DETERMINING THE YIELD AND CHEMICAL CHARACTERISTICS OF TRIMMINGS FROM HOT PROCESSED AND TRADITIONALLY PROCESSED CULL MEAT GOATS

by

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Abstract

Two experiments were completed as a part of this study. The objective of the first experiment was to determine the differences in chemical characteristics of trimmings from hot processed and traditionally processed cull meat goats. Crossbred cull doe goats (n=18) were assigned to one of 3 kills days with 6 replications per day. The sides of each goat were randomly assigned to hot processed (HP) or traditionally processed (TP). HP sides were fabricated within 2 h of slaughter, ground with 2% salt and dry ice and then held at 2^{o}C for 24h. TP sides were chilled at 2^{o}C for 24 h prior to fabrication and grinding. After sampling, 2% salt was added to remaining trim yielding 2 treatments: traditionally processed with no salt added (TPNS) and traditionally processed with salt added (TPS). As expected, the HP treatment had a higher ($P<0.0001$) ultimate pH than TP and a higher water holding capacity (WHC) than TPS ($P<0.002$) and TPNS ($P<0.001$) treatments. HP and TPNS had significantly higher ($P<0.0007$ and $P<0.0003$, respectively) percent moisture than TPS. Percent fat was similar ($P>0.19$) for all treatments. However, TPNS had more protein ($P<0.0001$) than either the HP or TPS treatments. HP and TPS had decreasing L* values until d 6 when values increased significantly while TPNS decreased steadily by day. HP and TPS differed significantly from TPNS until d 6 when no significant differences were seen. For all treatments, a* values showed decreasing values until d 6. For all treatments, b* values increased until d 5. The objective of the second experiment was to investigate the viability of composting as a means for disposing of goat tissues resulting from the slaughter and fabrication process. By-products from the slaughter of cull meat goats (n=18) were assigned to 3 treatment piles: bones, offal + head (OH), and whole (bones, skull, and offal). Bones and OH piles increased in temperature, with peaks at wk 7 and wk 9, while whole piles had elevated temperatures from wk 5 to wk 9. Bone piles had statistically lower temperatures through wk 3, but were not statistically different than other treatments through the duration of the study. Whole piles had higher ($P<0.0001$) temperatures over the 8 wk composting period than OH and bone piles. Bone decomposition progressed over 90 d; at d 60, bones in whole piles had greater ($P<0.05$) decomposition than in bone piles. Similarly, skulls decomposition increased over the 90 d

period. At d 60 and 90, skulls in whole piles had greater ($P<0.05$) decomposition than skulls in OH piles.

Keywords: compost, decomposition, goat, hot processing, pH, water holding capacity

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Chapter 1 - Literature Review

As the cultural demographics of the United States continue to evolve, consumer trends in food choices and purchasing behavior are also changing. An increase in international populations, who are accustomed to eating goat as a regular part of their diet, are steadily increasing the United States' demand for goat as a staple protein source. For this reason, it is important for the livestock industry to direct efforts to meet this demand. There has been substantial research conducted to assess the use of hot processing of cull animals in beef, pork, and lamb for use in processed meats. Similarly, cull goats are commonly marketed at a significantly lower price than young market animals. It is important now to consider how hot processing techniques can be utilized to increase the value and marketability of cull goat breeding stock.

Overview of the Goat Industry

Trends in Goat Consumption

The increasing demand for goat products in the United States can be largely attributed to changing population demographics. Because goat is a common protein source in many countries, demand in the United States is increasing as a result of an influx of cultural diversity. Goat meat is predominately imported from Australia and New Zealand; however, domestic production has increased steadily in recent years in order to meet demand (USDA APHIS, 2002). In 2007, it was estimated that production in the United States resulted in more than a 750,000 head deficit for the current demand (Solaiman, 2007). Hispanic, Muslim, Caribbean, and Chinese populations are the predominant ethnicities driving demand for goat meat (Larsen, 2004). While many ethnic groups incorporate goat meat into their diet, they have different preferences leading to product diversity in the market. Hispanic populations prefer cabrito (young goat) and Caribbean consumers prefer older bucks. Solaiman (2007) reported that Muslim consumers do not have specific age/sex requirements, but do require that animals be slaughtered under Halal requirements. Although demand may be slightly elevated during special holiday times, the demand for goat meat is fairly consistent year-round, which is indicative that goat meat is a

regular part of the diet in many cultures. Long-term growth and demand is expected in areas that have large Asian and African populations. Additionally, it is believed that ethnic populations are generally situated in heavily populated metropolitan areas as well as university towns. Therefore, production is typically in rural areas and then shipped to metropolitan areas (Larsen, 2004). Although consumption is greater on the East and West Coast, a gradual shift towards the Midwest is also being seen and is expected to continue in years to come (USDA APHIS, 2002).

Trends in Goat Production

The world goat population has been increasing 8% to 10% annually for the last 20 years (FAOSTAT, 2005). As of 2005, the United States' importation of goat meat accounted for 18% of the market (FAOSTAT, 2005). According to USDA-NASS, in 2009, the United States goat population was over 3 million animals and meat goats accounted for over 82% of the population. Additionally, meat goat inventory in the United States increased 34% between 2002 and 2007 and sales have increased 11%. As of 2007, Texas was the highest producing state with 38% of the total meat goat population (987,173 head) and 37.6% of sales (463,821 head). Tennessee and Oklahoma are the 2nd and 3rd highest meat goat producing states (124,967 and 117,324 head, respectively). Oklahoma has the 2nd highest sales (64,348 head) and Tennessee ranks 3rd highest for sales (59,677 head) of meat goats. In 2007, Kansas accounted for 1.7% of the total meat goat population (44,728 head) and 2.5% of sales (29,723 head) (USDA Census, 2007). Because of the diversity of ethnicities demanding goat meat, there are two predominant marketing schemes. First, direct sale of live goats to consumers is very common. This route encompasses selling live animals to consumers who harvest the animals themselves, the producer slaughtering the chosen goats for the consumer, or cooperative small-scale farming operations. Because direct sales are often not reported, sales estimates are difficult to measure. However, sales are expected to exceed the volume of federally inspected slaughter, 600,000 head in the 2003 fiscal year. The second marketing scheme is to sell live goats at auction. The animals are then shipped to slaughterhouses, particularly religious or custom slaughterhouses (USDA APHIS, 2002).

Conversion of Muscle to Meat

In living animals, skeletal muscle is the type of muscle responsible for locomotion and support. After harvest, skeletal muscle provides a nutritious food source for humans and is referred to as meat (Greaser, 1986). The conversion of muscle to meat entails a series of metabolic and physical changes. In living animals, oxygen is transported to cells by the bloodstream. In addition, blood transports compounds, such as energy-rich glucose, and is also responsible for transporting CO_2 and other by-products of metabolism to organs, such as the liver, lungs, and kidneys, for removal (Honikel, 2004). In the living animal, energy is stored in muscles either as glycogen, creatine phosphate (CP), or in fat in the form of triacylglycerols. When energy is needed reserves of CP, glycogen and triacylglycerols are broken down to produce adenosine triphosphate (ATP) (Honikel, 2004). At the time of death, blood flow through the animal is disrupted and ceases and oxygen is no longer transported to muscles. As a result, the citric acid cycle and the oxidative phosphorylation pathway can no longer be used to breakdown glycogen. Glycogen is therefore broken down anaerobically, resulting in the production of lactate (Honikel, 2004). In addition, energy stores can no longer be utilized, and by-products of metabolic processes can no longer be removed causing build-up within muscle (Greaser, 1986, Honikel, 2004). The rate of postmortem changes differs between muscle fiber types (red and white). Because different muscles are made up of varying amounts of red and white fiber types, the time required for the conversion from muscle to meat is not homogenous throughout the animal (Greaser, 1986). Shortly after harvest, pH is stable as CP is able to buffer the consumption of ATP (Honikel, 2004). During anaerobic glycolysis, the pH within muscle drops as hydrogen ions are released when glucose is broken down to lactate. The time required for pH levels to stabilize varies by species, but occurs once ATP supplies are fully utilized and glycogen stores are depleted (Honikel, 2004).

pH Decline

When animals are harvested, a multitude of changes to the characteristics of muscle occur as processes required for life are interrupted. When an animal is bled, blood is no longer transferring oxygen to muscle cells. As a result, aerobic glycolysis is no longer

possible and anaerobic glycolysis takes over (Romans et al., 2001). Postmortem pH decline occurs as a result of the by-products of anaerobic glycolysis, most notably lactic acid formation (Aberle et al., 2001, Honikel, 2004). Movement in living muscle is caused by the contraction and relaxation of sarcomeres, which are the basic unit of muscle. The initiation of both movements utilizes energy, in the form of ATP. Rigor mortis takes place as biological processes are discontinued and ATP is no longer produced. Once rigor mortis has taken place, muscle filaments are no longer able to freely relax and contract causing muscle to become stiff. The rate of muscle pH decline and the time required to reach its final pH is highly variable and is dependent on a number of factors including species, the ratio of red and white muscle fibers, the rate at which it cools (influenced by the temperature of the cooler, fat cover of the animal, etc.), and to what extent the animal may have experienced stress prior to death (Greaser, 1986, Romans et al., 2001). When muscle undergoes rapid or large pH decline that results in a pH close to the isoelectric point (IP), which is approximately 5.2 (Hamm, 1986), muscle will be pale and exhibit poor water holding capacity (WHC) (Aberle et al., 2001). Conversely, muscles that maintain a high pH will have a dark appearance and exhibit a greater WHC because water is tightly bound to protein (Aberle et al., 2001). Figure 1.1 illustrates that as the pH decreases and gets closer to the isoelectric point of myofibrillar proteins, fewer attractive forces are available to bind to water molecules (Aberle et al., 2001). This phenomenon is commonly referred to as the net charge effect. Although the final pH of beef and pork is generally 5.4-5.6, the pH of goat meat is highly variable based on breed, but averages a pH of 6.0 (Romans et al., 2001, Karakaya et al., 2006).

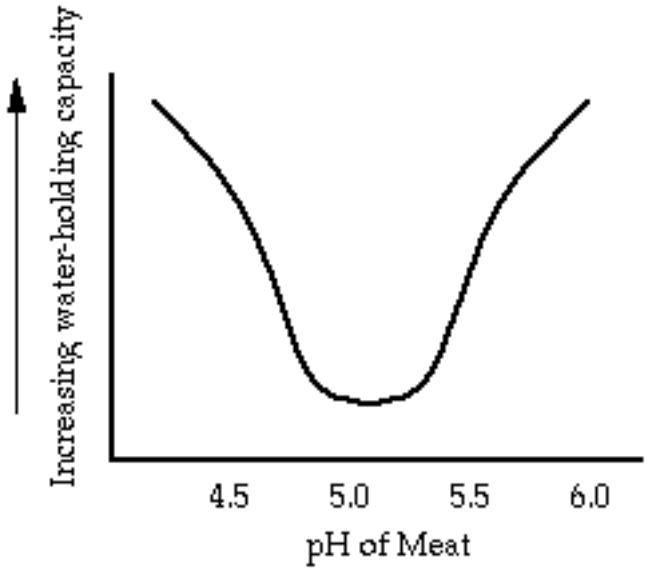

Figure 1.1 pH effect on water holding capacity (modified from Aberle et al., 2001)

Water Holding Capacity

In all species, lean muscle is made up of approximately 72% water (Romans et al., 2001). For this reason, the ability of meat to retain water is invaluable in maintaining product volume and, ultimately, the value of the finished product. According to Aberle et al. (2001), water holding capacity (WHC) is the ability of meat to hold both naturally occurring and added water throughout processing, such as cutting, heating, grinding, and pressing. Water holding capacity has a direct effect on the severity of shrinkage of meat during storage. After death, lactic acid formation and the corresponding decrease in pH caused by muscle metabolism reduces the availability of muscle proteins to bind water. Figure 1.2 demonstrates the method by which muscle proteins bind water molecules. The polarity of water molecules causes bound water to be tightly held to muscle proteins (Hamm, 1986) by electrostatic forces. Additional water molecules are then attracted to the bound water, however the strength of attraction gets progressively weaker (Aberle et al., 2001) causing free water to be held only by capillary forces (Hamm, 1986).

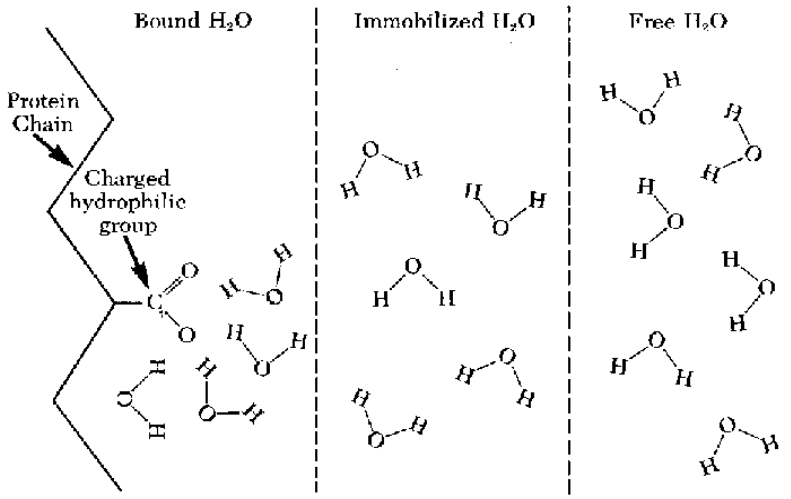

Figure 1.2 Meat protein effect on water binding (modified from Aberle et al., 2001)

Meat Color

A consumer's initial perception of quality of a meat product is based on appearance. For this reason, the predominant factor that will influence their purchasing decisions is color. The two primary proteins that contribute to meat color are: hemoglobin, the pigment of blood and myoglobin, which is the pigment of muscle (Aberle et al., 2001, Mancini and Hunt, 2005). In a properly bled animal, most of the hemoglobin is removed from muscle, so myoglobin content accounts for 80 to 90% of the total pigment (Aberle et al., 2001). Myoglobin content is highly variable and is affected by species, age, sex, muscle, and physical activity (Aberle et al., 2001) as well as pre-harvest handling, genetics, and diet among others (Mancini and Hunt, 2005). Meat pH and meat color are intimately linked; meat with a higher pH will result in a firmer texture due to a greater amount of bound water. According to Lawrie (1958), the firmer texture does not allow as much light to scatter off of the meat surface resulting in our eyes perceiving a darker color. Additionally, the ability of oxymyoglobin (bright-red color) formation is reduced. Muscle that has been excised from the carcass prior to chilling, commonly referred to as hot boning, tends to exhibit a darker color (Huffman, 1980, Claus et al., 1984). These findings are in line with that of Lawrie (1958) because hot boning has been shown to result in a higher ultimate pH.

Pre-rigor Processing

Hot processing, or hot boning, is the process by which meat is removed from the carcass prior to chilling. Pre-rigor processing refers to the removal of meat that has not yet undergone the chemical and physical changes of rigor mortis. Hot processing was common in meat processing prior to the invention of refrigeration (Hamm, 1986). It has not been widely adopted in the beef industry due to complications with grading and marketing programs. However, it now comprises a large sector of the whole-hog sausage industry. Pre-rigor processing allows the processor to salt the meat before the onset of rigor mortis, which inhibits the muscle pH from dropping to levels commonly seen with traditional processing (Romans et al., 2001). Hamm (1986) described that meat that had been hot processed had superior WHC as compared to meat that has been traditionally processed and chilled. Because of this, pre-rigor meat has better fat-emulsifying properties producing sausages with less moisture loss and reduced incidence of fatting out. The addition of salt can exacerbate the increased WHC benefits of hot processing. When salt ions bind to muscle proteins, there is an increase in the electrostatic repulsion between adjacent protein molecules, (Hamm, 1986) which increases the net charge effect allowing greater water retention between proteins.

Pre-rigor Processing of Goat Meat

The effect of rigor state on quality and stability of goat sausages was evaluated by Dzudie and Okubanjo (1998). Twelve African Dwarf goats were assigned to one of three treatments: pre-rigor, post-rigor, or 50:50 blend of pre- and post-rigor. Thiobarbituric acid (TBA) levels were significantly lower ($P < 0.05$) in pre-rigor sausage, indicating that pre-rigor grinding and salting reduces the rate of oxidation. TBA values may also be affected by the lower fat content. Further, ultimate pH was higher in pre-rigor sausage than sausage containing post-rigor meat. This was most likely the result of salting pre-rigor meat reducing the rate of glycolysis resulting in a reduction in the rate of pH decline. Similarly, water-holding capacity (WHC) was significantly higher ($P < 0.05$) in pre-rigor sausages. The higher pH and WHC are consistent with the moisture content of pre-rigor sausage that was higher ($P < 0.05$) than the moisture content of the post-rigor sausage and 50:50 blend

in both the raw and cooked form. The protein and fat contents were lower ($P < 0.05$) in pre-rigor sausage, which can be attributed to the higher water-holding capacity. There were no significant differences in ash content in the three treatments. Dzudie et al. (2000) cured loin sections, from Grassland African Dwarf goats (n = 6), using a curing brine (10g nitrite, 2.6g dextrose, and 2.5g phosphate) to evaluate effects of cooking methods and rigor state on eating quality of cured goat loins. They found that moisture content was higher in pre-rigor roasts ($P < 0.05$) cooked in a water bath compared with post-rigor roasts.

Sharma et al. (1988) researched the influence of hot boning on meat yield and physical characteristics of goat carcasses. Black Bengal goats (n = 15) at about one year of age were utilized. They reported that total meat yields were similar between hot boning and traditional processing procedures. Cooking losses were higher ($P < 0.05$) in chilled meat when compared to hot boned meat. However, drip loss was lower ($P < 0.05$) when thawing frozen, traditionally processed meat in comparison to frozen, hot boned meat, and may be attributed to the occurrence of thaw shortening.

Hot Processing in Other Species

Mandigo and others (1977) investigated the yields of cured ham, bacon, and loins in commercial accelerated pork processing. With the accelerated processing treatment, carcasses were cut within 1 h after slaughter. In the conventional treatment, carcasses were chilled for 24 h at 1.7 ^{o}C prior to carcass fabrication. The yield for smoked bone-in hams, bacon, and smoked pork loins were similar regardless of treatment. Some differences were found in weights during the initial processing, but were reduced after the completion of processing. In a previous study, Mandigo and Henrickson (1966) found no differences ($P > 0.05$) in the yield of finished ham produced from hot boned and traditional cold boned meat, but that hot processed hams were more tender ($P < 0.05$) based on shear values. Furthermore, proximate analysis found no differences ($P > 0.05$) in moisture content.

In 1979, Cross and others found that ground beef from hot processed carcasses had higher ($P < 0.05$) values for tenderness and juiciness. Additionally, hot processed ground beef exhibited a lower ($P < 0.05$) percent cooking loss. Although there were no differences ($P > 0.05$) in percent moisture or fat in the raw form, or percent fat in cooked ground beef,

percent moisture in the cooked ground beef was higher ($P < 0.05$) for hot processed compared to traditionally processed ground beef, indicating that ground beef from hot processed beef has a greater water holding capacity.

Challenges Associated with Hot Processing

Several researchers have found that there are some challenges associated with using hot processed meat, particularly in whole muscle applications. In 2009, Pivotto et al. researched the effect of hot processing and moisture enhancement on meat quality to improve meat quality of longissimus muscle in cull beef cows (n = 70) of known age and breed composition. They compared hot processed to conventionally chilled muscles and three different enhancement solutions (sodium tripolyphosphate/salt, sodium citrate/calcium ascorbate, and calcium lactate). Hot processed muscles had an increase in shear force and a decrease in tenderness ($P < 0.001$) due to decreases in sarcomere length ($P < 0.001$) compared to conventionally chilled muscles.

When comparing boning methods and postmortem aging on meat quality characteristics of pork loin, Li et al. (2009) used Chinese native black pigs (n = 30). Carcasses were split into three groups: hot boning of carcasses within 45 minutes postmortem, cold boning after chilling at 0 ^{o}C for 24 h, and cold boning after chilling at 0 ^{o}C for 36 h. Hot boned loins had lower shear values ($P < 0.001$) for raw meat compared to traditionally chilled loins. However, it was found that cold boning after 36 h produced more desirable color, lower cooking loss ($P < 0.0001$), and lower cooked shear values ($P < 0.001$) than hot boned pork loins in addition to benefits in tenderness, juiciness, and overall liking ($P < 0.0001$).

Regulatory Impacts on Goat Disposal

According to the USDA APHIS (2001), Scrapie, a transmissible spongiform encephalopathy (TSE), is a fatal, degenerative disease affecting the central nervous system of sheep and goats. Scrapie has a long incubation period and can remain dormant in an animal from 2-5 years when exposed at birth (Machen, 1997). According to FDA (1997), ruminant animal by-products cannot be used in feed for ruminants due to the risk of inclusion of specified risk materials (SRMs). Rendering companies are given the freedom

to choose what offal they will accept for processing. Because goat offal may contain TSEs, rendering companies will rarely accept the offal for processing. This requires processors to utilize other means of disposal; the most common disposal means is the landfill.

Composting

Due to increasing costs, limited landfill resources and increasing environmental regulations regarding waste disposal, food-processing companies are faced with challenges to address cost effective waste removal. Composting is a popular consideration for many reasons: reduction of organic by-products, the temperatures achieved during composting will kill many pathogens that may be present, and it can potentially generate revenue by producing a product that is marketable (Schaub and Leonard, 1996). Composting is a natural process in which aerobic microorganisms biodegrade organic matter (Tronina and Bubel, 2008) to create a nutrient rich substrate that can be used as a soil supplement (Schaub and Leonard, 1996, Sander et al., 2002, Fonstad et al., 2003). In order for decomposition to occur, the ratio of carbon to nitrogen (C:N) is integral. To promote microbial activity, the C:N should be between 25:1 and 35:1 (Schaub and Leonard, 1996, Tronina and Bubel, 2008). Wet, green materials such as leafy materials and meat by-products contain more nitrogen. Conversely, dry, brown materials such as straw, sawdust and paper contain more carbon (Rynk, 1992).

There are three common composting methods: passive piles/windrows, turned or aerated piles/windrows, and in-vessel systems. Passive piles are simply laid in a designated area, while windrows are three sided structures that add support and boundaries for the piles (Schaub and Leonard, 1996, Berge et al., 2009). Passive piles are the least advanced technology, but require the least initial investment and least labor. Compost that is being processed in passive piles is undisturbed after the piles have been created. This technique utilizes natural airflow for aeration (Schaub and Leonard, 1996), but due to the lack of uniformity of carcasses and meat production waste, this method can create uneven decomposition (Berge et al., 2009). Turned or aerated piles are established in the same manner as passive piles. However, in aerated systems, air is introduced to the interior of the piles through fans or duct systems (Berge et al., 2009). Turned piles are rotated either

manually or by using heavy equipment (Fonstad et al., 2003). Although there is a greater labor input, both methods boast improvements in aeration, temperature control, and uniformity of decomposition (Schaub and Leonard, 1996, Berge et al., 2009) over passive piles. In-vessel systems are usually smaller, completely contained structures, require the greatest investment, and utilizes the greatest amount of technology. The material to be composted is put into an insulated structure, such as a drum or bin, (Schaub and Leonard, 1996) in which the aeration, moisture content, and temperature can be easily regulated or manipulated (Berge et al., 2009). Due to space requirements, cost and efficiency, the passive and turned piles are the most commonly implemented by the livestock industry.

Livestock Composting

The cost of animal mortality pick-up has risen recently due to a decreased demand for rendered products as well as the closing of rendering plants throughout the United States (Keener et al, 2000). As the price for mortality disposal increases and concerns regarding size and utilization of landfills increases, composting has become increasingly popular to the livestock industry. Livestock composting has become a routine management practice on farms as a means of mortality disposal. With a well-designed program, composting can be a cost effective and efficient means of disposal that can be further utilized by providing fertilizer to be used on fields (Berge et al., 2009).

Stanford et al. (2009) explored the effects of cattle age and turning technology on disappearance of bone from mortality compost. Windrows were constructed and a base of barley straw was used with a minimum depth of 40 cm. The carcasses were placed on the straw and then covered with beef manure obtained from a feedlot. The first windrow utilized mature cattle (n = 24) that were greater than 30 months of age. The compost was turned at days 93 and 211, and at 310 days residual bone mass was collected. The second windrow contained calves (n = 23) that were less than 30 months of age. The compost was turned at days 72 and 190, and residual bone mass was collected after 289 days. One half of each windrow was rotated using a tractor and bucket; the other half was rotated with a grinding bucket. They found that there was a 44.1% and 38.7% disappearance of bone in mature cattle and calf piles, respectively. In a follow-up study, they found compost piles

with a mean temperature over 58 ^{o}C for a seven week period saw a 54% disappearance of long bones. Additionally, piles that were actively heating over a 9-10 month period had brittle bones that could be applied to fields.

Fonstad et al. (2003) evaluated the use of composting as an option for dead animal management in Saskatchewan. The compost pile was constructed by laying a base of a mixture of manure and straw that was approximately 0.6 m deep in a 4 x 6 m area. The first pile consisted of 5 pigs that were laid side by side and weighed a total of approximately 150 kg (all approximately 30 kg). The second group (n = 5) was laid next to the first group and weighed approximately 128 kg (one animal weighing 80 kg and 4 weighed 12 kg). Groups of animals were added as mortalities on the farm occurred until the mortalities in the pile totaled a weight of 2000-2500 kg. The piles were covered with another layer of a manure and straw mix. The pile was aerated by rotation with a front-end loader. Volume reduction was measured throughout the composting period and it was observed that the volume of the pile was reduced by 50-60% of the original volume. At the end of the composting period, the compost pile contained approximately 3900 kg of dry matter that was screened for bone fragments. The bone fragments recovered were less than 150 mm in length, brittle, and exhibited a spongy texture. The total mass of materials unsuitable for field application was 1.5 kg, or 0.04% of the original pile, that were recognizable as animal remains.

In 2003, Mukhtar et al. explored a low maintenance approach to large carcass composting utilizing bovine and equine mortalities. Three 3 m x 6 m bins were constructed using hay bales. Two bins were utilized for carcass compost piles, while the third stored horse bedding and waste. The compost bins were filled approximately 0.46 m deep with the horse bedding and waste. In the rear of the compost bins, 2 wooden pallets were laid down to allow aeration of static piles to reduce the frequency of pile turning. One horse was laid on its side on the pallet and covered with a 0.46 – 0.61 m layer of horse bedding. The pile was denoted HOP and was left untouched for 6 months. Two months later, 3 more piles were established: 1 horse pile without pallets (horse), 1 cattle pile on pallets (COP), and 1 cattle pile without pallets (cow). The piles were covered in a similar manner as the first pile. A tractor with a front-end loader was used to rotate the piles. The piles without pallets were turned at 3 and 6 months, and the piles on pallets were only turned at 6 months. After 6 months, the HOP pile was rotated and several large bones were identified. After 9

months, several partially or fully decomposed bones were observed. After 6 months, the COP pile was turned and it was observed that most of the cow carcass was biodegraded with no flesh or soft tissue intact, however a few large bones were intact. After 9 months, all 4 piles contained a few large bones. However, intact bones did not require screening or mechanical crushing prior to land application as they shattered and disintegrated easily upon application.

Little research has been conducted on composting by-products, offal, and waste associated with meat processing. However, the success of livestock composting is a positive indicator that composting can be an alternative, particularly for small processors, to dispose of waste during processing.

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Chapter 2 - Determining the yield and chemical characteristics of trimmings from hot processed and traditionally processed cull meat goats

1. Introduction

The United States has seen a gradual shift in cultural demographics and an increase in international populations who are accustomed to eating goat as a regular part of their diet. This shift has created an increase in the United States' demand for goat as a staple protein source. Between 2002 and 2007, meat goat inventory in the United States increased 34% and sales have increased 11% (USDA Census, 2007). With increasing goat production, there has been an increase in the number of cull goats, which are marketed at significantly lower prices than young market animals. There has been substantial research conducted to assess the use of hot processing of cull females in beef, pork, and lamb for use in processed meats. Hot processing has not been widely adopted in the beef industry due to marketing and grading, however it comprises a large sector of the whole-hog sausage industry. As a result, this technology may be useful to the goat industry in order to increase the value and marketability of cull breeding stock.

After harvest, the carcass immediately begins undergoing metabolic and physical changes. One of the most important attributes affecting meat quality is the postmortem pH decline, which occurs as a result of the by-products of anaerobic glycolysis, most notably lactic acid formation (Aberle et al., 2001, Honikel, 2004). When metabolic activity has ceased, carcasses are said to have undergone rigor mortis.

Pre-rigor processing, or hot boning, is the process by which meat is removed from the carcass prior to the onset of rigor. This is beneficial to processed meat producers because pre-rigor meat has been reported to have superior water holding capacity compared to traditionally processed and chilled meat (Hamm, 1986). Because of this, pre-rigor meat has better fat-emulsifying properties leading to sausages with less moisture loss and reduced incidence of fatting out. Furthermore, pre-rigor processing allows a processor to salt meat before the onset of rigor mortis, inhibiting the muscle pH from dropping to levels commonly seen with traditional processing methods (Romans et al., 2001). The addition of

salt increases the net charge by increasing the electrostatic repulsion between protein molecules, allowing for an even greater amount of water retention between proteins (Hamm, 1986).

Muscle that has been excised from the carcass prior to chilling, or hot boned, tends to exhibit a darker color (Huffman, 1980, Claus, et al., 1984). Muscles that maintain a high pH will have a dark appearance (Aberle et al., 2001) and will result in a firmer texture because water is tightly bound to protein. Lawrie (1958) described that this phenomenon results because not as much light scatters off of the firmer meat surface resulting in our eyes perceiving a darker color. Additionally, the ability of oxymyoglobin (bright-red color) formation is reduced.

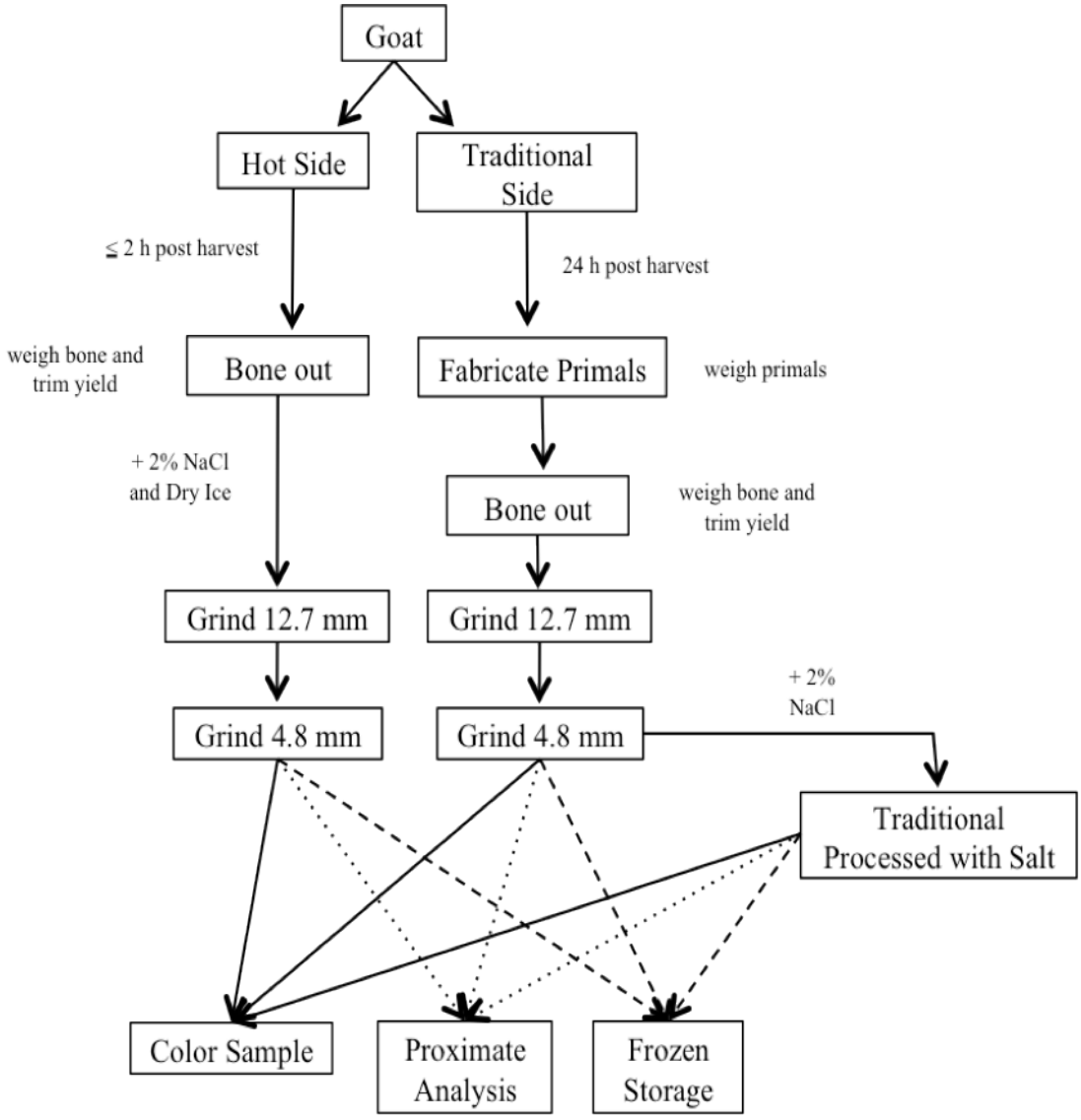
The benefits of hot processed meat for use in sausage production have been demonstrated in several species. However, there has been little research conducted to evaluate pre-rigor goat meat as a means to add value to cull goats in the meat processing industry. Therefore, the objective of this study was to compare the chemical characteristics and composition of hot processed and traditionally processed meat in cull doe goats.

2. Materials and Methods

2.1. Experimental Design

Eighteen cull doe goats were harvested. Harvest took place on 3 d and 6 goats were harvested per day. The left and right sides were assigned to 1 of 2 treatments: hot processing and traditional processing. For each harvest date, each treatment had 3 left and 3 right sides. The processing plan can be seen in the flow diagram in Figure 2.1 below.

Figure 2.1 Procesing schematic for cull doe goat processing



2.2. Live Animal Treatment

Procedures used in this experiment were approved by the Institutional Animal Care and Use Committee at Kansas State University (# 2823). Cull doe goats (n = 18) were purchased from a facility in Yates Center, KS that were consistent with the type of goat used in Kansas commercial goat operations. They were housed at the Kansas State University Sheep and Goat facility beginning in October 2009 until harvest in April 2010. For sanitation purposes, goats were sheared at the sheep and goat facility on the morning of

harvest prior to delivery. The goats were harvested within 4 h, which may have effected stress levels in some animals.

2.3. Harvest

Goats were harvested on three different days, with 6 goats harvested on each day. The goats were provided access to fresh water prior to harvest and were harvested within 4 h of delivery. Goat live weights were recorded and ranged from 21.79 kg to 63.56 kg. The goats were harvested under USDA inspection; each animal was rendered unconscious using captive bolt (Colt Special Stunner, .22 caliber, Birmingham, England), raised by shackling one leg and then exsanguinated. The time of death was recorded. The head and hide were removed, labeled and bagged for use in a compost study. Evisceration was completed as quickly as possible, and after post-mortem inspection the offal was labeled and bagged for use in a compost study. The goats were split using a handsaw, USDA inspected, and then weights for right and left sides were recorded. Carcass sides were randomly assigned to one of two treatments: hot processing where the muscle is removed prior to chilling or traditional processing where the muscle is removed after a 24 h chilling period.

2.4. "Hot" Processing

The sides assigned to the hot processing treatment were taken directly from the abattoir to the processing room to be deboned $\leq$ 2 h post mortem. Lean and fat were removed from the bone, and then weighed to determine the product yield. The trim was then mixed in a tabletop ribbon mixer (Mainco USA, Model # RM-20, St. Louis, MO) for 5 min with 2 % sodium chloride (NaCl). Pelleted, food-grade dry ice (Continental Carbonic, Beatrice, NE) was added during mixing until the temperature reached 2 ^{o}C. The trim was then ground in a grinder (Hobart Co., Model # 4732, Troy, OH) using a 12.7 mm plate and then reground using a 4.8 mm plate. The product was then stored, in a covered plastic lug at 2 ^{o}C for 24 h. After 24 h, samples were taken from each side for proximate analysis (% fat, moisture, protein) and water holding capacity. Additionally, a sample was taken for instrumental tristimulus color analysis. The remaining trim was then vacuum packaged and stored at -23 ^{o}C.

2.5. Traditional Processing

After the 24 h chilling period, the traditionally processed sides of each carcass were fabricated into primal cuts based on Institutional Meat Purchasing Specifications (IMPS) for hotel service (used for carcasses ≥ 18.14 kg). Primal weights were recorded for the 10-5-71 leg, 10-5-11 hindshank, 10-5-50 loin, 10-5-30 rack, 10-5-35 ribs, 10-5-22 square-cut shoulder, 10-5-10 foreshank, and 10-5-13 neck.

After primal weights were recorded, all cuts were deboned and weighed to determine total product yield. The trim was then ground in a grinder (Hobart Co., Model # 4732, Troy, OH) using a 12.7 mm plate and then reground using a 4.8 mm plate. A sample was taken for instrumental color and proximate analysis. The remaining trim was then reweighed and mixed in a tabletop ribbon mixer (Mainco USA, Model # RM-20, St. Louis, MO) for 5 min with 2% NaCl. Samples containing salt were collected for proximate analysis and instrumental color measurements. The remaining product was vacuum packaged and stored at -23 ^{o}C.

2.6. pH Measurement

The initial pH was taken and recorded (Hanna Instruments, Model# HI9025, Woonsocket, RI), after the carcass was split, in the semimembranosus muscle just caudal to the pubis bone. The sides assigned to traditional processing were chilled at 2 ^{o}C for 24 h. The pH was measured every 15 min for the first 8 h. The pH was then measured every 3-4 h throughout the remainder of the 24 h period. Sides assigned to the HP treatment had a pH measurement taken prior to fabrication. Measurements were then taken regularly in the ground product during 24 h period.

2.7. Instrumental Color Measurement

Following fabrication and weighing, samples were packaged on a styrofoam tray with PVC overwrap. Ground product was displayed for 6 d at 2 + 1.3 oC in open-top display cases (Tyler Refrigeration Corp., Model # DMF8 Code: 8424, Niles, MI) under continuous fluorescent lighting (2153 lux, 3000 K, Phillips Electronics, Model # F3218/ADV830, Andover, MA), which simulated retail display. To minimize effects of case location, packages were rotated within the case daily.

Instrumental color values including CIE L*, a*, and b* values were measured on samples of the ground goat meat using a calibrated Hunter Lab MiniScan (45/0 LAV, 2.54-cm diameter aperture, 10° standard observer, Illuminant A, Hunter Associates Laboratory, Inc., Model # 4500L, Reston, VA) every 24 h for 6 d. Each package was scanned in triplicate and the values were averaged for statistical analysis.

2.8. Water Holding Capacity

Water holding capacity (WHC) was performed using a slight modification to the method described by Grau and Hamm (1953). Hot processed samples, traditionally processed samples with added salt, and traditionally processed samples without added salt (n=54) were frozen in liquid nitrogen and then pulverized using a table-top blender (Waring, Model# 51BL32, Torrington, CT). Humid Whatman No. 1 filter paper (Whatman Inc., # 1001-0155, Piscataway, NJ), 15 cm, was prepared by placing filter papers above saturated KCl (35g/100ml at 20 ^{o}C) in a dessicator for 24 h. Filter paper was placed on a 15 cm^2 Plexiglas plate and 500 – 700 mg of pulverized tissue was placed on the filter paper. Each sample was tested in duplicate (n=108). Four samples were stacked and pressed using a Carver Press (Carver, Inc., Model B, Wabash, IN) for 5 minutes at 68,947,572.9 Pa. Samples were removed from the press and the meat film area was traced onto the filter paper. Papers were then stacked and dried flat. The meat film and purge areas were measured on each sample using MeatScan software (version 1.1.168, AEW Consulting, Lincoln, NE). A ratio of meat area to purge area was created; a larger number indicates a larger WHC.

2.9. Proximate Analysis

Hot processed samples, traditionally processed samples with added salt, and traditionally processed samples without added salt (n=54) were frozen in liquid nitrogen, and pulverized in a table-top blender (Waring, Model# 51BL32, Torrington, CT) and then analyzed for protein (AOAC, 1994), moisture, and fat (AOAC, 2003) at the Kansas State University Analytical Laboratory.

2.10. Statistical Analysis

The data was analyzed using the GLM procedure in SAS (SAS Institute, Inc., Cary, NC). Duncan's Multiple Range test was performed at the ($P < 0.05$) level of significance. Treatment, goat, and day were the main effects tested. For the instrumental color data, treatment x goat, treatment x time, and goat x time interactions were tested.

3. Results and Discussion

Animal Data

The data from goat 4 was removed from the study, as it was an outlier and exhibited abnormal meat characteristics (pH > 7.0 after 24 h, pink colored lean, and ice crystal formation in muscles during 24 h chilling) due to unknown causes. Table 2.1 contains the live animal and carcass data. The live weight of the goats ranged from 22 kg to 64 kg, and averaged 41 kg. The large variation of live weight is consistent what might be expected of cull does in commercial goat production. There was no difference ($P > 0.45$) between traditionally processed (TP) and hot processed (HP) side weights. The average dressing percent (DP) was 42.1% and ranged from 35% to 46.4%. The dressing percent of cull does is consistent with the findings of Ryan and others (2006). In their study, range-fed Boer crossbred goats not supplemented with a concentrate diet had a dressing percent of 41.8 %.

Table 2.1 Live goat and carcass data

	Live Weight (kg)	**HCW[1] (kg)**	**Dressing %**	**TP[2] Side (kg)**	**HP[3] Side (kg)**
Range	22.0 – 64.0	7.8 - 28.9	35.0 - 46.4	4.3 - 15.4	4.0 - 13.5
Mean	41.0	17.3	42.1	8.8	8.6
SEM[4]	2.3	1.2	0.8	0.6	0.6

[1]HCW: Hot carcass weight
[2]TP: Traditionally processed
[3]HP: Hot processed
[4]SEM: Standard error of the mean

Yield

The data for traditionally and hot processed side yields can be found in Table 2.2. The differences in trim weight were not significant ($P > 0.06$). The bone yield from hot

processed sides was greater ($P < 0.04$) than that of traditionally processed sides. Because bone structure should be similar for both sides, the difference could be attributed to fabrication difficulty due to hot, pliable muscle. This is consistent with the data from Sharma et al. (1988) who found no significant differences between total meat yields of black Bengal goats between traditional and hot processing methods. For this reason, adopting hot processing methods would not negatively impact income based on yield.

Table 2.2 Hot processed and traditionally processed cull doe goat yields

	HP[1]	TP[2]	SEM[3]	P-value
Trim Yield (kg)	6.35	6.5	0.05	0.06
Bone Yield (kg)	2.42[a]	2.17[b]	0.08	0.04

[1]HP: Hot processed
[2]TP: Traditionally processed
[3]SEM: Standard error of the mean
[ab] means across treatment within yield without a common letter differ ($P < 0.05$)

Data for primal cut yields is listed in Table 2.3. The standard error was lowest for the foreshank, hindshank, and neck; these cuts do not see large variation regardless of muscle condition. The largest variation was seen in the 4 major cuts: leg, loin, rack, and square cut shoulder and had a range of 1.04 kg to 3.36 kg, 0.35 kg to 2.1 kg, 0.28 kg to 1.22 kg, and 1.17 kg to 4.61 kg, respectively. This data indicates that primal weight is highly variable in cull doe goats. Primal weights in this study are lower than what was seen by Ryan and others (2006) who looked at market animals and would likely have greater muscling condition. Because animals are culled from production for many reasons, this data is expected to be representative of what processors should expect.

Table 2.3 Primal cut yield for traditionally processed sides (kg) of cull doe goats

	Range	Mean	SEM[1]
Leg	1.04 - 3.36	2.13	0.13
Hindshank	0.38 - 0.93	0.58	0.03
Loin	0.35 - 2.1	0.99	0.1
Rack	0.28 - 1.22	0.67	0.05
Breast	0.37 - 1.82	0.99	0.09
Sq. Shoulder	1.17 - 4.61	2.5	0.19
Foreshank	0.27 - 0.48	0.39	0.01
Neck	0.19 - 0.84	0.41	0.04

[1]SEM: Standard error of the mean

pH Decline

A pH decline was observed on both traditionally processed and hot processed sides. Measurements were taken over a 24 h period. The data for traditionally processed sides was plotted in Figure 2.2 and was observed to follow a similar pattern to that of postmortem decline in other species, though the rate is increased and reaches a higher ultimate pH. The average ultimate pH for traditionally processed sides was 6.06 as shown in Table 2.4. The majority of pH decline is completed by 3 hours after death, which may be attributed to minimal fat cover in goats. Additionally, sides may chill at an increased rate versus a whole carcass. The pH decline for hot processed sides can be seen in Figure 2.3; the pH decline reaches a significantly higher ($P < 0.03$) ultimate pH of 6.3 (Table 2.4). The initial pH decline was rapid, and then began to stabilize after 3 hours. A large amount of variation was seen in the pH measurements over time. This is likely caused by the pH variation between different muscles. Because ground meat comprises all muscles, a consistent sample is difficult to obtain.

Figure 2.2 pH decline in traditionally processed cull doe goats

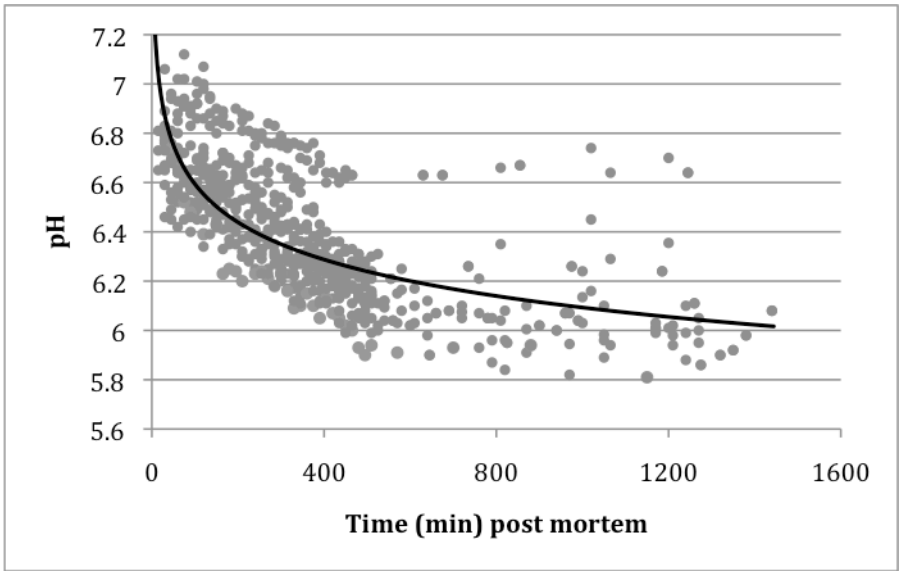


Figure 2.3 pH decline in hot processed cull goat meat

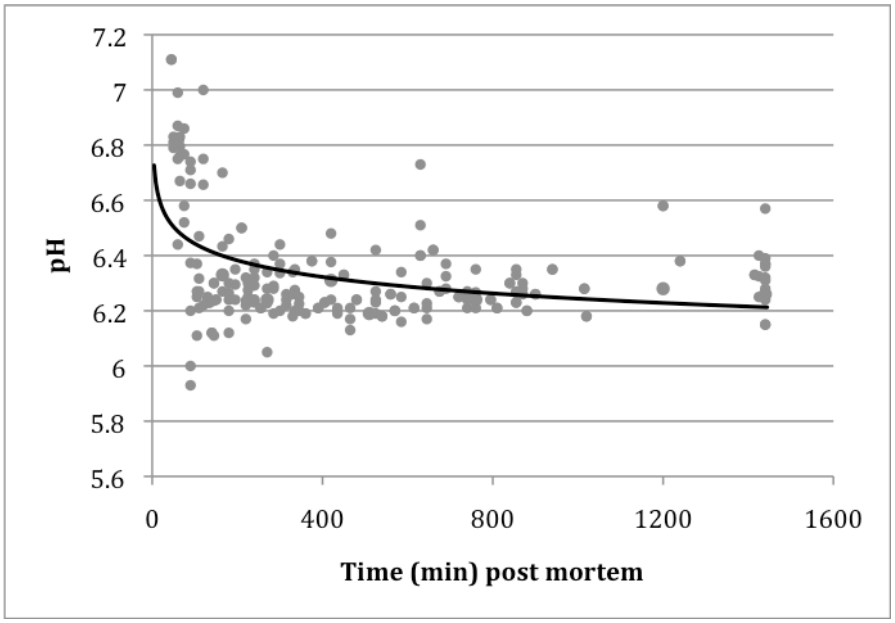


Table 2.4 Water holding capacity, proximate analysis and ultimate pH

	HP[1]	TPS[2]	TPNS[3]	SEM[4]
WHC[5]	0.66[a]	0.61[b]	0.53[c]	0.01
Moisture, %	70.02[a]	68.76[b]	70.14[a]	0.24
Fat, %	9.62	10.12	10.59	0.34
Protein, %	17.08[b]	17.32[b]	18.28[a]	0.15
Ultimate pH	6.30[a]	----	6.06[b]	0.03

[1]HP: Hot processed
[2]TPS: Traditionally processed with salt added
[3]TPNS: Traditionally processed with no salt added
[4]SEM: Standard error of the mean
[5]WHC: Water holding capacity
[abc] means within row without a common letter differ ($P < 0.05$)

Water Holding Capacity

Water holding capacity results can be found in Table 2.4. When using the WHC method developed by Grau and Hamm (1953), the area of meat and area of juice are made into a ratio. A larger number indicates a greater WHC. The HP meat had a higher WHC ($P < 0.002$, $P < 0.001$, respectively) than TPS and TPNS meat. This is consistent with the findings of Dzudie and Okubanjo (1998) who found the WHC of sausage made from pre-rigor meat to be higher ($P < 0.05$) than sausage made from post-rigor meat.

Proximate Analysis

The results for the proximate analysis can be found in Table 2.4. HP and TPNS had higher ($P < 0.0007$ and $P < 0.0003$, respectively) percent moisture than TPS. No difference ($P > 0.19$) was found between the treatments for percent fat. However, TPNS had a higher ($P < 0.0001$) percent protein than either the HP or TPS treatments. The percent fat findings are inconsistent with Dzudie and Okubanjo (1988) who found the protein and fat contents were significantly lower ($P < 0.05$) in the pre-rigor sausage.

Instrumental Color

The interactions of day x treatment for L* values can be seen in Figure 2.4. A day x treatment interaction was evident for L* values indicated by a significantly different relationship for the TPNS treatment versus HP and TPS treatments. There were no differences ($P > 0.86$ and $P > 0.33$, respectively) in day x treatment interaction seen for a* and b* values, as shown in Figure 2.5 and 2.6, respectively.

Figure 2.4 Day x Treatment interactions for L* values

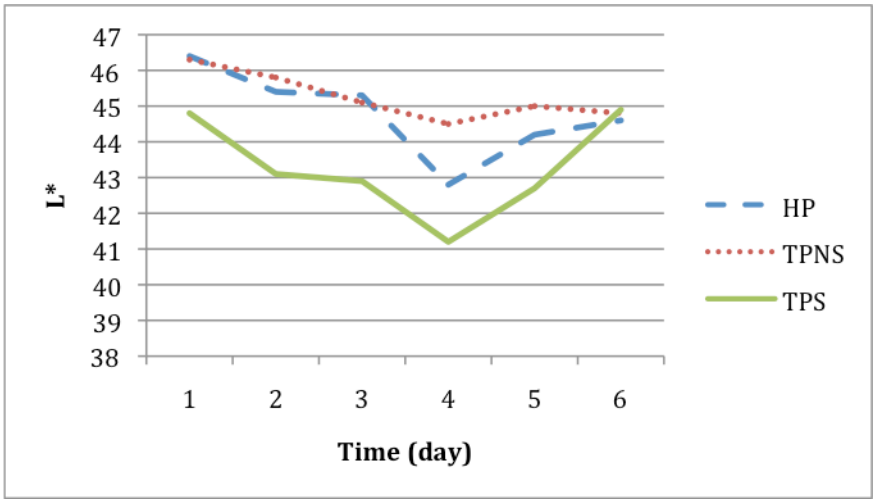


Figure 2.5 Day x Treatment interactions for a* values

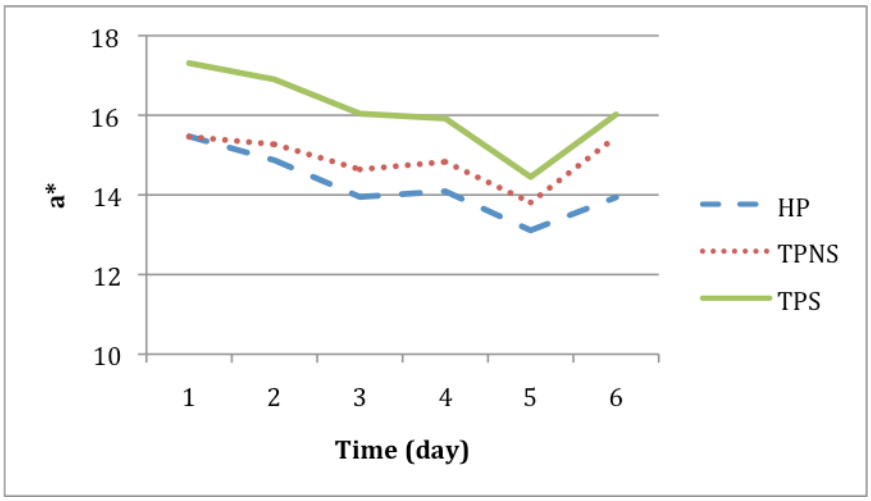
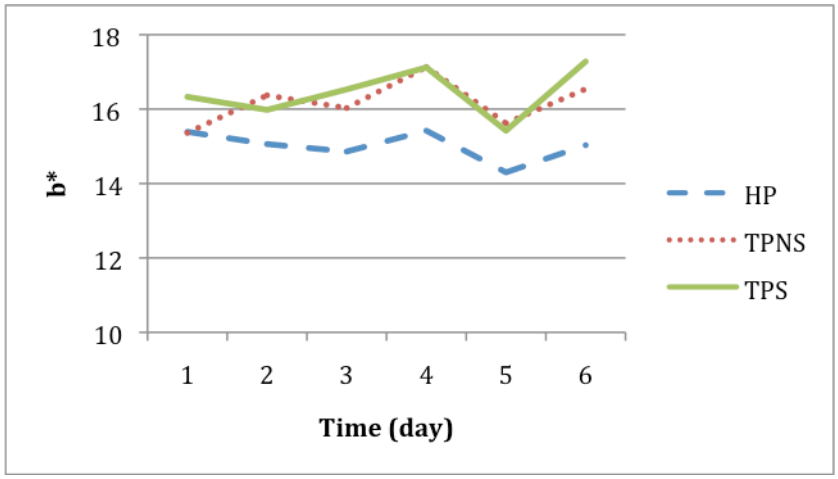


Figure 2.6 Day x Treatment interactions for b* values



Day x treatment interaction means for L* values can be seen in Table 2.5. For the HP treatment, day 1 had higher values ($P < 0.0001$, $P < 0.0001$, and $P < 0.003$, respectively) than days 4, 5, and 6. For days 1, 2, 3, 4, and 6, HP was not different ($P > 0.05$) than TPNS. HP meat had higher ($P > 0.05$) L* values than TPS, but both treatments followed the same trend over time. This indicates that while the HP treatment is darker than TPS treatment, salt may be responsible for some color changes over time.

Table 2.5 Day x treatment interaction means for L*, a* and b* values

	Treatment	Day					
		1	2	3	4	5	6
L*	HP	46.4^{ax}	45.4^{abx}	45.3^{abx}	42.8^{dy}	44.2^{cx}	44.6^{bcx}
	TPNS	46.3^{ax}	45.8^{abx}	45.1^{bcx}	44.5^{cx}	45.0^{bcx}	44.8^{bcx}
	TPS	44.8^{ay}	43.1^{by}	42.9^{by}	41.2^{cz}	42.7^{by}	44.9^{ax}
a*	HP	15.47	14.87	13.95	14.09	13.11	13.94
	TPNS	15.46	15.27	14.64	14.83	13.81	15.46
	TPS	17.31	16.9	16.04	15.92	14.45	16.02
b*	HP	15.39	15.06	14.86	15.42	14.3	15.03
	TPNS	15.36	16.37	16.03	17.13	15.62	16.54
	TPS	16.33	15.98	16.53	17.12	15.42	17.28

SEM: L* = 0.4, a* = 0.32, b* = 0.23

^{abcd} means across day within row without a common letter differ ($P < 0.05$)

^{xyz} means within day across column without a common letter differ ($P < 0.05$)

Because a day x treatment interaction was observed for L* values, day and treatment main effects will not be discussed. Day main effects for L*, a*, and b* values can be seen in Table 2.6. For a* values, day 1 and 2 had higher values ($P < 0.05$) than all other days of display indicating a decrease in redness over time. In looking at b* values, day 4 and 6 had higher ($P < 0.05$) values than all other days of display. Day 5 had lower b* values ($P < 0.05$) than all other days of display. The day effects for a* and b* values could be the result of the natural color changes that are observed over the shelf life of meat as surface discoloration occurs during the transition from red oxymyoglobin to brown metmyoglobin.

Treatment main effects for L*, a*, and b* values are found in Table 2.7. The TPS treatment had higher ($P < 0.05$) a* values than both the HP and TPNS treatments. Additionally, the HP treatment had lower ($P < 0.05$) a* values than either TPNS or TPS treatments. A similar trend was seen in b* values. TPS treatment had higher ($P < 0.05$) b* values than both the HP and TPNS treatments, while the HP treatment had lower ($P < 0.05$) b* values than either TPNS or TPS treatments

Table 2.6 Day main effects for L* a* and b* values

	Day						
	1	2	3	4	5	6	SEM
L*	45.8	44.8	44.4	42.8	44	44.8	0.23
a*	16.1^{a}	15.7^{a}	14.9^{b}	15.0^{b}	13.8^{c}	15.1^{b}	0.18
b*	15.7^{b}	15.8^{b}	15.8^{b}	16.6^{a}	15.1^{c}	16.3^{a}	0.13

^{abc} means across day within value without a common letter differ ($P < 0.05$)

Table 2.7 Treatment main effects for L* a* and b* values

Value	Treatment	Mean	SEM
L*	HP	44.8	0.16
	TPNS	45.3	0.16
	TPS	43.3	0.16
a*	HP	14.2^{c}	0.13
	TPNS	14.9^{b}	0.13
	TPS	16.1^{a}	0.13
b*	HP	15.0^{c}	0.09
	TPNS	16.2^{b}	0.09
	TPS	16.4^{a}	0.09

^{abc} means within value without a common letter differ ($P < 0.05$)

4. Conclusions

The yields of trim from hot processed and traditionally processed sides were not significantly different. Goat meat goes through rigor very rapidly with both hot processing and traditional processing treatments. Both processing types produce goat meat that should have favorable functional benefits for use in processed meats. Furthermore, the increased WHC and ultimate pH found in hot processed trimmings may have increased functional benefits for use in processed meats, particularly sausage. The color differences between treatments show significantly different a* values which may cause consumers to notice differences in the redness of the meat. Similarly, significantly different b* values may contribute to consumers recognizing a difference in color of meat from the three processing treatments.

Further research is needed to conduct taste panels comparing goat sausage made from hot processed and traditionally processed meat. Additionally, consumer panels are warranted to evaluate consumer acceptance of hot processed versus traditionally processed goat sausage.

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Chapter 3 - Investigating composting as a viable means of disposing of goat tissue resulting from the slaughter and fabrication process

1. Introduction

Scrapie, a transmissible spongiform encephalopathies (TSE), is a degenerative disease affecting the central nervous system of sheep and goats that is, ultimately, fatal (USDA APHIS, 2001). Scrapie is known to have a long incubation period and can remain dormant in animals exposed at birth for 2-5 years (Machen, 1997). The Food and Drug Administration (FDA, 1997) does not allow ruminant animal by-products to be used in feed for ruminants because of the risk of inclusion of TSE's. Rendering companies can choose what by-products they will accept and rarely accept goat by-products due to their associated risks. Therefore, processors frequently dispose of by-products at landfills.

Due to increasing costs, limited landfill resources and increasing environmental regulations regarding waste disposal, food-processing companies are faced with challenges to address cost effective waste removal. An alternative that is growing in popularity in the livestock community is composting. Composting is a natural process in which aerobic microorganisms biodegrade organic matter (Tronina and Bubel, 2008) to create a nutrient rich substrate that can be used as a soil supplement (Schaub and Leonard, 1996, Sander et al., 2002, Fonstad et al., 2003). Composting reduces the volume of organic by-products, and the temperatures achieved during composting will kill many pathogens (Schaub and Leonard, 1996).

There are three common composting methods: passive piles/windrows, turned or aerated piles/windrows, and in-vessel systems. Passive piles are simply laid in a designated area, while windrows are three sided structures that add support and boundaries for the piles (Schaub and Leonard, 1996, Berge et al., 2009). Due to space requirements, cost, and efficiency, the passive and turned pile composting methods are the most commonly implemented in the livestock industry. A well-designed composting program can be a cost effective and efficient means of disposal and has become a routine management practice on farms as a means of mortality disposal (Berge et al., 2009). Stanford et al. (2009) found

that there was a 44.1% and 38.7% disappearance of bone in mature cattle and calf piles, respectively. In a follow up study, they found that compost piles with a mean temperature over 58 ^{o}C for a 7 wk period saw a 54% disappearance of long bones, and piles that were actively heating over a 9-10 m period had brittle bones that could be applied to fields. Fonstad et al. (2003) found similar results. At the end of the composting period, the total mass of materials that were unsuitable for dispersal on fields was 1.5 kg, or 0.04% of the original pile that were recognizable as animal remains. In 2003, Mukhtar et al. compared passive and aerated pile composting for large carcasses. After 9 m, intact bones did not require screening or mechanical crushing prior to land application as they shattered and disintegrated easily upon application.

Livestock composting has shown great success as an alternative disposal method to rendering or landfill. However, little research has been conducted on the success of composting by-products and waste associated with meat processing. Therefore, the objective of this study was to determine the effectiveness of passive pile composting of offal from the processing of cull doe goats.

2. Materials and Methods

2.1. Experimental Design

Three treatments were used to compare compost temperatures. The first treatment contained only bones and is denoted by "bones." The second treatment contained the head and hide and offal and is denoted as "head + offal." The final treatment contained the bone, head and hide, and offal and is denoted as "whole." The bones, head and hide, and offal from each goat (n = 18) were randomly assigned to treatments. Four piles were made for each of the 3 treatments and the matter from 2 goats was used in each pile. The materials for bones piles were approximately 45 cm x 45 cm x 15 cm. The materials for the head + offal piles were approximately 60 cm x 60 cm x 45 cm. The materials for the whole piles were approximately 60 cm x 60 cm x 75 cm. The schematic for the composting piles can be seen in Figure 3.1. The numbers denote the material from each animal used.

Figure 3.1 Cull doe goat by-product composting schematic

Bones Bones: 11/1	**Bones** Bones: 7/18	**Whole** Bones: 11/1 Offal: 10/2 Head/Hide: 5/4	**Offal + Head** Offal: 15/18 Head/Hide: 11/9	**Offal + Head** Offal: 1/17 Head/Hide: 8/15	**Whole** Bones: 11/1 Offal: 3/6 Head/Hide: 10/18
Bones Bones: 13/3	**Whole** Bones: 6/12 Offal: 16/5 Head/Hide: 13/1	**Offal + Head** Offal: 11/9 Head/Hide: 7/16	**Offal + Head** Offal: 8/4 Head/Hide: 3/14	**Bones** Bones: 2/14	**Whole** Bones: 5/10 Offal: 7/13 Head/Hide: 6/17

2.2. Sample Preparation

During harvest, the hide, head, and offal were collected from each carcass, treated with denaturant (Great Lakes, CLD Green Denaturant) and stored in plastic bags. During the fabrication process, bones were labeled and bagged. The bags were then placed in 68.1 L plastic tubs (Sterilite Corp., Townsend, MA), and stored at -23 ^{o}C to preserve the material until composting began. Prior to composting, the material was thawed for 5 d in a 2 ^{o}C cooler, and then set out at room temperature for 36 h to allow the material temperature to increase. The head/hide, offal, and bones were randomly assigned to one of three treatment piles: bones only, whole (head/hide + offal + bones), or head/hide and offal piles. These piles were designed to simulate the type of piles small processors might use based on fabrication processes.

2.3. Compost Pile Preparation

Composting was completed at the Kansas State University Livestock Composting facility from May 6, 2010 to August 2, 2010. Approximately 0.6 m of straw was laid down as a base. Piles from the three treatments were randomly assigned to locations to minimize effects due to pile location. The samples were then laid in their specific pile location. Each pile was covered with approximately 0.6 m of straw, and cattle panels were put up to create a complete enclosure around the piles to protect the material.

2.4. Temperature Sampling

Temperatures of each compost pile were taken from the center of each pile and were measured weekly using a temperature probe (Taylor Precision Products, Model #3518N, Las Cruces, NM).

2.5. Decomposition Scoring

The compost piles were uncovered monthly to monitor and score the decomposition of the materials in each pile using the scoring system found in Table 3.1. Individual scoring systems were developed for: bones, offal, and head/hide. Bone piles were not given head or offal scores. Similarly, offal + head piles were not given bone scores. Five panelists completed the scoring after undergoing a decomposition scoring orientation. After scoring, the piles were re-covered to minimize heat loss.

Table 3.1 Goat by-product decomposition scoring scale

Scoring		
Bones	**Head / Hide**	**Offal**
1 – complete decomposition	1 – complete decomposition	1 – complete decomposition
2 – brittle bones / breakdown present	2 – brittle / breakdown present	2 – major decomposition / slightly present
3 – clean bones / no soft tissue	3 – clean bones / no hide / no soft tissue	3 – moderate decomposition / not identifiable
4 – clean bones / no muscle intact / cartilage present	4 – decomposition of hide / flesh / cartilage present	4 – slight decomposition / organs identifiable
5 – no bone decomposition / muscle on bones intact	5 – no decomposition / hide present	5 – no decomposition

2.6. Statistical Analysis

The data was analyzed using the GLM procedure in SAS (SAS Institute, Inc., Cary, NC). Duncan's Multiple Range test was performed at the ($P < 0.05$) level of significance. Treatment and week main effects and treatment x week interactions were tested for the compost temperatures. For the decomposition scoring, treatment, month, and scoring type were the main effects tested. The treatment x month x scoring type interaction was also tested.

3. Results and Discussion

Compost Temperatures

The interaction of treatment x week can be found in Table 3.2. For all 3 treatments, temperatures increased significantly over time. By week 8, temperatures decreased significantly for the bone piles. Whole piles exhibited significantly higher temperatures than bone piles, except for weeks 3, 6, and 7. Berge et al. (2009) states that temperatures between 43^{o} and 66 ^{o}C are optimal temperatures for compost microorganisms and that when compost temperatures are greater than 53 ^{o}C for 3 d, most pathogenic bacteria and parasites are killed and viruses are inactivated. Although all 3 piles had weeks in optimal compost temperature range, only whole piles reached high enough temperatures to kill pathogens.

Table 3.2 Compost pile temperatures (^{o}C) by week

Week	Treatment		
	Bones	Offal + Head	Whole
1	21^{fy}	34^{cx}	35^{fx}
2	27^{fy}	33^{cx}	38^{efx}
3	45^{abcx}	48^{abx}	50^{abcx}
4	37^{ey}	44^{abx}	45^{cdx}
5	45^{abcy}	50^{axy}	53^{abx}
6	47^{abx}	47^{abx}	53^{abx}
7	50^{ax}	48^{abx}	49^{abcx}
8	40^{cdey}	44^{abxy}	47^{bcdx}
9	48^{abx}	48^{abx}	54^{ax}
10	43^{bcdex}	44^{abx}	44^{cdx}
11	44^{abcdx}	49^{abx}	47^{bcdx}
12	38^{dex}	42^{bx}	42^{dex}

Standard error of the mean: 2.28

^{abcdef} means within treatment across week without a common letter differ ($P < 0.05$)

^{xy} means within week across treatment without a common letter differ ($P < 0.05$)

The data for treatment effects on compost temperatures can be found in Table 3.3. As expected, piles that contained only bones had the lowest average temperature. As the amount of by-products containing both moisture and organic material increased, so did the

average pile temperature. Berge et al. (2009) states that the ideal carbon-to-nitrogen ratio for carcass composting is between 25:1 and 30:1. There was no additional nitrogen added and nitrogen and carbon ratios were not conducted in this study, which could have better explained the differences between treatment temperatures.

Table 3.3 Mean compost pile temperature (^{o}C) by treatment

Treatment	Mean Temperature
Bones	40[c]
Offal + Head	44[b]
Whole	46[a]
SEM	0.66

[abc] means without a common letter differ (P <0.0001)

The mean pile temperature by week can be seen in Table 3.4. Temperatures were lowest initially; as bacteria and degradation of the compost material increased, pile temperatures increased accordingly. By wk 8, temperatures began to decline with a significant spike at wk 9. Although bones were still present, a significant portion of the material had been degraded and the piles were dry. As a result, temperatures began to decrease through wk 12. Temperatures of the piles in this study never reached high enough temperatures for efficient bone decomposition, as indicated by prior studies by Stanford et al. (2009). One likely explanation was that no additional nitrogen source was utilized. Additionally, because the goats utilized in this study were light, the by-products resulting from the harvest of goats did not provide a lot of material. A larger volume of material may be necessary to maintain temperatures required for bone decomposition.

Table 3.4 Mean compost pile temperature (^{o}C) by week

Week	Mean Temperature
1	30^{d}
2	32^{d}
3	48^{a}
4	42^{c}
5	49^{a}
6	49^{a}
7	49^{a}
8	44^{bc}
9	50^{a}
10	44^{bc}
11	47^{b}
12	41^{c}
SEM	1.31

SEM: Standard error of the mean
^{abc} means without a common letter differ ($P < 0.0001$)

Decomposition Scoring

The data for the decomposition scoring can be found in Table 3.5. The whole piles saw significantly greater decomposition of the skull. At the end of the study, there was not complete decomposition of any bones. However, thin bones, such as ribs, were brittle. Our data is consistent with the findings of Stanford et al. (2009) who indicated that compost piles maintaining a mean temperature greater than 58 ^{o}C over a 7 wk period would see a 54% disappearance of long bones. Because a nitrogen source was not added in this study, this could be one factor that inhibited greater decomposition. The bone density of cull goats may be a confounding factor. As animals age, bone density increases. For this reason, the compost ability of bones, especially long bones such as the femur and humerus, are denser and will not compost as easily

Table 3.5 Decomposition scoring

	Day 30			Day 60			Day 90		
Decomposition Score	Bone	Offal + Head	Whole	Bone	Offal + Head	Whole	Bone	Offal + Head	Whole
Bone	4.1[a]	N/A	3.8[a]	2.9[b]	N/A	2.4[c]	2.1[c]	N/A	2.1[c]
Head	N/A	4.1[a]	4[a]	N/A	4[a]	3.5[b]	N/A	2.9[c]	2.5[d]
Offal	N/A	3.6[a]	3.3[a]	N/A	1.1[b]	1.1[b]	N/A	1[b]	1[b]

Standard error of the mean: 0.13
[abc] values within row without a common letter differ ($P < 0.05$)

4. Conclusion

Bone piles had significantly lower compost temperatures than offal + head and whole piles. All 3 treatments reached insufficient temperatures to achieve bone decomposition. Although all 3 treatments reduced the volume of by-product waste, bones and skulls were not significantly decomposed in any treatment at the end of 90 d. Because goats are small, the material from 2 goats may have been insufficient to maximize temperature and reach temperatures that would allow for greater bone decomposition.

Studies to enhance uniform decomposition would be fruitful for small processors interested in composting as a waste removal alternative. Additionally, future studies measuring carbon-to-nitrogen ratios as well as using additional nitrogen sources to determine what level of added nitrogen is needed to maximize decomposition with minimal input.

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Appendix A - Animal Data

#	Live Weight (kg)	HCW (kg)	Dressing %	TP Side (kg)	HP Side (kg)
1	33	13.6	41.7	7	6.7
2	64	28.9	45.4	15.4	13.5
3	44	17	38.3	8.4	8.6
5	22	7.8	35.8	4.3	4
6	35	12.1	35	6.9	5.2
7	53	22.8	43.2	11.2	11.5
8	43	18.6	43.6	9.2	9.4
9	44	20.2	46.4	10.1	10.1
10	50	20.2	40.4	10	10.2
11	39	16.1	41.2	7.7	8.4
12	37	16.4	44.2	8	8.4
13	44	18.8	42.2	9.8	9
14	42	19	45.7	9.2	9.9
15	43	18.1	42.3	9.1	9
16	34	14	41.6	7	7
17	28	11.7	41.6	5.9	5.9
18	42	19.3	46.3	9.6	9.7
Mean	41	17.33	42.1	8.8	8.6
SEM	2.34	1.16	0.81	0.59	0.57

Appendix B - Wholesale Cut Yield

Side	Leg	Hind Shank	Loin	Rack	Ribs	Sq. Cut Shoulder	Foreshank	Neck	Total Trim	Total Bone
TP1	1.71	0.52	0.59	0.57	0.68	2.02	0.45	0.35	4.47	2.42
TP2	3.36	0.93	2.1	1.22	1.82	4.61	0.48	0.84	11.91	3.44
TP3	2.02	0.64	0.84	0.87	1.01	2.24	0.51	0.35	6.05	2.38
TP5	1.04	0.38	0.35	0.28	0.38	1.17	0.27	0.19	2.7	1.49
TP6	1.53	0.54	0.58	0.56	0.38	1.9	0.35	0.32	3.89	2.25
TP7	2.77	0.59	1.28	1.03	1.49	3.44	0.44	0.42	8.99	2.49
TP8	2.22	0.63	1.14	0.63	1.04	2.65	0.45	0.22	6.73	2.36
TP9	2.53	0.57	1.39	0.55	1.22	2.93	0.38	0.44	7.68	2.21
TP10	2.72	0.54	1.32	0.63	1.37	2.68	0.35	0.47	7.9	2.17
TP11	1.81	0.54	0.94	0.65	0.93	2.04	0.39	0.4	5.84	1.95
TP12	2.1	0.55	0.85	0.71	1.02	2.27	0.39	0.41	6.19	2.07
TP13	2.3	0.67	1.2	0.53	1.02	2.97	0.38	0.51	7.37	2.17
TP14	2.34	0.66	0.92	0.74	1.02	2.69	0.39	0.25	7.02	1.89
TP15	2.27	0.64	0.94	0.47	1.06	2.65	0.4	0.6	6.88	2.11
TP16	1.72	0.53	0.58	0.52	0.76	2.02	0.35	0.54	5	2
TP17	1.53	0.44	0.6	0.62	0.48	1.53	0.34	0.27	4.35	1.47
TP18	2.3	0.54	1.14	0.82	1.15	2.72	0.39	0.41	7.5	2.01
Mean	2.13	0.58	0.99	0.67	0.99	2.5	0.39	0.41	6.5	2.17
SE	0.13	0.03	0.1	0.05	0.09	0.19	0.01	0.04	0.52	0.1