DISSERTATION

# MANAGEMENT STRATEGIES TO IMPROVE BEEF FEEDLOT PERFORMANCE AND ASSESSMENT OF NUTRIENT COMPOSITION OF BEEF RETAIL CUTS

Submitted by

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ABSTRACT

MANAGEMENT STRATEGIES TO IMPROVE BEEF FEEDLOT PERFORMANCE AND ASSESSMENT OF NUTRIENT COMPOSITION OF BEEF RETAIL CUT

Two experiments investigating the impact of: (1) feeding frequency and (2) feedbunk management on feedlot steer performance were conducted. In experiment 1, three treatments (N=270) were utilized: (1) offered 100% of their ration at 0800 hours (h), (2) offered 60% of their ration at 0730h and 40% of their ration at 1300h, and (3) offered 34% of their ration at 0700h, 33% of their ration at 1000h, and 33% of their ration at 1400h. Average daily gain (ADG) was similar for steers fed once or twice per day (1.63 and 1.64 ± 0.02 kg/day, respectively). However, ADG, dry matter intake (DMI), hot carcass weight (HCW) and number of condemned livers were greater in steers fed three times per day compared to other treatments. In Exp. 2, 127 steers were utilized to investigate the impact of feedlot bunk scoring on steer DMI. Steers were randomly sorted into pens containing 9 steers per pen and placed into one of three groups. A 3 X 3 Latin square factorial arrangement of treatments was utilized. Factors included bunk score assignment, group, and period. Each group received each of the three bunk scoring assignments. Bunk scores were determined based on the amount of orts from the previous feeding. A score of 0 was a bunk devoid of all feed particles; a score of ½ was a bunk that contained trace to 2.26 kg of feed; and a score of 1 was a bunk that contained 2.27 to 9.05 kg of feed. During data collection, all bunks were observed at 0600h, 1000h, 1600h,

2200h, and 0200h the next morning. Overall DMI was greater for steers that consistently received enough feed to ensure 2.27 to 9.05 kg of orts each morning. By allowing 2.27 to 9.05 kg of orts each morning daily DMI was increased which could result in increased performance and decreased days on feed.

The objective of the third experiment was to determine the impact of timing of anthelmintic administration relative to vaccination on antibody titer response to vaccine components and subsequent rectal temperature and antibody response to an Infectious Bovine Rhinotracheitis (IBR) challenge. Thirty-three individually-fed, colostrum deprived Holstein bull calves (initial BW of 131 ± 4.2 kg) were utilized. Treatments consisted of: (1) dewormed 2 weeks prior to vaccination (DPV); (2) dewormed at the time of vaccination (DV); and (3) control – not dewormed (CONT). All calves were inoculated with infective larvae of brown stomach worms (*Ostertagia ostertagi*) and intestinal worms (*Cooperia* spp.) on day 1, 7, 10, 14, and 18 for a total dose of 235,710 infective larvae per calf. Calves (DPV and DV) were dewormed with a 10% fenbendazole suspension at 5 mg/kg body weight. The DPV group was dewormed two weeks prior to vaccination. On day 35, all treatments were vaccinated and DV calves were dewormed at the time of vaccination. All treatment groups developed antibody titers to vaccine components by day 15 post-vaccination. Animals dewormed at the time of vaccination had higher titers to BVD 1. On day 88 all calves were challenged with IBR and blood samples were obtained on day 0, 1, 3, 4, 6, 8, 10, and 12 post inoculation. Post IBR inoculation animals in all groups had elevated rectal temperatures. Control animals had greater rectal temperatures than DPV and DV on day 88, 89, and 97. These data

suggested that deworming before or at vaccination decreases parasite burden and rectal temperature following an IBR challenge in animals.

Experiments 4 and 5 were focused on beef retail cut nutrient composition. The objective of the first study was to determine if cooking method and degree of doneness (DOD) affect nutrient composition of beef strip loin steaks. Seven steaks were obtained from each strip loin for a total of 147 steaks. Steaks within strip loin were randomly assigned to one of six treatments. Treatments consisted of: 1) pan fried (PF), 60°C; 2) PF, 71°C; 3) PF, 77 °C; 4) grilled (GR), 60°C; 5) GR, 71°C; 6) GR, 77°C. Steaks were cooked fresh, immediately after fabrication. A set of raw steaks was used as a control group for nutrient analysis. Cooking time was greater ($P < 0.05$) for steaks that were PF compared to GR. Additionally, cooking time increased linearly ($P < 0.01$) with increased DOD. Cooked wt decreased linearly ($P < 0.01$) as DOD increased for PF steaks. Additionally, well done (77°C) steaks had lighter final weights ($P < 0.05$) than rare (62°C) steaks. Dry matter content of raw steaks decreased ($P < 0.01$) as DOD increased. Pan frying steaks resulted in greater ($P < 0.05$) DM% than GR steaks. Crude fat (CF) content increased for both PF and decreased ($P < 0.05$) for GR steaks. Medium (71°C) and well done (77°C) GR steaks had lower crude fat content than PF steaks or rare (62°C) GR steaks. Initial crude protein content of the steaks increased after cooking. Medium (70°C) and well done (77°C) GR steaks had higher ($P < 0.05$) crude protein content than any other DOD or PF steaks. Cooking method and temperature to which steaks are cooked play a major role in the nutrient composition of steaks and these factors should be accounted for when determining nutrient profiles of beef retail cuts.

Experiment 5 consisted of two separate experiments conducted to investigate factors that influence the nutrient composition of purge and cook drippings (CD). For experiment 1, twenty six chucks were Selected from carcasses based on QG (16 Choice and 10 Select), YG (11 YG 2 and 15 YG 3), and gender (12 heifer and 14 steer carcasses). Subprimals were fabricated into the following retail cuts: Brisket, Flat Half, Brisket, Point Half, Shoulder Roast, Shoulder Steak, Beef for Stew, Denver Cut, Boneless Country Style Beef Ribs, Classic Beef Roast, Chuck Eye Steaks, Under Blade Pot Roast, Under Blade Steak, Top Blade Steak, Mock Tender Steak, and Short Ribs for a total cuts sample size of N = 506. Each cut was cooked based on consumer popularity. For experiment 2, strip loins were removed from the right sides of 21 low Choice steer carcasses and aged for 14 d. Seven steaks were obtained from each strip loin. Steaks (N = 147) were randomly assigned to treatment within strip loin. Treatments consisted of 1) Pan Fried, 60°C 2) Pan Fried, 71°C 3) Pan Fried, 77 °C 4) Grilled, 60°C 5) Grilled, 71°C 6) Grilled, 77°C. A set of raw steaks was used as a control group for nutrient analysis. For both experiments, purge was collected from each cut immediately after package removal. In Exp. 1, cook drippings were collected into conical tubes immediately after cooking. Effects of YG and gender were minimal. Yield grade 2 cuts had greater ($P < 0.05$) DM cook drippings than YG 3 cuts. Based on gender, heifers tended ($P < 0.10$) to have lower DM cook drippings compared to steers. The DM content of purge differed ($P < 0.05$) between roasts steaks, and braised cuts (10.30, 10.33, and 9.68 ± 0.18). The Ash content of purge also differed ($P < 0.05$) between roasts, steaks, and braised cuts (3.10, 2.66, and 3.50 ± 0.19). Dry matter, ash, and crude protein of cook drippings were different ($P < 0.05$) relative to type of cut. Additionally, total purge and cook drippings

was greater ($P < 0.05$) for braised cuts compared to roasts or steaks. In Exp. 2, cooking method and degree of doneness influenced nutrient content. Medium (71°C) and well done (77°C) grilled steaks had higher ($P < 0.05$) DM and lower ($P < 0.05$) ash and protein than the raw or rare (62°C) steaks. Results of this study indicated that type of cut, cooking method, and degree of doneness contributes to the overall nutrient composition of purge and cook drippings from retail cuts.

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*I dedicate this dissertation to my mom and dad. For their love, support, and patience made this possible.*

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Feeding Frequency:

feeding frequency, feedlot management, performance, steers

Bunk Management:

cattle, dry matter intake, feed bunk management, feedlot management

Impact of Parasites on Vaccine Efficacy:

calves, gastrointestinal parasite, immunity, titers, vaccination

Degree of Doneness:

beef, cook method, degree of doneness, loin, nutritive value

Purge and Cook drippings:

beef, cook drippings, nutritive value, purge, retail cut

# CHAPTER I

# REVIEW OF LITERATURE

## *Trends in the Feedlot Industry*

A direct dichotomy exists between the cattle feeding industry and the consumer. The feedlot industry is continually changing to ensure they are meeting the ever changing demands of the consumer while keeping the business of growing cattle profitable. Environmental regulations, animal rights activism and the growing competition over land for housing versus land for growing food will not subside. These issues will only continue to become larger obstacles for the feedlot industry to overcome in the quest for producing affordable quality beef. The ultimate mission statement of the beef industry as a whole should be to serve the consumers needs while operating as stewards of the land by making a profitable living off of the production of cattle in a way that benefits all parties involved in the industry from farm to fork.

Cattle feeding has invariably become more concentrated. The number of feedlots has declined and the number of cattle being fed in confined feedlot operations has increased. In 1990 cattle on feed was 9.14 million, up 11% from 1988. There were 655,000 head of cattle on feed in Colorado. In 2000 there were 11.9 million head of cattle, up 8% from 1998. In 2006, there were 12.0 million head of cattle on feed in the United States and 1.10 million head of cattle on feed in Colorado (National Agricultural

Statistics Service, 1990-2006). As of December 1, 2010 there were 11.6 million head of cattle on feed in the United States. There were 1.22 million head of cattle on feed in Colorado. This is up 3% from 2009 (USDA, 2010). In 1972, 98.2% of feedlots had a one-time holding capacity of 1,000 head or less, in 1995 the total had dropped to 95.3%, and today, the U.S. Department of Agriculture doesn't count feedlots under 1,000 head into its statistical service cattle on feed totals (Ward and Schroeder, 2002; National Agricultural Statistics Service, 2010). Over the past 30 years, feeding cattle has become more regional. Ward and Schroeder (2002) indicated that in 1972, the leading cattle feeding states (in order) were: Texas, Iowa, Nebraska, Kansas, and Colorado. As of December, 2010 the leading cattle feeding states were: Texas, Nebraska, Kansas, Colorado, and Iowa. However, Texas has seen a 1.02 million head increase in cattle on feed while Iowa has seen a 1.0 million head decrease in cattle on feed over the last 38 years (National Agricultural Statistics Service, 1972 and 2010). In 1995, Iowa had the most feedlots of any state in the country (14,500), but the average size of the feedlot was 102 head (Ward and Schroeder, 2002). Today, a small number of firms account for the majority of the annual cattle on feed. To put this into perspective, JBS Swift has a combined feeding capacity of more than 960,000 head of cattle (JBS Five Rivers Cattle Feeding LLC) and the top 5 cattle feeding operations in the country (Table 1.1) finish about 30% of the total fed cattle in the country.

Predicting trends associated with the feedlot industry can be challenging. Economists and researchers alike believe that change is the only constant factor associated with feeding cattle. Environmental regulations, grain prices, and foreign competition will all bring forth novel challenges to the industry (Galyean, 2009; Ward

and Schroeder, 2002). Therefore, finding the best management practices which are comprised of the most current technologies and up to date research is being applied for maximum profitability to become achieved. This will be imperative to the survival of the feedlot industries in the United States

*Management strategies for improving performance*

*Receiving Calf Management:* The goal of any feedlot should be to transition calves from a "starter" ration onto "full feed" in as short a time as possible without causing digestive upsets or negatively influencing performance. Getting new cattle on to feed quickly is important for ensuring optimum health as poor cattle performance during the receiving phase often results in poor performance and health throughout the finishing phase (Chester-Jones and DiCostanzo, 1994). Transitioning calves from high-forage to high concentrate diets invariably causes changes within the ruminal environment. Before calves are weaned from cows they obtain the majority of their nutritional requirements from the cow and from grazing pasture forages with a main water source provided from a large water tank, a pond, or running stream. Therefore, when calves enter into a feedlot their eating behavior will be significantly altered. Calves must learn to eat from a feed bunk and drink from an automatic waterer (Loerch, 2000). Moreover, commodities such as silages and grains will be foreign to the calves and the risk of rejection to these types of feeds is high because they will not recognize them as a viable source of nutrition. Prior to the arrival of new calves into the feedlot, feedbunks and water tanks should be cleaned, and if appropriate, bedding should be provided. Incoming calves should be provided with 0.30 m of bunk space and 61 $m^2$ of pen space/hd (Chester-Jones and DiCostanzo, 1994). According to Loerch (2000), feed intake will be depressed by 50% the first week of

arrival and by 25% the second week. Several studies have investigated the effects of fasting and transit stress on ruminal bacteria counts. In a study conducted by Fluharty et al (1994), 8 ruminally fistulated 7–8 mo old steers were utilized to determine the effects of energy density and protein source on changes in the ruminal environment during the receiving period. They found that the ruminal bacteria concentrations were not reduced by weaning or by a 24 h fasting stress period and concluded that the ruminal microbial population was able to digest substrates immediately following weaning, trucking, and 24 h water and feed deprivation. These results indicate that reduced intake of weaned calves is more likely due to physiological stresses associated with feedlot introduction and not to metabolic issues mainly due to fasting.

The major issue with depressed intake is the risk of morbidity and mortality. Weight-loss during transit has been shown to average 0.61% of BW for every 100 miles of transit with 53% accounting for body and 47% from digestive tract water loss (Chester-Jones and DiCostanzo, 1994). Stress-induced immunosupression is a primary factor in respiratory disease in feedlot cattle after weaning, transporting, and receiving (Gibb et al., 2000). Bovine respiratory disease (BRD) in newly received calves is the most significant health problem facing the US beef cattle industry (Duff and Galyean, 2007). Fulton et al. (2002) determined that calves treated for BRD once and then returned to a normal feedlot environment returned $40.64 less, calves treated twice returned $58.35 less, and calves treated 3 or more times returned $291.93 less than un-treated calves. Although BRD is a viral/bacterial disease, Duff and Galyean (2007) pointed out that it is a “multifaceted” problem with numerous potential exacerbating factors and outcomes” (Figure 1.1). Vaccinations are arguably the most cost effective means for

preventing disease especially in feedlot environments. However, it is critical that good management practices are implemented in conjunction with vaccination programs to ensure that vaccine efficacy is not compromised. Most calves are vaccinated for respiratory type infections and dewormed at weaning. Sometimes, this takes place immediately prior to entering an onsite background facility or being transported to a feedlot (Bagley, 2001). Vaccination programs which include vaccines to IBR, PI3, BVD, and BRSV are an integral part of a solid calf management program (Duff and Galyean, 2007). Cytokine release associated with parasitic infestation can interfere with the immune response to other antigens potentially affecting an animal's ability to immunologically respond to vaccination (Urban, 2007). Additionally, Duff and Galyean (2007) concluded that more research is needed to determine how nutrition and management affect vaccine efficacy.

When calves are eating above maintenance requirements, they will be in a positive energy balance which could potentially allow the calves to deal with disease challenge better (Loerch, 2000). On day one in the feedlot 78% of calves will not eat, by day 10 around 15% of calves may not be eating (Boyles et al., 1998). Therefore, making calves acclimated to their environment and getting calves to the bunk is the first management challenge feedlot producers face. In a study conducted by Gibb et al (2000), 3 experiments were conducted to determine the effects of the presence of a trainer cow on behavior, performance, health, and feeding patterns of newly weaned beef calves. It was hypothesized that because feeding behavior is directly influenced by social facilitation the presence of a mature cow might help ease the stress associated with receiving. Interestingly, the presence of a mature cow caused the calves observed to lie down less

frequently and calves appeared to avoid the cow at the feed bunk. It was concluded that a foreign cow might actually be negatively affecting the stress of newly-received cattle. In a study conducted by Step et al. (2008), commingled calves of unknown health histories from multiple sources were utilized to determine if preconditioning strategies had an effect on health and performance over a 42-d receiving period. Pre-conditioning programs are pre-transport health programs including vaccination, anthelmintic treatments, feed bunk exposure, and delayed shipment for 3 – 6 weeks after weaning. It was hypothesized that pre-conditioned programs would decrease morbidity and mortality rates. Calves were from multiple sources or single ranches. Calves from the ranch were weaned and immediately shipped to the feedyard; weaned 45 d before shipping but received no vaccination; or weaned, vaccinated, and held on the ranch for 45 d before shipping. Weaning calves on the ranch and utilizing a preconditioning program before shipment resulted in improved ($P < 0.05$) health and performance during the receiving and feeding period compared to weaning and immediately transporting calves or purchasing high risk multiple origin calves.

*Feedbunk Management post-receiving phase:* Seventy to 80% of profit variability associated with feeding feedlot animals is attributed to the fed and feeder cattle prices and 6-16% of profit variability is attributed to corn prices (Lawrence et al., 1999). When researchers start to discuss feedlot management programs, feed intake seems to be the major focus. Daily feed intake is favorably related to the health and profitability of feedlot cattle (Loerch, 2000). Feed cost is the largest expense associated with feeding confined animals (Lawrence et al. 1999). Feed costs represent about 65% of the total cost for cattle feeders (Loerch, 2000). As of November, 2010 the average cost of gain/cwt for

steers, averaged over 13 ( > 20,000 hd capacity) feedlots in Kansas, was $73.34 ($66.81-$83.44), the average cost of gain for the steers was $91.25 ($85-$99), and the average days on feed was 135 (123-161) Additionally, as of the end of 2010, corn was $5.29/bu and ground alfalfa hay was $122.21/ton (Waggoner, 2010).

Management factors are important in terms of keeping feed costs minimized and for ensuring overall cattle health. Adequate feed bunk management should ensure that day-to-day variation in feed intake is minimized and overall feed intake is enhanced while providing the correct type and amount of nutrients to individual animals without leaving excess feed in the bunk (Duff, 2001). Cattle are inherently programmed to spend most of their time either eating or ruminating; therefore, altering feeding frequency could influence performance traits (Stricklin and Kautz-Scanavy, 1984). Developing a feed bunk management system for feedlot cattle which achieves maximum performance and avoids digestive upsets is challenging. The primary difficulty is that while intake and performance of individual cattle are of primary concern, feedlot production practices are most conducive to managing pens of cattle and not individual animals.

A feed bunk management system needs to be easy to use and sensitive enough to be able to detect changes in feed consumption. Feed bunk management has changed over the years. The original objective of the cattle feeder was to keep bunks full and provide feed at all times for the cattle. This approach often resulted in spoiled feed that was either wasted or may have contributed to reduced intake if cattle were forced to clean the bunk. In recent years "slick bunk" systems have become popular. These systems purposely allow bunks to become empty at some point during the night in an attempt to eliminate wasted feed and restrict feed intake. Restricted feeding programs have been

reported to improve feed efficiency (Galyean, 1999; Duff, 2001; Drager et al., 2004) and reduce digestive upsets associated with over consumption of feed (Schwartzkopf-Genswein et al., 2003). However, excessive intake restriction can reduce ADG resulting in reduced profitability as FE will be minimized and DOF could be increased.

Prichard and Bruns (2003) suggested that feed bunk management affects cattle intake by reducing over-consumption and altering cattle behavior to ensure reduced daily intake variation. Programmed feeding, multiple feed deliveries, and keeping the daily feeding times consistent have all shown to reduce feed intake fluctuation (Schwartzkopf-Genswein et al., 2003).

In most large feedlot operations, cattle are fed more than once a day. Feeding multiple times during the day is believed to keep feed fresh, reduce digestive upsets, and improve performance as feed trucks may entice cattle to the bunk and stimulate cattle to eat (Schwartzkopf-Genswein, 2000). Feeding more than once per day has been reported to increase feed intake by 2 to 5% and reduce digestive upsets in feedlot cattle (Anderson, 1990). Multiple factors can contribute to digestive upsets including environment, management, diet type, intake, feeding behavior, social behavior, and cattle type (Galyean and Eng, 1998). Subclinical acidosis and reduced performance in cattle can be attributed to inconsistent eating patterns and feeding behavior. These issues can cost as much as $15 to 20 per animal (Schwartzkopf-Genswein et al., 2003). The transition from high-forage to high-concentrate diets causes changes within the rumen environment and the need for gradual transition between these diet types is very important. When a rapidly fermentable carbohydrate such as corn is digested, fibrolytic bacteria are greatly reduced, amylolytic bacteria increase, and there is a drop in ruminal pH (Bevans et al, 2005). If

the rumen microbial population goes through this change too quickly acute or subacute acidosis can manifest. Acute acidosis is caused by ruminal acidity. Lactic acid (pKa=3.1) is over 10 times more acidic than the VFA's normally produced in the rumen (pKa=4.3) which causes a much greater decline in pH (Schwartzkopf-Genswein et al., 2003). Damage of the ruminal and intestinal wall cause a decrease in blood pH, dehydration, and mortality. Laminitis, polioencephalomalacia, and liver abscesses are often associated with acute acidosis (Owens et al., 1998). Subacute acidosis is difficult to diagnosis. After an animal recovers from acidosis, nutrient absorption might be greatly reduced within the rumen and feed intake is reduced causing a decline in performance (Owens, 1998; Bevans, 2005). Increasing dietary concentrates gradually in a "step-up" fashion over a 3-4 wk period is the most popular way producers try to minimize acidosis issues (Owens, 1998; Schwartzkopf-Genswein et al., 2003; Bevans, 2005).

Feedbunk management has been defined as the "art of matching feed offerings to feed intake on a timely basis each day" (Stanton et al., 1991). Cattle typically have greater ADG early in the feeding period and then slowly reach a plateau the closer they get to market weight. Increases in intake cause compensatory growth which is the rapid gain seen between 30-60 d after being introduced to high-concentrate rations (Loerch, 2000). Anderson (1990) showed that by increasing feed intake by 0.24 kg/d, the DOF could be reduced by 10 d. Therefore, it is important to have a well managed feeding program to ensure that performance is maximized and profits are obtained. By manipulating feed intake, ensuring feed delivery is consistent, and bunk management programs are in place feed efficiency can be maximized.

*Methods used to increase performance and carcass characteristics in feedlot programs:*

*Implant strategies:* Altering the hormonal status of cattle to improve performance is by no means a new concept. As Cook (2000) pointed out, the concept of castrating bulls and spaying heifers has long proven to be a hormonal altering means for enhancing growth performance. For the past 40 years, growth promoting implants have been used extensively in beef production. Implants are used to increase rate of gain and feed efficiency in cattle (Platter et al., 2003). Early implants were estrogenic agents which served to improve feed efficiency 5-10% and ADG 5-15% (ZoBell et al., 2000). Estrogens (Estradiol and Zeranol) are the hormones that are approved for use in cattle (Cook, 2000). In 1987, FDA approved the use of trenbolone acetate (TBA) in implants which enhanced muscle growth and further increased feed efficiency and ADG (ZoBell et al, 2000). Table 1.2 lists several brand names of implants as well as the type and amount of the hormone(s) that comprise the active ingredient(s). The reason for implant use in feedlot production practices is simple; implants reduce the cost of beef production. Implanting feedlot steers improves ADG and FE but hormonal implants have shown to decrease marbling in carcasses (Mader, 1994; Duckett et al., 1997; Roeber et al., 2000; Platter et al, 2003). In a summary of information presented at a symposium containing numerous reviews on the effects of implants, Duckett and Andrae, 2001, determined that estrogenic and androgenic combined implants have the largest increases in ADG (19 to 20%) Additionally, Duckett and Andrae, 2001, showed that marbling score was decreased by about 4% and Ribeye area was increased by 3-4%. The effect of implanting on the intramuscular lipid amount is thought to be reduced due to the increase in actual muscle area (Duckett and Andrae, 2001). In a study conducted by Mader (1994), steers were allotted to one of the following zeranol treatments: no zeranol (control), single

zeranol implant (36 mg) administered at the start of the finishing phase, a double (72 mg) implant administered at the start of the finishing period, a single implant administered at the start of the growing period followed by a single implant administered at the start of the finishing period, or a single implant administered at the start of the growing period followed by double implant administered at the start of the finishing period. Overall, steers that were implanted had 9.4% greater ($P < 0.10$) live weight gains and showed a tendency for 6.7% greater FE compared with control groups. Additionally, steers receiving the high-dose implant had reduced fat thickness ($P < 0.10$) and decreased marbling scores. In a study conducted by Roeber et al., (2000), seven implant strategies were compared to an un-implanted control group to determine carcass quality and consumer acceptability of the effects in steers. In contrast to the findings of Mader (1994), no fat thickness differences were found based on implant (or control) program. However, skeletal maturity was greater in implanted carcasses. Duckett and Andrae (2001) concluded that skeletal maturity can increase by as much as 10 points due to implanting strategy however, Roeber et al., (2000) concluded that the increase in skeletal maturity did not affect lean maturity scores of the carcasses. Additionally, consumers rated steaks in the control group as being tenderer than any of the implanted group steaks.

Research indicates that FE and ADG are improved with implants and that carcass traits related to muscle mass are enhanced (Mader, 1994; Duckett et al., 1997; Roeber et al., 2000; Platter et al, 2003). However, implants have shown to reduce marbling which is directly associated with palatability (Mader, 1994 and Roeber et al., 2000). Therefore, implant strategies need to be closely analyzed in regards to each individual feedlot

program to determine if utilizing implants is the appropriate strategy in terms of their specific production goals for maximizing profit.

*Feed additives and Antibiotics:* A number of feed additives have shown to have a positive effect upon stress reduction upon receiving. Yeast culture has shown to increase ruminal turnover rate, increase K, Cu, and Zn, and improve DMI in stressed feeder calves (Harrison et al., 1988; Adams et al., 1981; Cole et al., 1992). However, Cole et al., 1992 conducted two experiments to determine the effects of yeast culture on 1) the health and performance of stressed feeder calves and 2) DMI and weight loss of calves challenged with infectious bovine rhinotracheitis. It was determined that using yeast cultures in the diets of stressed calves is highly variable and some of the results reviewed in previous research seem to be correlated to the environmental, diet mineral concentrations, normal yeast in the diet, animal nutrient status etc., and although it was concluded that yeast culture additions to the diet of morbid claves reduced the number of treatments and had increased DMI, the positive effects might have been partly due to the beneficial effects on N and mineral metabolism.

Antibiotics such as chlortetracycline, oxytetracycline, bacitracin, and tylosin are often incorporated into receiving calf rations as they may reduce sickness and increase performance (Chester-Jones and DiCostanzo, 1994). However, the programs can be labor intensive, are expensive, and have mixed results. An alternative to feeding antibiotics for 14 – 21 days is to give an injection of antibiotics at the time of processing (mass treatment). Cole and McCollum (1997) noted that when high-risk cattle are introduced into the feedlot it may be more feasible (economically or labor concerns) to mass-treat al calves with an antibiotic such as tilmicosin as this has shown to decrease the incidence of

BRD. Liver abscesses can have major economic implications in the feedlot industry. On average, the incidence of abscesses averages 12-32% in grain-fed cattle (Brink et al., 1990). The National Beef Quality Audit (1995) listed liver condemnation second in a list of ten packer concerns and abscesses are the leading cause of liver condemnation in the United States. Cattle with abscessed livers have reduced animal performance and carcass yield (Brink et al., 1990). Liver abscesses are usually secondary to an acid-induced rumenitis which causes damage to the protective surface caused by sudden changes in high-energy diets and poor bunk management programs (Nagaraja and Chengappa, 1998). The control of liver abscesses in feedlot cattle is usually associated with antimicrobials. Tylosin is the most effective antimicrobial at controlling *F.necrophorum*, the gram positive organism implicated as the primary pathogen associated with abscesses (Nagaraja and Chengappa, 1998). Several early studies showed that tylosin reduces liver abscess incidence in cattle (Brown et al., 1975; Pendlum et al., 1978; Heinemann et al., 1978). Moreover, Potter et al. (1985) summarized the effects of monensin and Tylosin on cattle performance and incidence of liver abscesses from 14 previous trials where the interactions of monensin and tylosin were analyzed. It was concluded that tylosin improved weigh gain and feed efficiency.

*Ionophores*: Ionophores are fed to approximately 90% of all feedlot cattle in the U.S. (Boyle et al, 1998.). Monensin is a ruminal propionate enhancer which improves feed efficiency and decreases feed intake (Potter et al., 1985). A step-up program utilizing monensin (starting with 125 mg/hd/day) is recommended if intake levels are not at normal levels or there is a risk of calves going off feed (Boyles et al.). A similar step up procedure (starting at 150 mg/hd/d) can be used with lasalocid which is shown to be more

palatable than monensin products (Boyles et al.). The use of ionophores in a receiving calf diet (after the calves are eating regularly) has shown to reduce rumen acidosis and bloat as well as control coccidosis (Chester-Jones and DiCostanzo, 1994). When roughage levels are less than 12%, ionophores have shown to be very beneficial in reducing acidosis and bloat (Boyles et al.). In an early study, Gill et al., (1976) studies the effects of feedlot rations containing 14, 30, or 75% corn silage (DM) with or without 300 mg of monensin. Feed efficiency was improved by 6% across all roughage levels ($P < 0.01$) but the increase in FE had no effect on ADG or carcass parameters. Feed intake for steers fed monensin was 5-14% less than for the control cattle not fed monensin.

*β-adrenergic agonists:* The major role of a β-adrenergic agonist (β-AA) is to improve FE (Smith, 1998; Avendaño-Reyes et al., 2006; and Montgomery, 2009). Boyd et al., (1991) concluded that efficiency can be controlled by the amount of nutrients partitioned to fat versus muscle and β-AA allows metabolic regulation to ensure enhanced lean tissue growth. The physiological response is produced when a β-AA binds to a β-adrenergic receptor. The physiological β-adrenergic receptor agonists are norepinephrine and epinephrine and oral administration of some β-AA cause modification of growth and increased accretion of skeletal muscle (Mersmann, 1998). Feeding β-AA results in an increased net-uptake of AA by specific muscles (Quinn et al., 2008). Ractopamine (RAC) is a β1-AA which was introduced for use in cattle. Feeding β-AA (clenbuterol, cimaterol, zilpaterol) to cattle causes metabolic alterations which increase leanness and muscle accretion (Elam et al., 2009). Walker et al., (2006) hypothesized that because of these increases in leanness, the crude protein requirements could be altered in heifers fed RAC 28 d before slaughter. Dietary treatments were formulated to contain 13.7% crude protein

with 1) urea 2) solvent soybean meal or 3) expeller soybean meal with 0 or 200 mg of RAC-HCl/d. By feeding RAC, FE was increased ($P < 0.002$) by 17%. Carcass-adjusted daily gain and FE were not affected by protein source. Dressing percentage, LM area, fat thickness, yield grade, and marbling score were not affected by RAC. It was concluded that RAC improved ADG and FE and protein source had little effect on overall performance.

Gruber et al., 2007, looked at the effects of RAC on the performance and carcass characteristics of steers based upon different biological types (Continental crossbred, British crossbred, and Brahman crossbred). The study found similar results to previous studies in regards to enhanced growth and performance traits (increased ADG, FE, HCW, and LM area), however, no major differences were shown to exist in regards to biological type. Therefore, it was concluded that RAC elicited a consistent response among diverse biological cattle types.

*Biohydrogenation:* Food products that are derived from ruminant animals are the major source of Conjugated linoleic acids (CLA) in the human diet (Bauman et al., 1999). The reason that CLA's are of such great importance in the human diet is that they function as anticarcinogens (Duckett et al., 2002). In an early study aimed at determining the effect of temperature and time on mutagen (carcinogen) formation in pan-fried hamburger, Pariza et al. (1979) discovered that mutagenic inhibitory activity existed in raw and cooked animal tissue which was originally thought to only be found in plants. Further research has shown that CLAs can reduce tumors in animal models (Bauman et al., 1999; Duckett et al., 2002). Therefore, it can be concluded that CLA are a very important part of human nutrition.

Conjugated linoleic acid is found in milk and meat fat of ruminants and originates from 2 sources, both of which are associated with biohydrogenation of unsaturated fatty acids. Once source is the CLA formed during ruminal biohydrogenation of linoleic acid (Figure 1.2). The second source is CLA synthesized by the animal's tissues from C:18:1 *trans* 11 (Bauman et al., 1999). The extensive biohydrogenation of unsaturated fatty acids by rumen microorganisms results in primarily saturated fatty acids being absorbed from the small intestine and incorporated into adipose tissue regardless of diet composition (Dawson and Kemp, 1970). Unfortunately, the catch-22 of the biohydrogenation process in ruminants which creates CLA is also responsible for the high levels of saturated fatty acids in the fat of ruminant animals which most consumers consider to be an unhealthy and unfavorable part of eating beef.

In a study conducted by Duckett et al., (2002) they determined the effect of dietary lipid level or oil source on ruminal biohydrogenation and CLA concentrations in beef steers. The three dietary treatments were 1) typical corn (TC), 2) high-oil corn (HOC), and 3) TC diet with corn oil replacing corn so that it contained the same amount of lipid as the HOC (OIL). Ruminal biohydrogenation was greater ($P < 0.05$) for diets with higher lipid levels (diets 2 and 3). However, oil type did not affect biohydrogenation. The HOC diet did have greater ($P < 0.05$) biohydrogenation of oleic acid than the other treatments but linoleic acid biohydrogenation was lower for HOC than for OIL diets. Biohydrogenation of linolenic acid was greatest at 91%, followed by intermediate for linoleic (80%), and lowest for oleic acids (70%). It was concluded that feeding high oil corn or adding corn oil to typical finishing feedlot rations increased intake and increased biohydrogenation of 18-carbon unsaturated fatty acids. In contrast to

these results, a study aimed at determining whether soybean oil (SBO) supplementation at 4 different levels (0, 2.5, 5.0, or 7.5%) to high-concentrate diets fed to finishing beef cattle increased proportions of CLA, specifically CLA c9,t11 in ruminal contents and tissue lipids did not increase CLA c9,t11 content of beef (Beaulieu et al., 2002). It was concluded that if a market for high CLA beef was developed, alternative finishing methods for cattle would need to be examined as a high-corn finishing program diet favors the conversion of polyunsaturated fatty acids to isomers other than those leading to CLA9,11 in tissues. Unsaturated fatty acids including α-linolenic acid (*cis*-9, *cis*-12, *cis*-15-18:3) and linoleic acid (*cis*-9, *cis*-12-18:2), are abundant in grass and other forages ruminants consume (Jenkins et al., 2008) and so it can be concluded that finishing steers on high-forage diets would increase CLA concentrations but would also increase cost of production as ADG would drop, DOF would increase, and feeding frequency might increase in a feed yard due to bunk area constraints.

*Trends in the meat industry*

The beef industry has seen a drop in its retail meat market share (Lamb and Beshear, 1998). The poultry and pork sectors have both gained large percentages of the meat market share. Specifically, poultry has seen profits increase drastically over the past 20 years. Economists attribute the profits of the pork and poultry industries to their ability to vertically integrate their business models. The vertical integration has allowed them to become, to a larger extent, consumer-product driven and their ability to keep production cost minimized have had a direct correlation to low retail prices (Lamb and Beshear, 1998).

Packing plants have declined in number and increased in size at a very rapid rate (Table 1.3). Concentration of the meatpacking plants has lead to criticism and worry from packers and consumers alike (Ward and Schroeder, 2002)

*Nutrient composition of retail cuts:* Beef accounts for more than 20% of consumer's meat protein intake worldwide (Taha, 2003). Overall, meat consumption has risen in the United States as well as in most developed countries and beef represents 56% of all red meat consumed in the US (Daniel et al., 2010). There are two major components associated with meat quality 1) the nutrient composition of the retail cut which is objective and 2) consumer determined eating quality as defined by the flavor, juiciness, tenderness, and color, which is subjective (Bender, 1992).

Concerns regarding calories, fat, and cholesterol can influence a consumer's decision when it comes to purchasing preference. The Food Safety and Inspection Service (FSIS) recently decided to amend the Federal meat and poultry products inspection regulations. Nutrition labeling of the major cuts of single-ingredient, raw meat and poultry products on labels or at point-of-purchase will be required in 2012 (75 FR 82148). In order to achieve the most accurate nutrient profile for any retail cut, nutrient analysis of raw and cooked cuts should be performed to address the requirements for this labeling rule. By ensuring that proper nutritional labels are displayed with certain beef cuts, consumers would be able to compare different types of beef retail cuts to purchase the type of product that fits their nutritional and palatability needs.

For the past 20 years, the poultry industry has continued to see an exogenous growth whereas the beef industry has seen a slight decline in beef table cut demand (Eales and Unnevehr, 1988; Daniel et al., 2010). Lower poultry prices and human health

concerns related to red meat consumption are two of the largest factors that influence beef demand (Hahn, 1996; Moloney et al., 2001; Chao, et al., 2005; Pennings et al., 2002). Over the past twenty years the beef industry has worked diligently to remain competitive. Public health and consumer concerns regarding fat and cholesterol have caused an increased demand for leaner meat. A marked reduction in the proportion of fat from foods high in saturated fat has been seen in consumption patterns within the U.S. (Daniel et al., 2010).

Beef is an excellent source of protein, and is rich in vitamin $B_{12}$, iron, and zinc (Bender, 1992; USDA, 2008). However, cooking can lead to the loss of nutrients associated with protein degradation and lipid oxidation (Rodriguez-Estrada et al., 1997). Consumers prepare and cook steaks differently and to different degrees of doneness (Lorenzen et al., 1999). Lorenzen et al. (1999) reported that outdoor grilling was the most popular method for cooking the top loin steak followed by broiling, indoor grilling, pan frying, and other (including oven roasted uncovered, pan-broil, stir-fry, braise, simmer and stew, and deep fry). Regional demographics indicated that consumers in San Francisco and Philadelphia cooked their steaks to a lower degree of doneness (DOD) as compared to those in Chicago and Houston (Lorenzen et al., 1999). Variability associated with cooking techniques need to be considered when conducting research on beef retail cuts. The beef industry needs to ensure that accurate and detailed nutrient profiles are available for consumers to make informed purchasing decisions.

*Purge and Cookloss Nutrient Composition:* A beef carcass is comprised of water, muscle, connective tissue, fat, and bone. Approximately 75% of a carcass is comprised of water. The greatest variability associated with carcass composition is the total amount of fat

which can vary greatly in beef carcasses based on diet, genetics, and fabrication techniques (Bender, 1992; Committee on Technological Options to Improve Options to Improve the Nutritional Attributes of Animal Products, 1988).

The water holding ability of the muscle affects the appearance of the meat before cooking, the duration and consistency of cooking, and the juiciness of the meat upon mastication. Water molecules are highly polar and are attracted to the muscle protein by specific ionizable basic (arginine, histidine, lysine) and acidic (glutamic acid and aspartic acid) groups or by polar nonionic groups (cystine, cysteine, serine, methionine, threonine, tyrosine, and tryptophan; Wierbicki and Deatherage, 1958). Myofibrils, the spaces between myosin and actin/tropomyosin, are where most water is present within the muscle (Lawrie, 1991). Lean meat contains approximately 3.5 g of water per g of protein (Wierbicki and Deatherage, 1958). Water, when directly bound to hydrophilic groups on muscle protein, is considered to be "bound" water (Hamm, 1960). Water may also be located in the extracellular region of the muscle and is referred to as "free water" (Hamm, 1960; Wierbicki and Deatherage, 1958; Lawrie, 1991). During the thawing and/or cooking process, "free water" is released and is referred to as purge or cooking loss, respectively.

Pre-harvest stress factors can lead to significant meat quality defects. Stress can cause accelerated rigor mortis, reduce water holding capacity, and cause negative color effects (Sams, 1999). Improving meat quality has been extensively studied over the past 50 years and after the 1995 National Beef Quality Audit, Smith et al. (1996) determined that inadequate tenderness and low overall palatability were among the "top 10 quality concerns" in beef. Techniques such as aging, cooking method, blade tenderization, and

electrical stimulation have proved to be effective technologies to improve tenderness of strip loins aged for 14 d (Parish et al., 1993; Dransfiled, 1994;  Roeber et al., 2000; ). However, focusing on improving tenderness could have a negative effect on attributes such as juiciness and little data is available on the effects of these methods on nutritive value of the retail product (Nour et al., 1994; Moloney et al., 2001).

In order to achieve the most accurate nutrient profile for any retail cut, nutrient analysis of raw and cooked cuts should be performed to address the "meat labeling" ruling previously described. However, several factors such as thawing and cooking can alter the nutrient composition of the raw or cooked product (Moody et al., 1978; Rodriguez-Estrada et al., 1997). Traditionally, the nutrient composition of purge or cooking loss has been calculated by the difference in the actual nutrient composition of the raw and cooked product. However, determining the actual nutrient composition of purge (loss due to thawing) and drippings from cooking may assist in assessment of how technologies used to improve tenderness impact, end nutrient profile of beef retail cuts.

*Conclusions*

Feedlot production technologies will continue to change and develop each day. Concerns regarding animal welfare, the environment, and confined animal management will force the industry to change directions and develop novel approaches to beef production. The effects of the research and technologies used in the growing of cattle will directly influence the meat industry. Genetics, nutrition, and management strategies will influence overall profit and nutrient composition of the retail cuts that are produced for the consumers. The objective of this dissertation was twofold; 1) examine how feedlot

management practices effect overall beef cattle production and carcass characteristics and 2) determine how specific post-mortem preparation techniques affect overall nutrient composition of beef retail cuts.

The individual objectives are:

1) To examine the effects of ad libitum vs. slick bunk management systems, feeding frequency, and time of vaccination relative to deworming of feedlot steers to determine the effects of these management systems on animal performance and carcass characteristics.
2) To determine the differences in nutrient composition of retail cuts cooked to different degrees of doneness using different types of cooking methods and to determine the nutrient content of the purge and cook drippings of retail cuts due to the thawing, preparation, and cooking of the retail cuts.

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Table 1.1. Total capacity of large cattle feeding firms in the U.S-2011 (Source: independent websites of each company listed)

| Rank | Firm | One-time capacity |
|---|---|---|
| 1 | JBS Five Rivers Cattle Feeding LLC, Greeley, CO | 960,000 |
| 2 | Cactus Feeders, Inc., Amarillo, TX | 520,000 |
| 3 | Cargill Cattle Feeders LLC, Wichita, KS [1] | 350,000 |
| 4 | Friona Industries LP, Amarillo, TX | 275,000 |
| 5 | J.R. Simplot Co. [1] | 230,000 |

[1] Source: http://fdsmagissues.feedstuffs.com

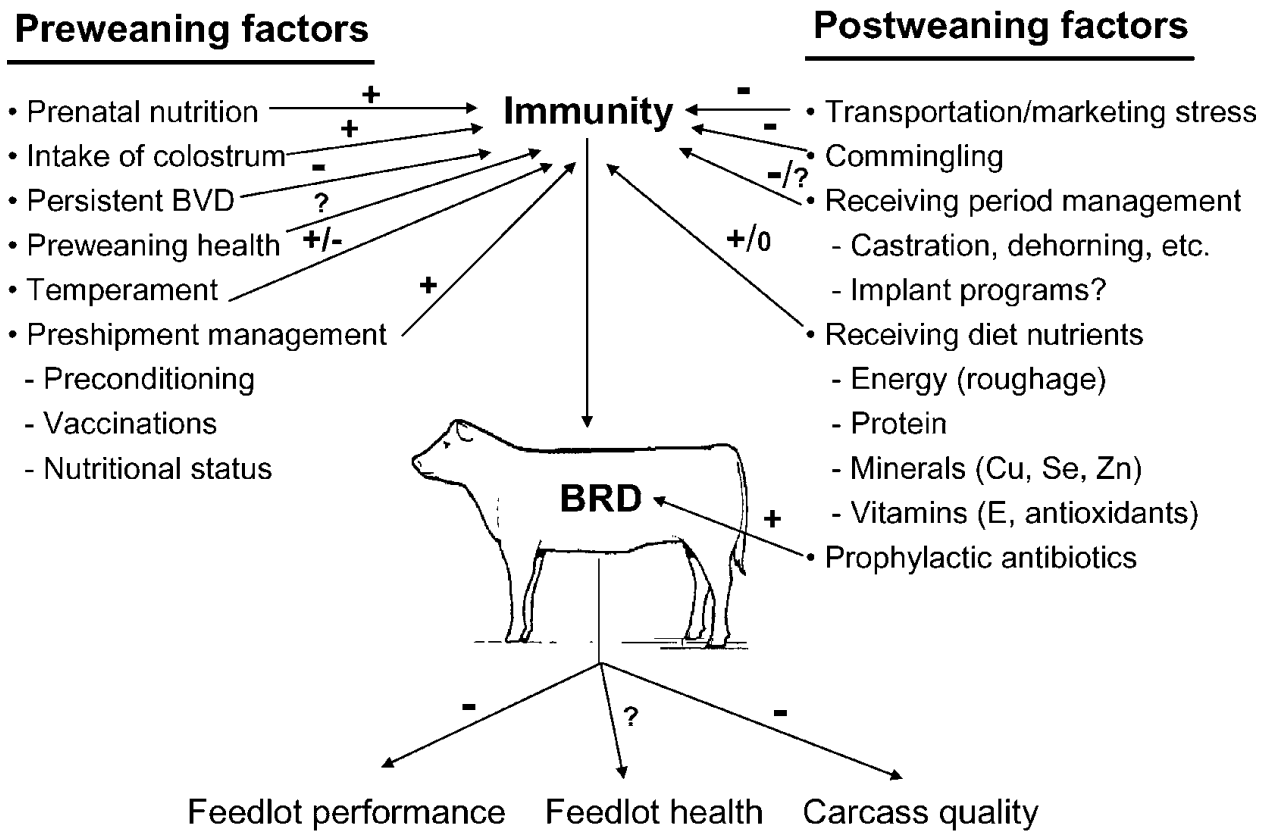


Figure 1. 1. (Duff and Galyean, 2007) Pre- and postweaning factors affecting bovine respiratory disease (BRD) in beef cattle and the resulting outcomes of the disease. + = decreased incidence or consequence; − = increased incidence or consequence; ? = effects not fully understood based on the available data. BVD = bovine viral diarrhea virus.

Table 1.2. Popular Implants currently available for use in feedlot cattle in the United States [1]

| Trade Name | Approved for: | Estimates of effective life (d) | Active ingredients/amounts (mg) | Type of hormone action |
|---|---|---|---|---|
| Ralgro | Steers/heifers | 60-80 | Zeranol 36 | Estrogenic |
| Ralgro Magnum | Steers | 80-120 | Zeranol 70 | Estrogenic |
| Synovex-C | Steers | 60-80 | Estrodiol Benzoate 10, Progesterone 100 | Estrogenic |
| Synovex-S | Steers | 80-120 | Estradiol Benzoate 20, Progesterone 200 | Estrogenic |
| Implus-S | Steers | 80-120 | Estradiol Benzoate 20, Progesterone 200 | Estrogenic |
| Component E-S | Steers | 80-120 | Estradiol Benzoate 20, Progesterone 200 | Estrogenic |
| Synovex-H | Heifers | 80-120 | Estradiol Benzoate 20, Testerone Propionate 200 | Estrogenic |
| Implus-H | Heifers | 80-120 | Estradiol Benzoate 20, Testerone Propionate 200 | Estrogenic |
| Component E-H | Heifers | 80-120 | Estradiol Benzoate 20, Testerone Propionate 200 | Estrogenic |
| Compudose | Steers/Heifers | 200 | Estradiol 25.7 | Estrogenic |
| Encore | Steers/Heifers | 400 | Estradiol 45 | Estrogenic |
| Component T-S | Steers | 80-90 | TBA [3], 140 | Androgenic |
| Finaplix-H | Heifers | 60-80 | 200 TBA | Androgenic |
| Component T-H | Heifers | 100-120 | TBA, 200 | Androgenic |
| Revalor-S | Steers | 60-80 | 120 TBA, 24 Estradiol | Estrogenic & Androgenic |
| Component TE-S | Steers | 100-120 | 120 TBA, 24 Estradiol | Estrogenic & Androgenic |
| Revalor-H | Heifers | 90-110 | 140 TBA, 14 Estradiol | Estrogenic & Androgenic |
| Synovex-Plus | Steers/Heifers | 90-110 | 200 TBA, 28 Estradiol | Estrogenic & Androgenic |
| Revalor 200 [2] | Steers/Heifers | 90-110 | 200 TBA, 20 Estradiol | Estrogenic & Androgenic |
| Revalor-XS [2,4] | Steers | 200 | . | Estrogenic & Androgenic |

[1] Adapted from ZoBell et al., 2000 and Cook, 2000

[2] Information obtained from www.revalor.com

[3] TBA=trenbolone acetate

[4]Revalor-XS delivers the same proven combination of TBA and estradiol as an initial dose of Revalor-IS and a terminal dose of Revalor-S in a single timed-release implant. One trip through the chute boosts cattle productivity and feed efficiency for up to 200 days.

Table 1.3. Total capacity of large beef slaughter firms in the U.S-2011 (Source: independent websites of each company listed)

| Rank | Firm | Process/yr |
|---|---|---|
| 1 | Cargill Meat Solutions | 7.6 mill |
| 2 | Tyson Foods | 4.5 mill |
| 3 | JBS USA | 1.50 mill |
| 4 | National Beef Packing Co. LLC | 14,000 |
| 5 | American Foods Group, LLC | 7,000 |

[1] Source: http://fdsmagissues.feedstuffs.com

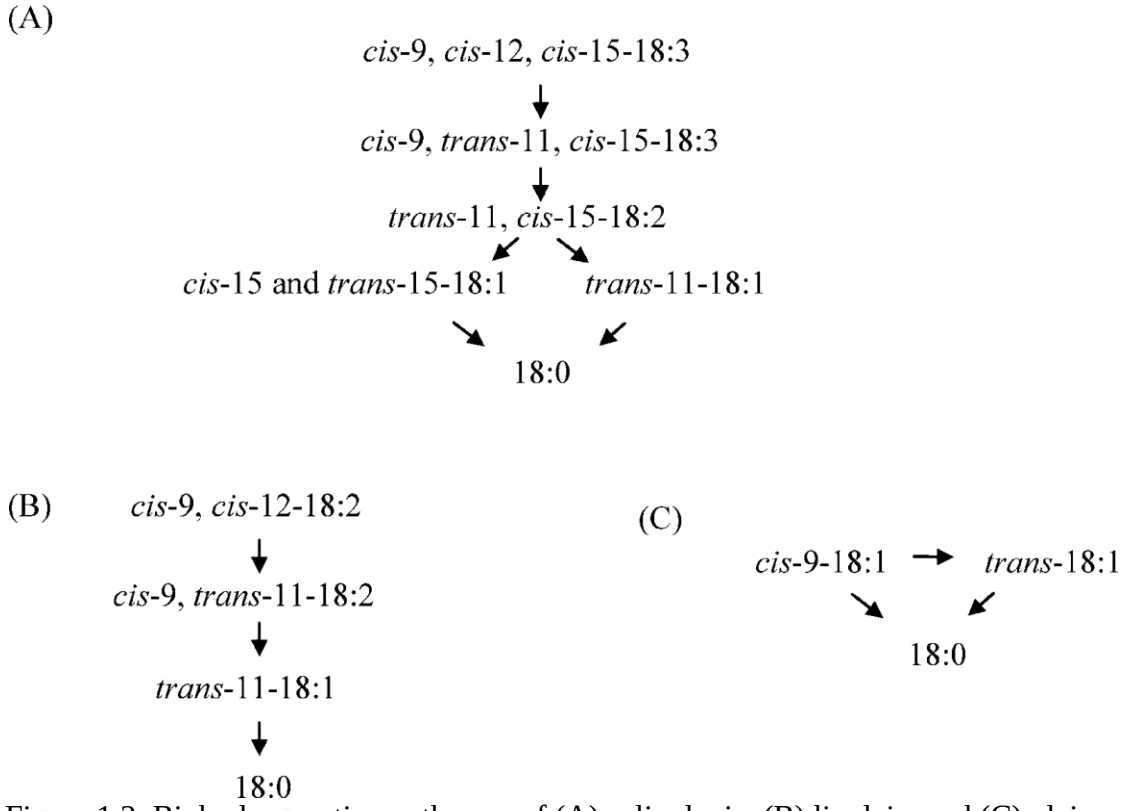


Figure 1.2. Biohydrogenation pathways of (A) $\alpha$-linolenic, (B) linoleic, and (C) oleic acids. Adapted from Harfoot and Hazlewood (1988).

# CHAPTER II

## EFFECT OF FEEDING FREQUENCY ON FEEDLOT STEER PERFORMANCE


## ABSTRACT

Two hundred and seventy crossbred yearling steers (mean initial BW = 318 kg) were utilized to determine the effect of feeding frequency on feedlot performance and carcass characteristics. Steers were stratified by BW and randomly assigned to pens. Pens were then randomly assigned to 1 of 3 treatment groups: once daily feeding (1X), twice daily feeding (2X), or three times per day feeding (3X). Steers were fed a standard high concentrate steam-flaked corn based finishing ration for 170 d. Steers were housed in pens measuring 6.1 x 18.3 m. Feed was delivered to steers in fence-line (3.7 m in length) concrete bunks (0.31 m per hd). Pen served as the experimental unit and cattle were harvested at a constant days on feed. Average daily gain was similar for steers fed 1X or 2X per day; however, ADG ($P < 0.03$) and ADFI ($P < 0.04$) were greater in steers fed 3X when compared to steers fed 1X or 2X. Feed efficiency was similar for all 3 treatment groups. Steers fed 3X had a greater HCW ($P < 0.01$) than steers fed 1X or 2X. No differences were detected between the treatment groups for USDA QG or YG. These data indicated similar performance between feeding 1 or 2 times per day; however, feeding 3 times a day increased ADG, ADFI, and HCW.

# INTRODUCTION

In most large feedlot operations, cattle are fed more than once a day. Feeding multiple times during the day is believed to keep feed fresh, reduce digestive upsets, and improve performance as feed trucks may entice cattle to the bunk and stimulate cattle to eat (Schwartzkopf-Genswein, 2000). Feeding more than once per day has been reported to increase feed intake by 2 to 5% and reduce digestive upsets in feedlot cattle (Anderson, 1990). Additionally, multiple feedings may help to maximize an individual animal's access to feed (Pritchard, 2003). In contrast, cattle fed once daily at consistent morning times had higher ADG and better feed efficiencies than cattle fed once in the afternoon or twice daily (Delehant et al., 1996). Moreover, ADFI was similar between feeding frequencies (Delehant et al., 1996; Ruiz and Mowat, 1987). Cattle fed once daily in the morning had higher dressing percentages and QG, larger loineye areas, and less backfat than cattle fed twice daily. The discrepancies between studies may be due to one or more of several factors including feedlot location, management strategies, diet composition, and/or cattle type.

Daily feed intake is favorably related to the health and profitability of feedlot cattle (Loerch, 2000). Cattle are inherently programmed to spend most of their time either eating or ruminating; therefore, altering feeding frequency could influence performance traits (Stricklin and Kautz-Scanavy, 1984).

The objective of the present study was to determine the impact of feeding 1, 2, or 3 times per day on overall performance and carcass characteristics of finishing feedlot steers at the Southeast Colorado Research Center (SECRC) located near Lamar, CO.

# MATERIALS AND METHODS

## *Steer Source and Processing*

Prior to the initiation of this experiment, all procedures were approved by the Colorado State University Animal Care and Use Committee. Two hundred and seventy crossbred yearling steers (mean initial BW = 318 kg) were used in this experiment. The experiment was conducted during late summer, fall, and early winter in southeast Colorado. Steers were from a previous receiving study at SECRC. Upon initiation of this study (d -1), all steers were weighed, assigned a breed type code, previous receiving study treatment code, implanted (200 mg progesterone and 20 mg estradiol; Vet Life, Des Moines, IA), and given an electronic identification tag. Initial data were sorted by weight and all steers that were ± 2 standard deviations from the mean initial BW were removed from the Exp. A sufficient number of the lightest remaining steers were then removed to obtain the 270 steers required for use in this study. To minimize the effects of the previous receiving experiment treatments, previous treatments were balanced across pens in this experiment.

## *Pen and Treatment Allotment*

Steers were ranked by BW and assigned a random number using the random number function in Microsoft Excel 2007 (Microsoft Inc., Seattle, WA). The lightest 135 steers were randomly assigned within each successive set of 5 steers based on the random number assigned to each steer with each successive random number being assigned to replicates 1 through 5 in succession. This process was repeated until all 135 light steers were assigned to a replicate. Next, the heaviest 135 steers were randomly assigned to

additional replicates that were numbered 6 through 10 using the same process as used for replicates 1 through 5. Steers were next sorted by replicate and breed type and randomly assigned within replicate and breed type to 1 of 3 treatment groups: once daily feeding (1X), twice daily feeding (2X), or 3 times a day feeding (3X). Each successive set of 3 steers were assigned to treatment based on successive random numbers to the 1X, 2X, and 3X treatments, respectively. On study d 0, steers were returned through the chute, weighed, tagged with a visual tag, and sorted into one of 30 pens each housing 9 head.

All treatments were fed a common finishing diet of steam-flaked corn grain, a roughage source, soybean meal, and a urea/limestone based vitamin and mineral supplement (Table 2.1). Diets were formulated to meet or exceed all nutrient requirements for finishing steers (NRC, 1996). Various roughages were used throughout the study reflecting roughage availability at SECRC. Feed calls were determined at 0630 h daily prior to the morning feeding. The bunk scoring system utilized was developed based upon ease of implementation and sensitivity. Bunk scores consisted of: n; a bunk that was devoid of all feed particles at the end of the work day or during the night (night slick) 0; a bunk devoid of all feed particles at morning (slick) ; ½; a bunk that contained trace to 2.26 kg of feed as fed (crumbs) at morning 1; a bunk that contained 2.27 to 9.05 kg of feed as fed at morning 2; a bunk that contained 9.06 to 18.80 kg of feed as fed at morning 3; a bunk that contained more than 18.80 kg of feed as fed at morning (feed looked virtually untouched by cattle). A 0.23 kg per hd increase feed call occurred every other day for bunks with a score of n (night slick bunks) and a .23 kg per hd increase feed call every third morning for cattle with a score of 0 (morning slick). Cattle with a bunk score of 1, 2, or 3 were cut by 0.91 kg, 1.82 kg, or 2.27 kg the day of the score. Bunks

with scores of 1 or 2 were scooped on d 3. Bunks with a score of 3 were scooped on d 1. A feed sample was collected and analyzed. The first day that cattle have a slick bunk after a feed cut, the cattle received half of the total kg cut back and were then bumped normally.

The 1X treatment was fed 100% of their ration starting at 0800 h; 2X steers were fed 60% of their total ration starting at 0730 h and the remaining 40% of their ration at 1300 h; and 3X steers were fed 34% of their ration starting at 0700 h, 33% of their ration at 1000 h, and the remaining 33% of their ration at 1400 h. Weigh backs were collected, weighed, and recorded throughout the study as feed became spoiled or on weigh days.

Steers were housed in pens measuring 6.1 x 18.3 m with a single continuous-flow automatic water fountain shared between every two pens. Feed was delivered to steers in fence-line (3.7 m in length) concrete bunks (0.31 m per hd) which had a 3.7 m wide and 6.1 m long concrete apron adjacent to the bunk to provide a solid area for steers to stand while eating. Steers were weighed individually on d -1, d 0, d 47, and d 169. Steers were pen weighed on d 83 and d 126.

Steers were harvested after 170 d on feed. On the shipping date, steers were transported approximately 274 km to a commercial abattoir, for harvesting. Trained personnel matched ear tag with carcass identification tag on the day of harvest. United States Department of Agriculture carcass grade data were obtained from the harvest plant carcass data sheets.

*Statistical Analysis*

Statistical analyses of data were performed using mixed model procedures as described by SAS (release 9.1, SAS Institute, Cary, NC). The model included fixed effects of treatment, time, treatment x time interactions where appropriate, and initial weight as a covariate to account for the light and heavy weight blocks. The covariate was initially included within the model to ensure that the *a priori* randomization resulted in all treatment groups being of equivalent initial BW. The covariate was removed when found non-significant. Random effects were pen within treatment. Treatment and treatment x period interactions were considered to be significant if $P < 0.05$. Linear and quadratic contrasts were utilized to determine overall treatment effects. All frequency data were analyzed using chi-square analysis, and within-class variances were compared using *F*-tests.

## RESULTS

### *Performance*

The effects of feeding frequency on feedlot performance are shown in Table 2.2. Initial body weights were similar ($P > 0.99$) across treatments. However, linear effects of feeding frequency on final BW were significant ($P < 0.05$) as final BW averaged 593, 593, and 604 kg for the 1X, 2X, and 3X treatments, respectively. Average daily gain ($P < 0.03$) and ADFI ($P < 0.04$) increased linearly as feeding frequency increased and averaged 1.63, 1.64, and 1.71 kg ADG and 9.24, 9.27, and 9.67 kg ADFI for the 1X, 2X, and 3X treatments, respectively. Gain to feed ratio was similar across all treatments and averaged 0.18.

### *Carcass Characteristics*

The effects of feeding frequency on HCW and dressing percentage are shown in Table 2.3. Hot carcass weight for the steers increased (linear, $P < 0.01$; quadratic, $P < 0.05$) with increased feeding frequency indicating that HCW was greater for steers fed 3X (370 kg) as compared to steers fed 1X (362 kg) or 2X (360 kg). Dressing percentages were similar ($P > 0.05$) between treatments and averaged 61.1%. No differences in YG or QG were detected between treatments (Table 2.3). A greater percentage of condemned livers ($P < 0.03$) were observed in cattle fed 3X and declined as feeding frequency decreased (Table 2.3).

## DISCUSSION

### *Feedlot Performance*

Individual feedlot operations should examine the effect of feeding frequency on cattle performance and overall profitability. By determining what effect the number of feed deliveries per day has on intake, feedlot managers can determine how many times per day feedlot cattle should be fed in order to achieve optimum profitability by keeping labor, equipment, and feed costs at a minimum. Multiple feedings may improve labor and equipment utilization in large feedlots if multiple truck loads and several employees are needed to distribute feed to all cattle. Conversely, in feedlots where multiple loads and several employees are not required to distribute adequate feed for an entire day, reducing the number of feedings may reduce labor, equipment maintenance, and repair costs.

Several early studies were conducted to determine the effects of feeding frequency on intake factors. Gibson (1981) reported improved performance results due

to increased feeding frequency in a meta-analysis of data obtained from 15 published reports. The meta-analysis analyzed 15 published data points for cattle and all experiments ran for a fixed time-period. The study investigated ADG and ADFI based on the number of meals per day (1 to 24). By examining the distribution of responses, the mean ADG ($P < 0.01$) was positively correlated with increased feeding frequency. Improved feed efficiency was also noted. It was concluded that the increased response of ADG to increased feeding frequency is most likely observed 1) in young animals, 2) in animals on diets which give low ADG if fed on one or two meals a day, 3) in animals fed diets with a high concentrate content, or 4) where increased feeding frequency increased ADFI. In an earlier Exp., Putnam et al. (1961) utilized eight Angus heifer calves to determine if feeding more frequently than twice daily had an effect on rumen volatile acids, protozoal population, and BW gains. Calves were fed either 2 times per day or 10 times per day. There was no difference in VFA profiles or protozoal counts; however, BW gains increased ($P < 0.05$) with increased feeding frequency.

In a study conducted by Goonewardene et al. (1995), 120 steers weighing 285 kg were utilized to determine if feeding 1, 2, or 3 times per d impacted cattle performance. No differences in ADG or feed efficiency ($P > 0.05$) were reported. Similar results were reported in a study designed to determine if 1 afternoon feeding versus 2 times per d feeding impacted animal performance. No differences in ADG or feed efficiency ($P > 0.05$) were found (Stanton et al., 1991). Additionally, a study conducted at the Clayton Livestock Research Center of New Mexico State University utilizing 3 groups of steers revealed no performance improvements based on feeding frequency (Lofgreen et al., 1982). Group 1 cattle were received off of dry native grass, group 2 was received from

wheat pasture, and group 3 was received from a growing program in the feedlot. Within each group, cattle were randomly assigned to either once or twice daily feeding. No differences were found to exist for ADG, feed intake, or feed efficiencies.

*Carcass Characteristics*

In contrast to the findings of the present study, Delehant and Hoffman (1996) reported that cattle fed once daily in the morning had higher dressing percentages than cattle fed once daily in the afternoon or twice daily (60.17% vs. 59.88% vs. 58.92%). These increases could be attributed to higher gains and feed efficiencies that were shown to exist in the cattle fed once daily in the morning. Another possible reason for the contradicting results could be variation in climate (southeast Colorado vs. Iowa) or time of year of the trial (late summer/fall vs. late fall winter). However, Delehant and Hoffman (1996) conducted a second experiment with similar same treatments and found dressing percentage to be higher (61.78% vs. 60.58% vs. 59.18%) in the twice daily feeding as compared to the cattle fed once daily in the morning or afternoon regardless of the fact that the once daily morning cattle had the greatest ADG. Additionally, similar to the current experiment, no treatment differences in QG and YG existed. A study utilizing 320 yearlings steers to determine the performance and carcass characteristics of cattle fed once vs. twice daily reported similar results to those found in this study; no differences in QG or YG were detected among feeding frequencies (Hanke et al., 1981).

Liver abscesses are diet-induced as the prevalence and severity of abscesses are negatively related to roughage level in the diet and liver abscesses are of great economic significance to the beef cattle industry (Nagaraja et al., 2007). Brink et al. (1990)

reported increased incidences of liver abscesses at harvest reduced HCW ($P < 0.001$) and DP ($P < 0.01$) relative to cattle experiencing no liver abscesses. Additionally, in contrast to the findings of this study, a greater incidence in liver abscesses decreased feed intake ($P < 0.10$) and feed efficiency ($P < 0.001$). It is not known why increased liver condemnations were observed for cattle fed 3X in the present study.

Maximizing consistent feed intake is very challenging and as shown above, results are mixed. Diet formulation, ingredient quality, ingredient variation, ingredient processing, diet conditioners, diet batching time and methods, quantity offered, starting time for feeding, stress management, weather changes, feeding frequency, water management, time of day fed, cattle type and bunk space have all been addressed as issues associated with intake consistency (Anderson, 1990; Prichard and Bruns, 2003). It is almost impossible to conduct a feed intake study without facing the challenges associated with an applied study of this magnitude. The main focus of this specific research study was to examine the best application of feeding frequency at a 1,300 head feedlot in southeast Colorado. Therefore, discrepancies will exist between literature based on the above confounding restraints of conducting feedlot trials based of the cattle available at the time, the management of the feedyard, and the environmental effects that are uncontrollable.

## IMPLICATIONS

Results of this study suggest that feeding frequency had an impact on steer performance. Average daily feed intake and ADG were greater for the steers fed 3X vs. those fed 1X or 2X Increased feeding frequencies may result in higher intakes and gains.

However, if managed properly, once a day feeding could result in greater profit margins. Once daily feeding would reduce labor and equipment operation costs as long as multiple loads are not required to deliver adequate feed to all of the cattle. However, at large feedyards, if the same number of total loads and equipment hours are needed to haul feed for the cattle, labor and equipment costs may not necessarily be reduced by once daily feeding. Additionally, because of the discrepancies that exist in the literature, it is important that each individual feedlot evaluate the effect of feeding frequency on total profit and loss to better identify the appropriate feeding frequency system for each operation.

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Table 2.1. Basal diet composition (%DM)

| Ingredient | Finishing Ration |
|---|---|
| Steam Flaked Corn | 71 to 81 |
| Roughage Source[1] | 8 to 15 |
| Soybean Meal | 2 to 4 |
| Yellow Grease | 3.50 |
| Condensed Corn Distillers Solubles | 3.00 |
| Supplement | 3.25 |

[1] Roughage sources used included: alfalfa hay, wheat silage, sorghum silage, and corn silage based on the forage availability throughout the study. Type of forage affected other ingredient amounts to balance crude protein and NEg

Table 2.2 Effects of feeding frequency on performance of finishing beef steers

| | Treatment [1] | | | | | Contrast *P*< | |
|---|---|---|---|---|---|---|---|
| Trait | 1X | 2X | 3X | SEM | Trt *P*< | Linear | Quadratic |
| Initial BW, kg [2] | 317 | 319 | 318 | 7.05 | 0.99 | 0.92 | 0.90 |
| Final BW, kg [3] | 593 | 593 | 604 | 3.49 | 0.05 | 0.03 | 0.22 |
| ADG, kg/d | 1.63 | 1.64 | 1.71 | 0.02 | 0.03 | 0.02 | 0.24 |
| ADFI, kg | 9.24 | 9.27 | 9.67 | 0.13 | 0.04 | 0.02 | 0.24 |
| FE [4], kg/kg | 0.18 | 0.18 | 0.18 | 0.01 | 1.00 | 1.00 | 0.95 |

[1]1X = fed once daily; 2X = fed twice daily; and 3X = fed three times daily

[2]A covariate of initial-BW was used in SAS analysis

[3] Final weights were shrunk by 4% to represent a standard industry shrink

[4]Abbreviations used: FE = feed efficiency (ADG/ADFI)

Table 2.3. Effects of feeding frequency on carcass characteristics and liver abscesses of finishing steers

| | Treatment [1] | | | | | Contrast *P*< | |
|---|---|---|---|---|---|---|---|
| Trait | 1X | 2X | 3X | SEM | Trt *P*< | Linear | Quadratic |
| HCW, kg | 362.1 | 360.7 | 370.9 | 2.26 | 0.01 | 0.01 | 0.05 |
| DP[2] | 61.1 | 60.8 | 61.4 | 0.21 | 0.18 | 0.29 | 0.12 |
| USDA YG [3] | 2.92 | 2.89 | 2.88 | 0.10 | 0.96 | 0.79 | 0.97 |
| QG[4] | 2.81 | 2.73 | 2.67 | 0.07 | 0.44 | 0.21 | 0.87 |
| Noncondemned livers, % | 85.54 | 82.14 | 69.88 | - | 0.03 | - | - |
| Abscessed livers, %[5] | 8.43 | 3.57 | 13.25 | - | 0.08 | - | - |

[1]1X = fed once daily; 2X = fed twice daily; and 3X = fed three times daily

[2] Final weights were shrunk by 4% to represent a standard industry shrink

[3] Abbreviations used: USDA = United States Department of Agriculture

[4] Quality grades were given a numerical code: 1 = Prime; 2 = Choice; 3 = Select; and 4 = Standard

[5] Abscessed liver scores include: A-; A; and A+ abscesses

# CHAPTER III

## EFFECT OF FEED BUNK MANAGEMENT ON FEEDLOT STEER INTAKE


## ABSTRACT

One hundred twenty seven yearling steers were utilized to determine the effects of bunk management on DMI and the pattern of feed disappearance from the feed bunk. Three 0630 h target bunk scores were compared: 0 – a bunk devoid of feed particles; ½ – a bunk containing up to 0.25 kg feed/head; and 1 – a bunk containing greater than 0.25 and up to 1.0 kg feed/head. Steers were fed at 0700 and 1130 h and bunks were observed at 1630, 2200, 0200, and 0630 h. Daily DMI for steers fed to a target score of 0 (9.74 kg) was less ($P < 0.05$) than for steers fed a target score of ½ (10.37 kg) which was less ($P < 0.01$) than for steers fed a target score of 1 (11.21 kg). Additionally, a treatment by time interaction ($P < 0.001$) for the estimated disappearance of feed from the bunk suggested that eating patterns differed by treatment. Despite additional feed available in the bunk from 0700 until 1600 h, steers fed to a target score of 0 consumed less feed from feed delivery until 1600 h than steers fed to a target score of ½ ($P < 0.001$) which consumed less feed from delivery through 1600 h than steers fed to a target score of 1 ($P < 0.01$). These data indicated that slick bunk management systems may restrict DMI in feedlot steers and alter feed consumption patterns.

# INTRODUCTION

Developing a feed bunk management system for feedlot cattle which achieves maximum performance and avoids digestive upsets is challenging. The primary difficulty is that while intake and performance of individual cattle are of primary concern, feedlot production practices are most conducive to managing pens of cattle and not individual animals. Multiple factors can contribute to digestive upsets including environment, management, diet type, intake, feeding behavior, social behavior, and cattle type (Galyean and Eng, 1998). Schwartzkopf-Genswein et al. (2003) estimated that digestive upsets may decrease performance and overall production costs by $15 to 20 per animal.

A feed bunk management system needs to be easy to use and sensitive enough to be able to detect changes in feed consumption. Adequate feed bunk management should ensure that day-to-day variation in feed intake is minimized and overall feed intake is enhanced while providing the correct type and amount of nutrients to individual animals without leaving excess feed in the bunk (Duff, 2001). Feed bunk management has changed over the years. The original objective of the cattle feeder was to keep bunks full and provide feed at all times for the cattle. This approach often resulted in spoiled feed that was either wasted or may have contributed to reduced intake if cattle were forced to clean the bunk. In recent years "slick bunk" systems have become popular. These systems purposely allow bunks to become empty at some point during the night in an attempt to eliminate wasted feed and restrict feed intake. Restricted feeding programs have been reported to improve feed efficiency (Galyean, 1999; Duff, 2001; Drager et al., 2004) and reduce digestive upsets associated with over consumption of feed

(Schwartzkopf-Genswein et al., 2003). However, excessive intake restriction can reduce ADG resulting in reduced profitability.

Prichard and Bruns (2003) suggested that feed bunk management affects cattle intake by reducing over-consumption and altering cattle behavior to ensure reduced daily intake variation. Therefore, the objective of the present study was to determine the effects of slick versus *ad libitum* bunk management on DMI and the pattern of DM disappearance from feed bunks.

## MATERIALS AND METHODS

Prior to the initiation of this experiment, care, handling, and sampling of the animals defined herein were approved by the Colorado State University Animal Care and Use Committee.

One hundred twenty seven crossbred steers (497 ± 19 kg) housed in 12 pens of 9 to 13 steers per pen were utilized in this experiment. The experiment was conducted during the early summer months (June and July) at Colorado State University's Southeast Colorado Research Center (SECRC) feedlot facility. Steers were housed in pens measuring 6.1 x 18.3 m with a single continuous-flow automatic water fountain shared between every 2 pens. Feed was delivered to steers in fence-line (3.7 m in length) concrete feed bunks which had a 6.1 m deep concrete apron adjacent to the feed bunk and water fountain to provide a solid area for steers to stand while eating or drinking. Before the initiation of the experiment, steers were pen weighed. Steers utilized were cattle that remained on hand at SECRC and were of varied DOF at the initiation of this experiment; therefore, 4 pens were assigned to 3 groups based on DOF and BW.

The experiment was conducted as a 3 X 3 Latin Square with 1 group of 4 pen replicates assigned to each cell of the square. For period 1, each cell of the square was randomly assigned to 1 of 3 feed bunk management treatments. Treatments were then rotated among the groups during each of 2 additional periods so that the 4 pens in each cell of the square were fed according to each of the 3 feed bunk management treatments over 3 periods.

The feed bunk scoring system utilized was developed based upon ease of implementation and sensitivity (Table 3.1). Feed bunk score treatments were based upon the amount of feed left in the bunk at 0630 h prior to the morning feed deliveries. Feed bunk score treatments consisted of: 0 – a feed bunk devoid of all feed particles (slick); ½ - a bunk that contained traces up to 2.26 kg of as-fed-feed (0.17 to 0.26 kg of as-fed feed/steer); 1 – a bunk that contained 2.27 to 9.05 kg of as-fed feed (*ad libitum*, 0.18 to 1.01 kg/steer).

An adaptation period of 10 d was implemented for each period prior to 4 d of data collection. The adaptation period was utilized to ensure the cattle were gradually transitioned from their previous feed bunk score treatment to their new feed bunk score treatment to avoid digestive disorders. During the 4 d data collection phase, all feed bunks were read at 1600, 2200, 0200, and 0630 h the next morning. Each morning after the feed bunk scores were assigned, feed intake from the previous d was determined by weighing the orts in each feed bunk and subtracting that amount from the total amount of feed delivered the previous day. Feed adjustments were made each morning prior to feeding based upon the collected bunk scores and total feed amounts per pen were adjusted daily. After 3 d of a feed bunk score of 3 (Table 3.1) the feed remaining in the

feed bunk was sampled, weighed, and discarded. Following each rainfall event and at the end of each 4 d data collection period, all feed from all feed bunks were weighed, sampled for DM analysis and discarded. Dry matter concentration of all weigh back samples were determined at SECRC by drying each sample in a 60ºC forced air oven for 48 h. Dry matter intake was calculated by subtracting the amount of DM weighed back from the amount delivered and dividing by head for the pen.

Diets were manufactured immediately prior to each feeding. All steers were fed 2 times daily with 60% of the daily feed allotment being delivered starting at 0700 hr and the remaining 40% of the daily feed delivered beginning at 1130 hr. All treatments were fed a common finishing diet containing steam-flaked corn, a roughage source, and a urea/limestone based vitamin and mineral supplement. Diets were formulated to meet or exceed all nutrient requirements for finishing steers (NRC, 1996).

The amount of as-fed feed that remained in the bunk at the end of each period when bunk score readings were obtained was estimated using the following assumptions: a score of 0 corresponded to 0 kg as-fed feed in the bunk; a bunk with a score of ½ was assumed to contain 1.13 kg as-fed feed (the average as-fed kg of a bunk score call of ½); and bunks with scores of 1, 2, or 3 were assumed to contain 5.68, 13.64, and 20 kg as-fed feed(the average as-fed kg of a bunk score call of 1, 2, 3), respectively. The amount of DM remaining in the bunk was calculated by multiplying the as-fed feed estimate by the DM concentration of the diet (80.1%). Estimated DM disappearance from feed delivery to 1600 h was calculated by subtracting the estimated amount of DM remaining in the bunk at 1600 h from the sum of the total kg of DM delivered to the bunk at 0700 and 1130 h. Estimated DM disappearance from 1600 to 2200 h, from 2200 to 0200 h, and

from 0200 to 0630 h was calculated by subtracting the amount of DM estimated in the bunk at 2200, 0200, and 0630 from the 1600, 2200, and 0200 h estimates, respectively. The amount of DM that disappeared from each bunk during each period was then divided by head count to express the results on a DMI per steer basis. Weather data were collected daily from the National Oceanic and Atmospheric Administration's National Weather Service for the point forecast reference in Lamar, CO 38.07°N 102.63°W (Elev. 1117 m). The weather station is located approximately 2 km from SECRC.

*Statistical Analysis*

Statistical analyses of data were performed using mixed model procedures as described by SAS (release 9.2, SAS Institute, Cary, NC) using methods appropriate for a Latin Square experimental design with replication. Pen served as the experimental unit. The model analyzing DMI included the fixed effects of bunk score treatment, period, and treatment by period interaction. Pen within treatment by period was the random effect. Bunk score and DM disappearance data were initially analyzed using a repeated measures analysis. Fixed factors in the models included bunk score treatment as a class variable, hour post delivery as a continuous variable (9, 15, 19, and 23.5 h representing the 1600, 2200, 0200, and 0630 h bunk readings), and hour by treatment. Pen within treatment by period was the subject of the repeated statement. Autoregressive order 1, compound symmetry, and unstructured covariance structures were tested with compound symmetry found as the most satisfactory fit for the bunk score data and unstructured covariance structure provided the most satisfactory fit for the DM disappearance data. Because the unstructured covariance structure provided the best fit for the DM disappearance data, suggesting no correlation between DM disappearance estimates at adjacent time points,

DM disappearance data expressed as either kg per steer or percentage of total disappearance were analyzed using bunk score treatment, period, treatment by period, time, time by treatment, and time by period as fixed classification effects. Pen within treatment by period was the random effect. Treatment, time, period, and the interactions were considered to be significant if $P < 0.05$.

An additional model was used to generate a quadratic prediction equation for bunk score for each treatment. Fixed effects in this model included bunk score treatment as a class variable, treatment by the continuous variable hour, and treatment by hour. The NOINT and HTYPE =1 options were requested in the model statement in order to generate a separate equation for each treatment and to provide sequential sums of squares which are appropriate for polynomial models (Littell et al., 2000). The subject of the repeated statement was pen within treatment by period. Compound symmetry covariance structure was used.

## RESULTS AND DISCUSSION

Feed bunk management influenced DMI ($P < 0.0001$). Daily DMI for the slick bunk steers fed to a target score of 0 (9.74 kg) were lower ($P < 0.05$) than for steers fed a target score of ½ (10.37 kg) which were lower ($P < 0.01$) than for the *ad libitum* steers fed to a target score of 1 (11.21 kg). Period of the study, and the period by treatment interactions were not significant ($P > 0.25$) sources of variation describing DMI. Feeding consistency is a common factor needed for any feed bunk management system to be successful (Milton, 2000). Therefore, every effort must be made to deliver feed to cattle at consistent intervals and in the appropriate quantities. In this experiment, steers were fed at a consistent rate in accordance with the required feed bunk score treatment.

Summer-time heat in the Great Plains can decrease performance and increase cattle mortality if exposed to long periods of intense heat (Davis et al., 2003; Mader et al., 2003). No steers were treated for any type of morbidity, including metabolic disorders, during the duration of this experiment. To ensure that adverse weather patterns were not influencing intake data, ambient temperature effects were analyzed. Average minimum and maximum temperature for each period, rainfall per period, and wind speed per period had no impact on DMI. The average daily minimum and maximum temperature for periods 1, 2, and 3 were 11 and 31.5°C, 16.5 and 32.8°C, and 17.5 and 35.0°C, respectively. Average wind speed for period 1, 2, and 3 was 6.8 km/h, 10.5 km/h, and 12.5 km/h, respectively. Average total precipitation for period 1, period 2, and period was 0.03, 0.01 and 0.32 cm. Based on data obtained from the National Oceanic and Atmospheric Administration, all weather data were within the average climate normal's collected from 1971 through 2000. Normal minimum and maximum temperatures for this time of year in Southeast Colorado are 16.0 and 33.0°C, respectively, and average precipitation is 5.8 cm/mo.

Feed bunk scores were collected four times daily at 9, 15, 19, and 23.5 h post-round 1 feeding (representing the 1600, 2200, 0200, and 0630 h bunk readings). The effect of treatment on bunk score is displayed in Figure 1. Treatment ($P < 0.0001$), hour ($P < 0.0001$), and treatment by hour ($P < 0.05$) were significant sources of variation influencing bunk score. By design, bunk scores were higher for pens fed to a score of 1 as compared with bunk scores for pens fed to a score of ½ ($P < 0.0001$) or 0 ($P < 0.0001$). However, average bunk scores for pens fed to a score of 0 and ½ were similar ($P > 0.53$) and averaged 0.63 and 0.73, respectively. At 0630 each morning (23.5 h post-initial

feeding) bunk score averaged 0.30 ± 0.04 and 0.36 ± 0.07 for pens fed to bunk scores of 0 and ½, respectively indicating that significant differences between the slick and trace bunk management systems were not established.

The presence of a treatment by time effect ($P < 0.05$) for bunk score indicated that treatment influenced the amount of feed remaining in the bunk at the various time intervals. Figure 2 shows the estimated amount of orts remaining in the bunk at each time point. For each time period of bunk reading (1600, 2200, 0200 and 0630 h) the slick bunk group had an estimated 7.32, 1.06, 0.72, and 0.65 ± 0.58 kg DM in the bunk, the trace bunk group had 8.19, 1.57, 1.40, and 1.07 ± 0.58 kg DM in the bunk, and the *ad libitum* group had an estimated 13.72, 6.23, 5.33, and 3.72 ± 0.57 kg DM in the bunk

Table 3.2 shows the disappearance of DM per steer from the bunk from the initial round 1 feeding at 0700 through 1600 h, from 1600 through 2200 h, from 2200 through 0200 h, and from 0200 through 0630 h. Dry matter disappearance estimated from bunk scores were affected ($P < 0.0001$) by treatment and time of day ($P < 0.0001$) and averaged 7.73, 8.24, and 8.84 kg/steer daily for the slick, traces, and ad libitum treatments, respectively. These estimates were approximately 2 kg/steer less than the observed (weighed) DMI estimates for each treatment. The interaction between bunk score treatment and time was significant ($P < 0.001$) for DM disappearance expressed on a kg per steer basis suggesting that the effects of treatment on DM disappearance depended upon time of day. The only time period when treatment differences in kg DM disappearance per steer were significantly different ($P < 0.05$) was from 0700 to 1600 h (bunk score 0 versus bunk score ½, $P < 0.01$; bunk score ½ versus bunk score 1, $P <$

0.01). Differences between treatments for the percentage of total feed that disappeared during each time period were not different (treatment by time interaction, $P < 0.17$).

Although treatment differences for DM disappearance from 0200 to 0630 were not significantly different there appeared to be numerically more feed available for consumption by steers during the early morning hours prior to feed delivery for the *ad libitum* fed steers as compared to the trace or slick bunk steers. It is interesting to note that the majority of treatment differences in DMI may have been due to differences in feed disappearance from 0700 to 1600 h and apparently not due to disappearance differences from 2200 to 0630 h. Steers fed to bunk scores of 0 or ½ appeared to consume less feed from 0700 to 1600 h even though the final feed deliveries for the day started at 1130 h and were likely completed by 1230 h.

Research conducted at the University of Saskatchewan has shown that major periods of eating are around sunrise, sunset, and midnight (Gonyou and Stricklin, 1984). If the feed bunk is slick by the evening prior to the last eating of the day, it is highly likely that some cattle did not consume their maximum daily intake. A study conducted by Putnam and Davis (1963) utilizing photoelectric relays and operation recorders to determine feeding patterns of beef steers fed *ad libitum* in drylots found that 79% of the total time spent at the feeder occurred between 6 am and 6 pm but that cattle also went to the bunk for short intervals of time all through the night. Therefore, in order to achieve maximum dry matter intake, a bunk management system needs to ensure that feed is available to all cattle for a majority of the evening to accommodate cattle eating patterns.

Slick feed bunk or limit-fed feed bunk management is a system which aims for all feed delivered to a pen to be consumed on a daily basis with a “slick” feed bunk for a

pre-planned duration of the time prior to the next day's feed delivery (Erickson et al., 2003). The success of this system is based on the premise that ADG will not be reduced and feed efficiency will be improved when DMI is restricted by 10% to 15% of maximum DMI (Pritchard, 1998). Loerch (1990) assessed restricted versus *ad libitum* intake in a series of 3 experiments where Exp. 1 was conducted to determine the effects of restricted intake of high-energy diets on cattle performance and diet digestibility, Exp. 2 was conducted to determine the effects of supplemental protein source and monensin on growing and finishing performance of cattle fed all-concentrate growing diets at a restricted intake, and Exp. 3 was conducted to determine the effects of limit feeding during the growing period on performance of steers fed 85 or 100 percent concentrate diets in the finishing period. In all experiments, steers were fed 1) a corn silage-based diet *ad libitum*, 2) a high-moisture corn and corn silage based diet with intake restricted to 20% of treatment 1, or 3) a high-moisture corn-based diet with intake restricted to 30% of treatment 1. It was concluded that DMI could be successfully restricted without significantly effecting finishing performance; however, in Exp. 1 and 2 ADG was lower ($P < 0.10$) in the restricted groups than the *ad libitum* group. In contrast, Drager et al. (2004) conducted an experiment investigating the effects of feeding cattle 1) *ad libitum* for 151 d, 2) 75% of treatment 1 DMI for 65 d, 95% of treatment 1 DMI for 65 d, and *ad libitum* access for 21 d, 3) 80% of treatment 1 DMI for 65 d, 100% of treatment 1 intake for 65 d, and *ad libitum* access to feed for 21 d or 4) 85% of treatment 1 DMI for 65d, 105% of treatment 1 DMI for 65d, and *ad libitum* access to feed for 21 d. By restricting feed intake of finishing steers, ADG was reduced ($P < 0.01$) and carcasses had lower

marbling scores ($P < 0.01$), HCW, LMA, and KPH percentages ($P < 0.05$) when compared to controls.

*Ad libitum* feed bunk management describes a feed delivery system which allows for feed to be in the feed bunk in amounts that allow for a complete total mixed ration to be present from the end of one feeding to the beginning of another feeding. If cattle are allowed to consume feed *ad libitum* and intake variation remains less than 1.8 kg per d performance levels and incidence of acidosis should not be increased (Cooper et al., 1999).

By measuring the total amount of feed that was removed from each of the feed bunks for each treatment, a difference existed ($P < 0.001$) between the total amount of feed that was placed in the feed bunk and the amount of un-eaten feed remaining in the feed bunk that required removal (Figure 3). Over all periods, the slick bunk group averaged 0.57 ± 0.63 kg removable orts, the trace group averaged 1.36 ± 0.63 kg removable orts, and the ad libitum group averaged 6.65 ± 0.63 kg removable orts per bunk. If too much feed is fed, cattle will sort feed and there could be an increased amount of orts that would not represent the total mixed ration remaining in the feed bunk. The goal of any feed bunk management system should be to provide nutritionally balanced, clean feed in a manner that allows for optimum performance at the lowest level of cost and labor. If producers were to implement a feed bunk management system that allowed *ad libitum* access to feed, the importance of accurate feed bunk readings and consistent feed deliveries would likely increase in order to prevent feed from becoming spoiled and require removal. The key component to a successful bunk management system is to ensure that the system is simple enough in practice to ensure that feed is

delivered consistently to cattle daily. Feed bunk management should encompass diet type, cattle, changes in climatic conditions, and feed bunk space (Pritchard and Burns 2003).

## IMPLICATIONS

Results of this study suggest that feed bunk management strategy impacted DMI of feedlot steers. Delivering adequate feed to allow *ad libitum* access to feed over a 24 h period increased DMI. In addition, it appears as if most of the differences in DMI could be attributable to differences in DM disappearance from the bunk from 0700 to 1600 h. Additional research is warranted to determine why steers fed to a target bunk score of 0 appeared to consume less DM from 0700 to 1600 h even though all feed delivered for the day was present in the bunks hours prior to 1600.

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Table 3.1. Southeast Colorado Research Center feed bunk reading and feed call score system[1]

| Score[2] | Amount in bunk, kg | Feed Delivery Changes |
|---|---|---|
| 0 | 0 | ↑ feed by 0.23 kg/steer every third morning |
| ½ | Trace-2.26 kg | Remains Same |
| 1 | 2.27-9.05 kg | ↓ feed by 0.91 kg/steer; on the third morning (SCOOP) [2] |
| 2 | 9.06-18.18 kg | ↓ feed by 1.82 kg/steer; on the third morning (SCOOP) [2] |
| 3[3] | > 18.19 kg | ↓ feed by 2.27 kg/steer; on the third morning (SCOOP) [2] |

[1] Slick bunk trt group requires a call of 0, Trace bunk trt group requires a call of ½, and the ad libitum group requires a call of 1. The scores of 2 and 3 are not desired as the excess feed will be scooped but were utilized on some days of the trial.
[2]Due to rain or a bunk score of 1 or 2 for three days or a call of 3 for one day feed bunks will be scooped. Orts were weighed and recorded and a sample will be collected for dry matter analysis.
[3] On the first day the feed bunk is slick (0) the pen will get ½ of total kg reduced back.

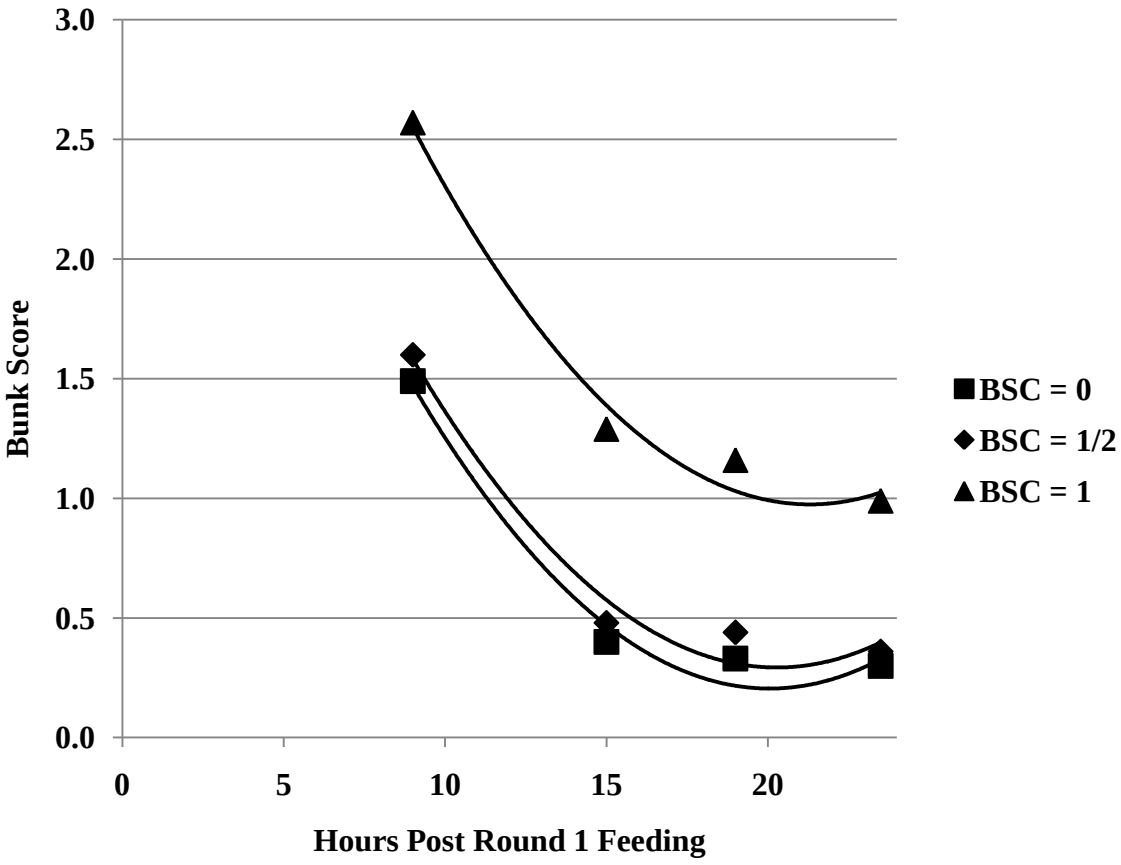


Figure 3.1. Feed bunk score treatments (BSC) consisted of: 0 – a feed bunk devoid of all feed particles (Slick); ½ - a feed bunk that contained a few crumbles up to 2.26 kg of as-fed feed (Trace) and; 1 – a feed bunk that contained from 2.27 to 9.05 kg of as-fed feed (ad libitum).

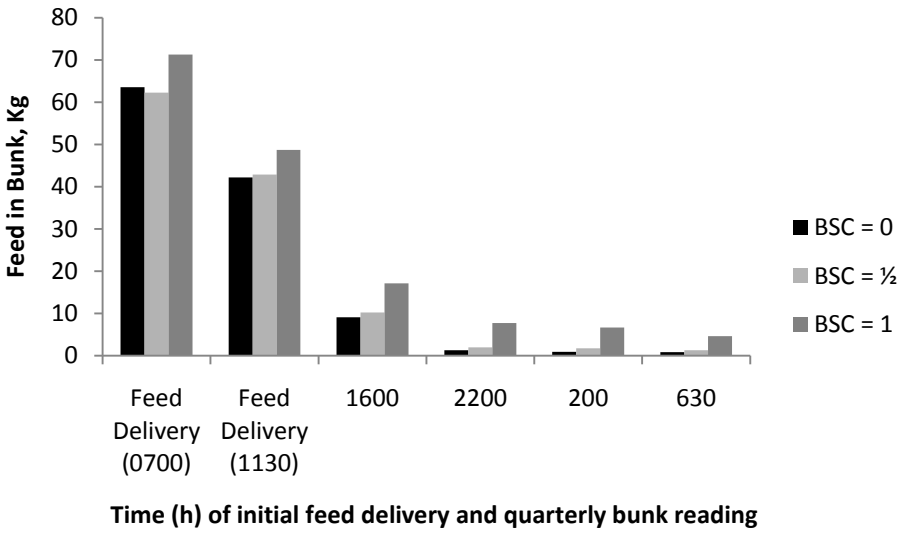


Figure 3.2. Average estimate (± 0.34 kg) of amount of feed in bunk based on initial feed deliveries and bunk scores, for pens of feedlot steers fed at specific levels of DMI to meet the desired feed bunk score. Feed bunk score treatments consisted of: 0 – a feed bunk devoid of all feed particles (Slick); ½ - a feed bunk that contained a few crumbles to 2.26 kg of as-fed feed (Trace) and; 1 – a feed bunk that contained from 2.27 to 9.05 kg of as-fed feed (*ad libitum*).

Table 3.2. Estimated disappearance of dry matter from feed bunks for pens fed to various feed bunk score treatments.

| | Bunk score = 0 | | Bunk score = ½ | | Bunk score = 1 | |
|---|---|---|---|---|---|---|
| Time[1,2] | kg/steer[3] | %[4] | kg/steer | % | kg/steer | % |
| 0700 to 1600 | 7.1225[a] | 92.12 | 7.5623[b] | 91.83 | 7.8815[c] | 89.14 |
| 1600 to 2200 | 0.5699 | 7.37 | 0.6215 | 7.55 | 0.7206 | 8.15 |
| 2200 to 0200 | 0.0355 | 0.46 | 0.0259 | 0.31 | 0.0872 | 0.99 |
| 0200 to 0630 | 0.0038 | 0.05 | 0.0254 | 0.31 | 0.1528 | 1.73 |
| Total | 7.7317 | 100.00 | 8.2351 | 100.00 | 8.8421 | 100.00 |

[1] Effect of time for the kilogram per steer analysis, $P < 0.0001$.

[2] Effect of time for the percentage of total disappearance analysis, $P < 0.0001$.

[3] Effect of treatment for the kilogram per steer analysis, $P < 0.0001$. Effect of treatment by time for the kilogram per steer analysis, $P < 0.001$.

[4] Effect of treatment for the percentage of total disappearance analysis, $P = 1.00$. Effect of treatment by time for the percentage of total disappearance analysis, $P < 0.17$.

[a,b,c] Means in the same row with different superscripts are different, $P < 0.01$.

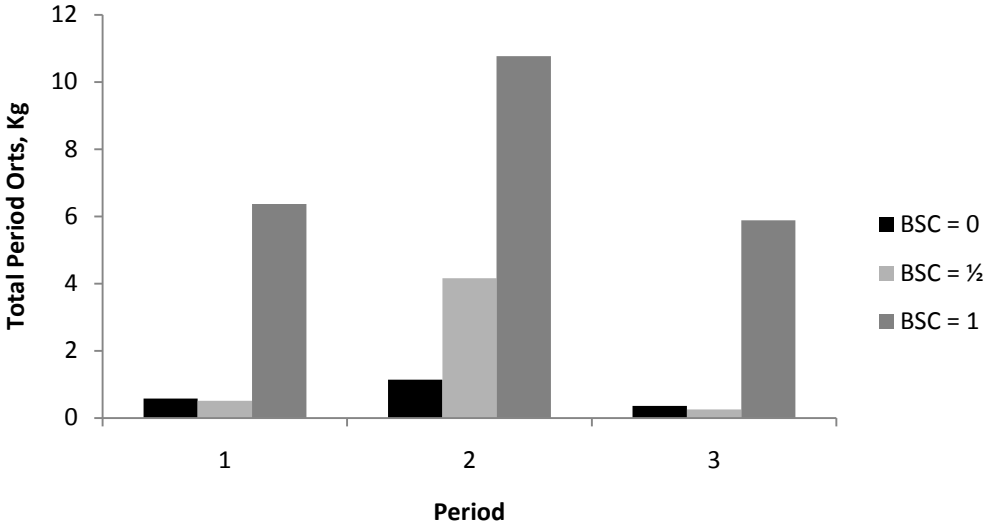


Figure 3.3. Total amount of orts scooped from feed bunks in each treatment, per period. Bunk score (BSC) 0: 0.57 ± 0.63; BSC ½: 1.36 ± 0.63; BSC 1: 6.65 ± 0.63) for pens of feedlot steers fed at specific levels of DMI to meet the desired feed BSC. Feed BSC treatments consisted of: 0 – a feed bunk devoid of all feed particles (slick); ½ - a feed bunk that contained from a few crumbles to 2.26 kg of as-fed feed (trace); and 1 – a feed bunk that contained from 2.27 to 9.05 kg of as-fed feed (*ad libitum*).

# CHAPTER IV

# IMPACT OF GASTROINTESTINAL PARASITES ON ANTIBODY TITER RESPONSES TO VACCINATION AND IBRV CHALLENGE

## ABSTRACT

Thirty-three colostrum deprived Holstein bull calves (initial BW of 131 ± 4.0 kg) were utilized to determine the impact of timing of anthelmintic administration relative to vaccination on antibody titer response to vaccine components. Colostrum deprived bull calves were from a single dairy to ensure that calves were sero negative for antibodies specific to vaccine components. When all bull calves were at least 3 mo of age, they were randomly sorted into individual pens and placed into one of three treatment groups, treatments consisted of: 1) dewormed 2 wk prior to vaccination (DPV); 2) dewormed at the time of vaccination (DV); and 3) Control – vaccinated but not dewormed (CONT). All calves were inoculated with infective larvae of brown stomach worms (*Ostertagia ostertagi*) and intestinal worms (*Cooperia* spp.) on d 1, 7, 10, 14, and 18 for a total dose of 235,710 infective larvae per calf. Calves (DPV and DV) were dewormed on d 21 or 35 with a 10% fenbendazole suspension at 5 mg/kg BW and vaccinated on d 35 of the study. Weekly fecal egg counts, blood, and rectal temperatures were collected throughout the experiment and feed intake and health status were recorded daily. Blood samples were obtained weekly to determine serum neutralizing antibody titers to IBRV (Infectious

Bovine Rhinotracheitis Virus), BVDV-1 (Bovine Viral Diarrhea Virus Genotype 1), BVDV-2 (Bovine Viral Diarrhea Virus Genotype 2), and PI-3 (Parainfluenza-3) and cytokine levels for IL-4 (Interleukin 4), IL-6 (Interleukin 6), TNF-α (Tumor necrosis factor-alpha), and IFN-γ (Interferon-gamma). There was a tendency ($P < 0.09$) for CONT calves to have higher IL-4 concentrations. By design, control calves had greater ($P < 0.01$) fecal egg counts during the experiment. All treatment groups developed antibody titers to IBRV, BVDV 1, BVDV 2, and PI-3 by d 15 post vaccination. On d 88, all calves were challenged with IBRV and blood samples were obtained on d 0, 1, 3, 4, 6, 8, 10, and 12 post inoculation. Post IBRV challenge calves in all groups had elevated ($P < 0.01$) rectal temperatures. All treatment groups developed increased SN titers for IBRV, BVDV 1, and BVDV 2following the IBRV challenge. Additionally, all treatment groups had increased rectal temperatures during the final 7 d of the IBRV challenge. Therefore, deworming before or at vaccination reduced parasite burden and decreased rectal temperature elevation following an IBRV challenge, but deworming strategy had no effect on antibody response to vaccination or IBRV challenge.

## INTRODUCTION

Gastrointestinal parasite burden is one of the largest health concerns for ruminants worldwide (Armour, 1980). Animal performance has been shown to decline in relationship to parasite burden (Lee, 1955; Reinhardt et al., 2006). Gastrointestinal parasitism results in a wide range of effects from subclinical disease to death depending upon parasite load, animal age and breed, plane of nutrition, and overall health status of the animal (Hawkins, 1993). The economic implications associated with parasite burden

have been extensively studied. Data indicate that calves treated with anthelmintics resulted in an improvement of $0.08 to $0.14/kg gain after 41 d post treatment (Leland et al., 1980). Additionally, Grimson et al. (1987) reported that average sale prices were greater for calves given antiparasitic treatments vs. untreated calves. Which reflects the perception by buyers that treated calves will out-perform untreated calves.

Vaccinations are arguably the most cost effective means for preventing disease, especially in feedlot environments. However, it is critical that good management practices are implemented in conjunction with vaccination programs to ensure that vaccine efficacy is not compromised. Most calves are vaccinated for respiratory type infections and dewormed at weaning often just prior to entering an onsite background facility or being transported to a feedlot (Bagley, 2001). Cytokine release associated with parasitic infestation can interfere with the immune response to other antigens potentially affecting an animal's ability to immunologically respond to vaccination (Urban, 2007). Deworming and vaccination are often performed at the same time; however, the most effective schedule to prepare calves for entry into the feedlot has not been determined. The objective of the present study was to determine whether the timing of anthelmintic administration relative to vaccination influences antibody titer response to vaccine components, rectal temperature and antibody titer response post an intranasal Infectious Bovine Rhinotracheitis Virus (IBRV) challenge.

# MATERIALS AND METHODS

Prior to the initiation of this experiment, care, handling, and sampling of the animals defined herein were approved by the Colorado State University Institutional Animal Care and Use Committee.

Thirty-three colostrum deprived Holstein bull calves (BW 131 ± 4.0 kg) were utilized in this experiment. Calves were obtained during the winter from a single local dairy immediately after birth and transported to Colorado State University's Agricultural Research Development and Education Center (ARDEC) located in Fort Collins, CO. Upon arrival, all calves were weighed, given a unique numerical identification ear tag, given 1.0 ml of a vitamin A and D solution (AgriPharm, Memphis, TN) and rectal temperatures were obtained. Calves were then housed in individual calf huts (1.5 x 1.9 m).

*Growing phase.* At 2 wk of age, a jugular blood sample was collected in a non-heparinized vacutainer tube (Becton Dickenson Co., Franklin Lakes, NJ) for the determination of infectious bovine rhinotracheitis virus (IBRV), bovine viral diarrhea type 1 (BVDV 1), bovine viral diarrhea type 2 (BVDV 2), and parainfluenza-3 (PI-3) antibody titers. Calves were bottle-fed whole milk twice daily for the first 2 wk of life. Calves were then gradually transitioned to a milk replacer diet (MAXI CARE 22-20 NT Medicated dairy herd & beef calf milk replacer) over a 2 wk period (Step 1: 60% whole milk and 40 % milk replacer; Step 2: 75% milk replacer and 25 % whole milk; and Step 3: 100% milk replacer). Calves remained on milk replacer for approximately 45 d. Calves had ad libitum access to water and medicated calf starter (20% crude protein, 7% crude

fiber, and 2.25 % crude fat) 3 d post birth. Calves were weaned when they were consuming 1.81 kg of starter ration for five consecutive d (approximately 60 d of age).

Once weaned, calves were fed once daily in the morning and gradually transitioned to an alfalfa-steam flaked corn based growing diet (Table 4.1). Diets were formulated to meet or exceed all nutrient requirements for growing Holstein bull calves (NRC, 1989). Once transitioned to the growing diet, calves were fed twice daily at 0700 and 1600 h in amounts adequate to allow ad libitum access to feed throughout the day and orts were weighed and recorded daily. When all calves were weaned and acclimated to the basal growing diet, calves were moved from the calf huts into individual pens (2.0 x 13.0 m) equipped with an automatic water fountain and a concrete feed bunk. All calves were fed the growing diet until the youngest calf was 3 mo of age.

This study was conducted during the summer and early fall. Upon initiation of the experiment, individual BW was obtained on 2 consecutive d and calves were blocked, by BW and age, to one of 3 treatment groups. Treatments consisted of: 1) dewormed 2 wks prior to vaccination (DPV); 2) dewormed at the time of vaccination (DV); and 3) Control- vaccinated but not dewormed (CONT). Individual feed intake and health status were recorded daily. Calves were determined to be morbid if rectal temperatures exceeded 39.7°C and were treated as prescribed by the attending veterinarian. Fecal samples, rectal temperatures, and a jugular blood sample (collected in a non-heparinized vacutainer tube; Becton Dickenson Co., Franklin Lakes, NJ) were obtained from each calf weekly.

*Parasite inoculation phase.* All calves (average age = 130 ± 22 d.) were orally inoculated with 23,571 infective larvae of brown stomach worms (*Ostertagia ostertagi*)

and intestinal worms (*Cooperia* spp.) on d 1, 7, 10, 14, and 18 for a total dose of 235,710 infective larvae per calf. Immediately before and at each parasite inoculation, a fecal sample was collected per rectum.

*Deworming phase.* On d 21 (3 wk post initial parasite inoculation) DPV calves were dewormed orally with a 10% fenbendazole suspension (Safe-Guard®, Intervet, Millsboro, DE) at 5 mg/kg BW two wk prior to vaccination. All calves were vaccinated subcutaneous with 2 mL of a modified-live virus respiratory vaccine containing IBRV, BVD type 1 and 2, PI-3, and BRSV (Vista® 5SQ, Intervet-Schering Plough Animal Health, and Desoto, KS).

*Post-vaccination phase.* Daily and weekly feed intake and health observations were recorded, and samples were obtained post-vaccination, as previously described. On d 88 (53 d post-vaccination), all calves were challenged intranasally with 4 mL of a solution containing 1.8 x $10^7$ cell culture infectious doses (CCID) of the Cooper strain of bovine herpesvirus-1 (BHV-1) via nebulization (2 mL/nostril). Blood samples were obtained from all calves on d 0, 1, 3, 4, 6, 8, 10, and 12 d post-inoculation and rectal temperatures were obtained every morning before feeding. Fourteen d post BHV-1 challenge, all calves were euthanized, and necropsies were performed for a separate experiment (data not presented).

*Analytical Procedures*

*Blood preparation.* Blood was stored on ice, transported to the laboratory and stored in a refrigerator at 5°C for 12 h to allow clot formation. Whole blood was then centrifuged at 1200 x *g* for 25 min at room temperature. The serum was harvested and stored in polyethylene tubes (12 mm X 75 mm) at -70°C. Serum was analyzed for IBRV,

BVDV 1, BVDV 2, PI-3 serum neutralizing (SN) antibodies using a microtiter serum neutralization format (Carbrey et al., 1971). Following heat-inactivation at 56$^{o}$C for 30 min, two-fold serial dilutions of serum were made in triplicate wells in a 96-well microtiter plate for each of the viruses. One hundred $TCID_{50}$ of IBRV, BVDV 1, BVDV 2, or PI-3 were added to duplicate columns of wells. The third column of diluted serum served as the serum control. The microtiter plates with virus and serum samples were incubated for 1 hr at 37$^{o}$C. A suspension of Madin-Darby bovine kidney (MDBK) cells at a concentration of 1 x $10^4$ cells/50ul were added to each well containing BHV-1 virus, and bovine turbinate (BT) cells were added to each well for BVDV 1, BVDV 2, or PI-3. The microtiter plates were incubated at 37$^{o}$C for an additional 3 d, and then cells were examined for cytopathic effects of each of the test viruses using an inverted light microscope. The reciprocal of the highest dilution at which the test virus was completely neutralized was recorded as the SN titers for each virus and sample.

*Fecal analysis.* Approximately 100 g of fresh fecal matter was placed in an individual plastic bag, labeled, and placed on ice. The samples were refrigerated until analyzed. Samples were shipped to an independent laboratory (Animal Production Consulting, Lincoln, NE) for analysis. The Modified Wisconsin Sugar Flotation Technique (Cox and Todd, 1962) was utilized to examine each individual fecal sample. A 3 g base sample was used for analysis. An egg per gram (EPG) count was determined by multiplying the total count by 150 and then dividing that number by 454.

*Cytokine immunosorbent assay.* Serum cytokine analysis was conducted utilizing an ELISA. Briefly, the antibodies captured specific proteins in the sample which were added to each well. When unbound proteins were removed via washing, a biotinylated

detecting antibody was added and bound to a second site on the target protein. Then the excess detecting antibody was removed and streptavidin-horseradish peroxidase was added. SUPERSIGNAL® ELISA Femto Chemiluminescent Substrate was used in this assay. The enzyme-substrate reaction produced a signal which was detected with a CCD camera. The amount of signal produced was directly proportional to the amount of each target protein in the sample (Thermo Fisher Scientific Pierce SearchLight Products, Woburn, MA).

*Statistical analysis.* Statistical analyses of data were preformed for a completely randomized block design utilizing the Mixed procedure of SAS (2003). Calf was considered the experimental unit. Where appropriate, repeated measures analysis were utilized. The model for ADG, DMI, EPG, and temperature contained treatment, d, and all possible interactions. Each period was analyzed independently. When treatment x d interactions were significant ($P < 0.05$), the effect of treatment was analyzed for each d. Logarithmic transformations were applied to all titer values.

## RESULTS AND DISCUSSION

### *Performance*

Performance was similar across all treatments. No BW, DMI, or ADG ($P > 0.05$) differences were shown to exists during the duration of this trial. These results were in contrast with previous studies in which feed intake was reduced in calves infected with *O. ostertagi* larvae (Horak et al., 1964; Fox et al., 2002). Earlier work reported weight loss in cattle infected with internal parasites (Anderson et al., 1965; Wiggin and Gibbs, 1990) and greater ADG in cattle treated with deworming agents (Flack et al., 1967). A

possible reason for the conflicting results between experiments may be due to the differences in the environmental conditions that the cattle were reared. In previous cited experiments cattle were raised in groups; whereas, cattle in this experiment were reared in individual pens. Additionally, although the parasite inoculation loads were similar between this study and earlier studies, the duration of days spent inoculating calves differed. Total infective larvae inoculations were given as a single dose in earlier studies (Horak et al., 1964; Fox et al., 2002) and parasite inoculation was carried out over several different days with smaller daily doses in this study.

During period 3 (post-vaccination phase), CONT calves had higher ($P < 0.04$) rectal temperatures (Figure 1) compared to DPV and DV treatments on d 49 and had the highest rectal temperature throughout the period. During period 4 (IBRV challenge phase), the CONT group had higher ($P < 0.01$) rectal temperatures on each sampling d except d 90 compared to the DPV and DV treatments. Determining bovine parasitic disease can be challenging and the measurement of fever (pyrexia) via rectal temperature has been shown to be a viable way to detect infection (Magona et al., 2008). Reinhardt et al. (2006) reported that heifers treated with a combination fenbendazole oral drench and an ivermectin pour on tended ($P < 0.15$) to have a lower morbidity rate (morbidity rates were determined by rectal temperatures > 39.7ºC and clinical symptoms) than heifers given an ivermectin pour on alone.

By the beginning of period 2 (approximately 14 d after initial infestation), eggs were detected in feces (Figure 2). By design, CONT animals had greater ($P < 0.01$) fecal egg counts for periods 2 and 3. By period 4, the fecal egg counts in the CONT group had reduced and no significant differences were detected. The decrease in fecal egg count

over time has been associated with the development of effective immunity to the parasites by the host (Gordon, 1948). After a parasite inoculation, T and B lymphocytes react to parasite antigens and help to protect the gastrointestinal tract from the parasites (Claerebout and Vercruysse, 2000). Cytokines play a major role in controlling parasitic infection and can help in the expulsion of adult worms. Immunity against *O. ostertagi* in ruminants is unique as a reduction of worm fecundity has been shown to occur in calves, possibly regulated by the local IgA response. Thus, fecal egg counts would only be reduced after a prolonged period of host-parasite contact (Claerebout and Vercruysse, 2000).

*Immune Parameters*

It is hypothesized that the effects of an *Ostertagia ostertagi* infection can cause interference in the infected calf's ability to produce an adequate immunological response to pathologic changes caused by infection which could cause an increased risk of susceptibility to disease (Wiggin and Gibbs, 1990).

All calves in all treatment groups developed SN titers for IBRV, BVDV 1, BVDV 2, and PI-3 by d 15 post vaccination (Figure 3). Additionally, DV animals had higher ($P < 0.02$) titers for BVDV during period 3 on d 66, 73, and 79. During period 1, the CONT calves had higher ($P < 0.02$) titers for PI-3. Although not significant, during periods 3 ($P < 0.12$) and 4 ($P < 0.77$), CONT calves had lower IBRV SN titers than the DPV and DV groups.

Cytokine concentrations were similar across all treatments (Table 4.2) and no period or period by treatment effects were detected. There was a tendency ($P < 0.09$) for CONT calves to have higher IL-4 concentrations. Additionally, there was a quadratic

effect ($P < 0.03$) associated with TNF-α concentrations such that concentrations of TNF-α were 344.49 ± 460.76 pg/ml, 1837.13 ± 460.76 pg/ml, and 665.62 ± 460.76 pg/ml for the DPV, DV, and CONT calves, respectfully.

Animals with parasitic infections have altered cell-mediated immune responses to non-parasitic antigens such as vaccines (Kullberg, 1992). Helminths infections can cause suppression of the host's immune response to vaccine components thus, inhibiting the efficacy of the vaccine. In a study conducted by Su et al. (2006), a gastrointestinal nematode-malaria model was utilized to determine if concurrent helminth parasitic infections impair the effects of vaccine induced protective immunity against malaria. A nematode infection indeed suppressed the Th-1 associated immune responses to immunization and reduced the protective efficacy of the vaccine. It was concluded that deworming would be an effective strategy for improving vaccine efficacy.

Alterations in immune responses to foreign non-parasitic antigens have been observed in murine models infected with parasites. In a study conducted by Kullberg et al. (1991), the effect of a *Schistosoma mansoni* infection down regulated Th-1 cytokine response for IL-2 and IFN-γ as compared to immunized uninfected controls. A down-regulated Th-1dependant immunity could lead to an increased susceptibility to infection as well as altered immune responses to vaccinations (Kullberg et al., 1991). *Fasciola hepatica* has been shown to cause an up regulation of Th-2 immune response, specifically associated with an increase in the cytokine IL-4, which inhibits certain Th-1 responses to foreign antigens (Flynn et al., 2007). Inhibition of the Th-1 immune response may decrease an animal's ability to respond to an intracellular pathogen such as *Mycobacterium bovis* (Flynn et al., 2007).

These prior studies suggest that specific parasite infections have significant effects upon the immunological ability of calves to properly combat a viral infection which could have implications regarding vaccine efficacy as parasitic infection could influence the ability of Th-1 and Th-2 immunity, leading to an up-regulated cytokine response to infection.

## IMPLICATIONS

These data indicated that deworming colostrum-deprived Holstein bull calves two wk prior to, or at the time of vaccination, reduced parasite burden and rectal temperature response following an IBRV challenge. However, timing of deworming relative to vaccination had no impact on SN titers to viral vaccine components, or cytokine response or toIBRV challenge. Further studies are needed to gain a more fundamental understanding of the relationship between parasite burden and vaccine efficacy in regards to the immunological associations and economic implications to cattle production.

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Table 4.1. Ingredient composition of basal diet

| Ingredient | %DM |
|---|---|
| Alfalfa Hay | 62.38 |
| Steam Flaked Corn | 15.60 |
| Calf Concentrate [a] | 18.02 |
| Cane Molasses | 4.00 |

[a] Premix contained: crude protein = 32.10%, crude fat = 1.78 %, crude fiber = 7.76 %, dry matter = 91.15%

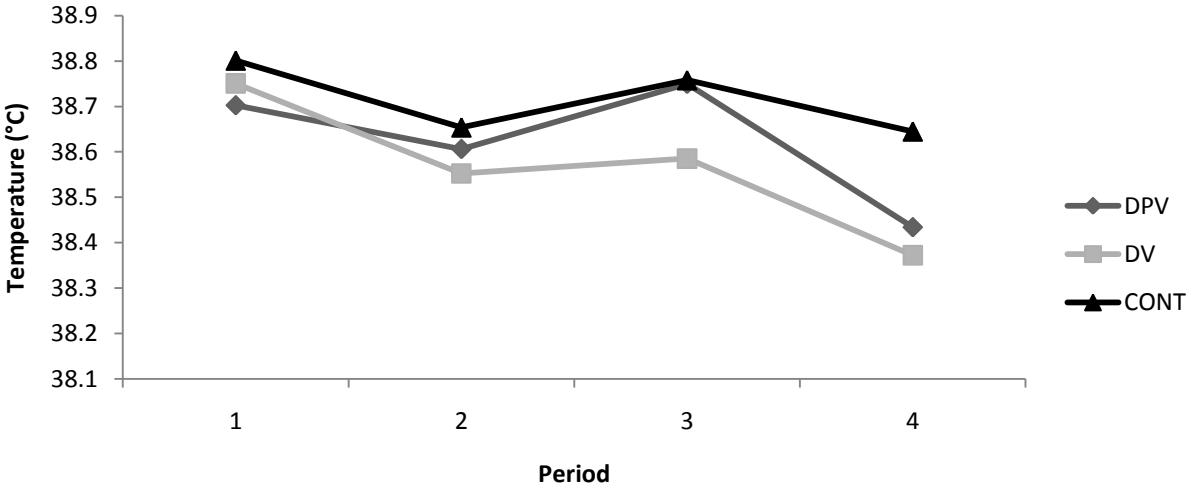


Figure 4.1. Average rectal temperature, °C, (± 0.13°C) of parasite inoculated calves (DPV) dewormed prior to vaccination, (DV) dewormed at vaccination, or (CONT) never dewormed but vaccinated by period where periods were broken down as follows: 1) period of parasite inoculation (2) period beginning post deworming of DPV (3) period directly proceeding vaccination of all treatments (4) the two wks post-harvest

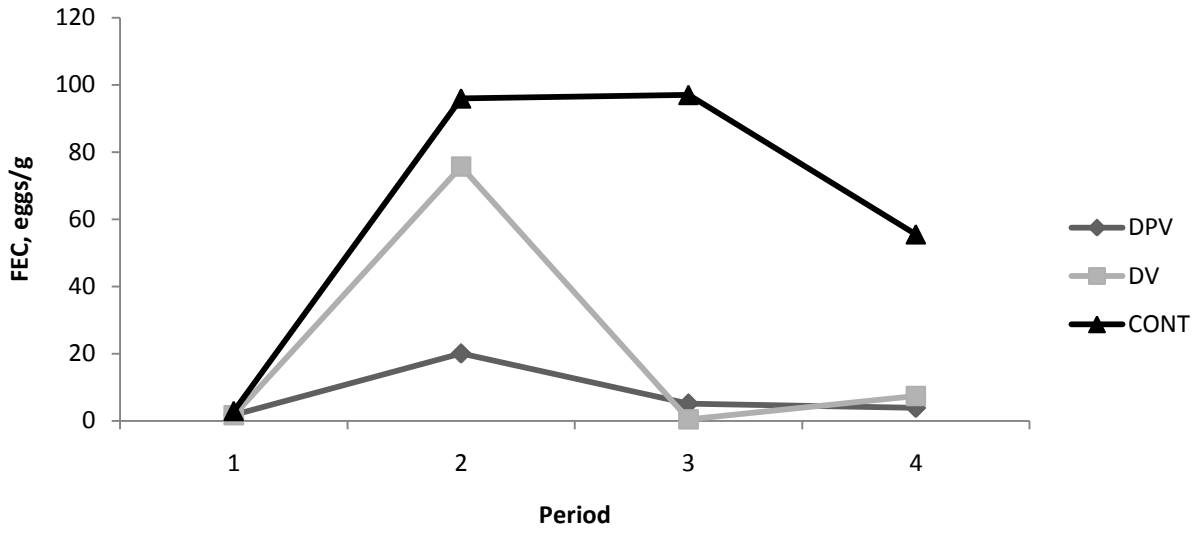


Figure 4.2. Average fecal egg counts (± 7.97 eggs/g) of parasite inoculated calves (DPV) dewormed prior to vaccination, (DV) dewormed at vaccination, or (CONT) never dewormed but vaccinated by period where periods were broken down as follows: 1) period of parasite inoculation (2) period beginning post deworming of DPV (3) period directly proceeding vaccination of all treatments (4) the two wks post-harvest

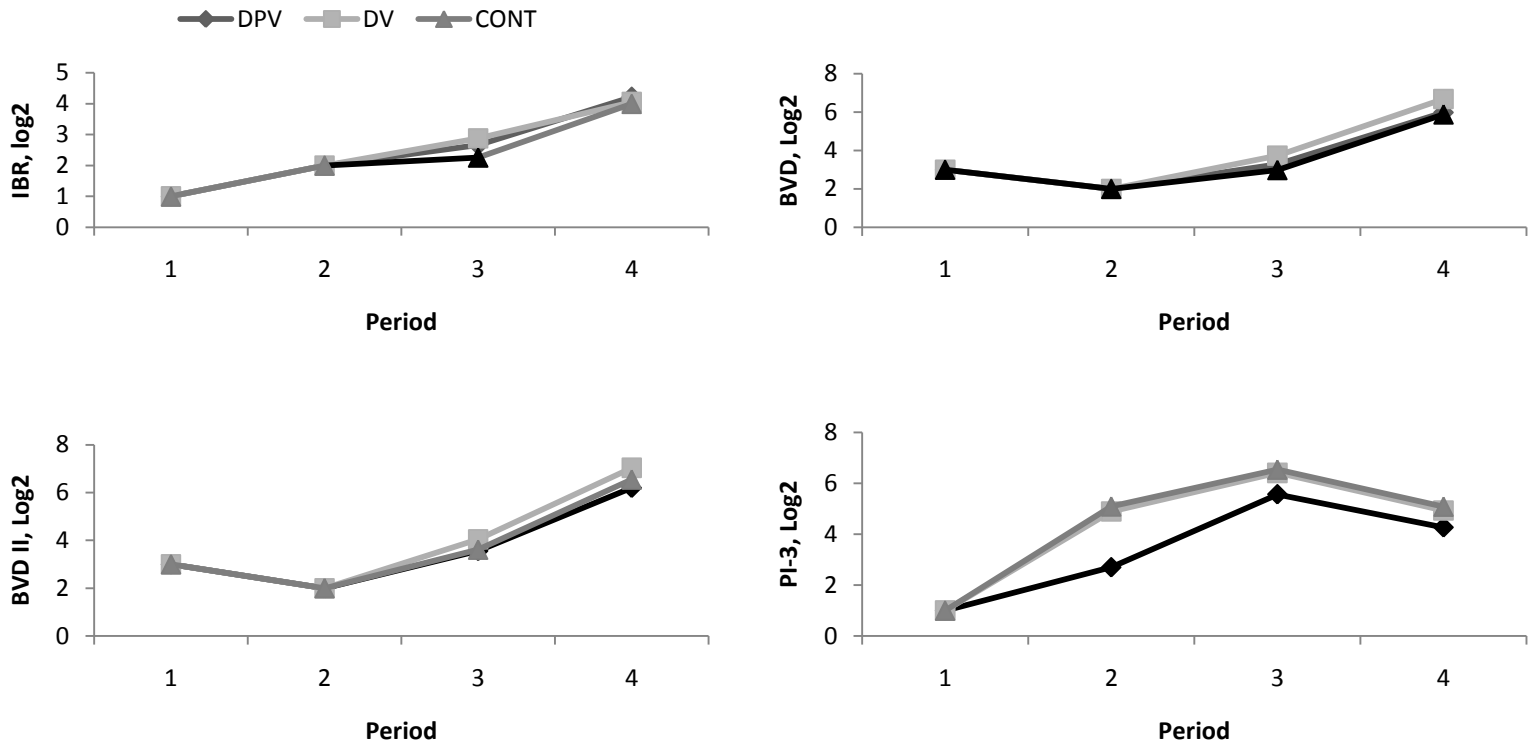


Figure 4.3. Titer responses (log transformed) for IBRV (± 0.16), BVDV 1 (± 0.29), BVDV 2 (± 0.26), and PI-3 (± 0.24) for parasite inoculated calves (DPV) dewormed prior to vaccination, (DV) dewormed at vaccination, or (CONT) never dewormed but vaccinated by period where periods were broken down as follows: 1) period of parasite inoculation (2) period beginning post deworming of DPV (3) period directly proceeding vaccination of all treatments (4) the two wks post-harvest. Abbreviations used: IBRV = Infectious Bovine Rhinotracheitis Virus, BVDV = Bovine Viral Diarrhea (Type 1), BVDV 2 = Bovine Viral Diarrhea (Type 2), and PI-3 = Parainfluenza.

Table 4.2. Influence of deworming calves prior to or at vaccination on cytokine levels

| | Treatment [a] | | | | | Contrasts *P*< | |
|---|---|---|---|---|---|---|---|
| Trait [b] | DPV | DV | CONT | SEM | Trt (P<) [c] | Linear | Quadratic |
| IL-4, pg/mL | 3.33 | 2.07 | 3.76 | 0.65 | 0.09 | 0.65 | 0.08 |
| IL-6, pg/mL | 119.37 | 171.09 | 139.15 | 33.60 | 0.61 | 0.77 | 0.48 |
| TNF-α, pg/mL | 344.49 | 1837.13 | 665.62 | 460.76 | 0.12 | 0.63 | 0.03 |
| IFN-γ, pg/mL | 72.96 | 87.49 | 89.52 | 30.96 | 0.83 | 0.71 | 0.87 |

[a] DPV = calves dewormed 2 weeks prior to vaccination, DV = calves dewormed at vaccination, CONT = calves were vaccinated but never dewormed after parasite inoculation.

[b] Abbreviations used: IL-4 = Interleukin-4, IL-6 = Interleukin-6, TNF-α = Tumor Necrosis Factor-alpha, and IFN-α = Interferon-gamma.

[c] P-values were considered significant if ($P < 0.05$).

# CHAPTER V

# EFFECTS OF DEGREE OF DONENESS ON THE NUTRITIVE VALUE OF BEEF STEAKS

## ABSTRACT

The objective of this study was to determine if cooking method and degree of doneness affect nutrient composition of beef strip loin steaks. Loins were collected from the right sides of 21 low Choice steer carcasses. After a 14 d aging period, samples were fabricated into steaks. Seven steaks were obtained from each strip loin (N = 147). Steaks were randomly assigned to one of six treatments within strip loin. Treatments consisted of: 1) pan fried (PF), 60°C, 2) PF, 71°C, 3) PF, 77 °C, 4) grilled (GR), 60°C, 5) GR, 71°C, 6) GR, 77°C. Steaks were cooked fresh, immediately after fabrication. A set of raw steaks was used as a control group for nutrient analysis. Cooking time was greater ($P < 0.05$) for steaks that were PF compared to GR. Additionally, cooking time increased linearly ($P < 0.01$) with increased DOD. Cooked wt decreased linearly ($P < 0.01$) as DOD increased for PF steaks. Additionally, well done (77°C) steaks were lighter ($P < 0.05$) than rare (62°C) steaks. Dry matter content of raw steaks decreased ($P < 0.01$) as DOD increased. Pan frying steaks resulted in greater ($P < 0.05$) DM%. Crude fat (CF) content of PF steaks increased ($P < 0.05$) whereas GR steaks decreased in CF content. Medium (71°C) and well done (77°C) GR steaks had lower crude fat content than PF

steaks or rare (62°C) GR steaks. Raw initial crude protein content of the steaks increased after cooking. Medium (70°C) and well done (77°C) GR steaks had greater ($P < 0.05$) crude protein content than any other DOD or PF steaks. Cooking method and temperature to which steaks are cooked can play a major role in the nutrient composition of steaks and these factors should be accounted for when determining nutrient profiles of beef retail cuts.

## INTRODUCTION

Beef accounts for more than 20% of consumer's meat protein intake worldwide (Taha, 2003). Overall, meat consumption has risen in the United States as well as in most developed countries and beef represents 56% of all red meat consumed in the US (Daniel et al., 2010). There are two major components associated with meat quality: 1) the nutrient composition of the retail cut, which is objective, and 2) consumer determined eating quality as defined by the flavor, juiciness, tenderness, and color, which is more subjective (Bender, 1992).

Concerns regarding calories, fat, and cholesterol can influence a consumer's decision when it comes to purchasing preference. The Food Safety and Inspection Service (FSIS) recently decided to amend the Federal meat and poultry products inspection regulations. Nutrition labeling of the major cuts of single-ingredient, raw meat and poultry products on labels or at point-of-purchase will be required by January, 2012 (75 FR 82148). In order to achieve the most accurate nutrient profile for any retail cut, nutrient analysis of raw and cooked cuts should be performed to address the requirements for this labeling rule. By ensuring that proper nutritional labels are displayed with certain

beef cuts, consumers would be able to compare different types of beef retail cuts to purchase the type of product that fits their nutritional and palatability needs.

For the past 20 years, the poultry industry has continued to see an exogenous growth whereas the beef industry has seen a slight decline in beef table cut demand (Eales and Unnevehr, 1988; Daniel et al., 2010). Lower poultry prices and human health concerns related to red meat consumption are two of the largest factors that influence beef demand (Hahn, 1996; Moloney et al., 2001; Chao, et al., 2005; Pennings et al., 2002). Over the past twenty years the beef industry has worked diligently to remain competitive. Public health and consumer concerns regarding fat and cholesterol have caused an increased demand for leaner meat. A marked reduction in the proportion of fat from foods high in saturated fat has been seen in consumption patterns within the U.S. (Daniel et al., 2010).

Beef is an excellent source of protein, and is rich in vitamin $B_{12}$, iron, and zinc (Bender, 1992; USDA, 2008). However, cooking can lead to the loss of nutrients associated with protein degradation and lipid oxidation (Rodriguez-Estrada et al., 1997). Consumers prepare and cook steaks differently and to different degrees of doneness (Lorenzen et al., 1999). Lorenzen et al. (1999) reported that outdoor grilling was the most popular method for cooking the top loin steak followed by broiling, indoor grilling, pan frying, and other (including oven roasted uncovered, pan-broil, stir-fry, braise, simmer and stew, and deep fry). Regional demographics indicated that consumers in San Francisco and Philadelphia cooked their steaks to a lower degree of doneness (DOD) as compared to those in Chicago and Houston (Lorenzen et al., 1999). Variability associated with cooking techniques need to be considered when conducting research on beef retail

cuts. The beef industry needs to ensure that accurate and detailed nutrient profiles are available for consumers to make informed purchasing decisions. Therefore, the objective of this study was to determine how cooking method (grilled (GR) and pan fried (PF)) and DOD (rare, medium, and well done) affect the nutrient composition of beef strip loin steaks.

## MATERIALS AND METHODS

*Selection*: Colorado State University personnel obtained carcass grade data. Each evaluator independently recorded measurements/assessments of fat thickness, longissimus muscle area, percentage of kidney, pelvic, and heart fat, lean maturity, skeletal maturity, overall carcass maturity, and marbling score. Strip loins (IMPS No. 180) were collected from the right sides of 21 low Choice steer carcasses after fabrication and immediately transported to the Colorado State University Meat Laboratory. At the Meat Laboratory, the strip loins were placed in a vacuum-sealed bag and aged at 2 °C for 14 d postmortem.

*Retail Cut Fabrication:* After reaching the appropriate length of aging time, samples were fabricated into 2.54 cm thick steaks. Steaks were trimmed to an external fatness not exceeding 0.32 cm. Seven steaks were obtained from each strip loin. Steaks were randomly assigned to treatment to ensure that location would not confound the experiment. The experiment was designed to contrast the effects of either pan frying steaks or grilling steaks on three different levels of doneness. Steaks were randomly assigned to one of six treatments based on cooking method and DOD. Treatments consisted of: 1) PF, 60°C, 2) PF, 71°C, 3) PF, 77 °C, 4) GR, 60°C, 5) GR, 71°C, 6) GR,

77°C. Steaks were cooked fresh, immediately after fabrication. A set of raw steaks was used as a control group for nutrient analysis.

*Cooking*: Steaks were cooked to achieve 3 levels of doneness; 1) rare = 60 °C; 2) medium = 71 °C; or 3) well done = 77 °C. Steaks that were grilled were cooked on a Next Grilleration (model # GRP99) pre-heated to a grill surfaces approximately 195°C. The PF steaks were cooked in a Calphalon Nonstick 30.48 cm Jumbo Fryer pre-heated to a pan surface of 195 °C. The steaks were cooked uncovered and without any additional liquid added to the pan. The steaks were initially browned for 4 minutes per side and then turned every 4 minutes until the required DOD was achieved. The steaks were removed from the pan or grill immediately after cooking and cook drippings (drippings) was collected from the pan or drip tray into BD Falcon 50 mL conical tubes. Cook drippings was calculated by taking the total raw retail cut weight minus the total cooked weight immediately after cooking.

Detailed information on the parameters associated with sample preparation included raw steak weight, internal temperature at time of removal from pan or grill, peak internal temperature, interior color as determined via visual inspection using the American Meat Science Association Beef Steak Color Guide (NAMP, 1997) and the level of surface browning which was based on a four point scale (not browned; moderately browned; well browned; and very well browned/charred) as described by Sinha et al. (1998).

*Chemical Analysis Procedures*

*Homogenization:* Each individual steak was inspected by a trained personnel for any inedible material (heavy connective tissue, refuse, etc.) and, if found, the inedible portion was removed from the steak. Then the steak was cut into 2.5 cm pieces. One liter of liquid nitrogen was placed into a metal pan and all of the pieces were placed into the liquid nitrogen. The samples were mixed until all of the pieces were completely frozen. The frozen sample was then transferred from the metal pan into a homogenizing bowl. The samples were homogenized in a Robot Coupe Blixer 7 BX 6V batch processor (M1-45-3; Robot Coupe USA, Inc., Jackson, MS 39236-6625) at 1500 rpm until powdered. The homogenized portion was then placed in a whirl pack bag and stored at -70°C.

*Moisture Analysis:* Moisture analyses were performed using the AOAC moisture removal process (AOAC, 1995). Samples (approximately2.0 g) were weighed out into aluminum tins (low form, aluminum, fluted; Fisher Scientific, Pittsburgh, PA 15275 and allowed to dry for 24 h at 100 °C in a forced air drying oven (Thelco lab oven, Mandel Inc., Guelph, Ontario, Canada N1G 4N4. ). Samples were allowed to cool in a desiccator and weighed. Loss in weight was reported as percent moisture.

*Percent Fat Determination:* Lipid was extracted using the Folch *et al.* (1957) method (AOAC, 2006). An approximate 1.0 g sample was homogenized (VirTishear drill, Virtis Co., Gardiner, NY 12525) in a 2:1 chloroform methanol solution. The homogenized sample was then placed on an orbital shaker (VWR Model DS 500, VWR Manufacturers LLC., Radnor, PA 19087) for 20 minutes. Afterwards, the homogenate was filtered through ashless filter paper (Grade 41, Whatman Inc. Piscataway, NJ 08854). Four ml of 0.9% NaCl was added to the filtered sample, and the sample was placed in a refrigerator for 24 h. When the filtrate separated into two phases, the lower phase was

then aspirated and placed into a pre-weighed scintillation vial. The vial was then dried under $N_2$ gas (Organomation Assoc, Inc., Berlin, MA 01503), allowed to air dry under a hood for 1 h, and then dried at 100 °C for 24 h in a forced air drying oven. Vials were allowed to cool in a desiccator then weighed.

*Percent Ash:* Ash was determined using the ashing method described in the AOAC (1995). Briefly, approximately 1.0 g of sample was placed into a dry, pre-weighed crucible. Samples were then placed into a Thermolyne box furnace (Thermo Fisher Scientific, Pittsburgh, PA 15275) at 600°C for 24 h. Samples were allowed to cool in a desiccator and weighed. Ash was calculated by taking the total amount of what was left in the crucible (post oven) divided by total amount of sample initially placed within the crucible (pre oven) and multiplied by 100 to give the percent ash value.

*Crude Protein Determination:* Crude protein was determined using the AOAC (1996) method (TruSpec CN Carbon/Nitrogen Determination Instruction Manual, December 2004, Leco Corp.St. Joseph, MI). To ensure that the machine was running properly, 10 blank samples were assessed on the machine until a plateau was reached, three additional blanks were then analyzed and the blank area was set using these values. After the blank calibration, a standard was used for calibration. A standard references of EDTA (9.75% nitrogen) was used. The calibration curve was checked before to a sample run to ensure that the curve went through the calibration point. A standard and blank was run in duplicate every 25 samples. Samples (approximately 0.1 g) were weighed into tinfoil cups (Leco Corp., St Jospeh, MI 49085-2396) and weights were recorded. Crude protein levels were determined by multiplying each protein level by the suggested nitrogen factor for meat sources based upon the specific (Jones) factor for conversion of

nitrogen content to protein content of 6.25 after optimizing each sample based on the standard (Merrill and Watt, 1973).

*Statistical Analysis:* Data were analyzed using mixed model procedures as described by SAS (release 9.2, SAS Institute, Cary, NC). The model included the fixed effects of cooking method and DOD. Steak was considered to be the experimental unit (N = 147). The random effect was loin. Means were separated using the least squares means (LSMEANS) statement with comparisons provided by utilizing the PDIFF function. Orthogonal contrasts were conducted to check for linear and quadratic effects on chemical analysis effects of differing cooking methods or DOD. Chemical analysis procedures were analyzed on a DM basis. Interactions were considered to be significant if $P < 0.05$.

## RESULTS AND DISCUSSION

Cooking method and DOD data are found in Table 5.1. Cooking time was greater ($P < 0.05$) for steaks that were PF compared to GR (Figure 1). Additionally, cooking time increased linearly ($P < 0.01$) with increased DOD. As expected, browning scores and DOD scores increased linearly ($P < 0.01$) for PF and GR steaks. Additionally, doneness scores increased ($P < 0.01$) as DOD increased. Sinha et al. (1998) reported that DM content was higher in grilled samples than in pan fried samples (beef hamburgers, steaks, and roasts).

No treatment differences ($P < 0.82$) in raw wt were detected. Cooked wt decreased linearly ($P < 0.01$) for PF as DOD increased. Additionally, well done (77°C) steaks were lighter ($P < 0.05$) than rare (62°C) steaks. This result may have been an

effect of muscle protein shrinkage due to high heat for a longer period of time which causes a greater amount of water release from not only the outer surface of the cut, but from the protein as well. Jones et al. (1992) concluded that surface area of a cut, cooking temperature, and DOD effect the moisture content of a cut. Moisture content will be reduced as surface area, cooking temperature, and DOD increase.

The amount of cook drippings in well done (77°C) steaks was greater ($P < 0.01$) for both PF and GR as compared to the rare (62°C) or medium (71°C) cooked steaks. Surface to volume ratio has been shown to be directly associated with specific cooking properties such as cooking times and cook yields. Gall et al. (1983) conducted a study investigating baking, broiling, deep frying, and cooking in a microwave oven on proximate composition of 4 types of fish. It was concluded that cook yield appeared to be influenced by cooking rate, nutrient composition, and cooking method. The size and surface area per unit of volume exposed to the cooking apparatus directly influenced cooking yield.

The results of chemical analysis of cooking method and DOD are shown in Table 5.1. Multiple studies have reported that cooking will lead to weight reduction which is predominately caused by a loss of water (Rodriguez-Estrada et al., 1997; Jones et al., 1992; Cannell, et al., 1989; Garrett and Hinman, 1971). When proteins within the muscle are exposed to heat they will begin to denature which will invariably be followed by aggregation of protein molecules which indicates a loss of protein solubility. Initially, coagulation of myofibrilar proteins will occur which causes the first release of free water within the myofibrillar; this will occur in conjunction with the release of surface water. As cooking temperature increases, the break-down of muscle filaments will occur.

Reduced water holding capacity, cooking temperature, and degree of doneness all result in increased DM content (Aberle et al., 2001). The DM content of raw steaks averaged 38.18% and there was a linear ($P < 0.01$) increase in DM content as DOD increased. Pan frying steaks resulted in greater ($P < 0.05$) DM as compared to grilling the steaks. The effects of cooking method or DOD had no impact ($P < 0.31$) on the ash content of cooked steaks. However, raw steaks had higher ($P < 0.05$) ash content than cooked steaks. The initial crude fat content of the steaks averaged 44.38% ± 1.22. Pan fried steaks increased in CF content whereas the GR steaks decreased in CF content. It is hypothesized that this could occur because the grills used for this study were slanted which would allow for cooking loss to drip down off of the meat; this could have resulted in a lower surface fat content as compared to the pan frying method in which the pans were flat on the cooking surface. Cooking method had an effect ($P < 0.05$) on crude fat content as medium (71°C) and well done (77°C) GR steaks had lower crude fat content than the PF steaks or rare (62°C) GR steaks. Additionally, the PF steaks crude fat content decreased linearly as DOD increased. A study examining the effects of different cooking methods (boiling, microwave, roasting, grilling, or pan frying) on lipid and protein components of hamburgers indicated a reduction ($P < 0.05$) in lipid content was found in all cooked samples as compared to a raw hamburger standard they compared the cooked values too. Additionally, they found that GR samples had a lower ($P < 0.05$) lipid content than PF samples (Rodriguez-Estrada, et al., 1997). A study conducted on cooking effect on fish fillets found results in contrast to the current study as lipid content of the sample increased after cooking; baked, broiled, deep fried, or microwave (Gall et al., 1983). This can be explained by the difference associated with initial moisture content as the total

amount of lipid within the muscle will increase as moisture content decreases. Several studies have reported initial fat content within the meat sample is the largest factor in overall crude fat and fatty acid composition. Kilgore and Luker (1964) conducted several experiments designed to study fatty acid composition of lard and cottonseed oil after repeated frying of chicken (high fat and protein source) or potatoes (high carbohydrate low fat and protein) and analyze the fat content of the chicken and potatoes post-frying. Data indicated that the fat content of the chicken depended upon the chicken itself and type of cooking had little effect of fat content or fatty acid composition. Additionally, Gall et al. (1983) concluded that moisture retention and lipid content lost during cooking was influenced by the original lipid content of the specific fish fillet.

Protein content within the cut will increase as moisture is lost during cooking which explains the linear increase due to cooking. The raw initial crude protein content of the steaks was 49.98% and increased after cooking. Medium (70°C) and well done (77°C) GR steaks had higher crude protein content than any other DOD or PF steaks.

## IMPLICATIONS

Results of this study show that cooking method and DOD have major effects on the basic chemical composition of strip loin steaks. Cooking yields and moisture content were negatively impacted by increased cooking temperatures. Additionally, pan frying steaks caused an increase in crude fat and a decrease in crude protein. Recent regulatory acts will soon require all single cut retail meat products to have nutritional labeling information provided. Further research in needed to ensure that proper nutritional

labeling information is provided to consumers based up the most popular methods of cooking and DOD as these factors have shown to have an impact upon nutritive value.

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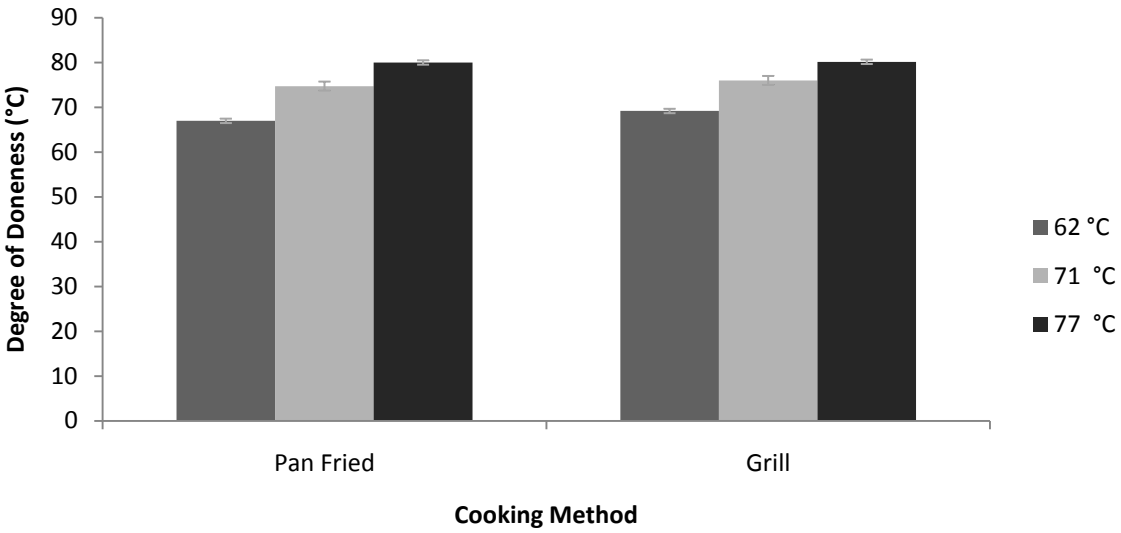


Figure 5.1. The average temperature each Degree of Doneness group was cooked to based on cooking method.

Table 5.1. Effects of Cooking Method on the nutrient analysis of loin steaks cooked to different degrees of doneness (62, 71, or 77°C) on least square means of main effects

| Item | Treatment [1] | | | | | | | SEM [3] | Significance (*P*-value) [2] | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PF, 62°C | PF, 71°C | PF, 77°C | GR, 62°C | GR, 71°C | GR, 77°C | Raw, 2.0°C | | PF (L) | PF (Q) | GR (L) | GR (Q) | PF x GR (L) | PF x GR (Q) |
| Cooking data | | | | | | | | | | | | | | |
| Cooking time, m | 14.29 | 17.38 | 19.90 | 9.01 | 10.10 | 11.43 | . | 0.63 | 0.01 | 0.70 | 0.01 | 0.61 | 0.01 | 0.93 |
| Final Temp, °C | 66.96 | 74.72 | 79.98 | 69.15 | 75.97 | 80.13 | . | 0.54 | 0.01 | 0.93 | 0.01 | 0.73 | 0.06 | 0.76 |
| Raw wt, g | 424.89 | 425.63 | 421.65 | 407.94 | 411.51 | 419.44 | . | 14.26 | 0.82 | 0.81 | 0.38 | 0.76 | 0.44 | 0.70 |
| Cook wt, g | 325.44 | 304.43 | 292.13 | 317.26 | 301.38 | 303.32 | . | 11.63 | 0.01 | 0.92 | 0.20 | 0.46 | 0.24 | 0.64 |
| Browning Score [4] | 2.24 | 2.57 | 2.71 | 2.38 | 2.90 | 3.24 | . | 0.13 | 0.01 | 0.76 | 0.01 | 0.95 | 0.14 | 0.86 |
| Doneness Score [5] | 3.05 | 4.00 | 5.04 | 2.95 | 4.05 | 4.90 | . | 0.09 | 0.01 | 0.03 | 0.01 | 0.51 | 0.89 | 0.29 |
| Cook drippings, % | 31.33 | 39.95 | 45.16 | 27.69 | 36.50 | 38.45 | . | 1.78 | 0.01 | 0.87 | 0.01 | 0.25 | 0.39 | 0.48 |
| Chemical Analysis, (%) | | | | | | | | | | | | | | |
| DM | 49.30 | 50.90 | 52.43 | 46.79 | 48.76 | 49.22 | 38.18 | 0.74 | 0.01 | 0.70 | 0.01 | 0.48 | 0.61 | 0.44 |
| Ash | 1.68 | 1.73 | 1.85 | 1.82 | 1.83 | 1.53 | 2.30 | 0.12 | 0.31 | 0.72 | 0.09 | 0.20 | 0.06 | 0.24 |
| Crude fat | 48.27 | 46.29 | 44.00 | 41.86 | 41.53 | 40.67 | 44.38 | 1.22 | 0.01 | 0.62 | 0.39 | 0.74 | 0.10 | 0.91 |
| Crude Protein | 48.97 | 50.37 | 50.26 | 50.87 | 52.21 | 53.58 | 49.98 | 1.33 | 0.32 | 0.60 | 0.05 | 0.81 | 0.50 | 0.59 |

[1] PF = pan fried to 62, 71, or 77°C; GR = grilled to 62, 71, or 77°C; Raw = purge analysis. All data were analyzed and are reported on a dry matter basis

[2] Probability of a linear (L) or quadratic (Q) effect of the cooking method and degree of doneness.

[3] N = 147

[4] Level of surface browning was based on a four point scale; 1) not browned; 2) moderately browned; 3) well browned; and 4) very well browned/charred (Sinha et al. 1998).

[5] Interior color was determined via visual inspection using the American Meat Science Association Beef Steak Color Guide (NAMP, 1997)

# CHAPTER VI

# NUTRIENT COMPOSITION OF PURGE AND COOK DRIPPINGS FROM CUTS FROM THE BEEF CHUCK AND THE IMPACT OF COOKING METHOD AND DEGREE OF DONENESS ON THE NUTRIENT CONTENT OF PURGE AND COOK DRIPPINGS FROM THE LOIN

## ABSRACT

Two separate experiments were conducted to investigate factors that influence purge, and cook drippings (CD) nutrient composition. For experiment 1, twenty six chucks were Selected from carcasses based on QG (16 Choice and 10 Select), YG (11 YG 2 and 15 YG 3), and gender (12 heifer and 14 steer carcasses). Subprimals were fabricated into the following retail cuts: Brisket Flat Half, Brisket Point Half, Shoulder Roast, Shoulder Steak, Beef for Stew, Denver Cut, Boneless Country Style Beef Ribs, Classic Beef Roast, Chuck Eye Steaks, Under Blade Pot Roast, Under Blade Steak, Top Blade Steak, Mock Tender Steak, and Short Ribs for a cut total of N = 506. Each cut was cooked based on the most popular consumer cook method. For experiment 2, strip loins were removed from the right sides of 21 low Choice steer carcasses, aged for 14 d. Seven steaks were obtained from each strip loin. Steaks (N = 147) were randomly assigned to treatment. Treatments consisted of: 1) pan fried (PF), 60°C, 2) PF, 71°C, 3) PF, 77 °C, 4) grilled (GR), 60°C, 5) GR, 71°C, 6) GR, 77°C. A set of raw steaks was used as a control

group for nutrient analysis. For both experiments, purge was collected from each cut immediately after package removal. In Exp. 1, cook drippings was collected into conical tubes immediately after cooking. The effects of YG and gender were minimal. Yield grade 2 cuts had higher ($P < 0.05$) DM cook drippings compared to YG 3 cuts. Heifers tended ($P < 0.10$) to have lower DM cook drippings as compared to steers. The DM content of purge differed ($P < 0.05$) between roasts, steaks, and braised cuts (10.30, 10.33, and 9.68 ± 0.18). The Ash content of purge was also differed ($P < 0.05$) between roasts, steaks, and braised cuts (3.10, 2.66, and 3.50 ± 0.19). Dry matter, ash, and crude protein of cook drippings were different ($P < 0.05$) relative to type of cut. Additionally, total purge and cook drippings was greater ($P < 0.05$) for braised cuts compared to roasts or steaks. In Exp. 2, cooking method and degree of doneness influenced nutrient content. Medium (71°C) and well done (77°C) grilled steaks had higher ($P < 0.05$) DM and lower ($P < 0.05$) ash and protein content than the raw or rare (62°C) steaks. Results of this study indicated that type of cut, cooking method, and degree of doneness contribute to the overall nutrient composition of purge and cook drippings from retail cuts.

Key Words: Beef, cook drippings, nutrient composition, purge, retail cut

## INTRODUCTION

A beef carcass is comprised of water, muscle, connective tissue, fat, and bone. Approximately 75% of a carcass is comprised of water. The greatest variability associated with carcass composition is the total amount of fat which can vary greatly in beef carcasses based on diet, genetics, and fabrication techniques (Bender, 1992;

Committee on Technological Options to Improve Options to Improve the Nutritional Attributes of Animal Products, 1988).

The water holding ability of the muscle affects the appearance of the meat before cooking, the duration and consistency of cooking, and the juiciness of the meat upon mastication. Water molecules are highly polar and are attracted to the muscle protein by specific ionizable basic (arginine, histidine, lysine) and acidic (glutamic acid and aspartic acid) groups or by polar nonionic groups (cystine, cysteine, serine, methionine, threonine, tyrosine, and tryptophan; Wierbicki and Deatherage, 1958). Myofibrils, the spaces between myosin and actin/tropomyosin, are where most water is present within the muscle (Lawrie, 1991). Lean meat contains approximately 3.5 g of water per g of protein (Wierbicki and Deatherage, 1958). Water, when directly bound to hydrophilic groups on muscle protein, is considered to be "bound" water (Hamm, 1960). Water may also be located in the extracellular region of the muscle and is referred to as "free water" (Hamm, 1960; Wierbicki and Deatherage, 1958; Lawrie, 1991). During the thawing and/or cooking process, "free water" is released and is referred to as purge or cooking loss, respectively.

Pre-harvest stress factors can lead to significant meat quality defects. Stress can cause accelerated rigor mortis, reduced water holding capacity, and negative color effects (Sams, 1999). Improving meat quality has been extensively studied over the past 50 years and after the 1995 National Beef Quality Audit, Smith et al. (1996) determined that inadequate tenderness and low overall palatability were among the "top 10 quality concerns" in beef. Techniques such as aging, cooking method, blade tenderization, and electrical stimulation have proven to be effective technologies to improve tenderness of

strip loins aged for 14 d (Parish et al., 1993; Dransfiled, 1994;  Roeber et al., 2000; ). However, focusing on improving tenderness could have a negative effect on attributes such as juiciness, and little data is available on the effects of these methods on nutritive value of the retail product (Nour et al., 1994; Moloney et al., 2001).

The Food Safety and Inspection Service (FSIS) recently ruled to amend the Federal meat and poultry products inspection regulations. Beginning January 2012, nutrition labeling of the major cuts of single-ingredient, raw meat and poultry products on labels or at point-of-purchase will be required (75 FR 82148). In order to achieve the most accurate nutrient profile for any retail cut, nutrient analysis of raw and cooked cuts should be performed to address the "meat labeling" ruling. However, several factors such as thawing and cooking can alter the nutrient composition of the raw or cooked product (Moody et al., 1978; Rodriguez-Estrada et al., 1997). Traditionally, the nutrient composition of purge or cooking loss has been calculated by the difference in the actual nutrient composition of the raw and cooked product. However, determining the actual nutrient composition of purge (loss due to thawing) and drippings from cooking may assist in assessment of how technologies used to improve tenderness impact, end nutrient profile of beef retail cuts.

Therefore, the objectives of the present experiments were to: 1) investigate the nutrient composition of purge and cook drippings (CD) of retail cuts of the chuck across QG, YG, and gender and  2) investigate the effects of cooking method and degree of doneness (DOD) of retail cuts of strip loins on the nutrient composition of purge and CD.

# MATERIALS AND METHODS

*Experiment 1*

*Selection:* Chucks were Selected from two commercial abattoirs. The chucks were Selected from carcasses based on QG, YG, and gender. Trained Colorado State University personnel obtained carcass grade data. Each evaluator independently recorded measurements/assessments of fat thickness, longissimus muscle area, percentage of kidney, pelvic, and heart fat, lean maturity, skeletal maturity, overall carcass maturity, and marbling score. Sixteen USDA Choice and 10 USDA Select, YG 2 and 3 (USDA, 1997) carcasses were Selected from which chucks were removed. Of these carcasses, 12 were heifers and 14 were steers. All chucks were shipped to Colorado State University for fabrication into retail cuts.

*Subprimal and Retail Cut Fabrication:* Subprimal fabrication of the chucks occurred on d 4 post mortem and the subprimals were allowed to age for 18 d post mortem in a cooler (3.0°C). Retail cuts were fabricated from the following subprimals as outlined by the USDA (1996) Institutional Meat Purchase Specifications (IMPS) and further defined by Uniform Retail Meat Identity Standards (URMIS) (2003): Brisket, Flat Half (IMPS No. 120 A), Brisket, Point Half (URMIS No. 1628), Shoulder Roast (IMPS No. 114 A), Shoulder Steak (IMPS No. 114 A), Beef for Stew (IMPS No. 135 A), Denver Cut (Serratus Ventralis steaks) (IMPS No. 116 A/E), Boneless Country Style Beef Ribs (IMPS No. 116 A/D), Classic Beef Roast (IMPS No. 116 A/D), Chuck Eye Steaks (IMPS No. 116 A/D), Under Blade Pot Roast (IMPS No. 116 A/E), Under Blade Steak (URMIS No. 1158), Top Blade Steak (IMPS No. 114 D), Mock Tender Steak (IMPS No. 114 D), and Short Ribs (IMPS No. 130). Purge was collected in a 50 ml

conical tube (Becton, Dickinson and Company, Franklin Lakes, NJ 07417) by carefully removing the cut from the packaging allowing for any excess purge loss to remain in the bag, the purge was then poured from the bag into the conical tube and the bag was turned inside out and scraped clean with a clean spatula. Total purge was weighed (g) for each cut.

*Cooking:* Retail cuts designated for cooking were placed in a single layer on trays in a cooler (3.2° C) for approximately 24 h before to sample preparation for cooking. A raw wt and internal temperature were collected immediately prior to cooking. Cuts were cooked according to their suggested cooking method (Labensky and Hause, 2007). Cuts that were grilled were cooked on a Next Grilleration (model # GRP99) pre-heated grill surfaces approximately 195°C, to an internal temperature of 70°C. Cuts designated to be braised were placed in Calphalon Dutch Ovens, covered with distilled water, placed in a preheated conventional oven at 120° C, and allowed to simmer in the covered Dutch oven for 2 h 30 m before removing the pot from the oven. Cuts that were designated to be roasted were placed in Calphalon Roasting Pans and cooked in a convection oven at 160°C to an internal temp of 60° C. The temperatures of the retail cuts were monitored utilizing a type K thermocouple which was placed in the geometric center of the thickest part of the cut and was recorded on an Omega Model HH21 Microprocessor Thermometer. After the retail cuts were cooked, they were placed in a cooler (3.0°C) uncovered for 12-24 h. Cook drippings was collected into conical tubes immediately after cooking. Cook drippings was calculated by taking the total raw retail cut weight minus the total cooked weight immediately after cooking.

*Experiment 2*

*Selection*: Carcasses were Selected based on grade data obtained from trained Colorado State University personnel as described above. The strip loins (IMPS No. 180) were collected from the right sides of 21 low Choice steer carcasses after fabrication and immediately transported to the Colorado State University Meat Laboratory. At the Meat Laboratory, the strip loins were placed in a vacuum-sealed bag and aged at 2°C for 14 d.

*Retail Cut Fabrication:* After reaching the appropriate length of aging time, samples were fabricated into steaks (2.54 cm). Seven steaks were obtained from each strip loin. Steaks with a strip loin were randomly assigned to treatment. Steaks were cooked fresh, immediately after fabrication. A set of raw steaks were used as a control group for nutrient analysis. Purge was collected from each loin immediately after removing from the package as describe previously.

*Cooking*: Steaks were either grilled or pan fried. Data collection processes and grilling technique are described above. The pan fried steaks were cooked in a Calphalon Nonstick 30.5 cm Jumbo Fryer pre-heated to a pan surface of 195 °C. The steaks were cooked uncovered and without any additional liquid added to the pan. The steaks were initially browed for 4 min per side and then turned every 4 min until the required DOD was achieved. The steaks were removed from the pan or grill immediately after cooking and CD (drippings) were collected as described above.

*Chemical Analysis Procedures for Exp. 1 and Exp. 2*

*Homogenization:* Retail cut samples were cut into 2.5 cm pieces. 1 liter of liquid nitrogen was placed into a metal pan and all of the pieces were placed into the liquid nitrogen. The samples were mixed until all of the pieces were completely frozen. The frozen sample was then transferred from the metal pan into a homogenizing bowl. The

samples were homogenized in a Robot Coupe Blixer 7 BX 6V batch processor (M1-45-3; Robot Coupe USA, Inc., Jackson, MS 39236-6625) at 1500 rpm until powdered. The homogenized portion was then placed in a whirl pack bag and stored at -70°C.

*Moisture Analysis:* Moisture analyses were performed using the AOAC moisture removal process (AOAC, 1995). Samples (approximately2.0 g) were weighed out into aluminum tins (low form, aluminum, fluted; Fisher Scientific, Pittsburgh, PA 15275 and allowed to dry for 24 h at 100 °C in a forced air drying oven (Thelco lab oven, Mandel Inc., Guelph, Ontario, Canada N1G 4N4. ). Samples were allowed to cool in a desiccator and weighed. Loss in weight was reported as percent moisture.

*Percent Fat Determination:* Lipid was extracted using the Folch *et al.* (1957) method (AOAC, 2006). An approximate 1.0 g sample was homogenized (VirTishear drill, Virtis Co., Gardiner, NY 12525) in a 2:1 chloroform methanol solution. The homogenized sample was then placed on an orbital shaker (VWR Model DS 500, VWR Manufacturers LLC., Radnor, PA 19087) for 20 minutes. Afterwards, the homogenate was filtered through ashless filter paper (Grade 41, Whatman Inc. Piscataway, NJ 08854). Four ml of 0.9% NaCl was added to the filtered sample, and the sample was placed in a refrigerator for 24 h. When the filtrate separated into two phases, the lower phase was then aspirated and placed into a pre-weighed scintillation vial. The vial was then dried under $N_2$ gas (Organomation Assoc, Inc., Berlin, MA 01503), allowed to air dry under a hood for 1 h, and then dried at 100 °C for 24 h in a forced air drying oven. Vials were allowed to cool in a desiccator then weighed.

*Percent Ash:* Ash was determined using the ashing method described in the AOAC (1995). Briefly, approximately 1.0 g of sample was placed into a dry, pre-

weighed crucible. Samples were then placed into a Thermolyne box furnace (Thermo Fisher Scientific, Pittsburgh, PA 15275) at 600°C for 24 h. Samples were allowed to cool in a desiccator and weighed. Ash was calculated by taking the total amount of what was left in the crucible (post oven) divided by total amount of sample initially placed within the crucible (pre oven) and multiplied by 100 to give the percent ash value.

*Crude Protein Determination:* Crude protein was determined using the AOAC (1996) method (TruSpec CN Carbon/Nitrogen Determination Instruction Manual, December 2004, Leco Corp.St. Joseph, MI). To ensure that the machine was running properly, 10 blank samples were analyzed on the machine until a plateau was reached, three additional blank were then analyzed and the blank area was set using these values. After the blank calibration, a standard was used for calibration. EDTA (9.75% nitrogen) was used as the standard reference. The calibration curve was checked before a sample run to ensure that the curve went through the calibration point. A standard and blank was run in duplicate every 25 samples. Meat samples (approximately 0.1 g) were weighed into tinfoil cups (Leco Corp., St Jospeh, MI 49085-2396) and purge and cook drippings samples were weighed into copper capsules (Leco Corp., St Jospeh, and MI 49085-2396) and initial weights were recorded. Crude protein levels were determined by multiplying each protein level by the suggested nitrogen factor for meat sources based upon the specific (Jones) factor for conversion of nitrogen content to protein content of 6.25 after optimizing each sample based on the standard (Merrill and Watt, 1973).

*Statistical Analysis*

For experiment 1 and 2, data were analyzed using the Mixed Models Procedures as described by SAS (release 9.2, SAS Institute, Cary, NC). For both experiments,

chemical analysis procedures were analyzed on a DM basis. Interactions were considered to be significant if $P < 0.05$. The model for experiment 1 included the fixed effects of gender, QG, YG, cooking method or type of cut, QG by gender, QG by YG, and QG by method or type interactions. The individual retail cut was considered to be the experimental unit. The random effect was individual animal. Means were separated using the least squares means (LSMEANS) statement with comparisons provided by utilizing the PDIFF function.

For experiment 2, the model included the fixed effects of cooking method and DOD. Steak was considered to be the experimental unit and the random effect was loin. Means were separated using the least squares means (LSMEANS) statement with comparisons provided by utilizing the PDIFF function. Orthogonal contrasts were conducted to check for linear and quadratic effects on chemical analysis effects of differing cooking methods or DOD.

## RESULTS AND DISCUSSION

*Experiment 1*

The effects of QG on the nutrient analysis of cut (raw and cooked), purge, and CD are shown in Table 6.1. Dry matter content in upper Choice raw cuts had a tendency ($P < 0.11$) to be higher than lower Choice or Select cuts (30.35, 30.01, and 28.59 ± 0.97 % DM respectively). A similar trend ($P < 0.06$) existed in the upper Choice cooked cuts (43.32, 42.05, and 41.15 ± 0.62 % DM respectively). An inverse relationship exists between the fat content and amount of water present within the muscle. Percent crude fat within the raw and cooked cut was greater ($P < 0.02$) in the upper Choice cuts than in the

lower Choice and Select cuts. This was expected because intramuscular fat is a major component of how QG is determined. In general, the greater amount of observed intramuscular fat the higher the QG (Aberle, et al., 2001).

In an early study, Forrest (1967) concluded that the fat content of boneless beef could be predicted based up the moisture content of the sample. Garrett and Hinman (1971) investigated the fat content of trimmed beef muscles taken from the round, loin, rib, and chuck of good and Choice heifer and steer carcasses with YGs of 2, 3, or 4. They reported that marbling score influenced ($P < 0.01$) the crude fat content of the retail cut. Moreover, all samples lost both fat and moisture during cooking but the amount of moisture lost was greater than that of the fat which resulted in an increased fat percentage. Therefore, they concluded that the result of moisture loss during cooking increased the fat percentage as compared to raw samples and water content was related to fat content. Quality grade was shown to affect ($P < 0.05$) the moisture content of the lean from multiple retail cuts utilized in an experiment examining the effects of QG and external fat trim levels on retail cuts from the brisket, chuck, rib, loin, sirloin, flank, and round (Wahrmund-Wyle et al., 2000). Choice retail cuts had significantly greater ($P < 0.05$) crude fat content compared to Select retail cuts.

In the present study, YG (Table 6.2) and gender (Table 6.3) had no impact ($P > 0.10$) on the nutrient composition of the raw or cooked cut or purge. However, YG did tend ($P < 0.06$) to have an effect on the DM content of the cooked cut as DM was greater in the YG 3 cuts as compared to the YG 2 cuts. Additionally, YG 3 CD had a lower($P < 0.05$) DM content than YG 2 CD. In a study looking at how fat content of trimmed beef retail cuts was influenced by QG, YG, marbling, and gender, Garrett and Hinman (1971)

reported that YG 2 and 3 carcasses had similar crude fat contents. The reason for the differences in the cooked cuts and cooking loss reported in the present experiment was difficult to explain. It could be that the steaks were trimmed to equal fat levels.

Dry matter content of the cooked cut and CD tended ($P < 0.10$) to be greater for steers as compared to heifers. Several studies have reported that steer carcasses have a higher lean and bone proportion and a lower fat proportion than heifer carcasses at equal YG (Keane and Drennan, 1987). Therefore, steers would have a greater amount of free water within a similar cut than heifers. This may lead to greater moisture loss during thawing or cooking.

Type of cut had a major influence of nutrient composition. Dry matter, ash, crude fat, and crude protein deferred ($P < 0.001$) between cooked cut types. Additionally, DM and ash differed ($P < 0.05$) in purge. Ash and crude protein were significantly different ($P < 0.01$) in CD. Moreover, the % purge and % CD were significantly different ($P < 0.001$) based on type of cut. The beef carcass contains over 100 different muscles and the chuck subprimal alone has 10 major muscles which vary in terms of muscle fiber type and functional roles (Jones et al., 2004) which is likely to lead to nutrient composition differences. Steaks had a much lower ($P < 0.05$) DM content than roasts or braised cuts. Similar results were reported in a study aimed at determining the effects of QG and trim level of 13 beef retail cuts. Braised cuts had lower ($P < 0.05$) moisture contents than roasted or broiled cuts and it was concluded this might be due to the heavier weights, slower cooking times, and lower cooking temperature (Wahrmun-Whyle et al., 2000). In a study conducted by Jones et al. (1992) cooking method influenced ($P < 0.05$) the moisture content of separable lean of cuts from the round, loin, and chuck. Roasted cuts

had the highest moisture content (62.9%), broiled cuts were intermediate (60.2%) and braised cuts had the lowest moisture content (57.4%). It was concluded that that roasting has a more beneficial effect on moisture content of a cut because, although all the cooking methods would cause the shrinking of the muscle proteins which causes the free water on the outer surface of the meat to be released or evaporate, the combination of these effects on such a large surface area causes a "skin" to form on the outside of the roast which helps to minimize further moisture loss from the interior of the roast. In contrast, cuts that are braised (such as stew meat or ribs) have a much smaller surface area that is exposed to the heat which will cause a greater amount of cook drippings during the cooking process.

*Experiment 2*

The results of the effects of cooking method and DOD on nutrient composition of purge and CD are shown in Table 6.5. Overall, cooking increased ($P < 0.05$) DM and crude fat composition. All pan fried steaks and steaks grilled to a "rare" DOD (62°C) had lower ($P < 0.05$) DM content as compared to steaks grilled medium (71°C) or well done (77°C). Additionally, steaks PF, 62°C had reduced ($P < 0.05$) crude fat content than all other treatment groups. Moreover, a linear ($P < 0.05$) increase in % CD existed as degree of doneness increased.

During cooking, denaturation of myofibrillar proteins will occur, specifically within the actomyosin complex. This denaturation causes muscle fibers to shrink and release of water (Murphy and Marks, 2000). The degree of heat applied to the muscle can have a significant effect upon the rate to which water holding capacity if affected (Bouton and Harris, 1972). The effect of myofibular denaturation occurs more quickly when

placed between two hot plates to grill as compared to with a pan frying method which would lead to the increased moisture and nutrient loss.

## IMPLICATIONS

The nutrient loss within the muscle was not affected by carcass Selection criteria. Quality grade, YG, and gender had only minor effects on water holding capacity of the muscle. However, effects of specific muscle type (cut), cooking method, and DOD all impacted water holding capacity of the muscle fiber. Moreover, cook drippings was found to contain approximately 55% protein, 28% crude fat, and 20% ash. The amount of cook drippings was shown to be different based upon the cooking method and DOD. The nutrient loss associated with this could have significant effects on the overall nutrient composition of the cut. Additionally, alternative uses for purge and cook drippings should be investigated as this study showed that purge and cook drippings contained a substantial amount of ash and protein. More detailed experiments should be conducted to examine more specific opportunities for reducing the water and nutrient loss of beef retail cuts to ensure the product the consumer is purchasing and eating is accurate in terms of it nutrition profile and meets the demands of consumers in regards to their desire for a healthy, lean product.

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Table 6.1. Least square means for nutrient analysis of raw and cooked cut, purge, and cook drippings by quality grade main effects.

| | Quality Grade | | | | |
|---|---|---|---|---|---|
| Item [1] | Select | Low Choice | Upper 2/3 Choice | SEM [2] | Trt *P*< |
| Raw Cut | | | | | |
| DM, % | 28.59 | 30.01 | 30.35 | 0.97 | 0.11 |
| Ash, % | 3.21 | 3.07 | 2.76 | 0.20 | 0.22 |
| Crude fat, | 18.88 | 19.26 | 23.65 | 1.01 | 0.02 |
| Crude Protein, % | 78.90 | 83.24 | 72.89 | 3.40 | 0.18 |
| Cooked Cut | | | | | |
| DM, % | 41.15 | 42.05 | 43.32 | 0.62 | 0.06 |
| Ash, % | 1.39 | 1.34 | 1.37 | 0.07 | 0.88 |
| Crude fat, % | 18.65 | 21.21 | 23.48 | 0.91 | 0.002 |
| Crude Protein, % | 81.52 | 77.96 | 78.49 | 1.9 | 0.28 |
| Purge | | | | | |
| DM, % | 10.04 | 10.15 | 10.11 | 0.18 | 0.90 |
| Ash, % | 10.89 | 11.08 | 10.73 | 0.24 | 0.59 |
| Crude fat, % | 4.64 | 4.67 | 4.53 | 1.07 | 0.97 |
| Crude Protein, % | 74.71 | 76.18 | 77.46 | 1.96 | 0.50 |
| Cook drippings | | | | | |
| DM, % | 8.86 | 8.97 | 11.73 | 2.77 | 0.58 |
| Ash, % | 21.32 | 20.21 | 19.69 | 1.00 | 0.10 |
| Crude fat, % | 29.11 | 22.33 | 38.75 | 28.12 | 0.82 |
| Crude Protein, % | 55.78 | 58.03 | 50.37 | 4.25 | 0.34 |
| Total weight loss | | | | | |
| Purge, % | 2.61 | 2.79 | 2.70 | 0.34 | 0.91 |
| Cooking loss, % | 57.27 | 58.38 | 54.99 | 2.53 | 0.43 |

[1] All analysis conducted on DM basis.

[2]N=506, means were considered significant if $P < 0.05$

Table 6.2. Least square means for nutrient analysis of raw and cooked cut, purge, and cook drippings by yield grade main effects

| Item [1] | Yield Grade 2 | Yield Grade 3 | SEM [2] | Trt *P*< |
|---|---|---|---|---|
| Raw Cut | | | | |
| DM, % | 29.34 | 29.95 | 0.55 | 0.41 |
| Ash, % | 3.01 | 3.01 | 0.20 | 0.99 |
| Crude fat, % | 20.17 | 21.03 | 0.81 | 0.48 |
| Crude Protein, % | 80.20 | 76.48 | 2.63 | 0.35 |
| Cooked Cut | | | | |
| DM, % | 41.43 | 41.91 | 0.53 | 0.06 |
| Ash, % | 3.13 | 3.34 | 0.14 | 0.32 |
| Crude fat, % | 20.54 | 21.69 | 0.69 | 0.23 |
| Crude Protein, % | 80.93 | 77.72 | 1.49 | 0.16 |
| Purge | | | | |
| DM, % | 10.19 | 10.01 | 0.14 | 0.40 |
| Ash, % | 10.93 | 10.87 | 0.19 | 0.84 |
| Crude fat, % | 4.60 | 4.64 | 0.48 | 0.93 |
| Crude Protein, % | 76.14 | 76.10 | 1.47 | 0.99 |
| Cook drippings | | | | |
| DM, % | 10.33 | 9.39 | 0.98 | 0.05 |
| Ash, % | 20.36 | 20.45 | 1.00 | 0.84 |
| Crude fat, % | 24.18 | 35.95 | 23.44 | 0.73 |
| Crude Protein, % | 53.89 | 55.57 | 3.07 | 0.69 |
| Total weight loss | | | | |
| Purge, % | 2.93 | 2.47 | 0.32 | 0.26 |
| Cooking loss, % | 56.43 | 57.33 | 1.65 | 0.69 |

[1] All analysis conducted on DM basis.
[2]N=506, means were considered significant if $P < 0.05$

Table 6.3. Least square means for nutrient analysis of raw and cooked cut, purge, and cook drippings by gender main effects

| | Gender | | | |
|---|---|---|---|---|
| Item [1] | Heifer | Steer | SEM [2] | Trt *P*< |
| Raw Cut | | | | |
| DM, % | 29.09 | 30.21 | 0.69 | 0.19 |
| Ash, % | 3.01 | 2.95 | 0.17 | 0.57 |
| Crude fat, % | 21.25 | 19.94 | 0.93 | 0.28 |
| Crude Protein, % | 77.54 | 79.14 | 3.04 | 0.67 |
| Cooked Cut | | | | |
| DM, % | 41.91 | 42.43 | 0.51 | 0.06 |
| Ash, % | 3.24 | 3.23 | 0.13 | 0.96 |
| Crude fat, % | 21.37 | 20.86 | 0.69 | 0.56 |
| Crude Protein, % | 78.62 | 80.03 | 1.54 | 0.48 |
| Purge | | | | |
| DM, % | 10.27 | 9.93 | 0.15 | 0.10 |
| Ash, % | 10.69 | 11.12 | 0.20 | 0.13 |
| Crude fat, % | 4.39 | 4.85 | 0.66 | 0.55 |
| Crude Protein, % | 75.74 | 76.50 | 1.56 | 0.71 |
| Cook drippings | | | | |
| DM, % | 8.41 | 11.31 | 1.29 | 0.10 |
| Ash, % | 21.02 | 19.79 | 1.00 | 0.12 |
| Crude fat, % | 31.41 | 28.71 | 19.75 | 0.92 |
| Crude Protein, % | 56.45 | 53.01 | 3.01 | 0.40 |
| Total weight loss | | | | |
| Purge, % | 2.68 | 2.73 | 0.29 | 0.89 |
| Cooking loss, % | 55.73 | 48.03 | 1.80 | 0.30 |

[1] All analysis conducted on DM basis.

[2]N=506, means were considered significant if $P < 0.05$

Table 6.4. Least square means for nutrient analysis of raw and cooked cut, purge, and cook drippings by type of cut main effects

| | Type of Cut | | | | |
|---|---|---|---|---|---|
| Item [1] | Roasts | Steaks | Braised | SEM [2] | Trt *P*< |
| Raw Cut | | | | | |
| DM, % | 29.70 | 29.54 | 29.70 | 0.70 | 0.99 |
| Ash, % | 3.15 | 3.08 | 2.80 | 0.17 | 0.03 |
| Crude fat, % | 19.08 | 20.08 | 22.64 | 0.80 | 0.001 |
| Crude Protein, % | 80.95 | 76.93 | 77.14 | 2.16 | 0.04 |
| Cooked Cut | | | | | |
| DM, % | 41.54 | 39.73 | 45.23 | 0.68 | 0.001 |
| Ash, % | 3.10 | 2.66 | 3.50 | 0.18 | 0.001 |
| Crude fat, % | 19.84 | 20.84 | 22.82 | 0.72 | 0.002 |
| Crude Protein, % | 80.42 | 81.57 | 78.40 | 1.95 | 0.10 |
| Purge | | | | | |
| DM, % | 10.30 | 10.33 | 9.68 | 0.13 | 0.001 |
| Ash, % | 11.08 | 11.05 | 10.57 | 0.19 | 0.04 |
| Crude fat, % | 4.54 | 4.94 | 4.37 | 0.73 | 0.78 |
| Crude Protein, % | 76.83 | 75.40 | 75.97 | 1.70 | 0.71 |
| Cook drippings [3] | | | | | |
| DM, % | . | 15.37 | 7.29 | 3.74 | 0.01 |
| Ash, % | . | 18.20 | 22.52 | 0.66 | 0.001 |
| Crude fat, % | . | 44.34 | 15.79 | 20.64 | 0.26 |
| Crude Protein, % | . | 61.10 | 48.35 | 5.19 | 0.001 |
| Total weight loss | | | | | |
| Purge, % | 2.51 | 2.31 | 3.29 | 0.38 | 0.001 |
| Cooking loss, % | 58.41 | 48.11 | 64.13 | 2.04 | 0.001 |

[1] All analysis conducted on DM basis.

[2]N=506, means were considered significant if $P < 0.05$

[3]Cooking loss proximate data was not collected for roasts as there wasn't enough sample to analyze

Table 6.5. Effects of Cooking Method on the nutrient analysis of purge or cook drippings of loin steaks cooked to different degrees on doneness (62, 71, or 77°C) on least square means of main effects

| Item [1] | Treatment [1] | | | | | | | SEM [3] | Significance (*P*-value) [2] | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PF, 62°C | PF, 71°C | PF, 77°C | GR, 62°C | GR, 71°C | GR, 77°C | Raw, 2.0°C | | PF (L) | PF (Q) | GR (L) | GR (Q) | PF x GR (L) | PF x GR (Q) |
| DM | 50.32$^{a}$ | 60.61$^{b}$ | 59.74$^{ab}$ | 68.48$^{ab}$ | 85.69$^{c}$ | 89.51$^{c}$ | 11.33$^{d}$ | 4.50 | 0.05 | 0.29 | 0.01 | 0.30 | 0.12 | 0.99 |
| Ash | 3.53$^{a}$ | 2.70$^{a}$ | 2.02$^{a}$ | 3.57$^{a}$ | 0.95$^{b}$ | 1.53$^{b}$ | 9.43$^{c}$ | 0.62 | 0.05 | 0.90 | 0.01 | 0.03 | 0.51 | 0.10 |
| Crude fat | 54.76$^{a}$ | 82.30$^{b}$ | 85.35$^{b}$ | 79.18$^{b}$ | 82.77$^{b}$ | 77.89$^{b}$ | 3.57$^{c}$ | 6.08 | 0.01 | 0.16 | 0.93 | 0.49 | 0.01 | 0.59 |
| Crude Protein | 15.19$^{a}$ | 12.74$^{a}$ | 14.99$^{a}$ | 10.44$^{a}$ | 3.38$^{b}$ | 1.99$^{b}$ | 79.18$^{c}$ | 2.77 | 0.88 | 0.43 | 0.02 | 0.50 | 0.10 | 0.93 |
| Cook drippings, % | 31.33$^{a}$ | 39.95$^{b}$ | 45.16$^{c}$ | 27.69$^{a}$ | 36.50$^{b}$ | 38.45$^{c}$ | . | 1.78 | 0.01 | 0.87 | 0.01 | 0.25 | 0.39 | 0.48 |

[1] PF = pan fried to 62, 71, or 77°C; GR = grilled to 62, 71, or 77°C; Raw = purge analysis. All data analyzed on a dry basis

[2] Probability of a linear (L) or quadratic (Q) effect of the cooking method and degree of doneness.

[3] n = 147

# APPENDIX A

**Figure 1.** Project Timeline

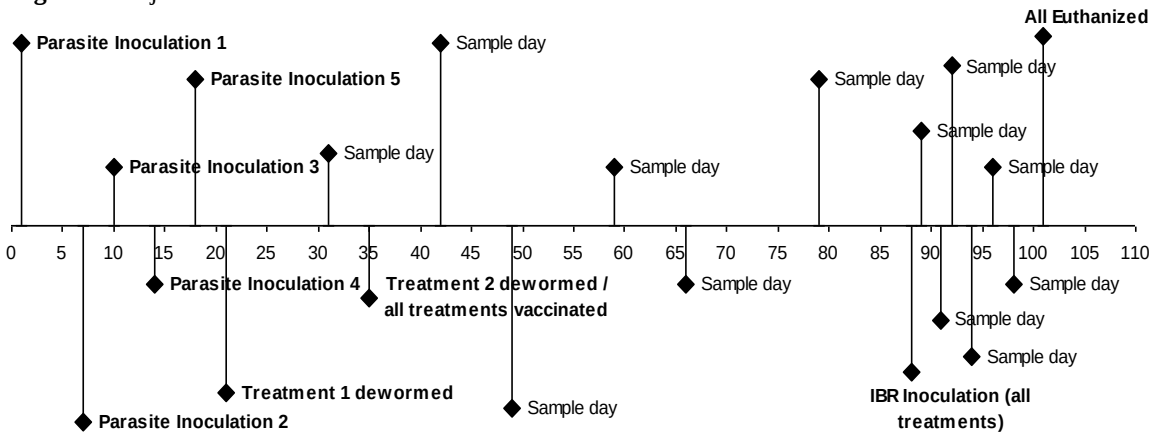


Figure A.1. The overall timeline (d) of the study with day 0 being the first day the calves were inoculated with parasites and the last day being the day the calves were euthanized post IBRV challenge.

Table A.1. Influence of deworming on Log 2 titer counts.

| | | Treatment [b] | | | | Significance of difference [c] (P<) | | Contrasts (P<) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Period | Item [a] | Trt 1 | Trt 2 | Trt 3 | SEM | Trt | Trt*Days | 1 vs 2 | 1 vs 3 | 2 vs 3 |
| | IBRV, log2 | | | | | | | | | |
| 0[d] | | 1.00 | 1.00 | 1.06 | 0.03 | 0.18 | 0.24 | - | - | - |
| 1[e] | | - | - | - | - | - | - | - | - | - |
| 2[f] | | - | - | - | - | - | -* | - | - | - |
| 3[g] | | 2.66 [a] | 2.88 [a] | 2.26 [b] | 0.21 | 0.12 | 0.35 | - | - | - |
| 4[h] | | 4.22 | 4.05 | 4.00 | 0.23 | 0.77 | 0.18 | - | - | - |
| | BVDV 1, log2 | | | | | | | | | |
| 0[d] | | 3.00 | 3.00 | 3.06 | 0.03 | 0.18 | 0.24 | - | - | - |
| 1[e] | | - | - | - | - | - | - | - | - | - |
| 2[f] | | - | - | - | - | - | -* | - | - | - |
| 3[g] | | 3.29 [b] | 3.74 [a] | 2.98 [b] | 0.17 | 0.001 | 0.02 | - | - | - |
| d 63 | | 2.67 | 2.40 | 2.00 | 0.23 | 0.20 | - | 0.44 | 0.09 | 0.22 |
| d 66 | | 3.38 [b] | 4.71 [a] | 3.00 [b] | 0.43 | 0.03 | - | 0.05 | 0.53 | 0.01 |
| d 73 | | 4.75 [a,b] | 5.71 [a] | 4.11 [b] | 0.46 | 0.07 | - | 0.17 | 0.33 | 0.02 |
| d 79 | | 5.38 | 5.71 | 4.78 | 0.38 | 0.24 | - | 0.55 | 0.27 | 0.10 |
| 4[h] | | 5.98 [b] | 6.68 [a] | 5.88 [b] | 0.34 | 0.24 | 0.70 | - | - | - |
| | BVDV 2, log2 | | | | | | | | | |
| 0[d] | | 3.00 | 3.00 | 3.17 | 0.05 | 0.03 | 0.02 | - | - | - |
| d 133 | | 3.00 | 3.00 | 3.50 | 0.31 | 0.35 | - | 1.00 | 0.33 | 0.19 |
| 1[e] | | - | - | - | - | - | - | - | - | - |
| 2[f] | | - | - | - | - | - | -* | - | - | - |
| 3[g] | | 3.56 [b] | 4.05 [a] | 3.61 [a,b] | 0.22 | 0.26 | 0.41 | - | - | - |
| 4[h] | | 6.20 [b] | 7.04 [a] | 6.54 [a,b] | 0.44 | 0.43 | 0.06 | - | - | - |
| | PI-3, log2 | | | | | | | | | |
| 0[d] | | 1.00 [a] | 1.04 [b] | 1.09 [b] | 0.05 | 0.40 | 0.63 | - | - | - |
| 1[e] | | 2.00 [b] | 2.14 [b] | 2.41 [a] | 0.08 | 0.002 | 0.002 | - | - | - |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| d 18 | 2.00 [b] | 2.27 [b] | 2.82 [a] | 0.15 | 0.003 | | - | 0.22 | 0.001 | 0.02 |
| 2[f] | 2.70 [b] | 4.89 [a] | 5.09 [a] | 0.35 | <0.0001 | | -* | - | - | - |
| 3[g] | 5.56 [b] | 6.40 [a] | 6.54 [a] | 0.44 | 0.24 | 0.54 | | - | - | - |
| 4[h] | 4.27 [b] | 4.93 [a] | 5.08 [a] | 0.35 | 0.23 | 0.74 | | - | - | - |

[a] Abbreviations used: IBRV = Infectious Bovine Rhinotracheitis, BVDV = Bovine Virus Diarrhea (Type 1), BVDV = Bovine Virus Diarrhea (Type 2) and PI-3 = Parainfluenza.
[b] Treatment 1 = calves dewormed 2 weeks prior to vaccination, 2 = calves dewormed at vaccination, 3 = calves were never dewormed after parasite inoculation. Treatments denoted with different subscripts differ significantly.
[c] P-values were considered significant if P was equal to or less than 0.05.
[d] P0 = receiving and development phase of claves
[e] P1 = period of parasite inoculation.
[f] P2 = the period beginning post deworming of trt 1.
[g] P3 = the period directly proceeding vaccination of all treatments.
[h] P4 = the two weeks post harvest where all treatments were challenged with IBRV.
*Only one day was analyzed for this period

Table A.2. Nutrient composition for individual raw cuts based on quality grade, yield grade and gender (means ± SD).

| Cut [a] | Item | % DM | %Ash | % Crude Fat | % Crude Protein |
|---|---|---|---|---|---|
| America's Beef Roast | Select | 28.30±1.47 | 0.917±0.130 | 5.721±1.043 | 22.50±1.17 |
| | Low Choice | 33.57±1.56 | 1.01±0.137 | 6.996±1.106 | 28.06±1.24 |
| | Upper 2/3 Choice | 30.40±1.56 | 0.887±0.137 | 7.638±1.106 | 24.05±1.24 |
| | Yield grade 2 | 36.26±1.37 | 0.897±0.116 | 7.168±0.990 | 26.44±1.07 |
| | Yield grade 3 | 29.40±1.21 | 0.968±0.103 | 6.409±0.878 | 23.47±0.95 |
| | HEIFER | 28.95±1.71 | 0.880±0.146 | 6.737±1.217 | 22.38±1.33 |
| | STEER | 31.32±1.07 | 0.959±0.091 | 6.745±0.759 | 25.71±0.83 |
| Chuck Eye Steak | QG 1 | 28.58±1.47 | 0.883± 0.13 | 5.546±1.043 | 21.55±1.17 |
| | QG 2 | 31.89±1.57 | 0.739±0.137 | 7.177±1.106 | 25.96±1.24 |
| | QG 3 | 33.02±1.66 | 0.875±0.147 | 8.223±1.183 | 23.27±1.33 |
| | YG 2 | 30.51±1.37 | 0.834±0.116 | 6.286±0.990 | 24.07±1.07 |
| | YG 3 | 31.38±1.26 | 0.832±0.107 | 7.365±0.911 | 23.06±0.98 |
| | HEIFER | 29.87±1.71 | 0.874±0.146 | 6.222±1.217 | 23.21±1.33 |
| | STEER | 31.44±1.10 | 0.816±0.094 | 7.138±0.781 | 23.65±0.85 |

| | | | | | |
|---|---|---|---|---|---|
| Beef for Stew | QG 1 | 29.51±1.39 | 1.092±0.123 | 3.618±0.990 | 25.57±1.11 |
| | QG 2 | 27.68±1.56 | 0.977±0.137 | 3.923±1.106 | 24.55±1.24 |
| | QG 3 | 29.69±1.66 | 0.856±0.147 | 4.898±1.183 | 23.29±1.33 |
| | YG 2 | 28.92±1.31 | 0.945±0.111 | 3.886±0.948 | 25.06±1.02 |
| | YG 3 | 29.03±1.26 | 1.030±0.107 | 4.247±0.911 | 24.19±0.98 |
| | HEIFER | 28.15±1.60 | 0.880±0.137 | 4.130±1.139 | 22.24±1.24 |
| | STEER | 29.37±1.10 | 1.041±0.09 | 4.047±0.78 | 25.72±0.85 |
| Country Style Beef Ribs | QG 1 | 28.42±1.39 | 0.871±0.123 | 7.14±0.990 | 22.18±1.11 |
| | QG 2 | 29.09±1.56 | 0.713±0.137 | 6.990±1.11 | 22.66±1.25 |
| | QG 3 | 28.42±1.66 | 0.802±0.15 | 7.472±1.18 | 21.86±1.33 |
| | YG 2 | 27.36±1.37 | 0.760±0.116 | 6.367±0.990 | 20.91±1.07 |
| | YG 3 | 29.63±1.21 | 0.834±0.103 | 7.826±0.878 | 23.29±0.95 |
| | HEIFER | 27.66±1.60 | 0.722±0.137 | 6.777±1.139 | 21.43±1.24 |
| | STEER | 29.09±1.10 | 0.838±0.094 | 7.376±0.781 | 22.63±0.85 |
| Shoulder Roast | QG 1 | 26.53±1.56 | 0.814±0.137 | 4.078±1.106 | 21.53±1.24 |
| | QG 2 | 27.99±1.56 | 0.971±0.137 | 3.786±1.106 | 22.51±1.24 |
| | QG 3 | 28.34±1.66 | 0.808±0.147 | 4.541±1.183 | 23.14±1.33 |
| | YG 2 | 26.56±1.37 | 0.805±0.116 | 3.950±0.990 | 21.72±1.07 |

| | | | | | |
|---|---|---|---|---|---|
| | YG 3 | 28.53±1.31 | 0.923±0.111 | 4.271±0.948 | 22.95±1.02 |
| | HEIFER | 27.20 ± 1.71 | 0.819±0.146 | 4.307±1.217 | 22.14±1.33 |
| | STEER | 27.76 ± 1.13 | 0.888±0.097 | 4.035±0.805 | 22.46±0.88 |
| Shoulder Steak | QG 1 | 26.91±1.39 | 0.942±0.123 | 4.091±0.990 | 21.97±1.11 |
| | QG 2 | 26.94±1.56 | 0.864±0.137 | 3.622±1.106 | 23.54±1.24 |
| | QG 3 | 27.81±1.67 | 0.770±0.147 | 4.370±1.183 | 22.46±1.33 |
| | YG 2 | 27.34±1.37 | 0.910±0.116 | 4.142±0.990 | 22.39±1.07 |
| | YG 3 | 27.04±1.21 | 0.837±0.103 | 3.921±0.878 | 22.78±0.95 |
| | HEIFER | 27.18±1.71 | 0.969±0.146 | 3.790±1.217 | 24.02±1.33 |
| | STEER | 27.17±1.07 | 0.830 ± 0.09 | 4.108±0.76 | 22.06 ± 0.83 |
| Denver Cut Steak | QG 1 | 28.63±1.97 | 0.806±0.174 | 7.142±1.399 | 19.23±1.57 |
| | QG 2 | 30.48±2.20 | 0.955±0.194 | 7.170±1.565 | 20.13±1.76 |
| | QG 3 | 31.88±2.54 | 0.581±0.224 | 9.797±1.807 | 18.65±2.03 |
| | YG 2 | 29.94±1.85 | 0.707±0.158 | 7.245±1.340 | 19.63±1.45 |
| | YG 3 | 30.18±1.85 | 0.892±0.157 | 8.389±1.340 | 19.15±1.45 |
| | HEIFER | 31.07±2.27 | 0.981±0.193 | 8.436±1.610 | 19.91±1.76 |
| | STEER | 29.56±1.60 | 0.709±0.137 | 7.505±1.139 | 19.13±1.24 |
| Mock Tender Steak | QG 1 | 26.99±1.39 | 1.019±0.123 | 4.149±0.990 | 21.72±1.11 |

| | | | | | |
|---|---|---|---|---|---|
| | QG 2 | 35.00±1.56 | 1.424±0.137 | 5.350±1.106 | 28.12±1.24 |
| | QG 3 | 28.50±1.80 | 0.974±0.159 | 4.430±1.277 | 23.35±1.44 |
| | YG 2 | 30.59±1.37 | 1.242±0.116 | 4.220±0.990 | 24.59±1.07 |
| | YG 3 | 29.57±1.26 | 1.059±0.107 | 4.957±0.911 | 23.99±0.98 |
| | HEIFER | 27.66±1.71 | 0.996±0.146 | 4.277±1.217 | 22.08±1.33 |
| | STEER | 31.02±1.10 | 1.203±0.094 | 4.761±0.781 | 25.16±0.85 |
| Short Ribs | QG 1 | 32.91±1.47 | 0.902±0.30 | 8.273±1.043 | 21.88±1.17 |
| | QG 2 | 31.64±1.66 | 0.611±0.147 | 8.465±1.183 | 23.38±1.33 |
| | QG 3 | 34.57±1.56 | 0.841±0.137 | 10.558±1.11 | 23.82±1.24 |
| | YG 2 | 32.39±1.31 | 0.743±0.111 | 9.849±0.948 | 21.82±1.02 |
| | YG 3 | 33.80±1.31 | 0.851±0.111 | 8.332±0.948 | 24.11±1.02 |
| | HEIFER | 32.00±1.60 | 0.779 ± 0.14 | 9.303±1.139 | 21.53 ± 1.24 |
| | STEER | 33.64±1.13 | 0.806 ± 0.10 | 8.985±0.81 | 23.68 ± 0.88 |
| Top Blade Steak | QG 1 | 27.83±1.39 | 0.922±0.123 | 5.074±0.990 | 21.95±1.11 |
| | QG 2 | 28.14±1.56 | 0.853±0.137 | 5.350±1.106 | 24.25±1.24 |
| | QG 3 | 31.31±1.66 | 0.748±0.147 | 7.593±1.183 | 24.41±1.33 |
| | YG 2 | 27.84±1.37 | 0.890±0.116 | 5.427±0.990 | 22.95±1.07 |
| | YG 3 | 29.74±1.21 | 0.822±0.103 | 6.214±0.878 | 23.71±0.95 |

| | | | | | |
|---|---|---|---|---|---|
| | HEIFER | 28.94±1.71 | 0.913±0.146 | 5.85±1.217 | 23.27±1.33 |
| | STEER | 28.89±1.07 | 0.828±0.091 | 5.874±0.759 | 23.41±0.83 |
| Underblade Roast | QG 1 | 28.97±2.2 | 0.949±0.194 | 5.341±1.565 | 24.24±1.76 |
| | QG 2 | 30.17±3.11 | 1.60±0.27 | 5.789±2.213 | 24.99±2.49 |
| | QG 3 | 32.40±2.2 | 0.872±0.194 | 6.800±1.565 | 24.59±1.76 |
| | YG 2 | 31.11±2.02 | 1.163±0.172 | 6.081±1.468 | 23.78±1.58 |
| | YG 3 | 30.06±2.02 | 0.934±0.172 | 5.948±1.468 | 25.28±1.58 |
| | HEIFER | 29.38±2.27 | 0.936±0.193 | 6.170±1.610 | 25.22±1.76 |
| | STEER | 31.38±1.85 | 1.124±0.158 | 5.911±1.315 | 24.07±1.44 |
| Underblade Steak | QG 1 | 29.07±2.20 | 1.009±0.194 | 4.608±1.565 | 22.25±1.76 |
| | QG 2 | 34.25±2.20 | 1.102±0.194 | 6.423±1.565 | 25.77±1.76 |
| | QG 3 | 29.78±2.20 | 0.911±0.194 | 7.747±1.565 | 20.86±1.76 |
| | YG 2 | 32.95±1.85 | 1.031±0.157 | 7.136±1.340 | 24.99±1.45 |
| | YG 3 | 29.12±1.85 | 0.983±0.157 | 5.383±1.340 | 20.93±1.45 |

| | | | | |
|---|---|---|---|---|
| HEIFER | 28.67±2.27 | 0.848±0.193 | 5.825±1.610 | 20.60±1.76 |
| STEER | 32.22±1.60 | 1.087±0.137 | 6.477±1.139 | 24.14±1.24 |

[a] America's Beef Roast = IMPS 116A/D; Chuck Eye Steaks = URMIS 1102, IMPS 116A/D; Beef for Stew = URMIS 1727, IMPS 135; Country Style Beef Ribs = IMPS 116 A/D; Shoulder Roast = URMIS 1132, IMPS 114 A; Shoulder Steak = URMIS 1133, IMPS 114A; Denver Cut Steak Steak = IMPS 116A/D; Mock Tender Steak = URMIS 116, IMPS = 116B; Short Ribs = URMIS 1127, IMPS 130; Top Blade Steak = URMIS 1144, IMPS 114D; Underblade Roast = URMIS 1151, IMPS 116A/E; Underblade Steak = URMIS 1158.

Table A.3. Nutrient composition means ± SD for individual cooked cut based on quality grade, yield grade and gender.

| | | % DM | %Ash | % Crude Fat | % Protein |
|---|---|---|---|---|---|
| America's Beef Roast | QG 1 | 34.99±1.47 | 0.872±0.130 | 6.976±1.043 | 29.78±1.17 |
| | QG 2 | 35.73±1.56 | 0.970±0.137 | 8.560±1.106 | 30.00±1.24 |
| | QG 3 | 39.62±1.80 | 0.923±0.159 | 9.439±1.277 | 27.67±1.44 |
| | YG 2 | 36.85±1.43 | 1.009±0.122 | 8.258±1.038 | 29.63±1.12 |
| | YG 3 | 36.15±1.26 | 0.850±0.107 | 8.102±0.911 | 29.05±0.98 |
| | HEIFER | 34.72±1.71 | 0.948±0.146 | 7.471±1.217 | 28.64±1.33 |
| | STEER | 37.21±1.33 | 0.907±0.097 | 8.475±0.805 | 29.59±0.88 |
| Chuck Eye Steak | QG 1 | 41.35±1.39 | 0.900±0.123 | 11.007±1.00 | 32.16±1.11 |
| | QG 2 | 41.44±1.56 | 0.961±0.137 | 11.480±1.11 | 28.90±1.24 |
| | QG 3 | 41.76±1.66 | 0.954±0.147 | 12.134±1.18 | 32.56±1.33 |
| | YG 2 | 41.67±1.31 | 0.940±0.111 | 11.077±0.95 | 32.24±1.02 |
| | YG 3 | 41.33±1.26 | 0.929±0.107 | 11.841±0.91 | 30.30±0.98 |
| | HEIFER | 41.58±1.60 | 0.868±0.137 | 11.782±1.14 | 31.10±1.24 |
| | STEER | 41.45±1.10 | 0.966±0.094 | 11.329±0.78 | 31.29±0.85 |
| Beef for Stew | QG 1 | 40.66±1.39 | 1.837±0.123 | 5.291±0.990 | 31.85±1.11 |
| | QG 2 | 41.83±1.56 | 1.711±0.137 | 5.852±1.106 | 31.82±1.24 |
| | QG 3 | 43.59±1.56 | 1.878±0.137 | 6.649±1.106 | 35.29±1.24 |
| | YG 2 | 40.79±1.31 | 1.810±0.111 | 5.50±0.948 | 32.03±1.02 |
| | YG 3 | 42.89±1.21 | 1.811±0.103 | 6.208±0.878 | 33.65±0.95 |
| | HEIFER | 40.97±1.60 | 1.785±0.137 | 5.863±1.139 | 32.91±1.24 |
| | STEER | 42.35±1.07 | 1.822±0.091 | 5.890±0.759 | 32.89±0.83 |
| Country Style Beef Ribs | QG 1 | 45.29±1.39 | 1.571±0.123 | 10.145±1.00 | 39.08±1.11 |

| | | | | | |
|---|---|---|---|---|---|
| | QG 2 | 46.31±1.80 | 1.726±0.159 | 12.218±1.28 | 32.93±1.44 |
| | QG 3 | 46.12±1.80 | 1.428±0.159 | 12.158±1.28 | 37.92±1.44 |
| | YG 2 | 44.75±1.43 | 1.541±0.122 | 10.613±1.04 | 37.83±1.12 |
| | YG 3 | 46.67±1.31 | 1.602±0.111 | 11.799±0.95 | 36.47±1.02 |
| | HEIFER | 47.09±1.71 | 1.546±0.146 | 11.954±1.22 | 37.92±1.33 |
| | STEER | 45.19±1.17 | 1.587±0.100 | 10.935±0.83 | 36.70±0.91 |
| Shoulder Roast | QG 1 | 40.97±1.47 | 1.884±0.130 | 5.663±1.043 | 32.59±1.17 |
| | QG 2 | 41.04±1.56 | 1.637±0.137 | 6.035±1.106 | 32.99±1.24 |
| | QG 3 | 41.22±1.56 | 2.173±0.137 | 6.745±1.106 | 32.33±1.24 |
| | YG 2 | 40.74±1.31 | 1.564±0.111 | 5.987±0.948 | 32.37±1.02 |
| | YG 3 | 41.38±1.26 | 2.206±0.107 | 6.259±0.911 | 32.88±0.98 |
| | HEIFER | 41.30±1.71 | 1.676±0.146 | 5.719±1.217 | 32.62±1.33 |
| | STEER | 40.98±1.07 | 1.924±0.091 | 6.287±0.759 | 32.64±0.83 |
| Shoulder Steak | QG 1 | 35.73±1.56 | 1.072±0.137 | 5.099±1.106 | 28.62±1.24 |
| | QG 2 | 36.49±1.56 | 1.137±0.137 | 5.363±1.106 | 27.15±1.24 |
| | QG 3 | 35.71±1.56 | 1.068±0.137 | 5.635±1.106 | 28.37±1.24 |
| | YG 2 | 35.40±1.37 | 1.115±0.116 | 5.625±0.990 | 28.39±1.07 |
| | YG 3 | 36.47±1.26 | 1.073±0.107 | 5.146±0.911 | 27.76±0.98 |
| | HEIFER | 36.55±1.85 | 1.012±0.158 | 6.176±1.315 | 25.86±1.44 |
| | STEER | 35.79±1.07 | 1.119±0.091 | 5.096±0.759 | 28.77±0.83 |
| Denver Cut Steak | QG 1 | 37.10±1.97 | 0.832±0.174 | 9.498±1.399 | 24.73±1.57 |
| | QG 2 | 40.28±2.20 | 1.007±0.194 | 8.787±1.565 | 27.49±1.76 |
| | QG 3 | 40.93±2.20 | 0.839±0.194 | 11.871±1.55 | 28.09±1.76 |
| | YG 2 | 37.39±1.85 | 0.876±0.157 | 9.476±1.340 | 25.15±1.45 |
| | YG 3 | 40.86±1.71 | 0.898±0.146 | 10.466±1.24 | 27.87±1.34 |

| | | | | | |
|---|---|---|---|---|---|
| | HEIFER | 36.89±2.27 | 0.856±0.193 | 9.753±1.610 | 25.04±1.76 |
| | STEER | 40.31±1.51 | 0.902±0.129 | 10.123±1.07 | 27.35±1.17 |
| Mock Tender Steak | QG 1 | 41.35±1.47 | 1.583±0.130 | 4.655±1.043 | 35.12±1.17 |
| | QG 2 | 41.34±1.56 | 1.346±0.137 | 8.042±1.106 | 34.87±1.24 |
| | QG 3 | 43.54±1.56 | 1.378±0.137 | 6.723±1.106 | 37.23±1.24 |
| | YG 2 | 42.64±1.31 | 1.537±0.111 | 7.166±0.948 | 36.13±1.02 |
| | YG 3 | 41.50±1.26 | 1.353±0.107 | 5.695±0.911 | 35.33±0.98 |
| | HEIFER | 42.29±1.71 | 1.745±0.146 | 5.665±1.217 | 35.42±1.33 |
| | STEER | 41.95±1.07 | 1.324±0.091 | 6.687±0.759 | 35.83±0.83 |
| Short Ribs | QG 1 | 45.59±1.56 | 1.31±0.137 | 10.617±1.11 | 35.34±1.24 |
| | QG 2 | 48.88±1.56 | 1.48±0.137 | 14.758±1.11 | 37.50±1.24 |
| | QG 3 | 49.40±1.56 | 1.318±0.137 | 16.921±1.11 | 36.18±1.24 |
| | YG 2 | 46.98±1.31 | 1.237±0.111 | 14.410±0.95 | 35.17±1.02 |
| | YG 3 | 48.93±1.31 | 1.501±0.111 | 13.787±0.95 | 37.51±1.02 |
| | HEIFER | 47.24±1.85 | 1.066±0.158 | 15.232±1.32 | 32.95±1.44 |
| | STEER | 48.19±1.07 | 1.470±0.091 | 13.721±0.76 | 37.47±0.83 |
| Top Blade Steak | QG 1 | 38.64±1.47 | 1.119±0.130 | 6.521±1.043 | 34.13±1.17 |
| | QG 2 | 39.61±1.56 | 0.925±0.137 | 7.777±1.106 | 32.78±1.24 |
| | QG 3 | 42.04±1.56 | 0.968±0.137 | 9.896±1.106 | 34.87±1.24 |
| | YG 2 | 39.54±1.31 | 0.932±0.111 | 7.932±0.948 | 33.61±1.02 |
| | YG 3 | 40.50±1.26 | 1.079±0.107 | 8.068±0.911 | 34.23±0.98 |
| | HEIFER | 39.03±1.71 | 0.943±0.146 | 7.895±1.217 | 34.82±1.33 |
| | STEER | 40.43±1.07 | 1.034±0.091 | 8.045±0.759 | 33.59±0.83 |
| Underblade Roast | QG 1 | 44.82±2.20 | 1.90±0.194 | 8.209±1.565 | 37.65±1.76 |
| | QG 2 | 44.87±2.20 | 1.369±0.194 | 9.186±1.565 | 36.33±1.76 |

| | | | | | |
|---|---|---|---|---|---|
| | QG 3 | 44.11±2.20 | 1.285±0.194 | 11.995±1.57 | 38.38±1.76 |
| | YG 2 | 42.63±2.02 | 1.446±0.172 | 9.592±1.468 | 38.33±1.58 |
| | YG 3 | 46.01±1.71 | 1.569±0.146 | 9.942±1.241 | 36.82±1.34 |
| | HEIFER | 40.54±2.62 | 1.391±0.223 | 8.405±1.859 | 34.50±2.03 |
| | STEER | 45.95±1.51 | 1.560±0.129 | 10.260±1.07 | 38.44±1.17 |
| Underblade Steak | QG 1 | 45.21±2.20 | 1.406±0.194 | 10.048±1.57 | 34.87±1.76 |
| | QG 2 | 43.87±3.11 | 2.743±0.275 | 8.600±2.213 | 38.44±2.49 |
| | QG 3 | 45.67±2.20 | 1.351±0.194 | 10.343±1.57 | 36.44±1.76 |
| | YG 2 | 44.34±2.26 | 1.461±0.192 | 8.855±1.642 | 37.81±1.77 |
| | YG 3 | 45.64±1.85 | 1.778±0.157 | 10.557±1.34 | 35.15±1.45 |
| | HEIFER | 44.70±2.62 | 1.823±0.223 | 8.728±1.859 | 33.66±2.03 |
| | STEER | 45.31±1.71 | 1.578±0.146 | 10.368±1.22 | 37.31±1.33 |

[a] Percent ash, crude fat, and protein are presented on a wet weight basis.

[b] America's Beef Roast = IMPS 116A/D; Chuck Eye Steaks = URMIS 1102, IMPS 116A/D; Beef for Stew = URMIS 1727, IMPS 135; Country Style Beef Ribs = IMPS 116 A/D; Shoulder Roast = URMIS 1132, IMPS 114 A; Shoulder Steak = URMIS 1133, IMPS 114A; Denver Cut Steak Steak = IMPS 116A/D; Mock Tender Steak Steak= URMIS 116, IMPS = 116B; Short Ribs = URMIS 1127, IMPS 130; Top Blade Steak = URMIS 1144, IMPS 114D; Underblade Roast = URMIS 1151, IMPS 116A/E; Underblade Steak = URMIS 1158.

[c] Quality grade group: SE = Select; LC = Low Choice; UC = Upper two-thirds Choice.

Table A.4. Nutrient composition means ± SD for individual purge samples by cut, based on quality grade, yield grade and gender.

| | | % DM | %Ash | % Crude Fat | % Protein |
|---|---|---|---|---|---|
| America's Beef Roast | QG 1 | 9.55±1.47 | 1.118±0.130 | 0.479±1.106 | 6.38±1.17 |
| | QG 2 | 9.35±1.66 | 1.053±0.147 | 0.348±1.106 | 7.09±1.24 |
| | QG 3 | 9.79±1.56 | 1.162±0.137 | 0.518±1.106 | 7.76±1.24 |
| | YG 2 | 9.52±1.43 | 1.102±0.123 | 0.472±0.990 | 7.05±1.07 |
| | YG 3 | 9.61±1.21 | 1.122±0.103 | 0.428±0.911 | 7.05±0.95 |
| | HEIFER | 9.55±1.71 | 1.077±0.146 | 0.476±1.217 | 6.99±1.33 |
| | STEER | 9.58±1.10 | 1.129±0.094 | 0.437±0.781 | 7.07±0.83 |
| Chuck Eye Steak | QG 1 | 9.92±1.47 | 1.047±0.130 | 0.671±1.106 | 7.63±1.24 |
| | QG 2 | 9.92±1.56 | 1.096±0.137 | 0.623±1.277 | 7.13±1.24 |
| | QG 3 | 10.26±1.66 | 1.036±0.147 | 0.475±1.399 | 7.62±1.33 |
| | YG 2 | 10.04±1.37 | 1.050±0.116 | 0.627±0.990 | 8.11±1.07 |
| | YG 3 | 10.00±1.26 | 1.069±0.107 | 0.574±1.161 | 6.85±1.022 |
| | HEIFER | 10.11±1.71 | 0.992±0.146 | 0.634±1.440 | 7.88±1.44 |
| | STEER | 9.98±1.10 | 1.088±0.094 | 0.594±0.861 | 7.30±0.85 |
| Beef for Stew | QG 1 | 10.77±1.39 | 1.136±0.123 | 0.307±1.043 | 8.13±1.11 |
| | QG 2 | 10.88±1.56 | 1.177±0.137 | 0.329±1.106 | 8.69±1.24 |
| | QG 3 | 10.64±1.66 | 1.091±0.147 | 0.299±1.183 | 7.79±1.33 |
| | YG 2 | 10.67±1.31 | 1.171±0.111 | 0.276±0.990 | 7.78±1.02 |
| | YG 3 | 10.86±1.26 | 1.104±0.107 | 0.342±0.911 | 8.62±0.98 |
| | HEIFER | 11.06±1.60 | 1.128±0.137 | 0.297±1.139 | 7.93±1.24 |
| | STEER | 10.63±1.10 | 1.141±0.094 | 0.319±0.805 | 8.35±0.85 |
| Country Style Beef Ribs | QG 1 | 9.90±1.56 | 0.998±0.137 | 0.448±1.043 | 7.25±1.17 |

| | | | | | |
|---|---|---|---|---|---|
| | QG 2 | 9.48±2.2 | 1.007±0.194 | 0.493±1.106 | 7.98±1.24 |
| | QG 3 | 10.12±1.66 | 1.045±0.159 | 0.587±1.277 | 8.13±1.44 |
| | YG 2 | 10.00±1.43 | 1.070±0.128 | 0.630±1.038 | 7.67±1.12 |
| | YG 3 | 9.77±1.51 | 0.962±0.128 | 0.400±0.911 | 7.78±0.98 |
| | HEIFER | 10.00±1.71 | 1.023±0.158 | 0.580±1.217 | 6.83±1.24 |
| | STEER | 9.82±1.31 | 1.012±0.112 | 0.464±0.805 | 8.21±0.91 |
| Shoulder Roast | QG 1 | 11.23±1.56 | 1.117±0.137 | 0.397±1.106 | 7.98±1.24 |
| | QG 2 | 11.66±1.56 | 1.183±0.137 | 0.329±1.106 | 8.41±1.24 |
| | QG 3 | 11.12±1.66 | 1.151±0.147 | 0.612±1.183 | 8.45±1.44 |
| | YG 2 | 11.33±1.37 | 1.167±0.116 | 0.394±0.990 | 8.01±1.12 |
| | YG 3 | 11.37±1.31 | 1.135±0.111 | 0.480±0.948 | 8.48±1.02 |
| | HEIFER | 11.77±1.71 | 1.113±0.146 | 0.353±1.217 | 8.07±1.33 |
| | STEER | 11.17±1.13 | 1.166±0.097 | 0.476±0.805 | 8.35±0.91 |
| Shoulder Steak | QG 1 | 11.03±1.39 | 1.133±0.123 | 0.541±0.990 | 8.07±1.11 |
| | QG 2 | 10.96±1.56 | 1.173±0.137 | 0.477±1.106 | 8.07±1.33 |
| | QG 3 | 10.33±1.66 | 1.139±0.147 | 0.322±1.183 | 7.57±1.33 |
| | YG 2 | 10.72±1.37 | 1.118±0.116 | 0.442±0.990 | 8.06±1.12 |
| | YG 3 | 10.88±1.21 | 1.171±0.103 | 0.473±0.878 | 7.83±0.95 |
| | HEIFER | 10.98±1.71 | 1.131±0.146 | 0.544±1.217 | 8.17±1.33 |
| | STEER | 10.74±1.07 | 1.154±0.091 | 0.427±0.759 | 7.82±0.85 |
| Denver Cut Steak | QG 1 | 10.85±1.97 | 1.183±0.174 | 0.187±1.565 | 8.24±1.76 |
| | QG 2 | 11.08±2.20 | 1.164±0.194 | 0.294±1.565 | 8.25±2.03 |
| | QG 3 | 8.99±2.54 | 1.005±0.224 | 0.322±2.212 | 6.20±2.49 |
| | YG 2 | 10.56±1.85 | 1.166±0.157 | 0.205±1.468 | 7.86±2.05 |
| | YG 3 | 10.36±1.85 | 1.098±0.157 | 0.309±1.468 | 7.75±1.45 |

| | | | | | |
|---|---|---|---|---|---|
| | HEIFER | 10.76±2.27 | 1.231±0.193 | 0.216±1.859 | 8.59±2.49 |
| | STEER | 10.31±1.60 | 1.083±0.137 | 0.275±1.217 | 7.56±1.33 |
| Mock Tender Steak | QG 1 | 10.41±1.47 | 1.141±0.130 | 0.510±1.277 | 7.89±1.17 |
| | QG 2 | 10.01±1.56 | 1.146±0.137 | 0.331±1.227 | 8.39±1.24 |
| | QG 3 | 10.70±1.80 | 1.147±0.159 | 0.427±1.277 | 7.92±1.44 |
| | YG 2 | 10.17±1.37 | 1.133±0.116 | 0.365±1.241 | 8.36±1.07 |
| | YG 3 | 10.50±1.31 | 1.155±0.111 | 0.459±0.990 | 7.81±1.02 |
| | HEIFER | 10.80±1.71 | 1.138±0.146 | 0.387±1.315 | 8.75±1.33 |
| | STEER | 10.14±1.13 | 1.147±0.097 | 0.441±0.930 | 7.77±0.88 |
| Short Ribs | QG 1 | 8.83±1.66 | 0.925±0.147 | 0.687±1.043 | 5.53±1.17 |
| | QG 2 | 8.86±1.66 | 0.890±0.147 | 0.521±1.183 | 6.38±1.33 |
| | QG 3 | 9.06±1.66 | 0.970±0.147 | 0.507±1.106 | 6.01±1.33 |
| | YG 2 | 8.80±1.43 | 0.89±0.123 | 0.570±0.948 | 6.08±1.07 |
| | YG 3 | 9.02±1.37 | 0.963±0.116 | 0.587±0.948 | 5.81±1.02 |
| | HEIFER | 9.50±1.85 | 1.008±0.158 | 0.575±1.139 | 6.00±1.33 |
| | STEER | 8.69±1.17 | 0.896±0.100 | 0.580±0.805 | 5.91±0.88 |
| Top Blade Steak | QG 1 | 10.34±1.39 | 1.101±0.123 | 0.327±0.990 | 7.26±1.11 |
| | QG 2 | 10.19±1.66 | 1.069±0.147 | 0.340±1.106 | 7.10±1.33 |
| | QG 3 | 9.55±1.80 | 1.135± 0.16 | 0.452±1.183 | 6.92±1.33 |
| | YG 2 | 10.22±1.37 | 1.114±0.116 | 0.367±0.990 | 7.62±1.07 |
| | YG 3 | 9.97±1.31 | 1.091±0.111 | 0.366±0.878 | 6.68±0.98 |
| | HEIFER | 10.46±1.85 | 1.083±0.158 | 0.347±1.217 | 7.39±1.33 |
| | STEER | 9.96±1.10 | 1.109±0.094 | 0.374±0.759 | 7.00±0.85 |
| Underblade Roast | QG 1 | 10.32±2.20 | 1.078±0.194 | 0.505±1.807 | 9.14±2.49 |
| | QG 2 | 9.92±3.11 | 1.168±0.275 | 0.565±2.213 | 8.06±3.52 |

| | | | | | |
|---|---|---|---|---|---|
| | QG 3 | 10.30±2.20 | 1.062±0.194 | 0.630±1.56 | 8.70±2.03 |
| | YG 2 | 10.07±2.02 | 1.030±0.172 | 0.549±1.468 | 8.84±1.77 |
| | YG 3 | 10.39±2.02 | 1.149±0.172 | 0.605±1.642 | 8.55±2.51 |
| | HEIFER | 10.27±2.27 | 1.112±0.193 | 0.475±1.859 | 9.24±2.49 |
| | STEER | 10.21±1.85 | 1.075±0.158 | 0.623±1.315 | 8.49±1.76 |
| Underblade Steak | QG 1 | 10.38±2.20 | 1.113±0.194 | 0.365±1.565 | 8.55±1.76 |
| | QG 2 | 9.96±2.20 | 1.113±0.194 | 0.706±1.565 | 7.49±1.76 |
| | QG 3 | 11.28±2.20 | 1.204±0.194 | 0.505±1.807 | 9.21±2.03 |
| | YG 2 | 10.26±1.85 | 1.144±0.157 | 0.481±1.340 | 8.20±1.45 |
| | YG 3 | 10.82±1.85 | 1.144±0.157 | 0.583±1.468 | 8.52±1.58 |
| | HEIFER | 10.34±2.27 | 1.104±0.193 | 0.609±1.610 | 9.07±1.76 |
| | STEER | 10.64±1.60 | 1.163±0.137 | 0.481±1.217 | 7.93±1.33 |

[a] Percent ash, crude fat, and protein are presented on a wet weight basis.

[b] America's Beef Roast = IMPS 116A/D; Chuck Eye Steaks = URMIS 1102, IMPS 116A/D; Beef for Stew = URMIS 1727, IMPS 135; Country Style Beef Ribs = IMPS 116 A/D; Shoulder Roast = URMIS 1132, IMPS 114 A; Shoulder Steak = URMIS 1133, IMPS 114A; Denver Cut Steak Steak = IMPS 116A/D; Mock Tender Steak Steak= URMIS 116, IMPS = 116B; Short Ribs = URMIS 1127, IMPS 130; Top Blade Steak = URMIS 1144, IMPS 114D; Underblade Roast = URMIS 1151, IMPS 116A/E; Underblade Steak = URMIS 1158.

[c] Quality grade group: SE = Select; LC = Low Choice; UC = Upper two-thirds Choice.

Table A.5. Nutrient composition means ± SD for individual cook drippings samples by cut, based on quality grade, yield grade and gender.

| | | % DM | %Ash | % Crude Fat | % Protein |
|---|---|---|---|---|---|
| Chuck Eye Steak | QG 1 | 12.29±1.66 | 2.67±0.147 | 2.013±1.277 | 6.43±1.57 |
| | QG 2 | 10.09±1.80 | 2.245±0.159 | 1.658±1.399 | 5.66±1.57 |
| | QG 3 | 29.60±1.56 | 2.311±0.137 | 1.610±1.183 | 6.16±1.44 |
| | YG 2 | 12.26±1.43 | 2.753±0.122 | 1.984±1.038 | 6.49±1.34 |
| | YG 3 | 23.70±1.37 | 2.101±0.116 | 1.475±1.161 | 5.78±1.18 |
| | HEIFER | 12.28±1.43 | 2.741±0.122 | 2.013±1.074 | 5.74±1.33 |
| | STEER | 23.69±1.37 | 2.112±0.117 | 1.502±1.074 | 6.37±1.17 |
| Beef for Stew | QG 1 | 6.53±1.97 | 1.358±0.174 | 0.357±1.399 | 2.90±1.57 |
| | QG 2 | 5.21±1.97 | 1.074±0.174 | 0.852±1.399 | 3.66±1.57 |
| | QG 3 | 7.33±2.20 | 1.481±0.194 | 0.599±1.564 | 2.82±1.76 |
| | YG 2 | 6.58±1.60 | 1.352±0.136 | 0.610±1.161 | 2.64±1.25 |
| | YG 3 | 5.90±1.85 | 1.211±0.157 | 0.593±1.340 | 3.82±1.45 |
| | HEIFER | 6.14±1.71 | 1.284±0.146 | 0.527±1.220 | 2.63±1.33 |
| | STEER | 6.43±1.71 | 1.299±0.146 | 0.679±1.217 | 3.67±1.33 |
| Shoulder Steak | QG 1 | 9.87±1.47 | 2.274±0.130 | 8.516±1.04 | 6.56±1.24 |
| | QG 2 | 8.94±1.66 | 2.181±0.147 | 0.846±1.183 | 5.93±1.57 |
| | QG 3 | 9.49±1.66 | 2.253±0.147 | 0.807±1.183 | 6.43±1.33 |
| | YG 2 | 10.06±1.51 | 2.38±0.128 | 0.882±1.094 | 8.06±1.12 |
| | YG 3 | 9.10±1.21 | 2.149±0.103 | 5.734±0.876 | 7.83±0.95 |
| | HEIFER | 9.06±1.43 | 2.083±0.122 | 7.638±0.090 | 6.12±1.17 |
| | STEER | 9.79±1.26 | 2.360±0.107 | 0.9099±0.893 | 6.55±1.06 |
| Denver Cut Steak | QG 1 | 10.59±1.97 | 2.422±0.174 | 2.721±1.399 | 6.18±2.03 |

| | | | | | |
|---|---|---|---|---|---|
| | QG 2 | 11.47±2.20 | 2.460±0.194 | 7.427±1.565 | 6.44±1.76 |
| | QG 3 | 10.48±2.20 | 2.435±0.194 | 19.088±1.565 | 5.67±2.03 |
| | YG 2 | 10.65±1.85 | 2.498±0.157 | 6.545±1.340 | 6.62±1.45 |
| | YG 3 | 10.98±1.71 | 2.385±0.146 | 11.485±1.241 | 5.41±1.77 |
| | HEIFER | 10.91±1.85 | 2.405±0.158 | 3.994±1.315 | 6.18±1.76 |
| | STEER | 10.76±1.71 | 2.465±0.146 | 13.672±1.217 | 6.10±1.44 |
| Mock Tender Steak | QG 1 | 4.86±1.56 | 1.085±0.137 | 0.553±1.106 | 3.00±1.24 |
| | QG 2 | 6.80±1.80 | 1.168±0.159 | 0.614±1.183 | 3.05±1.43 |
| | QG 3 | 6.81±1.97 | 1.381±0.174 | 0.638±1.399 | 2.52±1.57 |
| | YG 2 | 7.62±1.60 | 1.413±0.136 | 0.557±1.094 | 3.28±1.25 |
| | YG 3 | 4.80±1.37 | 1.026±0.116 | 0.627±0.990 | 2.60±1.07 |
| | HEIFER | 5.74±1.51 | 1.204±0.129 | 0.471±1.074 | 3.06±1.17 |
| | STEER | 6.21±1.43 | 1.175±0.122 | 0.698±0.971 | 2.74±1.11 |
| Short Ribs | QG 1 | 7.51±2.54 | 1.411±0.224 | 1.024±1.807 | 3.11±2.03 |
| | QG 2 | 12.21±4.40 | 0.751±0.389 | 0.890±3.129 | 3.83±3.52 |
| | QG 3 | 7.49±2.54 | 0.730±0.224 | 4.177±1.81 | 2.39±2.03 |
| | YG 2 | 8.39±2.61 | 1.026±0.222 | 1.064±1.896 | 2.88±2.05 |
| | YG 3 | 8.01±2.26 | 1.024±0.192 | 3.325±1.642 | 2.92±1.77 |
| | HEIFER | 6.82±2.27 | 1.267±0.193 | 1.076±1.601 | 3.07±1.76 |
| | STEER | 9.98±2.62 | 0.702±0.223 | 4.063±1.859 | 2.68±2.03 |
| Top Blade Steak | QG 1 | 9.87±1.56 | 2.373±0.137 | 0.650±1.106 | 6.41±1.24 |
| | QG 2 | 11.62±1.80 | 2.713±0.159 | 1.576±1.277 | 6.86±1.76 |
| | QG 3 | 11.07±1.56 | 2.60±0.147 | 1.389±1.183 | 6.82±1.33 |
| | YG 2 | 10.94±1.43 | 2.571±0.123 | 0.985±1.094 | 6.84±1.18 |
| | YG 3 | 10.65±1.31 | 2.526±0.116 | 1.294±0.948 | 6.49±1.12 |

| | | | | |
|---|---|---|---|---|
| HEIFER | 10.34±1.37 | 2.476±0.117 | 1.151±1.019 | 6.44±1.17 |
| STEER | 11.22±1.37 | 2.626±0.122 | 1.170±0.971 | 6.85±1.11 |

[a] Percent ash, crude fat, and protein are presented on a wet weight basis.

[b] America's Beef Roast = IMPS 116A/D; Chuck Eye Steaks = URMIS 1102, IMPS 116A/D; Beef for Stew = URMIS 1727, IMPS 135; Country Style Beef Ribs = IMPS 116 A/D; Shoulder Roast = URMIS 1132, IMPS 114 A; Shoulder Steak = URMIS 1133, IMPS 114A; Denver Cut Steak = IMPS 116A/D; Mock Tender Steak= URMIS 116, IMPS = 116B; Short Ribs = URMIS 1127, IMPS 130; Top Blade Steak = URMIS 1144, IMPS 114D; Underblade Roast = URMIS 1151, IMPS 116A/E; Underblade Steak = URMIS 1158.

[c] Quality grade group: SE = Select; LC = Low Choice; UC = Upper two-thirds Choice.

APPENDIX B

Feeding Frequency (Chapter 2):

```
proc mixed scoring=2;
class pen        trt       ;
model dp= trt  /ddfm=kenwardroger;
random pen (trt);
lsmeans trt/pdiff;
contrast 'linear' trt 1 0 -1;
contrast 'quadratic' trt 1 -2 1;
run;

proc mixed scoring=2;
class pen        trt       ;
model cw= trt /ddfm=kenwardroger;
random pen (trt);
lsmeans trt/pdiff;
contrast 'linear' trt 1 0 -1;
contrast 'quadratic' trt 1 -2 1;
run;

proc mixed scoring=2;
class pen        trt       ;
model fin= trt  /ddfm=kenwardroger;
random pen (trt);
lsmeans trt/pdiff;
contrast 'linear' trt 1 0 -1;
contrast 'quadratic' trt 1 -2 1;
run;

proc mixed scoring=2;
class pen        trt       ;
model dp= trt inwt /ddfm=kenwardroger;
random pen (trt);
lsmeans trt/pdiff;
contrast 'linear' trt 1 0 -1;
contrast 'quadratic' trt 1 -2 1;
run;

proc mixed scoring=2;
class pen        trt       ;
model cw= trt inwt/ddfm=kenwardroger;
random pen (trt);
lsmeans trt/pdiff;
contrast 'linear' trt 1 0 -1;
contrast 'quadratic' trt 1 -2 1;
run;
```

```
proc mixed scoring=2;
class pen        trt       ;
model fin= trt inwt  /ddfm=kenwardroger;
random pen (trt);
lsmeans trt/pdiff;
contrast 'linear' trt 1 0 -1;
contrast 'quadratic' trt 1 -2 1;
run;

proc glimmix;
CLASS trt pen;
MODEL yn= trt/ ddfm=SAT;
*error=binomial;
*link=logit;
*random id;
lsmeans trt/ pdiff;
run;

proc mixed scoring=2;
class pen        trt       ;
model yn= trt  /ddfm=kenwardroger;
random pen (trt);
lsmeans trt/pdiff;
contrast 'linear' trt 1 0 -1;
contrast 'quadratic' trt 1 -2 1;
run;

proc freq;
tables trt*yn/exact measures chisq nopercent nocol;
run;

proc glimmix;
CLASS trt pen;
MODEL yg= trt/ ddfm=SAT;
*error=binomial;
*link=logit;
*random id;
lsmeans trt/ pdiff;
run;
```

```
proc glimmix;
CLASS trt pen;
MODEL qg= trt/ ddfm=SAT;
*error=binomial;
*link=logit;
*random id;
lsmeans trt/ pdiff;
run;

proc mixed scoring=2;
class pen        trt       ;
model qg= trt  /ddfm=kenwardroger;
random pen (trt);
lsmeans trt/pdiff;
contrast 'linear' trt 1 0 -1;
contrast 'quadratic' trt 1 -2 1;
run;

proc mixed scoring=2;
class pen        trt       ;
model yg= trt  /ddfm=kenwardroger;
random pen (trt);
lsmeans trt/pdiff;
contrast 'linear' trt 1 0 -1;
contrast 'quadratic' trt 1 -2 1;
run;
```

Bunk Management (Chapter 3):

```
proc mixed covtest cl;
class period trt time score kg hd scooped;
model trt= period|scooped/ddfm=kenwardroger;
repeated score;
lsmeans period|scooped/adjust=tukey;
run;

proc mixed;
class pen per trt time score kgscore;
model kgscore = trt/ddfm=kenwardroger;
random pen / type=sp(pow)(time);
repeated time;
lsmeans  trt/ pdiff;
run;
```

```
proc mixed;
class pen per trt time score kgscore;
model score = trt/ddfm=kenwardroger;
random pen / type=sp(pow)(time);
repeated time;
lsmeans trt;
run;

proc mixed;
class pen per trt time score kgscore;
model kgscore = trt|time/ddfm=kenwardroger;
random pen / type=ar(1);
repeated time;
lsmeans trt|time;
run;

proc mixed;
class pen per trt time hdhramt;
model hdhramt= time|trt/ddfm=kenwardroger;
lsmeans time|trt/ adjust=tukey ;
run;

proc mixed covtest cl;
class pen period trt time score kg hd scoopedpen per trt
      time score kgest hd lbssc lbsscdm KGDM;
model trt= period|KGDM/ddfm=kenwardroger;
repeated score;
lsmeans period|KGDM/adjust=tukey;
run;
```

Impact of Parasites on Vaccine Efficacy (Chapter 4):

```
proc mixed method=reml data=dmi covtest cl;
class idtrt time dmi addmi;
model dmi= time|trt /ddfm =satterth;
random trt;
repeated time/subject = id type=sp (pow) (time);
lsmeans time|trt/pdiff;
run;
```

```
Proc sort; by trt;
*cytokines * trt;
proc mixed covtest cl;
class  day per id trt il4 il6 tnf ifn;
model il4=trt/ddfm =satterth;
repeated per/subject = id type=cs;
lsmeans trt/adjust= tukey;
contrast 'linear' trt 1 0 -1;
contrast 'quadratic' trt 1 -2 1;
run;

proc mixed covtest cl;
class  day per id trt il4 il6 tnf ifn;
model il6=trt/ddfm =satterth;
repeated per/subject = id type=cs;
lsmeans trt/adjust= tukey;
contrast 'linear' trt 1 0 -1;
contrast 'quadratic' trt 1 -2 1;
run;

proc mixed covtest cl;
class  day per id trt il4 il6 tnf ifn;
model tnf=trt/ddfm =satterth;
repeated per/subject = id type=cs;
lsmeans trt/adjust= tukey;
contrast 'linear' trt 1 0 -1;
contrast 'quadratic' trt 1 -2 1;
run;

proc mixed covtest cl;
class  day per id trt il4 il6 tnf ifn;
model ifn=trt/ddfm =satterth;
repeated per/subject = id type=cs;
lsmeans trt/adjust= tukey;
contrast 'linear' trt 1 0 -1;
contrast 'quadratic' trt 1 -2 1;
run;
```

```
proc glm;
class day per id trt il4 il6 tnf ifn;
model il4= trt;
lsmeans trt/pdiff;
means trt/ lsd snk regwq
        lines alpha=0.05;
run;

proc glm;
class day per id trt il4 il6 tnf ifn;
model il6= trt;
lsmeans trt/pdiff;
means trt/ lsd snk regwq
        lines alpha=0.05;
run;

proc glm;
class day per id trt il4 il6 tnf ifn;
model tnf= trt;
lsmeans trt/pdiff;
means trt/ lsd snk regwq
        lines alpha=0.05;
run;

proc glm;
class day per id trt il4 il6 tnf ifn;
model ifn= trt;
lsmeans trt/pdiff;
means trt/ lsd snk regwq
        lines alpha=0.05;
run;

Proc sort; by trt;
*count by trt;
proc mixed covtest cl;
class idtrt       count   period day;
model count=period trt trt*period/ddfm =satterth;
repeated period/subject = id type=cs;
lsmeans period trt trt*period/adjust= tukey;
run;
```

```
*count without interaction;
proc mixed covtest cl;
class idtrt        count   period day;
model count=period trt /ddfm =satterth;
repeated period/subject = id type=cs;
lsmeans period trt/adjust= tukey;
run;

*IBRV;
proc mixed;
class trt period;
model ibr=period|trt /ddfm =kr;
lsmeans period|trt /adjust= tukey;
run;

*bvd;
proc mixed covtest cl;
class trt period;
model bvd=period trt trt*period/ddfm =satterth;
lsmeans period  trt trt*period/adjust= tukey;
run;

*bvd2;
proc mixed covtest cl;
class trt period;
model bvd2=period trt trt*period/ddfm =satterth;
lsmeans period  trt trt*period/adjust= tukey;
run;

*pi3;
proc mixed covtest cl;
class trt period;
model pi3=period trt trt*period/ddfm =satterth;
lsmeans period  trt trt*period/adjust= tukey;
run;
```

```
*temp;
proc sort; by time;
proc mixed covtest cl;
class idtrt        time temp;
model temp= time trt time*trt  /ddfm =kr;
lsmeans time trt /adjust= tukey;
run;

*temp change;
proc mixed covtest cl;
class idtrt        time temp;
model chg= time trt  /ddfm =kr;
lsmeans time trt  /adjust= tukey;
run;
```

Degree of Doneness (Chapter 5):

```
Proc mixed;
Class CM DOD loin steak ;
Model  Cookloss= steak/ddfm=SAT s ;
Random loin;
LSMeans steak / PDiff at means;
contrast 'PF linear' steak -0.749269 0.0936586 0.6556101 0 0 0 0;
contrast 'PF quad' steak  0.3244428 -0.811107 0.4866643 0 0 0 0;
contrast 'grill linear' steak 0 0 0 -0.749269 0.0936586 0.6556101 0;
contrast 'grill quad' steak 0 0 0 0.3244428 -0.811107 0.4866643 0;
contrast 'DOD linear' steak -0.749269 0.0936586 0.6556101 0.749269 -0.0936586 -
0.6556101 0;
contrast 'DOD quad' steak  0.3244428 -0.811107 0.4866643 0.3244428 -0.811107
0.4866643 0;
contrast 'PFbyGRILL linear' steak -0.749269 0.0936586 0.6556101 0.749269 -0.0936586
-0.6556101 0;
contrast 'PFbyGRILL quad' steak  0.3244428 -0.811107 0.4866643 -0.3244428 0.811107
-0.4866643 0;
run;

Proc mixed;
Class CM DOD loin steak ;
Model  pro = steak/ddfm=SAT s ;
Random loin;
```

```
LSMeans steak / PDiff at means;
contrast 'PF linear' steak -0.749269 0.0936586 0.6556101 0 0 0 0;
contrast 'PF quad' steak  0.3244428 -0.811107 0.4866643 0 0 0 0;
contrast 'grill linear' steak 0 0 0 -0.749269 0.0936586 0.6556101 0;
contrast 'grill quad' steak 0 0 0 0.3244428 -0.811107 0.4866643 0;
contrast 'DOD linear' steak -0.749269 0.0936586 0.6556101 0.749269 -0.0936586 -
0.6556101 0;
contrast 'DOD quad' steak  0.3244428 -0.811107 0.4866643 0.3244428 -0.811107
0.4866643 0;
contrast 'PFbyGRILL linear' steak -0.749269 0.0936586 0.6556101 0.749269 -0.0936586
-0.6556101 0;
contrast 'PFbyGRILL quad' steak  0.3244428 -0.811107 0.4866643 -0.3244428 0.811107
-0.4866643 0;
run;
```

Purge and Cook drippings (Chapter 6):

```
proc sort data=PURCL;
by  QG YG Gend Cut method ID;
proc means data=PURCL noprint;
by  QG YG Gend Cut method type ID;
where method ne 0 and dmCL ne .;
var dmCUT dmCL     ashCL          cfCL           protCL;
output out=IDCutmethodCLMeans   n=    NdmCUT NdmCL                NashCL
        NcfCL          NprotCL
                                                              mean= dmCUT
dmCL  ashCL          cfCL           protCL;
proc print;
run;
```

```
proc mixed  covtest;
class QG YG Gend method Cut ID;
model dmCL   =        QG
                                        YG
                                        Gend
                                        QG*Gend

                                        method
                                        Cut(method)
                                        QG*method
                                        Method*Gend/ ddfm=sat;
random ID(QG YG Gend);
repeated / group=qg;
lsmeans           QG
                                        YG
                                        Gend
                                        QG*Gend
                                        method
                                        Cut(method)
                                        QG*method
                                        QG*Gend ;
lsmeans  method Cut(method) / pdiff;
run;
```

```
proc mixed  covtest;
class QG YG Gend type Cut ID;
model dm0CUT =      QG
                                    YG
                                    Gend
                                    QG*Gend

                                    type
                                    Cut(type)
                                    QG*type
                                    type*Gend / ddfm=sat;
random ID(QG YG Gend);
*tried repeated / group = qg (BIC=734),cut (BIC=692), type (729.2);
repeated / group=qg;
lsmeans         QG
                                    YG
                                    Gend
                                    QG*Gend
                                    type
                                    Cut(type)
                                    QG*type
                                    QG*Gend ;
lsmeans  type Cut(type) / pdiff;
run;
```

```
Proc mixed;
Class CM DOD loin steak ;
Model  cp = steak /ddfm=SAT s ;
Random loin;
LSMeans steak / PDiff at means;
contrast 'PF linear' steak  -0.749269  0.0936586  0.6556101  0  0  0  0;
contrast 'PF quad' steak  0.3244428  -0.811107  0.4866643  0  0  0  0;
contrast 'grill linear' steak  0  0  0  -0.749269  0.0936586  0.6556101  0;
contrast 'grill quad' steak  0  0  0  0.3244428  -0.811107  0.4866643  0;
contrast 'DOD linear' steak  -0.749269  0.0936586  0.6556101  0.749269  -0.0936586
-0.6556101  0;
contrast 'DOD quad' steak  0.3244428  -0.811107  0.4866643  0.3244428  -0.811107
0.4866643  0;
contrast 'PFbyGRILL linear' steak  -0.749269  0.0936586  0.6556101  0.749269  -
0.0936586              -0.6556101  0;
contrast 'PFbyGRILL quad' steak   0.3244428  -0.811107  0.4866643  -0.3244428
0.811107       -0.4866643  0;
run;

proc sort data=PUR;
by  QG YG Gend Cut type ID;
proc means data=PUR noprint;
by  QG YG Gend Cut type type ID;
var dmPUR              ashPUR         cfPUR          protPUR;
output out=PURGE    n=    NdmPUR                  NashPUR       NcfPUR
         NprotPUR
                                                                mean= dmPUR
         ashPUR         cfPUR          protPUR;;
proc print;
run;
```

```
dm'output;clear;log;clear;';
proc mixed  covtest;
class QG YG Gend type Cut ID;
model cfPUR =          QG
                                    YG
                                    Gend
                                    QG*Gend

                                    type
                                    Cut(type)
                                    QG*type
                                    type*Gend / ddfm=sat;
random ID(QG YG Gend);
*tried repeated / group = qg (BIC=734),cut (BIC=692), type (729.2);
repeated / group=qg;
lsmeans          QG
                                    YG
                                    Gend
                                    QG*Gend
                                    type
                                    Cut(type)
                                    QG*type
                                    QG*Gend ;
lsmeans  type Cut(type) / pdiff;
run;
```

```
proc mixed  covtest;
class QG YG Gend type Cut ID;
model protCUT =       QG
                                    YG
                                    Gend
                                    QG*Gend

                                    type
                                    Cut(type)
                                    QG*type
                                    type*Gend / ddfm=sat;
random ID(QG YG Gend);
*tried repeated / group = qg (BIC=734),cut (BIC=692), type (729.2);
repeated / group=qg;
lsmeans          QG
                                    YG
                                    Gend
                                    QG*Gend
                                    type
                                    Cut(type)
                                    QG*type
                                    QG*Gend ;
lsmeans  type Cut(type) / pdiff;
run;
```

Other Helpful SAS code:

*Import and Export Data:*

```
proc import     out=work.SASname
          datafile="C:\Larry\Consulting
\FileName.xls"
          dbms=excel replace;
sheet="SheetName";
getnames=YES;
mixed=NO;
scantext=YES;
usedate=YES;
scantime=YES;
run;
```

```
proc export data=work.SASname
   outfile="C:\Larry\Consulting
\FileName &sysdate"
           dbms=excel replace;
sheet="SheetName";
run;
```