i]Within a row, least squares means lacking common superscript letters differ, $P < 0.05$.
[1]Probability values for linear ($P < 0.001$) and quadratic ($P = 0.934$) effects of slaughter age.

Figure 2.2. Effect of age at slaughter on average daily gain of goat kids.



[a – d]Within a row, least squares means lacking common superscript letters differ, $P < 0.05$.
[1]Probability values for linear ($P = 0.255$) and quadratic ($P < 0.001$) effects of slaughter age.

Conclusion

Due to an increase in demand of goat meat in the market and the ability to add on-farm income to producers, meat goat production is rapidly growing in popularity in the United States. Animal performance is an important aspect that can be influenced by age, especially during critical growing periods, such as the first few months of life. Goat growth rates have been researched to some extent during both pre- and post-weaning growth periods, but findings are not consistent. Goat kids slaughtered at 8 different age end-points ranging from 135 to 450 d of age grew at a linear rate as d of age increased over the duration of the project. Currently there are no USDA quality or yield grades for goats, but they are still under inspection during slaughter when the meat is intended for public consumption. As hypothesized, carcass measurements (weights, DP, LEA, etc.) are influenced by age of the animal and increase as chronological age increases, but have not been extensively observed in goats. Age at slaughter had a significant influence on carcass characteristics such as HCW, CCW, DP, and LEA, where measurements increased with increasing d of age for goat kids slaughtered at ages ranging from 135 to 450 d of age. Consumers in the market use visual color to determine the value of meat they purchase and lean color of goat meat can be influenced by age, such as young kids (cabrito) having a lighter color compared to older animals where L^* values of the LM, SM, BF, and RF decreased as age at slaughter increased for kids slaughtered at 8 different age end-points ranging from 135 to 450 d of age. Tenderness is an influential factor for consumers and influenced by age of the animal at time of slaughter, normally with younger animals having more tender meat. Longissimus muscle Warner-Bratzler shear force was not affected by age at slaughter, whereas SM and BF shear force values increased with increasing age as kids were slaughtered from 135 to 450 d of age. Meat quality characteristics, such as sarcomere length are virtually nonexistent in the literature for goat meat, but our study found sarcomere length increased in the BF as age at slaughter increased, whereas LM lengths increased only until about 270 d of age, and SM sarcomere lengths were not affected by age at slaughter. Most goat meat in the United States is consumed during the holidays, meaning that goats are slaughtered at a particular time of year instead of a particular age. Slaughter age end-points need to be further defined to help producers raise quality goat meat desired by consumers. Therefore, goat producers can raise goats to slaughter up to 270 d of age without majorly jeopardizing meat tenderness but also efficiently producing larger carcasses to provide more meat for increased demand in the market. With defined slaughter age end-points, producers have the ability to alter production practices to increase supply during demanding times in the market with quality goat meat.

IACUC Forms

From: Busalacki, Aimee

Sent: Friday, July 18, 2014 9:26 AM

To: Caldwell, James

Subject: ACUC approval notice

Dear Dr. Caldwell,

This email is to inform you that your ACUC project proposal “Age endpoint effect on carcass measurements and tenderness in goats” has been approved effective 6/9/14. Your project ACUC approval number for this proposal will be #14-14. Please use this for recording purposes. The project is approved as it is written for 3 years from this date. If you have any further questions or comments, please feel free to contact me. Thank you.

Aimee K. Busalacki, Ph.D.

Associate Professor of Biology

Department of Life & Physical Sciences

Lincoln University

125 Founders Hall

(573) 681-5123 (office)

(573) 681-5944 (fax)

busalackia@lincolnu.edu

modification to extend the protocol in order to avoid any interruptions.

UNIVERSITY OF ARKANSAS

Office of Research Compliance

MEMORANDUM

To:	Jason Apple
From:	Craig Coon, IACUC Chair
Date:	February 06, 2015
Subject:	IACUC Approval
Expiration Date:	February 5, 2017

The Institutional Animal Care and Use Committee (IACUC) has APPROVED your protocol # 15032 "Age endpoint effect on carcass measurements and tenderness in goats"

In granting its approval, the IACUC has approved only the information provided. Should there be any further changes to the protocol during the research, please notify the IACUC in writing (via the Modification form) prior to initiating the changes. If the study period is expected to extend beyond February 5, 2017 you can submit a modification to extend project up to 3 years, or submit a new protocol. By policy the IACUC cannot approve a study for more than 3 years at a time.

The IACUC appreciates your cooperation in complying with University and Federal guidelines involving animal subjects.

CNC/aem
cc: Animal Welfare Veterinarian

Administration Building 210 • 1 University of Arkansas • Fayetteville, AR 72701-1201 • 479-575-4572
Fax: 479-575-3846 • http://vpred.uark.edu/199