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Live and Carcass Characteristics of Boer- and Savannah-Cross Kid Buckling Goats Fed Dried Distillers Grain with Solubles

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LIVE AND CARCASS CHARACTERISTICS OF BOER- AND
SAVANNAH-CROSS KID BUCKLING GOATS FED DRIED
DISTILLERS GRAIN WITH SOLUBLES

A Thesis

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Master of Science

in

The School of Animal Sciences

by
James Neil Maynard
B.S., The Ohio State University, 2012
August 2015

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ABSTRACT

The available supply of domestic goat meat has not matched the increased demand for goat meat. High cost of production is a concern of goat producers, with feed being a major factor in input expenses. Increasing slaughter weight of kid meat goats would increase the available goat meat, but requires added nutrition beyond that obtained from typical forage based systems for goat production. Savannah bucklings (n=31) and Boer bucklings (n=28) were stratified by weight and breed and were randomly assigned a treatment of 0 (T1), 15 (T2), 30 (T3), or 45 (T4) percent dried distillers grain with solubles (DDGS). One goat from each pen was harvested on day 0 (H1), and every 21 days (H2, H3, H4) so that equal numbers of goats from each breed were sacrificed each harvest time. Bucklings and feed refusal were weighed weekly. Data was analyzed for ANOVA using Proc Mixed for fixed effects of treatment, harvest time and breed. There were no significant interactions for any traits measured. Breed did not affect ($P>0.05$) live performance, carcass traits, or cutability. Average daily gains (ADG) tended to linearly decrease with inclusion of DDGS, but significant difference were only observed in the second 21 days with T4 goats having the lowest ($P<0.05$) ADG. Treatment had no effect on feed efficiency. Goats in H4 had the highest ($P<0.05$) 1 and 3-hour temperatures and goats in H1 had the lowest ($P<0.05$) 1 and 3-hour pH values. The H4 carcasses had the largest ribeye areas and heaviest weights for most primal cuts. Carcasses and most primal cut weights of T4 goats were lighter ($P<0.05$) than those of goats in T1 and T2. Percentage of primal cuts in relation to the cold carcass did not differ ($P>0.05$) for treatments, but were influenced by harvest time. Warner-Bratzler shear force did not differ ($P>0.05$) for treatments and harvest time. The level and length of time feeding

DDGS can affect goat carcass characteristics. This study found no differences in live traits, carcass characteristics, or meat from Boer- and Savannah-cross buckling kid goats.

CHAPTER 1: INTRODUCTION

Historically, goats in the U.S. were produced for mohair production, but the industry transformed in the 1990's and now is largely concentrated for the purpose of meat production (NASS, 2011). The demand for goat meat continues to rise (Pinkerton and McMillin, 2014a), while the supply of domestic goat has declined 11% in the past seven years (Pinkerton, 2014a). A USDA funded survey by LSU researchers reported that goat producers identify the high cost of production as a negative impact on goat production (Gillespie et al., 2013). In all livestock enterprises, the single greatest production expense is feed (Solaiman, 2010).

It is estimated that 79% of producers sell directly to the consumer, while 65 % utilize live auctions (Gillespie et al., 2013). An estimated 100,000 goats were harvested in non-inspected, informal settings in 2013 (Pinkerton and McMillin, 2014b). It is typical of commercial producers to sell goats directly after they have been weaned. Very few kid goats are finished in confinement feeding in contrast with the cattle, swine, and lamb industries. Ethnic consumers do not wish to purchase goat meat containing fat, limiting the time that goats can be fed concentrate diets (Pinkerton and McMillin, 2013). Over conditioned goats have been typically subjected to lower prices, although the price differentials have decreased with the lower supply of market kid goats in 2014 (Pinkerton, 2014b). Feeding concentrate diets have been shown to significantly improve live performance and carcass quality of goat kids, although inclusions of concentrates increase the quantity of fat (Ryan et al., 2007; Safari et al., 2009). One suggested way to increase market share of goat meat is by increasing the size of market goats sold (Pinkerton and McMillin, 2014b). Traditional grains such as soybean meal are expensive

and do not provide a cost benefit to feed goats, while some byproducts might be an appropriate replacement.

Dried distillers grain with solubles (DDGS) is an affordable protein source to replace soybean meal in growing lamb and goat diets (Huls et al., 2006; Gurung et al., 2009). Dried distillers grain with solubles is a byproduct that remains after dry-grind ethanol plants extract ethanol from grain, typically corn (USGC, 2012). Some producer concerns include the nutrient variability between batches that occur during the drying phase, along with the high sulfur content of DDGS (USGC, 2012).

While limited research has been reported on the effect of DDGS on goat production, no literature sources gave data for a 100% concentrate diet. Producers are seeking information on the cost benefit of finishing kid goats on 100% concentrate diets in order to increase live weights and/or conformation. Furthermore, no data is available to compare the live performance and carcass characteristics of Boer and Savannah bucklings in a feedlot setting. The objective of this study was to determine the effects of 0, 15, 30, and 45% DDGS on live performance, carcass traits and meat characteristics of Boer and Savannah cross buckling kid goats.

CHAPTER 2: REVIEW OF LITERATURE

2.1 History of U.S. Goat Production

The goat industry has experienced drastic changes involving inventory and types of production in the last 20 years, debatably more than any other livestock commodity. Prior to the early 1990's, the majority of goats in the United States were bred for fiber production (NASS, 1990). The primary fiber goat breed is the Angora produced for their mohair production, which is used for fine apparel and carpets (Anderson, 2001). In 1993, U.S. Congress passed a bill phasing out the Wool Act of 1954, with incentive payments for wool and mohair planned to cease in 1996 (Anderson, 2001). Since then, the numbers of Angora goats have declined, and market experts predict a continual trend is inevitable (Pinkerton and McMillin, 2014b). In the same year of Congress' decision, the introduction of the Boer goat breed into the U.S. transformed the goat industry (Machen, 1997).

The inclusion of this new meat breed, coupled with an increase in goat meat consumers to the United States, opened new avenues for producers. When the Boer goat first arrived in the U.S., their value far exceeded practical affordability for commercial producers. With the increase in supply of full blood goats, as well as the high value for commercial slaughter kids, commercial producers can now afford to improve their herd with high quality genetics (Machen, 1997).

Thirty-five percent of producers raising goats for meat have been in the industry for five years or less compared to 15.4% and 22.9% for fiber and dairy goat producers respectively (APHIS, 2012). Currently, many breeds of goats are used in U.S. meat production, including Boer, Kiko, Spanish, Savannah, and Myotonic goats (Gurung and

Solaiman, 2010), along with dairy and fiber breeds when less superior kids are produced or when production falls below the operation's desired threshold (Pinkerton and McMillin, 2014b). A survey of 584 operations found that 75% of operations use Boer goats, 32% use Kiko, 10% use Spanish, 32% use mixed goats, and <10% of producers use various breeds (Gillespie et al., 2013). Significant variation has been reported within different breeds of meat goats for carcass yield traits (Browning, 2012).

2.2 Major Breeds in Meat Production

2.2.1 The Boer Goat

The Boer goat breed was developed in the Eastern Cape of South Africa in the early 1900's using different indigenous breeds to provide a superior meat breed (Malan, 2000). The Improved Boer Goat registry of South Africa was developed in the summer of 1959 to build upon and improve this breed (Machen, 1997). The breed was introduced to the U.S. through New Zealand, and then later from Australia due to the restrictions for importations from South Africa directly into the United States (Blackburn and Gollin 2009). Easily recognized by their white body and brown/red head, the Boer goat brought a higher level of muscling and conformation that was uncommon in the United States (Machen, 1997). Boer kids are fast growing, with suggested feedlot average daily gains of 0.2 kg (0.44 lb.) (Gurung and Solaiman, 2010). The Boer goat exhibited three criteria that Blackburn and Gollin (2009) credited towards their success in becoming an economically viable breed. These were being able to “comparatively produce in the environment compared to the previous breeds, possess multiple superior traits that cannot be found in current residing breeds, and capture breeder's interest to the extent that a large enough population will arise.” Blackburn and Gollin (2009) credited the easily

marketable conformation coupled with its rapid growth weight for allowing the Boer breed to establish quickly. Likewise, concerns of over-introduction of Boer breeding in other breeds and reducing the numbers of goats indigenous to the U.S. are a relevant threat and have led to some small producers maintaining pure bloodlines of native goats (Blackburn and Gollin, 2009).

2.2.2 The Savannah Goat

The Savannah goat, like the Boer goat, came from South Africa. The Savannah breed developed on DSU Cilliers and Sons ranch with a group of indigenous does and a large white buck. After generations of natural selection in the harsh savanna conditions, the breed caught interest and a breed association was developed in 1993. The Savannah goat is characterized as being all white, with dark pigmented skin everywhere (Campbell, 1999). Their all white color may be advantageous for marketing goats for religious ceremonies (Gurung and Solaiman, 2010). The first Savannah goats came to the U.S. in 1994, but a lack of registry in the United States contributed to their ancestry records being lost. In 1999, Brian Payne with Keri-Rose Livestock and Consulting, who was also a major contributor to the introduction of the Boer goat breed, imported Savannah embryos into Canada, and then later to the United States (Payne, 2013). The North American Savannah Association currently emphasizes performance testing and the contribution of the Savannah breed on increasing revenue for commercial goat producers (Payne, 2013).

2.2.3 The Kiko Goat

The Kiko breed originated in New Zealand through the mating of feral females with bucks from dairy breeds including Anglo Nubian, British Toggenburg, and Saanen. After generations of interbreeding, the Kiko was selected based on survivability and weight gain in pasture conditions (Batten, 1987). The breed was established in 1986, and imported into the United States in the 1990's (Gurung and Solaiman, 2010). The Kiko goat is a meat breed, but they are highly credited for their mothering ability and longevity in a herd. Kiko dams should be preferred over Spanish and Boer does for increased birth to weaning performance of kids (Browning and Leite-Browning, 2011). Kiko dam offspring have shown to have higher pre-weaning average daily gains compared to offspring of Boer dams (Browning and Leite-Browning 2009). Furthermore, Browning and Leite-Browning (2009) reported Boer dams to have more incidences of lameness requiring hoof care compared to Kiko dams. Kiko dams have also been reported to have fewer difficulties from internal parasites compared to Boers (Browning and Leite-Browning, 2009). It is suggested that this is due to the differences in the environments in which the breeds originated. Carcasses from Boer goats have been reported to have more desirable carcass scores than those from Kiko goats although there were no differences in boneless meat yields (Browning et al., 2012). Different combinations of the popular Boer X Kiko offspring are referred to as American BoKi, International MeatMaker, or American MeatMaker (Gurung and Solaiman, 2010). In 2003, a genetic improvement program began in New Zealand to create a breed called Kikonui using Kiko goats and focusing on survival, adaptability, and superior reproductive and growth rates (Batten, 2014).

2.2.4 The Myotonic Goat

The myotonic goat has many names including the Tennessee fainting goat, Tennessee wooden-leg goat, and the nervous goat (Gurung and Solaiman, 2010). Little is known about the true origination of the breed, but it is believed that John Tinsley, alleged to be from Canada, moved to Tennessee in the 1800's with four goats that would unusually stiffen up when scared. A second theory is that the goats were a result of a spontaneous mutation in a Tennessee herd around 1885 (OSU, 2004). The condition that makes these goats unusual is referred to as myotonia congenital. This genetic disorder causes muscle cells to experience prolonged contractions (SVF, 2011) This muscle contraction is referred to as fainting, although it is not a true faint because it is not neurological (Pryce, 2014). These contractions can vary in severity, from not noticeable to goats falling down for multiple seconds. Similar conditions observed in other animals, including humans, have indicated that the contractions are painless (Pryce, 2014). The myotonia congenital disorder is a recessive condition and not expressed in crossbred offspring (Gurung and Solaiman, 2010). The population of myotonic goats is small, and breed conservation groups have intervened to ensure continuation of the breed. There has been very little research reported on the live performance or carcass quality of myotonic goats. It is suggested that there is an increased tenderness of meat from myotonic goats (Gurung and Solaiman, 2010).

2.2.5 The Spanish Goat

Prior to the early 1990's and the introduction of multiple meat breeds of goats, the Spanish goat was a large contributor to the goat meat consumed in the U.S. The term Spanish suggests that the goat arrived to the United States through Mexico, but this is not

always precise (Shelton, 1978). In the southwestern United States, the term Spanish is often used to refer to a goat that is not of Angora or dairy descent, and is considered a “brush” goat (Shelton, 1978).

The hardiness of this breed has established through natural selection in the harsh conditions of Texas and Mexico (Shelton, 1978), and has made it a popular cross with the Boer goat (Rhone, 2013). Typically in producing Boer X Spanish cross goats, the dam is preferred to be the Spanish goat. Spanish does have been reported to have higher birth weights when crossed with a Boer buck, compared to Boer dams on Spanish bucks, although weaning weights were not significant (Browning and Leite-Browning, 2011). Furthermore, no differences in dressing percentages were reported between kids of Spanish and Boer dams (Browning and Leite-Browning, 2011). There is immense variation between Spanish goats, and proper evaluation and selection should take place before acquiring them (Shelton, 1978).

2.2.6 The Angora Goat

The Angora goat originated in the mountainous regions of Central Asia (Webb et al., 2012). Identified by their long silver-white hair, the Angora is suitable for warm and cold regions, but not adapted to humid climates (Webb et al., 2012). The Angora breed has been genetically selected for their mohair production, which should grow at a minimum of 2.54 centimeters per month (AAGBA, 2011). Mohair production was popular in the United States, but the Angora breed has been declining in inventory since 1989 (NASS, 2011). The Angora goat inventory in 1989 consisted of almost 2 million head (NASS, 2011), substantially greater than the estimated 2013 inventory of 140,500 (NASS, 2014). Despite favorable prices of \$4.25 (NASS, 2014) and \$4.85 (NASS, 2015)

per pound, the United States produced an estimated 16.2 million pounds less mohair than in 1988 (NASS, 2011). The government established an incentive program for both wool and mohair in 1954, but in 1993, Congress passed a phase out of the program, which ended in 1996 (Anderson, 2001). In the mid 1990s, 85% of mohair production was exported to India and the United Kingdom to be processed, and shipped to other countries including the former Soviet Union. A decrease in government support, combined with struggling exports and drought conditions led to the decline in Angora goat inventory (Anderson, 2001), which industry experts expect to never return to previous production stature (Pinkerton and McMillin, 2014b). A slight promising increase was observed between 2014 and 2015, but is yet to be seen if this trend continues (NASS, 2015).

2.2.7 Dairy Goats

Dairy goats are genetically selected for milk production, and therefore are physiologically different than meat goats. Dairy breeds are referred to as being wedge shaped, compared to the square and stout adjectives used to describe meat breeds (Webb et al., 2012). Dairy goats contribute to the supply of domestic goat meat through wethers and culls (Pinkerton 2014b). In 1992, dairy goats had the fewest numbers of the three main types of goats, but in 2014 there were more dairy goats than Angora goats, but still much lower than meat goats (Pinkerton and McMillin, 2015). As of January 1st, 2015, the U.S. inventory for dairy goats was 365,000 head (Pinkerton and McMillin, 2015). The most prominent breeds of dairy goats in the U.S. include the Alpine, LaMancha, Nubian, Oberhasli, Saanen, and Toggenburg (Park and Haenlein, 2010). The Alpines originated in Switzerland and are known for their excellent milking ability. The LaMancha is the only major dairy breed originating in the United States, and are easily identified by their short

ears. LaMancha females do not produce the quantity of milk as other breeds, but are more utilized for their high fat content. The Nubian was developed in England and is recognized as an all-purpose breed. The Nubian is typically all brown with speckled ears, and are a more muscular type dairy goat that can be used in mostly tropical countries to upgrade milk fat and meat. The Oberhasli originates from the mountains of Switzerland and are recognized for their dark color and black stripes on their face. The Saanen originated in the Saanen Valley of Switzerland, and is known as the most prestigious of all dairy breeds. The Saanen breed is characterized by large, heavy milking goats, and are one of the most widely distributed dairy goat breeds in the world. The Toggenburg originated in northeastern Switzerland and are recognized as the oldest known Swiss dairy goat breed. Toggenburgs are a slightly smaller breed that produces best in cooler environments (Gurung and Solaiman, 2019). People worldwide consume milk produced by goats more than any other livestock and dairy goats are a vital protein source especially to underdeveloped countries (Park and Haenlein, 2010).

2.3 Current Industry

Mohair production in the United States have continued to decline in the 21st century, despite prices being consistently high, \$4.25 per pound in 2013 (NASS, 2014), and \$4.85 in 2014 (NASS, 2015). A slight increase in angora goats was observed between 2014 and 2015 (NASS, 2015). An overview of the sheep and goat industry reported that 82% of goats are used for meat production (NASS, 2014) while slightly more than 70% were reportedly used for meat in 2009 (NAHMS, 2009). The 2015 report in Figure 1 shows the trend for total goat numbers, meat goats, angora goats, and milk goats in the United States over the last 24 years (Pinkerton and McMillin, 2015). As the

size of an operation increases, the percentage of goats used for meat production increases, whereas the percent of goats utilized for pets or brush control decreases (NAHMS, 2009). The size of meat goat operations varies with the source of the information. As of 2010, the average meat goat operation consisted of approximately 20 head, with approximately 128,000 operations (NASS, 2011) A survey of 584 operations in 2012 reported the average farmer owned 36 breeding age does (Gillespie et al. 2013). Meat and other goats, excluding dairy and fiber, amounted to 2.28 million goats in the United States at the beginning of 2014 (NASS, 2014). Texas leads the U.S. with 870,000

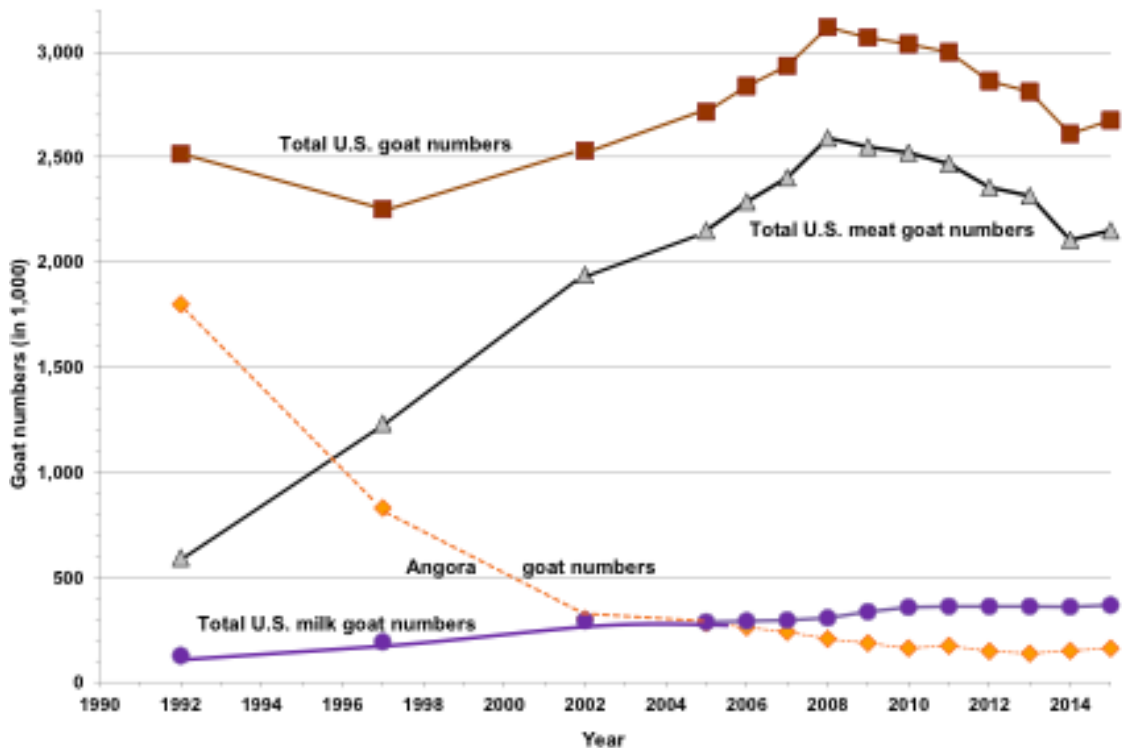


Figure 1. Trends in total goat numbers, meat goats, Angora goats, and milk goats in the United States.

head (NASS, 2014). The national number of meat goats is still currently in decline, down two percent from 2013, and slightly over twelve percent from the national high in 2008 (NASS, 2014). This decline is highly credited to the record drought conditions observed

in the Southwest (Pinkerton and McMillin, 2014b). The number one challenge facing producers is the high cost of producing goats (Gillespie et al., 2013). Like the goat industry, cattle and sheep have also observed a steady decline in inventory over this time although there was a reported 2.4% increase in Texas goat numbers, which suggest that the consequences of the drought are beginning to subside (NASS, 2014). Some industry experts remain optimistic that given ideal weather conditions, the national goat inventory will rise again (Pinkerton and McMillin, 2014a), and early 2015 reports appear to be optimistic (Pinkerton and McMillin, 2015). In regards to increasing U.S. meat goat inventory, it is recommended to increase the number of goat farms, the size of herds, the size of goats being marketed, the number of kids per doe, or a combination of these solutions (Pinkerton and McMillin, 2014b).

Domestic goat slaughter numbers have a similar trend as the national inventory numbers, with a steady decline from the peak in 2008. In 2013, 689,200 goats were harvested in federal and state inspected plants (Pinkerton and McMillin, 2014b). Figure 2 illustrates the annual domestic slaughter and the imports as a percent of the total estimated number of animals. An important note is that before 2006, values are from slaughter in federally inspected plants, and after 2006, the numbers included slaughter from federal and state inspected plants (Pinkerton and McMillin, 2014b). It is predicted that 100,000 additional goats are slaughtered annually in uninspected conditions and not recorded in official data (Pinkerton and McMillin, 2014b).

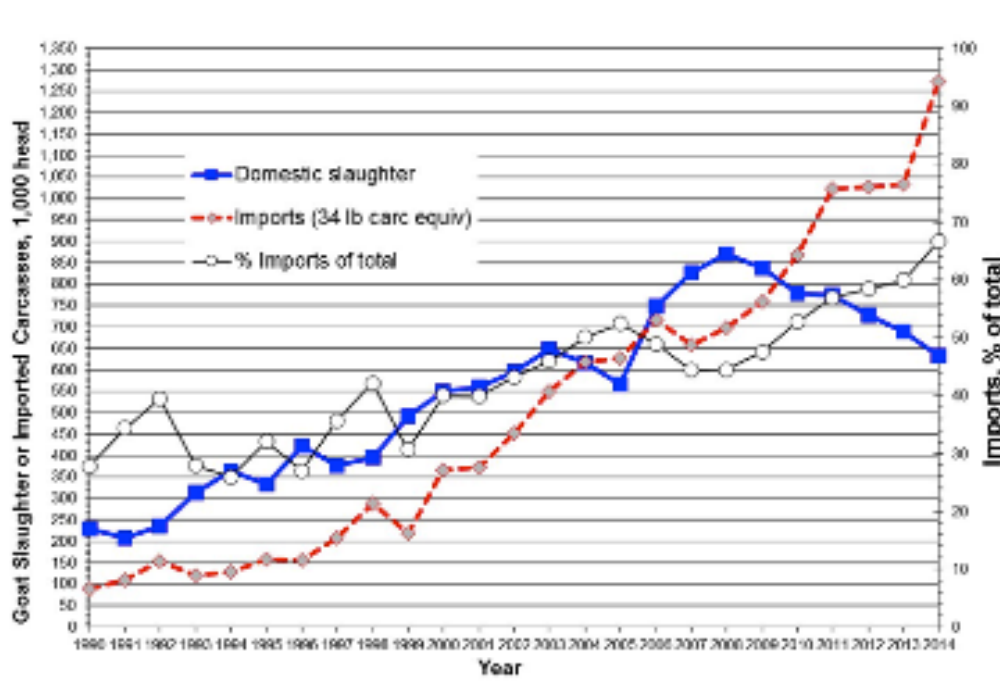


Figure 2. Domestic slaughter and import trend over the last 20 years

A survey of 584 farms reported that 79% of producers marketed their goats directly to the consumer (Gillespie et al., 2013). Ethnic demand is the major component for goat meat production (Sande et al., 2005), with many goats slaughtered for religious holidays such as Easter, Ramadan, and Christmas (Gillespie et al., 2013). The United States philosophy encourages people to celebrate their diverse cultural backgrounds (Sande et al., 2005). The annual growth of U.S. immigrant population from 1987-1990 was 3.7%, while the meat-goat herds increased approximately 9.6% annually during 1997-2000 (Sande et al., 2005). Goat consumption is part of many ethnic cultures, and quantities consumed have shown to be inelastic to changes in price (Sande and Houston, 2007). Opposing results have been reported by Worley et al. (2004), suggesting price is a key determinant in meat choices of Somali consumers.

Goat producers in the United States struggle to produce even half of the goat meat that is estimated to be consumed annually in the United States (Pinkerton, 2014).

Although goats are growing at a faster percent than any other U.S. livestock commodity, the U.S. is the largest importer of goat meat (Sande and Houston, 2007). The biggest exporter of goat is Australia, meeting about fifty percent of the demand for goats in the States (Pinkerton, 2014). As of 1998, Philadelphia, San Francisco, and Miami seaports received 83% of goat meat imported into the U.S. (Gipson, 1999) while 87% of the goat meat was imported into Philadelphia, Los Angeles and Miami in 2014 (USITC, 2015). Dr. Frank Pinkerton and other leading market experts believe that Australia will continue to grow its export business. Unlike the United States where producers make marginal profits, the population and harvest of feral goats in Australia is immense, allowing for low input cost and a high net return (Pinkerton, 2014) The number one challenge that U.S. producers face is the high cost of producing goats (Gillespie et al., 2013). Feral goat carcasses imported from Australia typically have less fat than the grain finished wethers seen in the U.S. (Sande et al., 2005). The price discount was not as evident, possibly due to the lower number of goats produced, and the growing demand for goat meat (Pinkerton, 2014). Reports indicate that consumers prefer fresh domestic goat meat to frozen imported goat meat (Harrison et al., 2013).

2.4 Consumer Preference

Despite the consumer lack of awareness of goat meat in the western hemisphere, Malan (2000) reported that 60% of the red meat consumed worldwide is goat (Malan, 2000). This number is thought to be increasing as global trends toward eating higher amounts of lean protein continue. In the United States, the three categories of goat consumption are ethnic demand, health-food demand, and gourmet-restaurant demand (Sande et al., 2005). A 3-ounce serving of goat meat has 122 calories with 2.58 grams of

fat and 23 grams of protein. Goat meat compares with chicken that has 120 calories with 3.5 grams of fat and 21 grams of protein (Malan, 2000). The lean characteristics of goat meat can make it marketable to health conscious consumers (Tshabalala et al., 2003). Goat meat from kids fed the same diet as lambs was interpreted to have a more desirable fatty acid composition conducive to human health (Lee et al., 2008).

The meat goat industry is hindered by lack of structure and funding for consumer education and marketing. In a consumer preference, only 12.8% of 2000 general respondents had consumed goat meat in the last year (Harrison et al., 2013). More than 3 out of 4 people in the general population survey had never tried goat meat. Moreover, of the people who had not eaten goat meat, 84.9 % had either not heard of eating goat meat or goat meat was not available to them in their grocery. Of the general respondents, only 2.9% indicated that they would never consume goat meat under any situation. This survey indicated potential for growth in the goat industry as the main reason people didn't consume goat meat regularly was its lack of presence in grocery stores and dining room tables. Of the 2,000 respondents that did consume goat meat in the previous year, 59.4% of them consumed it for no specific occasion, suggesting goat meat can be marketed between religious holidays although, many producers still raise goats to be marketed during religious occasions. Thirty-three percent of goat meat consumers indicated that the method of slaughter was an important aspect in the purchase, further indicating the religious ramifications that are held by goat meat consumers (Harrison et al., 2013). The three largest goat consuming ethnic groups in the U.S. have different preferences, with Hispanics preferring young, 15-25 lb. live weight goats, Muslims

preferring 70 lb. live weight kids and people from the Caribbean commonly preferring mature goats (Gipson, 1999).

2.5 Growth Patterns

An animal's growth is a result of the interaction between genetic potential, nutritional plane, hormones, and environment (Webb et al., 2012). The three tissues most commonly found in a livestock growth curve are muscle, bone, and fat. Of these three, the most variation is observed in fat (Mahgoub et al., 2012). Carcass tissue distribution of lean, fat, and bone is dependent on multiple factors including animal maturity, sex, breed, and nutrition (Mahgoub et al., 2012). Some breeds of goats can influence carcass and meat quality (Kadim et al., 2003). Boers have been observed to outperform Spanish goats when concentrates were provided, but not on complete forage diets (Ngwa et al., 2009). Johnson et al. (1995) implied that sex had a larger influence on carcass characteristics than breed in comparing intact males, castrated males, and females of Florida native, Nubian X Florida native and Spanish X Florida native. Females grow at a slower rate, followed by castrated males and intact male goats, respectively (Allan and Holst, 1989).

When animals are born, fat is the lowest percentage of body weight of the three main tissues (Webb et al. 2012). Body fat percentages increase with days on feed (Mahgoub and Lu, 1998; Mahgoub et al., 2004), with concentrate feeding increasing the internal fat in Boer X Spanish and Spanish wethers (Ngwa et al., 2009). Sex class is also a contributor to the amount of fat in goat carcasses. Mahgoub and Lu (1998) reported male goats to have less carcass fat than female goats. Buck kids have been reported to have a lower concentration of fat compared to does and wethers of the same breed and nutritional plane (Mahgoub et al., 2004). Furthermore, castration has been reported to

influence fat accumulation, resulting in wethers having higher fat content than buck kids (Ruvuna et al., 1992; Solaiman et al., 2011). Goats do not deposit as much fat intramuscularly (Santos et al., 2008) or subcutaneously compared with sheep (Mahgoub et al., 2012). Fat deposited subcutaneously over the *Longissimus dorsi* is often not thick enough to accurately measure in market ready kids (McMillin et al., 2013). Goats compare favorably to lambs in meat yield, due to the higher fat content of sheep carcasses (Tshabalala et al., 2003; Sen et al., 2004). Furthermore, Mahgoub et al. (2004) reported the highest proportion of fat in goat kids to be deposited intermuscularly, followed by subcutaneous, omental, kidney, mesenteric, scrotal/udder, and pelvic, respectively.

Of the three tissues, muscle is the highest proportion at birth (Webb et al., 2012). Similar to fat, muscle tissue variation is seen among sexes. Buck kids have been reported to have a higher proportion of lean muscle in the forequarter while does and wethers have a higher proportion in the hindquarter (Mahgoub et al., 2004). Buck kids have been reported to be more efficient at producing lean compared to wethers (Solaiman et al., 2011). Mahgoub and Lu (1998) reported that Dhofari goats, a small maturing breed, had a higher percentage of muscle compared to the larger Batina goats. Batina goats mature at 10-15 kg heavier than Dhofari goats. It is important to note that the goats were harvested at a particular weight; therefore, observed differences could be due to stage of maturity (Mahgoub and Lu 1998). The ratio between muscle and bone has shown to be different between live weights of 6 kg and 25 kg (Marichal et al., 2003).

The percentage of bone in relation to the body weight remains mostly constant throughout an animal's life (Webb et al., 2012). When comparing two breeds of goats from Oman, Mahgoub and Lu (1998) reported the smaller maturing breed to have a lower

percentage of bone compared to the larger maturing breed when both breeds were at the same weight. Tshabalala et al. (2003) reported differences in proportion of bone between Boer goats and goats indigenous to South Africa. After puberty, the length of bone growth begins to slow, but the bone diameter continues to increase until maturity (Webb et al., 2012). Castration manipulates bone growth by causing longer bones with smaller diameter compared to bucks (Webb et al., 2012).

Live evaluation of an animal is important in order to select a goat at the right time in its growth curve for the desired market. Variation in preferences for types of live goats exists among consumers based on different ethnicities, which makes it difficult to approve an acceptable live goat grading system (Webb et al., 2012). Slaughter method is important for consumers selecting goats for harvest (Harrison et al., 2013). The conformation selection criteria (USDA, 2001; McMillin and Pinkerton, 2008) should be referenced when selecting goats with the optimal muscle to bone ratio. Ideal market goats should exhibit a “pronounced outside leg, full back strip, and thick outside shoulder” (USDA, 2001).

Dressing percentage calculated as $(\text{carcass weight} \times 100) / \text{live weight}$, is a measure of the proportion of the live goat that entered the cooler as a carcass (McGregor, 2012). Kadim et al. (2003) reported dressing percentages of 53-57% in three breeds of goats. These numbers are comparable to averages of other reports (Johnson and McGowan, 1998; Mahgoub and Lu, 1998). Gurung et al. (2009) reported average dressing percentages to be lower, between 42.2-45.1% while McMillin et al. (2013) reported average dressing percent to be 48%. The report by McMillin et al. (2013), unlike the others, included a large variation of breeds at different stages of maturity. Dressing

percentages between Boer x Spanish, Boer x Angora, and Spanish have been reported as being similar (Cameron et al., 2001). Wethers have a higher dressing percent than bucklings (Solaiman et al., 2011). Allan and Holst (1989) reported intact males to have lower dressing percentages at 20 kg live weight than wethers and does, but that significant difference was not observed at 26 kg live weight. Dressing percentage in goats has been reported to increase with age (Ruvuna et al., 1992). Intensive feeding has shown to improve dressing percentage compared to non-intensive feeding (Johnson and McGowan, 1998). Moreover, Ryan et al. (2007) also reported higher dressing percentages in concentrate fed goats compared to range fed goats. Hair breeds of lambs have been reported to have higher dressing percentages than meat goats, which can be partially due to their greater amount of fat (Tshabalala et al., 2003). Dressing percent can have large variation, as it is dependent upon the hours of fasting prior to slaughter, hide weight, and sex (McGregor, 2012). After fasting for 24 hours, the digestive tract of goats is approximately 16% of the live weight (Owen and Norman, 1977).

2.6 Meat Properties

2.6.1 pH of Muscle

As the body muscles attempt to provide energy following harvesting, glycogen metabolism results in lactic acid production. This process takes place until glycogen is no longer available. When glycogen is inadequate to generate adenosine tri-phosphate (ATP) to break the bond between actin and myosin, myosin and actin can no longer be held apart, and rigor mortis begins. The accumulation of lactic acid results in a decline of pH from the live animal at 7.2 to 5.5 in meat (Lawrie, 1992).

Many variables can affect the rate in which pH declines in muscle during postmortem glycolysis. Species that have greater amounts of fast twitch (white) fibers have a more rapid pH decline compared to species with a greater amount of slow twitch (red) muscle fibers (Lawrie, 1992). Differences in ultimate pH have been observed between muscles (Kannan et al., 2001) as a direct result of the differences in proportion of white to red fibers among muscles. The use of electrical stimulation can be used to speed up this pH decline and reduce cold shortening which develops when carcasses still going through glycolysis are exposed to temperatures below 0° C. Applying electrical stimulation to goat carcasses resulted in a lower 24 hour pH (Cetin and Topcu, 2009). Kerth et al. (1999) reported that electrically stimulated lamb carcasses had a lower pH for the first four hours after harvest ($P < 0.03$). Electrical stimulation of goat meat results in a lower pH and hastened rigor mortis caused by the acceleration of glycolysis (Cetin et al., 2012). Muscle glycogen concentrations of electrically stimulated carcass sides have been reported to be lower than controls immediately after application of treatment (Gadiyaram et al., 2008).

Ultimate pH is predominantly affected by the amount of glycogen present in the muscle tissue at time of harvest. Insufficient amounts of glycogen result in a higher pH and darker muscle tissue, so carcasses are commonly referred to as dark cutters. Ultimate pH values exceeding 6.0 have been reported in goat meat (Nuñez Gonzalez et al., 1983; Kannan et al., 2001; Swan et al., 1998). Stressful pre-slaughter handling partly contributes to high ultimate pH in goats (Webb et al., 2005). Simela et al. (2004) reported no difference in ultimate pH of goats harvested within 2 months of purchase (non-conditioned) and those slaughtered between 6-10 months after purchase (conditioned).

Goats that experience transportation stress immediately prior to slaughter have higher ultimate pH values than goats that are not transported (Kadim et al., 2006). Male lamb and goats have been shown to have higher ultimate pH values than females (Santos et al, 2008) while castrated male goats have been reported to have lower ultimate pH values than intact males (Abdullah and Musallam, 2007). Differences in ultimate pH between breeds of goats have also been reported (Swan et al., 1998;Kadim et al., 2003).

2.6.2 Color of Postmortem Muscle

The consumer puts emphasis on color as an indicator of meat quality (Kadim and Mahgoub, 2012). Muscle color is related to the concentration and form of myoglobin, compound bound to iron, and pH of the muscle (Kadim and Mahgoub, 2012). Myoglobin concentration is variable with multiple factors including species, maturity, sex, and movement of the specific muscle, as concentrations are different for each muscle group (Ledward, 1992). The majority of research studies use a Minolta-branded instrument to measure the color of meat (Tapp et al, 2011), recording three values, L* (0=black; 100=white), a* (-value=green; + value=red) b*(-value=blue; +value=yellow) based upon the reflectance of light across the spectrum reflected back to the sensor in the colorimeter (McGuire, 1992).

Muscle color is associated with the maturity of a goat, with a darker red indicating a higher concentration of myoglobin, and used to characterize an older goat. Kannan et al. (2003) found 24-30 month old goats had lower L* values and higher a* and chroma values compared to younger goats 6-12 months of age. Furthermore, Solaiman et al. (2012) also found differences in L*, a*, and b* with slaughter age. When glycogen levels are excessively low, a carcass does not reach an ultimate pH of 5.5, resulting in dark, firm

and dry meat (DFD). Meat that is considered DFD has lower numerical values for L*, a*, and b* compared to normal meat (Bass et al., 2008). Young goats transported before slaughter had lower glycogen concentrations and lower a* chroma values (Kannan et al., 2003). Transportation immediately prior to slaughter lowered L* a* and b* values in the *M. Longissimus dorsi* of goats (Kadim et al., 2006). Santos et al. (2008) found no differences in meat color between sexes of suckling kid goats, but goat carcasses were lighter than lamb carcasses of the same chronological age. Solaiman et al (2012) found no differences in color between Kiko and Boer goat kids. Color differences have been observed between goat muscles, potentially related to the difference in pH also observed in those muscles (Kannan et al., 2001). Goat meat of light pink, medium red, and dark red color were preferred, in order of preference, by 2000 goat meat consumers (Harrison et al., 2013).

2.6.3 Shear Force

Warner-Bratzler shear force (WBSF) has been shown to accurately predict the meat tenderness rating of a consumer (Shackelford et al., 1991). Differences can be due to sex, breed, age, species, and muscles (Lawrie, 1992). Destefanis et al. (2008) classified WBSF values greater than 52.68 N as being tough and less than 42.87 N as being tender using beef *Longissimus thoracis* as a model. Reducing stress prior to slaughter has shown to result in more tender goat meat (Kadim et al., 2006). Transporting goats long distances in hot weather immediately prior to slaughter can result in less tender meat (Kadim et al., 2014). Females have been reported to have more tender goat meat than intact and castrated males of the same age (Johnson et al., 1995). Goats weighing 25 kg at slaughter have been observed to have higher shear force values in the *Longissimus dorsi* and

Semimembranosus muscle than goats weighing 6 kg (Marichal et al., 2003). Some breeds contain less collagen in the muscle and therefore have more tender meat, as is the case of Angora goats producing more tender meat than Boer goats (Kadim and Mahgoub, 2012). Furthermore, Swan et al. (1998) reported Cashmere goats to have more tender *Semimembranosus* muscles than Boer or Boer X Cashmere, but observed no differences in the *Longissimus* muscles between breeds. Johnson et al. (1995) found no difference in meat tenderness between breeds and reported that sex had a greater influence on meat characteristics than did breed when comparing does, castrated males, and intact males of Florida native, Nubian X Florida native, and Spanish X Florida native goats. Suckling kids have been reported to have more tender meat than suckling lambs (Santos et al., 2008). Other reports suggest that lamb meat is more tender than goat meat (Lee et al., 2008; Riley et al., 1989; Schönfeldt et al., 1993; Sen et al., 2004). Furthermore, Tshabalala et al. (2003) found sheep patties to contain less connective tissue, and therefore be more tender than goat patties. However, Sen et al., (2004) reported sheep meat to have a higher shear force value than goat meat, but a sensory panel did not distinguish a significant difference in tenderness.

Goat carcasses are typically small, with little to no fat cover, and therefore carcasses temperatures can decrease rapidly during postmortem chilling. This rapid decline in carcass temperature may result in cold shortening and result in tougher meat (Kannan et al., 2006). Abdullah and Musallam (2007) reported intact males to decrease in temperature at a faster rate than castrated males, which had a higher percentage of fat. Santos et al. (2008) reported no differences in tenderness between suckling lambs and goats and also reported no differences in fat covering. It may be suggested that the lack of

subcutaneous fat on goat carcasses, compared to lambs, can lead to cold shortening, which would contribute to differences in tenderness between the two species. A difference in tenderness between lambs and goats is thought to be due to pre-/post-slaughter handling rather than intrinsic differences between the two species (Warmington and Kirton, 1990).

Tenderness of goat meat can be improved through carcass aging, the holding of carcasses for specified times in chilled conditions after slaughter. The rate of tenderness through aging can be dependent on the species and the type of muscle fibers (Lawrie, 1992). Aging of goat carcasses for fourteen days has been reported to improve tenderness, although aging at three days had no effect (King et al., 2004). Kadim et al. (2003) reported that six days of aging significantly increased tenderness compared with fewer days of aging. Differences in tenderness were not observed by Kannan et al. (2006) between carcasses aged for 1, 3, and 6 days, although the lack of tenderness differences among aging treatments was attributed to potential cold shortening. The shortened length of sarcomeres in the *Longissimus dorsi* muscle led to this hypothesis (Kannan et al., 2006).

Electrical stimulation has been reported as an effective method to improve tenderness in lamb and goat carcasses (Biswas et al., 2007; Cetin and Topcu, 2009; Gadiyaram et al., 2008; Kadim et al., 2014; Kerth et al., 1999; King et al., 2004). McKeith et al. (1979) reported that meat from electrically stimulated carcasses was more tender than from controls regardless of the stage of slaughter at which carcasses received the electrical stimulation. Tenderness differences can be observed among different levels of voltage administered to the carcass (Cetin et al., 2012). Sarcomeres of goat meat from

electrically stimulated carcasses have been reported to be longer (Kadim et al., 2014). Goat carcasses administered electrical stimulation before rigor mortis have a faster decline in pH and begin rigor mortis faster, which would reduce the opportunity for cold shortening (Cetin et al., 2012).

Hanging carcasses from the pelvic bone, with both front and hind legs tied together has shown to decrease meat tenderness values compared to carcasses conventionally hung by the Achilles tendon (Basinger et al., 2004). The same study showed no differences in meat tenderness between conventionally hung carcasses and carcasses also hung from the Achilles tendon, but cut between the 12th and 13th thoracic vertebrae (Basinger et al., 2004).

2.6.4 Goat Meat Flavor

Consumers who have never tasted goat may automatically assume that it is similar to that of lamb, but the meats are significantly different with lamb meat having a stronger aroma than that of goat meat (Schönfeldt et al., 1993). Tshabalala et al. (2003), however, reported that patties from Boer goats had a stronger aroma than patties of sheep meat from two hair sheep breeds. Schönfeldt et al. (1993) did not clarify the breed of sheep studied. Tshabalala et al. (2003) reported goat meat to have a stronger aroma, and lambs to have a more intense overall flavor, which was attributed to the higher fat content. Goats have less intramuscular fat (marbling) than lambs (Santos et al., 2008). Goats deposit more visceral fat and have less subcutaneous fat than lambs (Mahgoub et al., 2012).

Differences in intensity of goaty flavor have been reported among breeds (Tshabalala et al., 2003). The age at slaughter affects the sensory analysis of cooked goat

meat (Madruga et al., 2000). Differences in appearance, goaty aroma, roasted meat aroma, flavor, juiciness, tenderness and texture were not observed between castrated and intact males by Madruga et al. (2000). Other research has reported that castrated males tend to have a higher water holding capacity than intact males (Abdullah and Musallam, 2007). Differences in diet can affect fat deposition and change flavor profiles (Tshabalala et al., 2003). Goats fed concentrate diets were shown to have less off-flavor in the meat than goats on a range diet (Ryan et al., 2007). Taste panelists from the United States may have different opinions than foreign panelists when evaluating sheep and goat meat (Griffin et al., 1992).

2.7 Goat Nutrition

Goats have a ruminant digestive system consisting of four compartments of the stomach, the rumen, reticulum, omasum, and abomasum. This system is designed for fermentation by bacterial population that allows utilization of forages that are indigestible by non-ruminant animals (NRC, 2007). Unlike other ruminants such as cattle and sheep, goats typically select forages classified as browse, and can provide usable products in environments that cattle and sheep cannot (Dove, 2010). Goats select forages that are higher from the ground than cattle or sheep (Sanon et al., 2007). When provided with different forage options, goats have been reported to consume forages higher in dry matter such as cereal grains, over brassica species and clovers (Bateman et al., 2004). This difference in grazing preference is a reason some producers use goats in their production setting (Gillespie et al., 2013). Farmers can graze species of livestock together to take advantage of the forage selection habits of each species (Radcliffe et al., 1991). Over four years, Radcliffe et al. (1991) showed that lambs grazed with goats were heavier

than lambs grazed separately. Goats co-grazed with sheep were reported to consistently consume less clover than sheep (Gurung et al., 1994). Co-grazing goats with dairy heifers has been reported to decrease the population of weeds and not sacrifice the average daily gain of heifers (Dennis et al., 2012). Stocking rate is one of the most important management decisions in co-grazing livestock, and considerations must be made regarding the animal body weights and production state, their preference for particular forages, the desired length of forage the producer wishes to maintain, and the productivity of a particular pasture (Animut and Goetsch, 2008). Stocking rate and available forage can have an effect on goats and lambs performance when co-grazed (Animut et al., 2005). Over stocked lambs and goats can result in lower or even negative weight gains (Norton et al., 1990).

Nutrient requirements for all species depend on the animal's stage of physiological growth and development (NRC, 2007). In all production situations, the goal of producers must be to optimize animal production while minimizing the input cost (Solaiman, 2010). A mature doe in maintenance will require fewer nutrients than a doe lactating for twin kids. Likewise, a growing Nubian kid raised to be a dairy buck has different requirements than a Boer kid raised for meat production. A twenty-kilogram Boer kid fed for maximum growth requires 194 grams of protein per day compared to a dairy kid at the same weight that requires only 151 grams (NRC, 2007). Concentrate feeding of goat kids showed average daily gain:dry matter intake ratios for Boer X Spanish, Boer X Angora and Spanish goats of 263, 261, and 235 g/kg respectively (Cameron et al., 2001).

A greater percentage of goats in the United States are supplemented with concentrate diets compared to other countries such as Australia and Brazil (Pinkerton, 2014a; Johnson et al., 1986). Johnson et al. (1986) reported that cattle in North Brazil were the first livestock to receive supplements, and goats were almost never provided with supplements. In the United States, it is predicted that 30% of producers use a dry lot in their production scheme (Gillespie et al., 2013). Providing pasture goats with low levels of grain concentrate may actually increase intake of forages (Huston, 1994). Goats raised for livestock exhibition are fed concentrates exclusively, causing heavier conditioning and resulting in fatter carcasses. Goats rarely put on intramuscular fat, but accumulate large amounts of kidney, pelvic and heart fat, with does accumulating larger percentages than bucklings (Santos et al., 2008). Feeding concentrates increased internal fat for Boer X Spanish and Spanish wethers (Ngwa et al., 2009). Safari et al. (2009) showed an increase of 9% fat in goats fed concentrate diets compared to those given no concentrates. Market prices are lower for heavy conditioned goats to compensate for the additional fat that will be trimmed from the carcass, but this price difference was not as evident in 2014 (Pinkerton, 2014b). It is predicted that this decrease in price is due to the lack of supply and the continual growth in demand for goat meat. As a way to meet the demand, producers can market heavier goats (Pinkerton, 2014b).

The most efficient and rapid way to put additional weight on goat kids is through high concentrate feeding. Johnson and McGowan (1998) found that intensively raised goats had heavier slaughter and carcass weights compared to semi-intensively raised goats, without having additional fat over the ribeye or estimated KPH, even though intensively raised kids had a greater amount of flank streaking. Ryan et al. (2007)

reported goats fed concentrate diets at either 50%, 70%, or 90% had increased live weights, hot carcass weights, dressing percentages, ribeye areas, actual and adjusted body wall widths, leg circumferences and carcass lengths when compared to range fed goats. Ryan et al. (2007) reported that feeding concentrates increased marbling scores and kidney and pelvic fat contrary to what was observed by Johnson and McGowan (1998). Corrigan et al. (2008) observed a quadratic effect when comparing the same level of concentrates, with 70% being optimal for final body weight ($P=0.02$) and daily gain ($P<0.01$), and observed a linear increase in gain efficiency ($P=0.03$) with 90% being optimal. Furthermore, Safari et al. (2009) reported a linear increase in average daily gain in goats with inclusion of concentrate. Lambs given concentrates were shown to have higher average daily gains and once harvested, had higher dressing percentages and quality grades compared to forage only lambs (Summers et al., 1978). Goats prefer pellet feed over meal and liquid (Bateman, et al. 2004). Although feeding concentrate diets has been shown to be beneficial, the cost effectiveness depends on the operation and a cost-benefit analysis should be assessed prior to feeding goats (Safari et al., 2009).

Feeding of concentrates can have different effects on goats based on quantity and quality of feed, breed, and sex. Diet influenced tenderness of goat meat (Argüello et al., 2005), but other studies found no difference in meat tenderness with different diets (Abdullah and Musallam, 2007; Adam et al., 2010; Johnson and McGowan, 1998). Carlucci et al. (1998) reported that meat from extensively reared kids was more tender and juicy than intensively raised goats, but extensively raised goats were smaller. Suckling on dams versus milk replacer has been reported to affect tenderness and juiciness of meat in the Majorera breed, with kids suckling on the dam having lower

shear force values and higher water holding capacity (Argüello et al., 2005). Increasing energy levels in the diet increased percentage of fat and decreased percentage of muscle. This was more likely for castrated males compared to intact males (Abdullah and Musallam, 2007). Average daily gains increased with inclusion of crude protein at 15% vs. 10% (Ivey et al., 2000). Furthermore, Ivey et al. (2000) observed no differences in total fleece weight of goats between crude protein levels, but there was a linear increase in weight with increased energy in the diet (2.00, 2.35, and 2.70 Mcal/kg; DM basis). Adam et al. (2010) reported no differences in chemical composition of goat meat between goats fed sorghum- and molasses-based diets. Boer goats had improved live performance on concentrate diets compared to Spanish goats (Ngwa et al., 2009). Furthermore, crossbred Boer goats fed concentrates had higher average daily gains and dry matter intake compared to Spanish goats over a 16-week period (Cameron et al., 2001).

2.8 Dried Distillers Grain with Solubles

In any livestock commodity, the single greatest cost is feed (Solaiman, 2010). Goat producers strongly agree that the high cost of goat production is a challenge facing the industry (Gillespie et al., 2013). Utilizing by-products that are less expensive can help reduce this challenge. The additions of byproducts such as soybean hulls and corn gluten feed have shown to increase carcass weight and dressing percentages in goats (Moore et al., 2002).

The addition of dried distillers grain with solubles (DDGS) to a ration has been shown to replace soybean meal in finishing lamb diets (Felix et al., 2012; Huls et al., 2006; Schauer et al., 2008). Dried distillers grain with solubles is commonly referred to as a protein source, but can also be used to provide energy, depending on the animal's

nutritional requirement. A limited amount of small ruminant producers utilize DDGS as a viable feedstuff due to the lack of sufficient research on DDGS for lambs and goats (Pezzanite et al., 2010).

Dried distillers grain is a byproduct from dry-grind ethanol plants, which are responsible for producing 60% of the ethanol used in the United States (USGC, 2012). Ethanol plants are concentrated in the Midwest, with 213 refineries in the U.S. as of 2015 (RFA, 2015). Starch from a corn kernel is used to produce ethanol and the remaining portion becomes distiller's grain. One bushel of corn (25.4 kg) produces 11.8 liters of ethanol and 7.7 kg of DDGS. Other starch sources can be used, but corn is easily the most predominant because of its abundance and high yield (USGC, 2012).

High levels of variation in composition exist among distiller grains, causing difficulty in evaluating the true nutritional value of each batch (USGC, 2012). Distiller grains can be fed as wet or dry, but wet distillers grains have a short shelf life and are commonly only utilized for dairy cow operations (Pezzanite et al., 2010). The drying phase is responsible for the greatest variation in nutrient value. Under extremely hot temperatures, protein can become bound, resulting in poor amino acid digestibility by the ruminant animal. There is no standardization system for DDGS, therefore color is commonly used to suggest the digestible protein available. A dark color would suggest heat damage, and a light orange color is preferred (USGC, 2012).

In order to extract the ultimate amount of ethanol, sulfuric acid is commonly added during the dry grind process to keep pH at the desired level for optimal yeast propagation and fermentation (USGC, 2012). Moreover, sulfuric acid is a lower cost acid that is commonly used to for cleaning tanks (USGC, 2012). Corn based DDGS can be

expected to have approximately 0.39% sulfur (NRC, 2007), but this can vary depending on the source (USGC, 2012). Sulfur recommendations are set at 0.26% dry matter for growing goats (NRC, 2007). Recent concern has been on possible sulfur toxicity developing into sulfur-induced polioencephalomalacia (PEM) (Gould, 2011).

Polioencephalomalacia is a neurological disorder commonly associated with a deficiency in thiamin (B1) (Gould, 2011). In healthy ruminants, Vitamin B1 is produced by bacteria in the digestive system (NRC, 2007). Animals on high concentrate diets with small particle size consume feed rapidly and produce less saliva, resulting in a lower rumen pH. A low rumen pH alters bacteria populations, which can result in PEM, along with other dietary complications (Owens et al., 1998). Unless treated early with an intramuscular injection of thiamin (B1), PEM will result in fatality (Gould, 2011).

It has recently been discovered that sulfur can induce PEM without altering the thiamin status (Gould, 2011). Instead, sulfur-associated PEM results from the accumulation of hydrogen sulfide (H₂S) gas from the digestion of high sulfur diets (Gould, 2011). Rations have been fed to lambs and goats with sulfur level of 0.35% without symptoms of PEM (Felix et al., 2012; Gurung et al., 2009). Diet levels exceeding 0.6% sulfur have been reported to put lambs at risk for PEM (Morrow et al., 2013). Inclusion of thiamin at 142 mg/hd/d in the ration is thought to prevent a thiamin deficiency and reduce the possibility of PEM (Schauer et al., 2008). Furthermore, Olkowski et al. (1992) reported that inclusion of thiamin in the diet at 243 mg/kg prevented clinical signs of PEM in sheep, although small brain lesions still occurred. Uwituze (2011) reported lower dry matter intake and average daily gain of steers fed high sulfur diets (0.65%) compared to moderate sulfur diets (0.42%). In addition to sulfur,

high levels of phosphorus can cause urinary calculi in ruminants if a 2:1 calcium phosphorus ratio is not maintained. Addition of ammonium chloride has shown to prevent these incidences of urinary calculi (Pezzanite et al., 2010).

Inclusion of DDGS in the diet of growing goats at 31% had no effect on dry matter intake, growth, or quality of the carcass (Gurung et al., 2009). Furthermore, Schauer et al. (2008) reported that inclusion of DDGS up to 60% in lamb diets did not sacrifice live performance and carcass traits. However, Felix et al. (2012) reported a quadratic effect with 20% DDGS being optimal for average daily gain in lambs compared with 0%, 40%, and 60% DDGS. Zelinsky et al. (2006) fed 17% DDGS and reported average daily gains in lambs of 0.349 kg as did Felix et al. (2012) of 0.358 kg with 20% DDGS. Schauer et al. (2008) included a longer fiber source in lamb diets and did not observe the negative effect in average daily gain at high DDGS inclusion that was observed with lambs in Felix et al. (2012). It's important to note that all treatments of Felix et al. (2012) had higher average daily gains than all treatment levels in Schauer et al. (2008). The limited research on the effects of DDGS on small ruminant live performance and carcass quality has suggested that it can serve as an effective feedstuff without compromising performance in some production scenarios. This research was designed to compare 0, 15, 30, and 45% DDGS fed for 0, 21, 43, and 63 days on live performance, carcass characteristics, and meat characteristics of Boer and Savannah cross buckling kid goats.

CHAPTER 3: MATERIALS AND METHODS

3.1 Animal Use

The Louisiana State University Agricultural Center Institutional Animal Care and Use Committee approved the research protocol (AS2014-20) for care and use of live animals. Animals were housed at the Central Research Station in Baton Rouge, Louisiana.

3.2 Animal Procurement

Savannah x Spanish bucklings (n=31) and Boer crossbred bucklings (n=8) were purchased from rancher Elgin Pape in Harper, Texas and transported approximately 885 kilometers to Baton Rouge, Louisiana. Additional bucklings of Boer descent (n=20) were purchased from an order buyer and transported 32 kilometers from Plaquemine, Louisiana to Baton Rouge. It is a common practice for commercial producers to refrain from castrating intact males and allow them to remain as bucklings. There is no price difference between intact male kids and castrated male kids, therefore all goats remained intact for this study. After arrival at the Central Research Station, all animals were given Prohibit® (AgriLabs, Ltd. St. Joseph, MO) orally and vaccinated with 2 cc of *Clostridium perfringens* types C&D-tetanus toxoid (CD/T) (Boehringer Ingelheim Inc., St. Joseph, MO) subcutaneously under supervision of a Louisiana State University (LSU) veterinarian. Fecal exams were done by the LSU veterinarian hospital on randomly selected goats before and after treatment to ensure efficacy of the anthelmintic. The internal parasite load was sufficiently high so all goats received another dose of Prohibit orally prior to the introductory phase of the study to ensure that internal parasites did not affect live performance. Twenty-one days after vaccination, all goats received the second

injection of CD/T. Goats were provided shelter, along with bermudagrass-clover pasture and 113 grams of textured feed (Purina Goat Chow, Purina Mills, LLC. St. Louis, MO) daily until they recouped weight loss due to shipping.

3.3 Animal Nutrition

The nutrient analysis of the Purina® feed is in Table 1.

Table 1. Guaranteed Analysis of Purina® Goat Chow

Nutrient Composition	
Crude Protein (MIN).....	16.00 %
Crude Fat (MIN).....	2.50 %
Crude Fiber (MAX).....	9.00 %
Calcium (CA) (MIN).....	0.80 %
Calcium (CA) (MAX).....	1.30 %
Phosphorus (P) (MIN).....	0.60 %
Salt (NACL) (MIN).....	0.75 %
Salt (NACL) (MAX).....	1.25 %
Copper (CU) (MIN).....	39.00 ppm
Copper (CU) (MAX).....	42.00 ppm
Selenium (SE) (MIN).....	0.60 ppm
Vitamin A (MIN).....	5000.00 IU/lb
Vitamin E (MIN).....	50.00 IU/lb

An LSU ruminant nutritionist balanced goat rations using the Nutrient Requirements for Small Ruminants (NRC, 2007). Diets were balanced to meet the requirements for crude protein and energy; however treatments were not formulated to be isonitrogenous or isocaloric. The calculated nutrient value of rations are in Table 2. Feed ingredients were purchased and mixed by Kentwood Co-op (Kentwood, Louisiana) to the desired formulations (Table 3). Rations needed for the duration of the feed trial were all delivered to Central Research Station immediately prior to the study in super bags weighing approximately 780 kilograms.

Table 2. Calculated ration nutrient value

Nutrient, %	0%	15%	30%	45%
Crude Protein	17.00	17.00	17.00	18.50
Total Digestible Nutrients	78.30	78.70	78.80	78.70
Crude Fat	3.30	4.40	5.60	6.50

Table 3. Ingredients for buckling rations

Ingredients, %	0%	15%	30%	45%
Ground Corn	70.83	62.18	53.12	39.16
48% Soybean Meal	15.59	8.76	2.38	0
Cotton Seed Hulls	7.57	8.44	8.37	9.19
Dried Distillers Grain	0	15.00	30.00	45.00
Calcium	1.23	1.22	1.55	1.62
Sweetlix® mineral	1.16	1.16	1.16	1.17
Ammonium Chloride	0.58	0.58	0.58	0.58
Copper Sulfate	3.23×10^{-6}	5.79×10^{-7}	5.79×10^{-7}	5.83×10^{-7}
Molasses	3.04	3.03	3.03	3.04
Price per cwt	\$17.95	\$16.09	\$14.29	\$13.44

Multiple samples were taken from random locations in each super bag and mixed thoroughly for assessment of nutrient value. Feed formulation samples were analyzed by the Louisiana State University Agricultural Chemistry laboratory for protein, crude fat, crude fiber, moisture, acid detergent fiber, and minerals including boron, calcium, copper, iron, magnesium, manganese, phosphorus, potassium, sodium, sulfur, and zinc (Table 4). The percentage of sulfur in the ration linearly increased with inclusion of DDGS. Although levels exceeded the recommended level of 0.26% (NRC, 2007), studies

have reported feeding diets of 0.35% sulfur to lambs and goats without reported signs of PEM (Felix et al., 2012; Gurung et al., 2009).

Table 4. Analysis of feed ingredients

Nutrient composition as fed	0%	15%	30%	45%
Protein, %	15.70	17.30	16.50	18.80
Crude Fat, %	2.20	3.40	3.10	3.60
Crude Fiber, %	5.12	5.83	7.62	7.90
Moisture, %	8.76	8.60	8.82	8.19
Acid Detergent Fiber, %	7.40	8.70	11.00	11.10
Boron, ppm	24.60	17.40	17.40	<15.0
Calcium, %	0.543	0.960	0.752	1.06
Iron, ppm	93.00	112.00	87.20	145.00
Magnesium, %	0.155	0.191	0.193	0.243
Manganese, ppm	37.90	58.90	103.00	52.50
Phosphorus, %	0.370	0.471	0.494	0.604
Potassium, %	0.840	0.771	0.733	0.824
Sodium, %	0.099	0.120	0.122	0.176
Sulfur, %	0.199	0.252	0.303	0.380
Zinc, ppm	52.90	74.30	62.00	86.30

3.4 Animal Introduction

Savannah bucklings (n=31) and Boer bucklings (n=28) were stratified by weight and breed to allocate the two heaviest goats from each breed to pens (n=16) in descending weight order. Each pen (11 pens of 4 goats and 5 pens of 3 goats) was randomly assigned a treatment of 0% (T1), 15% (T2), 30% (T3), or 45% (T4) DDGS.

Pens were 2.5 m X 5 m with a height of 1.65 meters. Floors were concrete, and there was no bedding to prevent consumption of unmeasured elements. The end of each pen was slatted, typical for swine sow confinement, and washed down daily to prevent fecal accumulation. Water was provided through a nipple system, commonly seen in commercial swine production, but an additional five-gallon bucket was provided to allow ad libitum water consumption. The introductory phase consisted of 14 days. Goats were provided with the textured bagged feed (Purina Goat Chow, Purina Mills, LLC. St. Louis, MO) for an additional 10 days as they adjusted to the confined environment. Goats were administered Corid® (Merial Limited, Duluth, GA) orally for the first five consecutive days for the treatment of coccidiosis. For the last four days of the introductory phase, experiment diets were gradually mixed in with the textured feed to allow time for the rumen to transition until the diets were completely composed of the experimental diets.

3.5 Live Animal Measurements

On October 12th, goats were weighed for the trial starting weight. Linear measurements were recorded for chine length, loin length, rump length, withers height, hip height, heart girth, barrel circumference, chest width, and chest depth while referencing the guidelines illustrated by McMillin et al. (2013). The distance between the inside of each buckling horns were measured with a tape measure as the horn width, and hip width was measured at the pins using a linear caliper. Live conformation scores were assigned using two trained researchers (McMillin and Pinkerton, 2008). Linear measurements were repeated every 21 days until all goats were harvested. Least squares means were analyzed by taking the difference between measurements for 0-21 (n=48), 0-42 (n=32), and 0-63 (n=16).

3.6 Live Animal Care

Each pen of goats was given feed once daily at 4% of their body weight as fed, which exceeded consumption and allowed for the tracking of feed refusal. Stainless steel nursery pig feeders were used (76 cm wide x 13 cm deep) with four feed openings (Style T, Smidley Mfg., Inc. Britt, IA). Adjusted feed flow was set at 3 cm. Feeders were placed on top of lightweight concrete blocks so the feeder bottom was 19 cm above the floor. One day per week, prior to feeding, the feed remaining in each feeder was vacuumed (2.5 horsepower shopvac, Shopvac Corporation, Williamsport, PA) from each feeder, weighed and recorded as refusal. At this time, each animal was reweighed, and feed was adjusted to 4% of the pen weight, which ensured refusals. The equation used for feed allowance was $\text{live weight} * 0.04 = \text{feed provided daily}$.

During the feeding phase, on November 4th, one goat on the control diet exhibited signs of polioencephalomalacia (PEM). The goat was treated immediately with a 2 cc intramuscular injection of thiamin. The goat responded within 6 hours and maintained normal behavior, and therefore was not removed from the study. No other occurrences of illness were observed.

3.7 Harvesting Procedures

On day 0, one goat from each pen was harvested (H1) to establish a baseline and one goat from each pen was harvested every 21 days (H2, H3, H4) so that equal numbers of goats from each breed were sacrificed each time. The selected bucklings were removed and grouped into a holding pen without feed, twenty-four hours prior to slaughter. There was some aggression among goats while in the holding pen, with increased aggression as goats became larger. Goats were allowed ad libitum access to water at all times. Animals

were transported approximately 6.5 kilometers from the Central Research Stations to the LSU Meat Laboratory on the morning of harvest. All goats were reweighed immediately exiting the trailer. Goats were rendered unconscious via captive bolt under the observation of Louisiana Department of Agriculture and Forestry state meat inspectors and exsanguinated. All hides were removed by pulling with an electric cable hoist (Model Number W154236, Yale Eaton, Forest City, Arkansas). After evisceration, carcasses were washed with water warmer than 35° C and weighed. Carcasses were chilled overnight at 3° C prior to carcass evaluation.

3.8 Carcass Measurements

Temperature and pH were measured at the time of hide removal and at 1 hour, 3 hours and 24 hours after stunning. Temperature was measured using a digital temperature probe (model C28 KTYPE, Comark, Everett, WA) inserted into the center of the *M. Semimembranosus* as described by Kerth et al. (1999). Muscle pH was measured using a pH meter (Model 2000, VWR Scientific Radnor, PA) by inserting a glass probe tip electrode (5658-60, Cole-Parmer Instrument Co., Vernon Hills, IL) into the middle of the *M. Semimembranosus*. The 1-hour pH and temperature were recorded on some carcasses before they entered the cooler, depending upon the efficiency of the slaughter process.

After 24 hour chilling, the circumferences of the rear legs at the widest dimension (center of the legs), of the rear legs at the tail, of the body at the heart girth (3rd and 4th ribs), and of the body at the chest (1st rib) and the length from the first rib to the aitch bone were recorded using a tape measure. Carcass conformation was evaluated independently by two experienced meat scientists (McMillin and Pinkerton, 2008). Researchers estimated the percent kidney, pelvic and heart fat (KPH); flank color; and fat

score (McMillin and Pinkerton, 2008). Goats were ribbed using a handsaw between the 12th and 13th rib. Right and left ribeye areas of each carcass side were traced on an acetate pad (aquabee acetate pad, Bee Paper Company, United States). A digital planimeter (Topcon Model KP-82N, Japan) was used to trace ribeye areas to the closest one-hundredth square inch, which was converted to square centimeters.

After carcasses were ribbed between the 12th and 13th rib, the exposed *M. Longissimus dorsi* was allowed to bloom 20 minutes. A Minolta spectrophotometer (model CM 508d, Konica Minolta, USA) was placed on the surface of each ribeye to measure L*, a* and b* color values. The spectrophotometer aperture opening was 10.31 mm, illumination type D65, with an optical geometry of 45° and an observer angle of 2°. The color of the flank muscle (*Rectus abdominis*) and the color of fat deposited in the fore flank were also measured with the spectrophotometer.

Twenty-four hours post mortem, carcasses were split into left and right sides down the backbone using a band saw (Butcher Boy model number SA20-F, Lasar Mfg. Company, Inc. Los Angeles, CA). Right sides were fabricated into primal cuts using the food service style (USDA, 2001), with an additional transverse cut between the 4th and 5th ribs. To obtain individual shank weights for this cut that is usually sold bone-in, carcasses were cut at the joint connecting the humerus bone to the radius and ulna, which was a deviation from the Fresh Goat IMPS food service style (USDA, 2001). Primal cuts were further separated into sub-primal cuts and retail cuts. Sub-primal cuts (foreleg without shank and trotters, shoulder without neck, back and loin, and the hind legs without shank and trotters) were manually deboned and fat removed with a knife to obtain boneless lean. Weights were recorded for KPH, foreleg with shank and trotter, foreleg and shank

with trotter removed, foreleg with shank and trotter removed, fore trotter, fore shank, boneless foreleg, shoulder with neck, shoulder without neck, neck, boneless shoulder, ribs with breast plate, ribs with breast plate removed, hind leg with shank and trotter, hind leg and shank with trotter removed, hind leg with shank and trotter removed, hind shank, hind trotter, boneless hind leg, back and loin with lip on, lip, *M. Longissimus dorsi*, *M. Psoas major*, and *M. Semimembranosus*. Cutting instructions similar to these have been reported on goats of different sizes (McMillin et al., 2013).

The *M. Semimembranosus* muscles were individually packaged in 20.32 cm x 25.4 cm 3-mil standard barrier nylon-polyethylene pouches (Item # 75001910, Prime Source, USA) and vacuum packaged (Turbovac, Howden Food Equipment B.V., The Netherlands). Packages were stored for 24 hours at 3°C. Samples were removed from packages 48 hours post mortem, placed on a uncovered metal baking pan (43.18 cm x 63.5 cm x 2.54 cm), and cooked in a broiler oven (Hotpoint Co., Div. of General Electric Company, Chicago, IL) at a surface temperature of 116°C to an internal temperature of 70°C. The broiler oven had an opening of 68.58 cm x 41.91 cm and was 59 cm deep. Samples were cooked at 17.78 cm from the radiant heat source. Cooked samples were chilled at 3°C overnight on clean baking pans (43.18 cm x 63.5 cm x 2.54) covered with a sheet of meat wrapping paper. Seventy-two hours postmortem, cylindrical cores (n=3) of 12.5 mm diameter (Schönfeldt et al., 1993) were removed from cooked meat parallel with the muscle fibers. Samples were measured with a Warner-Bratzler shear attachment (Schönfeldt et al., 1993) by shearing perpendicular to the longitudinal orientation of the muscle fibers (Texture Technologies Corp. Scarsdale, New York). The load cell was 25 kg, crosshead speed was 100 mm per minute and peak force was measured in grams.

3.9 Data Analysis

The SAS (Version 9.4, SAS Inst. Inc., Cary, NC) Proc Mixed procedure was used to analyze the data. Fixed effects in the model included treatment, harvest time and breed, along with two- and three-way interactions. Means were determined by least squares means analysis and differences were determined at $P < 0.05$. Proc Corr was conducted to determine Pearson correlation coefficients with scatter and matrix plots for additional data representation.

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Live Performance

Least squares means and standard errors of average daily gain (ADG) for levels of DDGS are in Table 5. Goats fed in confinement have been observed to have aggressive behavior (Dove, 2010), so goats were stratified by weight to prevent submissive and smaller goats from consuming less feed and having poorer daily gains. It was not observed that goats within a pen fought with one another. Gains tended to linearly decrease with increased inclusion of DDGS, but significant differences were only observed in the second 21 days with goats in T4 having the lowest ($P < 0.05$) ADG. Second and third 21 day ADG showed a similar trend in regards to inclusion of DDGS as found by Gurung et al. (2009). Gurung et al. (2009) reported ADG for all treatments averaged 0.127 kg/d, while this study reported daily gains over all treatments for the second and third trial to be 0.187 and 0.162, respectively. The first 21 day ADG were much lower, 0.061. From week 1 to week 2 T3 goats were the only treatment group to gain weight, and goats in T1, T2, and T4 all lost weight. Gains for the first 21 days are likely lower due to goats becoming accustomed to their new diets. Potential solutions for getting goats accustomed to different diets more quickly include providing the diet as a creep feed so kids are exposed to the feed earlier, or penning weaned kids with goats already accustomed to the diet (Dove, 2010). Breed had no effect ($P > 0.05$) on average daily gain in any of the comparisons. The average live weight for each treatment over the feed trial is represented in Figure 3.

Least squares means for the influence of treatment and breed on live weights and weight gains are in Table 6. Despite goats being randomly assigned to pens, and pens

randomly assigned to treatments, goats in T3 were the heaviest ($P<0.05$) at the beginning of the feed trial. Goats in T3 remained the heaviest until day 42.

Table 5. Least squares means and standard errors for the influence of treatment on average daily gain

Trait	% DDGS				SEM ^a
	0%	15%	30%	45%	
ADG, kg/d					
First 21 Days (n=48)	0.065	0.052	0.076	0.049	.032
Second 21 Days (n=32)	0.265 ^b	0.178 ^{bc}	0.203 ^b	0.100 ^c	.034
Third 21 Days (n=16)	0.189	0.184	0.162	0.113	.036
After 42 Days (n=32)	0.176	0.140	0.123	0.080	.025
After 63 Days (n=16)	0.182	0.155	0.122	0.092	.038

^aStandard error is reported as the average for the combined 4 treatments and 4 harvest times

^{bc}Least squares means with different letters are different ($P<0.05$)

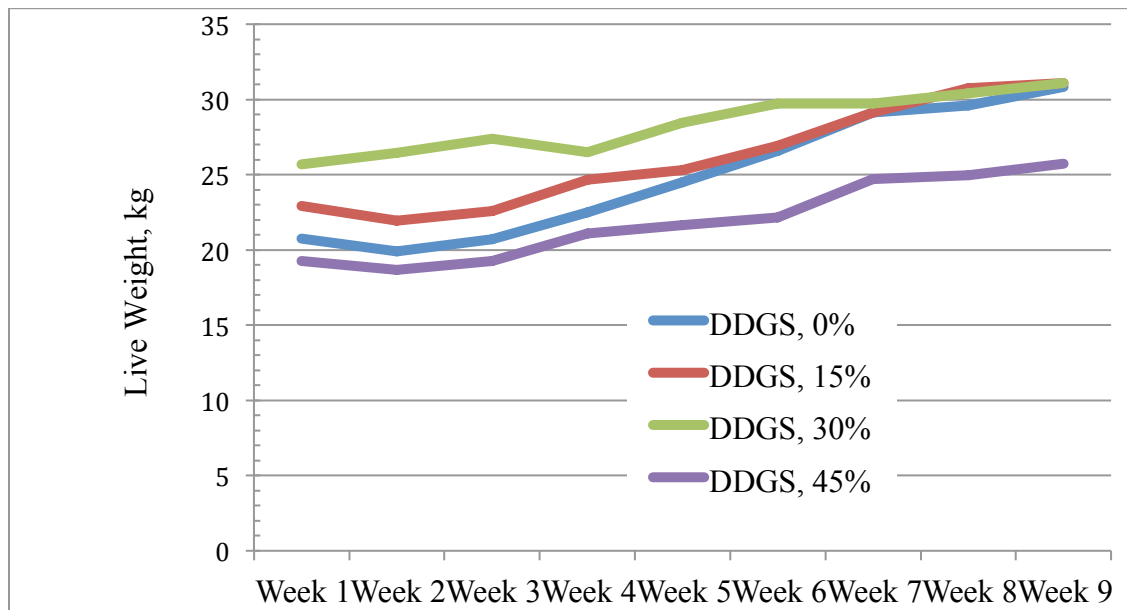


Figure 3. Average buckling weight for treatments over 9 weeks

At day 63 there were no differences ($P>0.05$) in live body weight among all the treatments. There were no differences ($P>0.05$) in weight gain as an absolute or as a percentage of the body weight during the first 21 days (n=48) or the third 21 days (n=16).

During the second 21 days, T1 and T3 goats gained a greater amount ($P<0.05$) than T4 goats. This similar trend was seen when observing weight gain as a percentage of the body; with T1 goats having the largest percent gain and T4 goats having the least weight gain. The higher gains reported during the second 21 days are expected to be a compensatory gain, as a result of goats growing poorly during the first 21 days. Goats were at different weights at the start of the trial, but there was no association with the beginning weight and the rate of growth. Breed had no effect ($P>0.05$) on live weight or weight gain as an absolute or percentage.

Table 6. Least squares means and standard errors for influence of treatment and breed on live weights and weight gains as an absolute and percentage of body weight

Trait	% DDGS				SEM ^a	Breed		SEM ^a
	0%	15%	30%	45%		1	2	
Live Weight, kg								
Day 0	21.04 ^{cd}	22.49 ^c	25.57 ^b	20.00 ^d	0.76	21.61	22.82	0.54
Day 21	22.11 ^{cd}	24.00 ^c	27.56 ^b	20.26 ^d	1.08	23.06	23.91	0.77
Day 42	28.07 ^b	28.41 ^b	30.73 ^b	23.20 ^c	1.49	27.05	28.15	1.06
Day 63	33.11	33.00	33.11	27.00	2.91	31.30	31.81	2.06
Weight Gain, kg								
First 21	1.36	1.10	1.59	1.02	0.68	1.53	1.00	0.48
Second 21	5.56 ^b	3.74 ^{bc}	4.25 ^b	2.10 ^c	0.72	3.94	3.88	0.51
Third 21	3.97	3.86	3.40	2.38	0.75	3.40	3.40	0.53
Weight Gain, %								
First 21	6.36	4.94	6.07	4.93	3.03	6.79	4.36	2.14
Second 21	25.87 ^b	15.30 ^c	16.26 ^{bc}	9.85 ^c	3.44	17.26	16.38	2.43
Third 21	13.51	13.08	11.09	9.36	2.08	11.95	11.56	1.47

^aStandard error is reported as the average for the combined 4 treatments and 4 harvest times

^{bcd}Least squares means with different letters are different ($P<0.05$)

Breed was confounded within pen for feed intake during the first 42 days, therefore in order to analyze the influence of breed on daily feed intake and feed conversion, data was analyzed using the last 21 days on feed with one goat per pen (n=16). The sampling unit was each individual goat. Table 7 reports the least squares means and standard errors for intake measurements during the last 21 days on feed. Daily feed intake as a percentage of the goats' body weights was calculated using the equation (feed consumed per day/42 day weight) * 100. Feed conversion ratio was calculated using the equation (last 21 day feed consumed/last 21 day weight gain) to determine the amount of feed needed for one kilogram of gain. Treatment and breed had no effect (P>0.05) on feed conversions.

Table 7. Least squares means and standard errors for the influence of treatment and breed on intake and efficiency during the last 21 days

Trait	%DDGS				SEM ^a	Breed		SEM ^a
	0%	15%	30%	45%		1	2	
Feed intake, kg/d	0.94	0.97	0.98	0.77	0.09	0.90	0.94	0.06
Feed intake, %/d	3.27	3.32	3.29	3.12	0.18	3.23	3.27	0.13
Last 21 day gain, kg	3.97	3.86	3.40	2.38	0.75	3.40	3.40	0.53
FCR, kg ^b	5.48	5.48	7.42	7.82	1.3	6.45	6.64	0.93
G:F ^c	0.20	0.19	0.16	0.14	0.03	0.18	0.16	0.17

^aStandard error is reported as the average for the combined 4 treatments and 4 harvest times

^bFeed conversion ratio (FCR)= Feed intake/weight gain

^cG:F=Weight gained/feed consumed

4.2 Live Linear Measurements

Least squares means and standard errors for linear measurement differences are in appendix tables A.1, A.2, and A.3. Least squares means were analyzed by taking the difference between measurements for 0-21 (n=48), 0-42 (n=32), and 0-63 (n=16).

Differences in linear measurements from day 0-21, 0-42, and 0-63 were not different ($P>0.05$) among treatments and between breeds for the majority of measurements.

Differences that were observed were likely due to sampling error. Linear measurements were inconsistent with time of measuring because the goats were not trained to stand in a consistent stance; therefore differences likely were due to sampling error rather than growth changes. Future linear measurement research recommendations include measuring on a level ground, always measuring each goat in the same exact location and replication of daily measurements to reduce error.

Least squares means and standard errors for live conformation at 0, 21, 42, and 63 days are in Table 8. Goats in T3 began with a more desirable conformation score ($P<0.05$) than T1, T2, or T4 goats, but no significant differences in conformation were observed after 21 days on treatment. The goats in T1 and T2 improved the most in live conformation from day 0 to day 63 and T4 goats decreased slightly. All treatment goats remained as selection 2 kids indicating no economic differences between treatments for live conformation score. Breed did not affect ($P>0.05$) live conformation score.

Table 8. Least squares means and standard errors for the influence of treatment and breed on live conformation

Trait	%DDGS				SEM ^a	Breed		SEM ^a
	0%	15%	30%	45%		1	2	
Live Conf., Day 0	239 ^c	249 ^c	264 ^b	240 ^c	5.46	253	243	3.86
Live Conf., Day 21	241	252	262	236	7.80	253	243	5.52
Live Conf., Day 42	256	256	256	234	8.30	254	247	5.87
Live Conf., Day 63	272	277	267	232	14.36	276	249	10.16

^aStandard error is reported as the average for the combined 4 treatments and 4 harvest times

^{bcd}Least squares means with different letters are different ($P<0.05$)

4.3 Carcass Characteristics

Least squares means and standard errors for treatment and harvest time effect on *M Semimembranosus* temperature and pH are in Table 9. Temperature differences for treatments were only observed for 3 hours post mortem, with T4 carcasses having the lowest temperature, which may partially be due to T4 carcasses being lighter. Heat transfer from lighter carcasses would be faster than with heavier carcasses. Carcasses in H4, which were the heaviest ($P < 0.05$), had the highest initial, 1 hour and 3 hour temperatures. After 24 hours of cooling, no differences ($P > 0.05$) in temperatures were observed. Previous research has indicated this is adequate time for temperature equilibration among carcasses of varying weights (Abdullah and Musallam, 2007). Values for *M. Semimembranosus* pH reported by Kannan et al. (2001) were slightly higher, 6.07 ± 0.09 , compared to the least squares means in Table 9. *Semimembranosus* pH was not affected by treatment, but harvest time did affect pH, with H1 goat carcasses having the lowest pH initially and at 1 hour, 3 hours, and 24 hours. Nuñez Gonzalez et al. (1983) reported no difference in ultimate pH values between 8, 12, 16, 20, and 24 kg live weight goats using the *M. Biceps femoris*. As the bucklings matured, researchers observed increased aggression in the holding pens prior to harvest, which could have resulted in higher ultimate pH values. Aggression is commonly observed when goats are in confinement and preventative measures should be part of an operations protocol (Dove, 2010).

Least squares means and standard errors for lean and fat color are presented in Table 10. Treatment had no effect on color of lean tissue measured at the *M. Longissimus dorsi* and *Rectus abdominis*. Contrarily, other studies have reported that diet can affect

Table 9. Least squares means and standard errors for the influence of treatment and harvest time on muscle temperature and pH

Trait	%DDGS				SEM ^a	Harvest Time				SEM ^a
	0%	15%	30%	45%		1	2	3	4	
Temperature, C°										
Initial	38.06	38.49	38.29	37.22	0.483	37.81 ^{cd}	36.41 ^d	38.52 ^{bc}	39.31 ^b	0.486
1 hour	32.48	32.65	32.03	30.58	0.888	33.61 ^b	30.26 ^c	27.96 ^c	35.91 ^b	0.894
3 hour	15.73 ^b	16.02 ^b	16.53 ^b	11.19 ^c	0.948	14.13 ^c	11.71 ^c	13.49 ^c	20.14 ^b	0.954
24 hour	1.22	1.45	1.37	1.30	0.122	1.47	1.24	1.33	1.29	0.123
pH										
Initial	6.40	6.32	6.44	6.42	0.075	6.17 ^c	6.34 ^{bc}	6.44 ^b	6.42 ^b	0.075
1 hour	6.35	6.32	6.21	6.39	0.072	5.94 ^c	6.52 ^b	6.41 ^b	6.40 ^b	0.073
3 hour	6.15	6.06	6.03	6.08	0.077	5.76 ^c	6.28 ^b	6.10 ^b	6.18 ^b	0.078
24 hour	5.80	5.76	5.72	5.81	0.049	5.61 ^c	5.74 ^{bc}	5.89 ^b	5.86 ^{bc}	0.050

^aStandard error is reported as the average for the combined 4 treatments and 4 harvest times

^{bcd}Least squares means with different letters are different (P<0.05)

the color of flank tissue (Johnson & McGowan, 1997). The a* values for fat were higher in T4 carcasses compared to other treatments, indicating more of a red color. This may be due to the minimal amount of fat covering of these carcasses, which would allow the red color of the underlying lean tissue to affect the reflected light that was measured. Felix et al. (2011) reported L* values increased in lambs with inclusion of DDGS despite a decrease in marbling score. Furthermore, Felix et al. (2011) reported lamb fat became more yellow in color with inclusion of DDGS, but no differences (P>0.05) in b* were observed in the present study. Meat goats deposit fat differently than other ruminants, and are reported to have less subcutaneous fat (Mahgoub et al., 2012). Harvest time tended to linearly increase estimated flank color values, which was an expected trend because color of muscle darkens as animals mature. Flank L* values were lowest (P<0.05) for H4

carcasses. Color is considered to be one of the most important subjective measurements of quality (Kadim and Mahgoub, 2012) and because carcasses are typically not ribbed, the flank color is used as a determinant for physiological maturity. Differences in color of the *M. Longissimus dorsi* were not observed ($P>0.05$) with harvest time. Solaiman et al. (2012) found that slaughter age with 4 harvests over 85 days significantly affected L^* , a^* , and b^* . Kannan et al. (2003) reported goats that were a year older had lower L^* values, but higher a^* values.

Table 10. Least squares means and standard errors for the influence of treatment and harvest time on muscle color

Trait	%DDGS				SEM ^a	Harvest Time				SEM ^a
	0%	15%	30%	45%		1	2	3	4	
Loin Eye Color ^b										
L^*	39.51	40.67	38.25	41.51	0.920	40.96	39.90	40.70	38.38	0.926
a^*	15.33	15.55	14.99	15.62	0.540	15.31	15.01	14.94	16.24	0.544
b^*	10.47	11.17	10.32	11.22	0.380	11.24	10.48	10.64	10.80	0.382
Fat Color ^b										
L^*	73.22	74.17	69.21	72.85	2.77	71.33	74.92	69.66	73.55	2.79
a^*	1.56 ^d	1.19 ^d	1.66 ^d	3.15 ^c	0.487	0.75	2.08	2.53	2.19	0.490
b^*	8.49	8.27	8.49	8.81	0.913	6.08 ^d	8.60 ^{cd}	9.90 ^c	9.48 ^d	0.919
Flank Color ^b										
L^*	45.22	46.94	45.41	50.37	2.08	52.33 ^c	47.71 ^{cd}	45.57 ^d	42.33 ^d	2.09
a^*	13.38	14.28	13.81	14.12	0.642	15.93 ^c	14.09 ^{cd}	13.43 ^{de}	12.15 ^e	0.647
b^*	3.14	3.45	1.72	4.03	1.09	4.58	2.61	3.31	1.83	1.10
Flank, Subjective										
	170	179	176	155	9.26	140 ^d	174 ^c	183 ^c	184 ^c	9.32

^aStandard error is reported as the average for the combined 4 treatments and 4 harvest times

^b L^* 0=black; 100=white; a^* -value=green, +value=red; b^* -value=blue, +value=yellow; 100=light pink, 200=reddish pink

^{cde}Least squares means with different letters are different ($P<0.05$)

Least squares means and standard errors for the influence of treatment and harvest time on meat characteristics are in Table 11. Dressing percentages were affected ($P < 0.05$) by treatment with T4 having the lowest dressing percentage. Bucklings in T4 were lighter in weight, although Marichal et al. (2003) reported no differences in dressing percentages between slaughter weights of 6 kg, 10 kg, and 25 kg. Gurung et al. (2009) reported a decreasing trend in dressing percentage of 44.6, 45.1, 44.7, and 44.2 with goats fed DDGS at 0%, 10.3%, 20.6% and 31.0% respectively. Felix et al. (2011) did not observe a difference in dressing percentage in lambs fed 0%, 20%, 40%, and 60% DDGS. Dressing percent tended to linearly increase with days on feed, with H4 goats having the highest ($P < 0.05$) desirable dressing percentage. McMillin et al. (2013) reported dressing percentages to average 48%, with variation of 5%, which are consistent with the dressing percentages reported in Table 11.

Goats in T4 had the smallest ($P < 0.05$) ribeye areas, which may be due to their lighter carcass weights. Other reports using lambs or goats indicated level of DDGS did not affect ribeye area (Felix et al., 2011; Gurung et al., 2009; Schauer et al., 2008). Ribeye area linearly increased with harvest time, with H4 goats having the largest ($P < 0.05$) ribeye areas. The least square mean for ribeye areas of H4 goats was 9.1 cm^2 , which is comparable to the research results of Gurung et al. (2009) whose 4 treatments together averaged 9.7 cm^2 after 57 days on feed. Solaiman et al. (2012) did not observe differences in ribeye areas with harvest time despite reporting comparable average daily gains with the present study. Treatment had no ($P > 0.05$) effect on Warner-Bratzler shear force values. Despite cold carcass weight and subjective fat score differences with day of harvest, harvest time had no effect on Warner-Bratzler shear force. It was expected that

carcasses with a higher fat score would dissipate heat at a slower rate and be more tender due to reduced cold shortening (Kannan et al., 2006), although sarcomere lengths were not measured for this experiment. Marichal et al. (2003) reported differences in tenderness when comparing 10 kg kids to 25 kg live weight kids. For this study, the differences in cold carcass weights from day 0 to day 62 were 6.5 kilograms. Although cooking methods were different, cooking yields were consistent with Swan et al. (1998). Breed had no influence on any carcass characteristics. No previous studies have compared the carcass quality characteristics of Boer and Savannah bucklings.

Table 11. Least squares means and standard errors for the influence of treatment and harvest time on meat characteristics

Trait	%DDGS				SEM ^a	Harvest Time				SEM ^a
	0%	15%	30%	45%		1	2	3	4	
Hot CW, kg	12.33 ^{de}	12.18 ^e	14.16 ^d	9.76 ^f	0.693	9.55 ^f	10.56 ^{ef}	12.32 ^e	15.99 ^d	0.695
Cold CW, kg	12.07 ^d	12.13 ^d	13.95 ^d	9.61 ^e	0.706	9.32 ^f	10.42 ^{ef}	12.17 ^e	15.86 ^d	0.711
Dressing % ^b	49.76 ^d	47.83 ^{de}	49.43 ^d	45.90 ^e	0.813	45.15 ^e	46.97 ^e	47.39 ^e	53.42 ^d	0.818
KPH ^c	2.4	2.7	2.6	2.4	0.294	1.9 ^e	2.1 ^e	2.6 ^{de}	3.4 ^d	0.296
Fat Score ^c	1.43	1.52	1.47	1.24	0.171	0.99 ^f	1.25 ^{ef}	1.64 ^{de}	1.78 ^d	1.42
Body Wall, cm	0.79	0.74	0.86	0.66	0.06	0.58 ^e	0.76 ^{de}	0.84 ^d	0.89 ^d	0.06
Carcass conf.	247.6 ^{de}	264.4 ^d	266.5 ^d	230.7 ^e	9.99	226.9 ^e	241.2 ^e	269.2 ^d	271.9 ^d	10.05
REA cm ²	7.55 ^d	6.90 ^{de}	8.19 ^d	5.74 ^e	0.082	5.74 ^e	6.58 ^e	6.97 ^e	9.16 ^d	0.083
Cook Yield, %	79.39	75.58	76.67	78.19	1.10	76.87	78.37	77.14	77.46	1.10
Shear Force	6627	6318	7295	6613	431.9	7221	6172	6839	6621	434.7

^aStandard error is reported as the average for the combined 4 treatments and 4 harvest times

^bDressing % = Hot carcass weight / 24 hour shrunk live weight * 100

^cValues are a subjective score

^{de}Least squares means with different letters are different (P<0.05)

4.4 Linear Carcass Measurements

Least square means and standard errors for linear carcass measurements are in Table 12. Breed had no effect ($P>0.05$) on any carcass measurements. Goats in T4 had the lowest ($P<0.05$) value for every linear measurement, while T3 goats tended to have larger measurements, which was consistent with carcass weights. Linear measurements increased with harvest time. There were no differences between H1 and H2 goats, but significant differences between goats in H3 and H4. The H4 goats had the highest ($P<0.05$) linear body circumference and carcass length measurements. Measurements of H3 goats were greater ($P<0.05$) than goats in H2 and H1 only for circumference around the body at the chest.

Table 12. Least squares means and standard errors for the influence of treatment and harvest time on carcass linear measurements

Trait, cm	%DDGS				SEM ^a	Harvest Time				SEM ^a
	0%	15%	30%	45%		1	2	3	4	
Circumference center leg	44.22 ^{bc}	45.00 ^b	46.60 ^b	41.69 ^c	.945	41.23 ^d	42.72 ^{cd}	45.04 ^c	48.53 ^b	.951
Circumference at tail	45.65 ^b	45.99 ^b	48.13 ^b	42.03 ^c	.899	41.90 ^d	43.31 ^d	46.55 ^c	50.04 ^b	.905
Circumference at ribs	61.79 ^b	62.03 ^b	63.91 ^b	59.02 ^c	.815	59.61 ^d	59.77 ^d	62.30 ^c	65.07 ^b	.821
Circumference at chest	60.99 ^c	60.82 ^c	63.84 ^b	56.49 ^d	.997	56.85 ^d	58.05 ^d	61.75 ^c	65.48 ^b	1.00
Rib to aitch	59.25 ^{bc}	58.81 ^{cd}	61.42 ^b	56.63 ^d	.772	56.91 ^c	58.01 ^c	58.93 ^c	62.26 ^b	.777

^aStandard error is reported as the average for the combined 4 treatments and 4 harvest times

^{bcd}Least squares means with different letters are different ($P<0.05$)

4.5 Carcass Cuts

Least square means and standard errors for carcass primal weights are in Table 13 for treatment and harvest time. Weights of all cuts from the carcass are in appendix

table A.4. Breed had no effect ($P>0.05$) on carcass or cut weights. The T4 carcasses had the lowest ($P<0.05$) carcass weights and primal weight cuts for most traits, and T3 goats had the highest ($P<0.05$) primal weights for most cuts. No differences were found between goats in T1 and T2. All primal cuts linearly increased in weight due to harvest time. Goats in H4 had the heaviest ($P<0.05$) primal weights. There were no ($P>0.05$) differences in primal cut weights between H1 and H2 goats, indicating that goats needed to be on a concentrate diet for more than 21 days in order to see differences in primal weights.

Table 13. Least squares means and standard errors on the influence of treatment and harvest time on carcass primal weights

Trait, kg	%DDGS				SEM ^a	Harvest Time				SEM ^a
	0%	15%	30%	45%		1	2	3	4	
CCW	12.07 ^c	12.13 ^c	13.95 ^c	9.61 ^d	0.706	9.32 ^e	10.42 ^{de}	12.17 ^d	15.86 ^c	0.711
KPH	0.31	0.36	0.39	0.29	0.035	0.19 ^e	0.26 ^e	0.40 ^d	0.50 ^c	0.036
Foreleg	1.19 ^d	1.21 ^d	1.43 ^c	0.98 ^e	0.064	.98 ^e	1.10 ^e	1.24 ^d	1.50 ^c	0.065
Bnls. Foreleg	0.58 ^d	0.61 ^d	0.76 ^c	0.46 ^e	0.047	0.44 ^e	0.56 ^{de}	0.63 ^d	0.80 ^c	0.048
Shoulder	1.22 ^c	1.19 ^{cd}	1.36 ^c	0.94 ^d	0.089	0.93 ^d	1.05 ^d	1.15 ^d	1.57 ^c	0.089
Bnls. Shoulder	0.48 ^c	0.43 ^{cd}	0.53 ^c	0.33 ^d	0.047	0.29 ^d	0.34 ^d	0.40 ^d	0.72 ^c	0.047
Leg	1.79 ^d	1.79 ^d	2.11 ^c	1.44 ^e	0.093	1.39 ^e	1.67 ^{de}	1.80 ^d	2.25 ^c	0.093
Bnls. Leg	1.00 ^{cd}	0.95 ^d	1.15 ^c	0.75 ^e	0.064	0.70 ^e	0.85 ^{de}	0.99 ^d	1.30 ^c	0.065
Back and Loin	1.09 ^{cd}	1.11 ^c	1.26 ^c	0.90 ^d	0.070	0.85 ^e	0.86 ^e	1.15 ^d	1.49 ^c	0.070
Boneless Lean ^b	2.69 ^c	2.62 ^c	3.16 ^c	2.02 ^d	0.194	1.87 ^e	2.18 ^{de}	2.67 ^d	3.76 ^c	0.195

^aStandard error is reported as the average for the combined 4 treatments and 4 harvest times

^bBoneless separable lean from the foreleg, shoulder, leg, back and loin

^{cd}Least squares means with different letters are different ($P<0.05$)

Primal cut weights as a percentage of the cold carcass weight were analyzed for differences among DDGS treatments, harvest times, and breed. Carcass tissue distribution is affected by stage of maturity, nutrition, breed and sex (Mahgoub et al., 2012). Least square means and standard errors of primal cuts as a percentage of the cold carcass weight are in Table 14. All cuts as a percentage of cold carcass weight are in the appendix table A.5. Breed had no effect ($P>0.05$) on primal cut weights as a percentage. When calculated as a percentage, primal cuts were not different ($P>0.05$) for levels of DDGS. This would indicate that primal cut weight differences seen in Table 13 for treatment were a result of differences in carcass weights, but not due to differences in the amount of tissues deposited in one location compared to other locations. Harvest time did affect the deposition of tissue on a percentage basis. The H3 and H4 goats had higher ($P<0.05$) percentages of kidney fat compared to goats in H1 and H2. The H4 goats had the lowest percentages of foreleg and leg, no differences for shoulder, but had the highest percent of boneless meat. Leaving goats as intact males could have contributed to this pattern of tissue deposition. The percentage of boneless meat increased linearly with days on feed, 19.83, 20.55, 21.77, and 23.51, respectively. Mahgoub et al. (2005) reported a difference in muscle:bone and muscle:fat among slaughter weights. This data would indicate that the longer goats are fed concentrate diets, the higher percentage of boneless meat a carcass possesses, although the maturity at harvest influences the proportion of lean tissue in each primal.

4.6 Correlation of Linear Measurements

Correlations of live linear measurements with body weight, dressing percent, hot carcass weight, ribeye area and the primal cuts including foreleg, shoulder, leg, back, loin

and boneless meat are in Table 15. High correlations of linear measurements with carcass traits could be advantageous for producers to use as a selection tool to estimate the

Table 14. Least squares means and standard errors on the influence of treatment and harvest time on carcass primal weights as a percentage of cold carcass weight

Trait, kg	%DDGS				SEM ^a	Harvest Time				SEM ^a
	0%	15%	30%	45%		1	2	3	4	
KPH	2.45	2.84	2.64	2.89	0.182	2.15 ^d	2.29 ^d	3.25 ^c	3.12 ^c	0.183
Foreleg	10.08	10.13	10.35	10.42	0.189	10.62 ^c	10.65 ^c	10.23 ^c	9.47 ^d	0.188
Bnls. Foreleg	4.86	4.99	5.41	4.77	0.187	4.70	5.26	5.12	4.96	0.189
Shoulder	10.08	9.89	9.61	9.72	0.448	9.86	10.03	9.45	9.96	0.451
Bnls.Shoulder	3.66	3.37	3.58	3.22	0.220	2.97 ^d	3.13 ^d	3.24 ^d	4.49 ^c	0.221
Leg	15.05	14.93	15.14	15.23	0.227	15.01 ^d	16.18 ^c	14.88 ^{de}	14.29 ^e	0.228
Bnls. Leg	8.15	7.83	8.19	7.72	0.162	7.49 ^d	8.13 ^c	8.10 ^c	8.18 ^c	0.163
Back and Loin	8.98	8.93	9.07	9.29	0.245	9.09 ^c	8.25 ^d	9.49 ^c	9.44 ^c	0.246
Boneless Lean ^b	21.73	21.14	22.24	20.55	0.495	19.83 ^e	20.55 ^{de}	21.77 ^d	23.51 ^c	0.498

^aStandard error is reported as the average for the combined 4 treatments and 4 harvest times

^bBoneless separable lean from the foreleg, shoulder, leg, back and loin

^{cdef}Least squares means with different letters are different (P>0.05)

desired carcass traits. Goats were harvested at different times so the linear measurements taken immediately prior to slaughter were those analyzed for correlations with carcass characteristics. Body weight and heart girth were highly correlated (0.91). This strong correlation between body weight and heart girth has been reported previously (Mohammed and Amin, 1996). Heart girth has the potential to be a valuable measurement for weight prediction, and has shown to account for approximately 90% of the variation in live weight (McGregor, 2012). Furthermore, this may propose difficulty in genetically selecting offspring for increased internal capacity due to the high

correlation it has with weight. Heart girth and chest width were the most highly correlated linear measurements with primal cut weights. Some industry individuals have claimed a high correlation between horn width and body thickness. Therefore the width between horns for each goat was measured to test this hypothesis. Correlation coefficient values showed a low correlation with all the traits except for the primal shoulder weight ($P>0.05$). Although significant ($P<0.05$), horn width had the lowest correlations, 0.30-0.41, of all the linear measurements with weight and carcass traits.

Table 15. Pearson correlation coefficients of live linear measurements with weight and carcass traits

	Body Length ^a	Withers Height	Hip Height	Heart Girth	Barrel Circ.	Chest Width	Chest Depth	Horn Width	Hip Width
Body wt. ^b	0.65**	0.67**	0.71**	0.91**	0.76**	0.85**	0.60**	0.34*	0.75**
Dressing % ^c	0.53**	0.47**	0.46**	0.65**	0.28*	0.70**	0.23	0.30*	0.58**
HCW	0.65**	0.65**	0.69**	0.88**	0.67**	0.86**	0.52**	0.35*	0.74**
REA	0.50**	0.56**	0.59**	0.77**	0.57**	0.75**	0.52**	0.37*	0.69**
Primal Cuts, kg									
Foreleg	0.61**	0.65**	0.66**	0.86**	0.63**	0.87**	0.47**	0.41**	0.72**
Shoulder	0.52**	0.52**	0.59**	0.78**	0.55**	0.74**	0.43**	0.15	0.68**
Back & Loin	0.60**	0.60**	0.65**	0.87**	0.65**	0.83**	0.47**	0.33*	0.72**
Leg	0.58**	0.63**	0.65**	0.83**	0.63**	0.87**	0.45**	0.43**	0.75**
Boneless Lean	0.62**	0.61**	0.66**	0.86**	0.64**	0.85**	0.47**	0.30*	0.72**

^aBody Length=Chine length + Loin Length + Rump Length

^bWeight of goats directly out of the pen without fasting

^cDressing %=Hot carcass weight/24 hour shrunk live weight * 100

* P-value<0.05

**P-value<0.01

Correlations were analyzed to determine the association of live linear measurements taken immediately prior to slaughter with carcass linear measurements

taken 24 hours after chilling. All live linear measurements showed correlations ($P < 0.05$) with carcass linear measurements (Table 16).

Table 16. Pearson correlation coefficients of live linear measurements with carcass linear measurements

Trait	Circumference Center leg	Circumference at tail	Circumference at ribs	Circumference at chest	Rib to aitch
Chine Length	0.43**	0.41**	0.36**	0.43**	0.38**
Loin Length	0.34**	0.36**	0.38**	0.40**	0.42**
Rump Length	0.63**	0.67**	0.70**	0.70**	0.74**
Withers Height	0.62**	0.64**	0.61**	0.69**	0.70**
Hip Height	0.64**	0.66**	0.66**	0.67**	0.74**
Heart Girth	0.83**	0.87**	0.91**	0.89**	0.81**
Barrel Circumference	0.63**	0.67**	0.71**	0.64**	0.62**
Chest Width	0.85**	0.88**	0.74**	0.81**	0.73**
Chest Depth	0.48**	0.49**	0.59**	0.55**	0.54**
Horn Width	0.45**	0.40**	0.35*	0.32*	0.34*
Hip Width	0.74**	0.78**	0.62**	0.69**	0.62**

*P-value < 0.05

** P-value < 0.01

Correlation analyses were conducted to determine the relationship of carcass conformation score and primal cuts to the linear carcass measurements. The

circumferences at the center of the leg and at the tail were most highly correlated, -0.74 and -0.78, respectively, with carcass conformation. This would indicate that as the circumference increased the carcass conformation also increased. All of the carcass linear measurements were correlated ($P < 0.01$) with carcass conformation. Furthermore, the linear carcass measurements were highly correlated with the primal cut weights and the amount of boneless meat. Correlation coefficients for carcass conformation and primal cuts with carcass linear measurements are in Table 17.

Table 17. Pearson correlation coefficients of carcass conformation and primal cuts with carcass linear measurements

Trait	Carcass Conf.	Foreleg	Shoulder	Leg	Back/Loin	Boneless Meat
Circumference center Leg	-0.74**	0.95**	0.78**	0.95**	0.91**	0.94**
Circumference at tail	-0.78**	0.95**	0.85**	0.96**	0.94**	0.96**
Circumference at ribs	-0.65**	0.89**	0.78**	0.89**	0.88**	0.89**
Circumference at chest	-0.67**	0.92**	0.84**	0.93**	0.90**	0.93**
Rib to aitch	-0.55**	0.85**	0.79**	0.86**	0.83**	0.85**

*P-value < 0.05

**P-value < 0.01

4.7 Correlation of Carcass Characteristics

Correlations were analyzed on particular traits that may affect color to determine their relationships with the *Longissimus dorsi*, *Rectus abdominis*, and fat tissue L^* , a^* , and b^* values. Correlation coefficients are in Table 18. Age is known to influence the concentration of myoglobin and color of lean (Ledward, 1992). Weight is commonly associated with age of growing goats and there was an observed correlation with lean

color. As carcass weight increased, the *Longissimus dorsi* L* and b* and the *Rectus abdominis* L*, a* and b* decreased. An ultimate pH value greater than 6.0 results in lean tissue that is dark in color (Ledward, 1992). Ultimate pH is determined to be the muscle pH 24 hours post stunning. Ultimate pH was not correlated with any lean color tissues, despite pH being greater than 5.5, which is considered normal (Ledward, 1992). Goats are rarely ribbed in a commercial environment, but can be graded for lean maturity using a trained individual. The subjective flank score was moderately correlated, -0.52, with the L* *Rectus abdominis*, which shows the relationship of the subjective score with the objective color measurement. Lagoda et al. (2002) reported similar correlations with visual and objective flank color on veal, although the L* correlation was slightly higher at -0.67.

Table 18. Pearson correlation coefficients for carcass characteristics and goat meat color

Trait	Carcass wt.	24 hr. pH	Sub. Flank Color	Fat Score
<i>Longissimus dorsi</i>				
L*	-0.52***	-0.21	-0.49***	-0.38***
a*	0.09	0.05	0.04	-0.01
b*	-0.32**	-0.22	-0.31**	0.32**
<i>Rectus abdominis</i>				
L*	-0.60***	-0.24	-0.52***	0.55***
a*	-0.52***	-0.18	-0.24	-0.23
b*	-0.32**	0.01	-0.08	-0.07
Fat				
L*	-0.17	-0.01	-0.21	-0.14
a*	0.11	0.32**	0.05	0.12
b*	0.30**	0.23	-0.01	0.32**

** P-value<0.05

***P-value<0.01

Correlations were determined in a matrix plot for carcass weight, 24-hour pH, shear force, ribeye area, dressing percent, and carcass conformation to determine the relationships among the traits. The correlation coefficients are in Table 19. Carcass weight was strongly correlated ($P < 0.001$) with ribeye area, dressing percent and carcass conformation. This was expected as Table 11 showed that least squares means for ribeye area, dressing percent and carcass conformations significantly increased with days on feed. Larger and/or heavier muscled bucklings had higher dressing percentages, as indicated by correlation coefficients for dressing percent with live conformation prior to slaughter (-0.51), carcass weight (0.81), and boneless meat (0.81). Carcass conformation is shown to be a valuable assessment of muscling as it was correlated with ribeye area, a measurement commonly used as a reference for the amount of muscling in carcasses.

Table 19- Pearson correlation coefficients for carcass characteristics and goat meat quality

Trait	Carcass wt.	24 hr. pH	Shear Force	REA	Dressing %	Carcass Conf.
Carcass wt.	1.00	0.18	0.05	0.89**	0.81**	-0.72**
24 hr. pH		1.00	-0.16	0.11	0.28*	-0.09
Shear Force			1.00	0.10	0.10	-0.12
REA				1.00	0.73**	-0.67**
Dressing %					1.00	-0.58**
Carcass Conf.						1.00

*P-value<0.05

**P-value<01

CHAPTER 5: SUMMARY AND CONCLUSIONS

5.1 Summary

There is little scientific documentation available on the effect of finishing goat kids exclusively with concentrate diets at different inclusion rates of dried distillers grain with solubles (DDGS). Furthermore, no research has evaluated the differences in live performance and carcass characteristics of Savannah-cross kid bucklings. The objective of this study was to determine the effects of 0, 15, 30, and 45% DDGS on live performance, carcass traits and meat characteristics of 28 Boer- and 31 Savannah-cross buckling kid goats. Breed did not affect ($P>0.05$) live performance, carcass traits, or cut weights as an absolute or percentage. Average daily gains (ADG) tended to linearly decrease with inclusion of DDGS, but significant differences were only observed in the second 21 days with T4 goats having the lowest ($P<0.05$) ADG. Treatment had no effect on feed efficiency or live conformation. Carcasses in H4 had the highest ($P<0.05$) 1 and 3-hour temperatures and H1 had the lowest ($P<0.05$) 1 and 3-hour pH values. Carcasses in H4 had the largest ribeye areas and heaviest weights for most primal cuts. Carcasses and most primal cut weights of T4 goats were lighter ($P<0.05$) than those goats of T1 and T2. Percentages of primal cuts in relation to the cold carcass did not differ ($P>0.05$) among treatments, but were influenced by harvest time. Warner-Bratzler shear force did not differ ($P>0.05$) due to treatments or harvest time. The level and length of time feeding DDGS can affect goat carcass characteristics. This study found no differences between Boer- and Savannah-cross buckling kid goats.

5.2 Conclusions

Data from this study suggests that dried distillers grain with solubles can be fed to growing buckling kid goats with an inclusion rate up to 45% without consistently affecting feed efficiency or average daily gain and feed intake as an absolute or percentage of animal body weight. Results from this study suggest that inclusion level of DDGS may affect carcass weight, dressing percent, ribeye area, carcass conformation and primal cut weights although observed differences could be due to differences in initial weights rather than a treatment effect. Inclusion rate of DDGS had no effect on the percent of primal cuts in relation to the cold carcass weight, indicating no changes in growth patterns at different body locations. These results suggest that carcass characteristics and weights are affected by harvest time. In order to observe a difference in carcass primal weights, goats should be fed a concentrate diet for greater than 21 days. Results from this study suggest that there are no differences in live performance, carcass characteristics or cut weights between Boer- and Savannah-cross buckling kid goats when finished in a feedlot setting.

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APPENDIX: SUPPLEMENTAL TABLES

Table A.1. Least squares means and standard errors for the influence of treatment and breed on linear measurement differences from day 0-21

Trait, cm	%DDGS				SEM ^a	Breed		SEM ^a
	0%	15%	30%	45%		1	2	
Chine Length	-2.39 ^c	-1.08 ^{bc}	0.74 ^b	-2.81 ^c	0.88	-1.59	-1.19	0.62
Loin Length	-0.57	-0.13	-0.61	-1.21	0.49	-0.80	-0.46	0.34
Rump Length	-0.42 ^b	-0.55 ^b	-1.43 ^c	-0.97 ^{bc}	0.27	-0.93	-0.76	0.19
Withers Height	-2.22	-1.63	-1.78	-1.25	0.77	-1.86	-1.58	0.54
Hip Height	-1.10	-0.11	-2.24	-1.63	0.83	-1.63	-0.91	0.59
Heart Girth	0.25	0.51	0.23	0.15	0.99	0.54	0.03	0.70
Barrel Circumference	-1.42	-1.65	-2.50	-1.12	1.86	-0.19	-3.15	1.31
Chest Width	3.07	2.29	4.13	1.71	0.80	2.82	2.78	0.57
Chest Depth	-0.21	0.51	-2.03	-0.55	0.97	-0.54	-0.60	0.69

^aStandard error is reported as the average for the combined 4 treatments and 4 harvest times

^{bcd}Least squares means with different letters are different (P<0.05)

Table A.2. Least squares means and standard errors for the influence of treatment and breed on linear measurement differences from day 0-42

Trait, cm	%DDGS				SEM ^a	Breed		SEM
	0%	15%	30%	45%		1	2	
Chine Length	-1.33	0.00	1.27	-1.59	1.08	-0.48	-0.35	0.76
Loin Length	0.73	0.48	-0.13	-0.60	0.60	0.25	-0.02	0.42
Rump Length	0.16	0.16	-0.86	-0.35	0.45	-0.25	-0.19	0.32
Withers Height	0.32	0.35	-0.67	0.76	0.87	0.05	0.33	0.61
Hip Height	2.10 ^b	1.87 ^b	-1.49 ^c	0.92 ^{bc}	0.96	0.92	0.98	0.68
Heart Girth	5.91	5.97	4.41	2.92	1.34	4.51	5.10	0.95
Barrel Circumference	5.18	2.92	1.84	0.16	2.17	3.84	1.21	1.54
Chest Width	7.84	5.52	6.48	5.21	1.29	5.95	6.57	0.91

Chest Depth 4.06^b 3.87^b -0.10^c -1.21^c 1.15 1.83 1.49 0.81

^aStandard error is reported as the average for the combined 4 treatments and 4 harvest times

^{bc}Least squares means with different letters are different (P<0.05)

Table A.3. Least squares means and standard errors for the influence of treatment and breed on linear measurement differences from day 0-63

Trait, cm	%DDGS				SEM ^a	Breed		SEM ^a
	0%	15%	30%	45%		1	2	
Chine Length	0.064	1.461	1.397	1.207	0.938	0.857	1.207	0.663
Loin Length	0.254	1.651	0.699	0.191	0.737	0.699	0.699	0.521
Rump Length	1.461 ^b	2.100 ^b	-0.889 ^c	0.699 ^{bc}	0.617	0.318	1.365	0.436
Withers Height	3.112	3.493	0.826	0.191	1.732	2.096	1.715	1.225
Hip Height	6.668 ^b	3.048 ^{bc}	0.572 ^c	-0.508 ^c	1.447	3.016	1.873	1.023
Heart Girth	8.573	6.731	4.382	4.699	2.109	6.858	5.334	1.491
Barrel Circumference	1.969	3.874	2.985	0.381	3.209	3.651	0.953	2.269
Chest Width	10.48	7.112	5.588	5.715	2.418	7.144	7.303	1.710
Chest Depth	7.493	-1.207	-1.969	1.969	2.383	3.842	-0.699	1.685
Horn Width	-0.318	0.381	0.064	0.127	0.231	0.127	0.00	0.164
Hip Width	5.461	1.270	2.921	1.207	2.196	3.524	1.905	1.553

^aStandard error is reported as the average for the combined 4 treatments and 4 harvest times

^{bc}Least squares means with different letters are different (P<0.05)

Table A.4. Least squares means and standard errors for the influence of treatment and harvest time on carcass cut weights

Trait, kg	%DDGS				SEM ^a	Harvest Time				SEM ^a
	0%	15%	30%	45%		1	2	3	4	
CCW	12.07 ^c	12.13 ^c	13.95 ^c	9.61 ^d	0.706	9.32 ^e	10.42 ^{de}	12.17 ^d	15.86 ^c	0.711
KPH	0.31	0.36	0.39	0.29	0.035	0.19 ^e	0.26 ^e	0.40 ^d	0.50 ^c	0.036
Foreleg	1.19 ^d	1.21 ^d	1.43 ^c	0.98 ^e	0.064	.98 ^e	1.10 ^e	1.24 ^d	1.50 ^c	0.065
Trotter Off	1.12 ^d	1.13 ^d	1.33 ^c	0.91 ^e	0.061	.91 ^e	1.04 ^{de}	1.15 ^d	1.39 ^c	0.061

Shank Off	0.84 ^{de}	0.88 ^d	1.04 ^c	0.71 ^e	0.055	0.67 ^e	0.80 ^{de}	0.91 ^d	1.08 ^c	0.055
Fore Trotter	0.09	0.09	0.10	0.08	0.007	0.080 ^d	0.082 ^d	0.98 ^{cd}	0.104 ^c	0.007
Fore Shank	0.26 ^{cd}	0.25 ^{cd}	0.29 ^c	0.22 ^d	0.017	0.23 ^d	0.24 ^d	0.24 ^d	0.32 ^c	0.017
Bnls. Foreleg	0.58 ^d	0.61 ^d	0.76 ^c	0.46 ^e	0.047	0.44 ^e	0.56 ^{de}	0.63 ^d	0.80 ^c	0.048
Shoulder	1.22 ^c	1.19 ^{cd}	1.36 ^c	0.94 ^d	0.089	0.93 ^d	1.05 ^d	1.15 ^d	1.57 ^c	0.089
Neck Off	0.85 ^c	0.82 ^{cd}	0.98 ^c	0.63 ^d	0.073	0.66 ^d	0.75 ^d	0.79 ^d	1.09 ^c	0.073
Neck	0.37	0.36	0.37	0.31	0.029	0.27 ^e	0.30 ^{de}	0.36 ^d	0.48 ^c	0.029
Bnls. Shoulder	0.48 ^c	0.43 ^{cd}	0.53 ^c	0.33 ^d	0.047	0.29 ^d	0.34 ^d	0.40 ^d	0.72 ^c	0.047
Ribs Whole	0.53 ^d	0.54 ^d	0.65 ^c	0.41 ^e	0.038	0.41 ^e	0.45 ^{de}	0.55 ^d	0.71 ^c	0.038
Trimmed	0.39 ^d	0.41 ^{cd}	0.49 ^c	0.29 ^e	0.031	0.32 ^d	0.37 ^d	0.39 ^d	0.50 ^c	0.031
Leg	1.79 ^d	1.79 ^d	2.11 ^c	1.44 ^e	0.093	1.39 ^e	1.67 ^{de}	1.80 ^d	2.25 ^c	0.093
Trotter off	1.71 ^d	1.68 ^d	1.98 ^c	1.34 ^e	0.089	1.30 ^e	1.58 ^d	1.69 ^d	2.14 ^c	0.089
Shank off	1.46 ^d	1.42 ^d	1.72 ^c	1.12 ^e	0.084	1.09 ^e	1.31 ^{de}	1.46 ^d	1.85 ^c	0.085
Hind Trotter	0.10 ^{de}	0.12 ^{cd}	0.13 ^c	0.09 ^e	0.010	0.09	0.11	0.12	0.13	0.010
Hind Shank	0.24	0.26	0.27	0.22	0.015	0.21 ^d	0.27 ^c	0.23 ^d	0.28 ^c	0.015
Bnls. Leg	1.00 ^{cd}	0.95 ^d	1.15 ^c	0.75 ^e	0.064	0.70 ^e	0.85 ^{de}	0.99 ^d	1.30 ^c	0.065
Back and Loin	1.09 ^{cd}	1.11 ^c	1.26 ^c	0.90 ^d	0.070	0.85 ^e	0.86 ^e	1.15 ^d	1.49 ^c	0.070
Back Strip	0.63 ^c	0.63 ^c	0.72 ^c	0.48 ^d	0.050	0.44 ^e	0.43 ^e	0.65 ^d	0.95 ^c	0.051
Lip off	0.35 ^{cd}	0.35 ^{cd}	0.39 ^c	0.27 ^d	0.030	0.25 ^e	0.24 ^e	0.36 ^d	0.50 ^c	0.030
<i>Psoas major</i>	0.060	0.054	0.067	0.046	0.008	0.034 ^e	0.045 ^{de}	0.066 ^{cd}	0.081 ^c	0.008
<i>Semimembranosus</i>	0.28 ^d	0.29 ^{cd}	0.35 ^c	0.23 ^d	0.022	0.20 ^e	0.23 ^e	0.29 ^d	0.42 ^c	0.022
Boneless lean ^b	2.69 ^c	2.62 ^c	3.16 ^c	2.02 ^d	0.194	1.87 ^e	2.18 ^{de}	2.67 ^d	3.76 ^c	0.195

^aStandard error is reported as the average for the combined 4 treatments and 4 harvest times

^bBoneless separable lean from the foreleg, shoulder, leg, back and loin

^{cde}Least squares means with different letters are different (P<0.05)

Table A.5. Least squares means and standard errors on the influence of treatment and harvest time on carcass cutability percentages

Trait, %	% DDGS				SEM ^a	Harvest Time				SEM ^a
	0%	15%	30%	45%		1	2	3	4	
KPH	2.45	2.84	2.64	2.89	0.182	2.15 ^d	2.29 ^d	3.25 ^c	3.12 ^c	0.183
Foreleg	10.08	10.13	10.35	10.42	0.189	10.62 ^c	10.65 ^c	10.23 ^c	9.47 ^d	0.188
Trotter off	9.58	9.38	9.63	9.61	0.245	9.77 ^{cd}	10.15 ^c	9.49 ^d	8.80 ^e	0.236
Shank off	7.11	7.26	7.49	7.45	0.171	7.24 ^{de}	7.77 ^c	7.54 ^{cd}	6.78 ^e	0.172
Fore trotter	0.77	0.79	0.72	0.91	0.064	0.87	0.82	0.83	0.68	0.064
Foreshank	2.23	2.13	2.15	2.37	0.156	2.54 ^c	2.35 ^{cd}	1.95 ^d	2.04 ^d	0.157
Bnls. foreleg	4.86	4.99	5.41	4.77	0.187	4.70	5.26	5.12	4.96	0.189
Shoulder	10.08	9.89	9.61	9.72	0.448	9.86	10.03	9.45	9.96	0.451
Neck off	7.10	6.81	6.89	6.62	0.414	6.97	7.11	6.41	6.93	0.417
Neck	2.98	3.10	2.73	3.12	0.179	2.89	2.94	3.06	3.03	0.180
Bnls. shoulder	3.66	3.37	3.58	3.22	0.220	2.97 ^d	3.13 ^d	3.24 ^d	4.49 ^c	0.221
Ribs whole	4.31	4.46	4.53	4.14	0.130	4.33	4.20	4.49	4.43	0.131
Trimmed	3.25	3.41	3.43	3.04	0.124	3.39	3.48	3.10	3.15	0.125
Leg	15.05	14.93	15.14	15.23	0.227	15.01 ^d	16.18 ^c	14.88 ^{de}	14.29 ^e	0.228
Trotter off	14.34	14.03	14.24	14.24	0.207	14.04 ^d	15.25 ^c	13.93 ^d	13.62 ^d	0.209
Shank off	12.15	11.78	12.25	11.76	0.202	11.70 ^d	12.49 ^c	12.02 ^{cd}	11.73 ^d	0.204
Hind trotter	0.86	1.05	0.94	1.01	0.079	0.99	1.07	0.97	0.82	0.080
Hind shank	2.14	2.25	1.99	2.49	0.141	2.34 ^d	2.77 ^c	1.91 ^{de}	1.85 ^e	0.142
Bnls. Leg	8.15	7.83	8.19	7.72	0.162	7.49 ^d	8.13 ^c	8.10 ^c	8.18 ^c	0.163

Back and Loin	8.98	8.93	9.07	9.29	0.245	9.09 ^c	8.25 ^d	9.49 ^c	9.44 ^c	0.246
Back Strip	5.06	4.95	5.06	4.83	0.198	4.68 ^e	4.04 ^f	5.31 ^d	5.87 ^c	0.200
Lip off	2.74	2.73	2.78	2.70	0.116	2.67 ^d	2.31 ^e	2.87 ^{cd}	3.10 ^c	0.117
<i>Psoas major</i>	0.46	0.43	0.47	0.45	0.037	0.36 ^d	0.44 ^{cd}	0.52 ^c	0.49 ^c	0.037
<i>Semimembranosus</i>										
	2.27	2.33	2.45	2.31	0.083	2.19 ^d	2.19 ^d	2.37 ^d	2.62 ^c	0.084
Boneless lean ^b	21.73	21.14	22.24	20.55	0.495	19.83 ^e	20.55 ^{de}	21.77 ^d	23.51 ^c	0.498

^aStandard error is reported as the average for the combined 4 treatments and 4 harvest times

^bBoneless separable lean from the foreleg, shoulder, leg, back and loin

^{cdef}Least squares means with different letters are different (P>0.05)

VITA

James Maynard, son of Neil and Julie Maynard, was raised on a farm in Carroll, Ohio, where he spent his early years competitively showing livestock and raising Boer goats. He graduated from Bloom-Carroll High School in 2008, and enrolled at Ohio State University Agricultural Technical Institute where he received his associate degree in livestock science in 2010. In the fall of 2010, he enrolled in The Ohio State University and majored in animal science. At Ohio State, he developed a passion for meat science while serving on the collegiate meat judging team and working in the meat laboratory. It was his desire to pursue meat science and goat production that led him to Louisiana State University in January of 2013. Following graduation, James will return to Ohio and continue to raise goats and explore his passion in the field of Animal Science.