Effects of Backgrounding Crossbred Steers Implanted with Revalor XS on Carcass Characteristics and Fresh and Processed Beef Quality

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In loving memory of my Grandpa, Morris Chamberlain. I would not be where I am today if it was not for him. I will love you forever, Grandpa.

1951 – 2017

Abstract

The objective of this study was to determine how backgrounding beef cattle affects carcass characteristics, as well as fresh and processed beef quality. The impact of utilizing a moderate energy backgrounding diet was evaluated using 95 crossbred steers (initial body weight: 329.5 ± 16 kg) that were randomly assigned to 1 of 15 pens. Each pen was randomly assigned to one of two dietary treatments. Dietary treatments included a traditional high energy (HigE) finishing diet (n = 7) or a moderate energy (ModE) backgrounding diet (n = 8). HigE cattle were fed a high energy finishing diet for all 193 d; ModE cattle were fed the moderate energy diet for 63 d followed by 130 d the same as HigE. All steers received Revalor®-XS on d 1. Steers were weighed every 28 d. Upon completion of feeding treatment, steers were slaughtered at a commercial abattoir. Hot carcass weight (HCW), 12th rib backfat (BF), ribeye area (REA), marbling score, USDA Yield Grade, USDA Quality Grade, and percent kidney, pelvic, and heart fat (KPH) were recorded 48 h postmortem. Two steers were randomly chosen from each treatment pen for further meat evaluation. Strip loins (IMPS #180) were retrieved and first evaluated for vacuum purge loss and objective backfat color. The strip loins were then fabricated into 2.54 cm thick steaks for evaluation of drip loss, Warner-Bratzler shear force (WBSF), sensory evaluation, and subjective and objective color score evaluation. Shoulder clods (IMPS #114) were ground and evaluated for ground beef retail shelf life (objective and subjective color). Bologna was then made using the remaining ground beef and was evaluated for objective and subjective color, as well as sensory evaluation. Carcass and fresh meat data were analyzed using the mixed procedure of SAS® (Version 9.4) with treatment as a fixed effect and pen as a random effect. Pen was the experimental unit. Sensory data were analyzed using the mixed procedure of SAS® (Version 9.4) with treatment as a fixed effect and panelist as a random effect. Significance was determined at $p \leq 0.05$, while trends were determined at $p \leq 0.10$. There was no treatment effect on HCW (0.16), BF (P = 0.51), REA (P = 0.82), YG (P = 0.44), or KPH (P = 0.85). However, marbling was higher for HigE cattle (P = 0.02). For steaks, no moisture loss attributes differed between treatments: purge loss (P = 0.40), drip loss (P = 0.41) and cook loss (P = 0.71). Backfat a* (P = 0.43) and b* (P = 0.18) values were not affected by treatment, however, L* (P = 0.06) tended to be higher for HigE cattle. Warner-Bratzler shear force values of strip steaks did not differ between treatments (P = 0.72). There were no treatment effects for any of the steak subjective sensory attributes evaluated: overall liking (P = 0.85), flavor liking (P = 0.78), texture liking (P = 0.55), toughness (P = 0.45), juiciness (P = 0.76), and off-flavor (P = 0.40). Steak objective color score did not differ between treatments: L* (P = 0.39), a* (P = 0.55), and b* (P = 0.68). Steak subjective color (P = 0.11), discoloration (P = 0.21), and desirability (P = 0.10) scores also showed no differences between treatments. Ground beef objective color scores did not differ between treatments: L* (P = 0.41), a* (P = 0.51), b*(P = 0.49). Ground beef subjective color (P = 0.23), discoloration (P = 0.29), and desirability (P = 0.32) did not differ between treatments. Bologna objective L* (P = 0.18), a* (P = 0.98) and b* (P = 0.99) values did not differ between treatments. There was no difference in subjective color analysis for bologna samples: color (P = 0.78), discoloration (P = 0.61), desirability (P = 0.58). Sensory analysis for bologna found no differences in overall liking (P = 0.21), flavor liking (P = 0.36), texture liking (P = 0.49), toughness (P = 0.16), juiciness (P = 0.63), or off-flavor (P = 0.87). Overall, feeding a backgrounding diet before finishing led to similar carcass characteristics with a lower reliance on concentrate feed ingredients.

Keywords: backgrounding, beef quality

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Chapter 1

Review of Literature

Introduction

The United States is the largest producer of beef in the world – providing approximately 20% of the world's beef (USDA, 2018). With the rapidly decreasing number of small farms and rapidly increasing number of larger more specialized farms, and limited land and resources to sustain these large farms, there is a need to find cost effective ways to minimize waste and maximize production (USDA, 2017).

With rising feed costs already accounting for up to 70% of total production costs of livestock (Gunn and Schwab, 2016), there is opportunity to decrease feed costs and maximize feed efficiency. Corn is the biggest feed cost for finishing beef producers, averaging $167.31/head in 2017 (FINBIN, 2017). Other direct expenses for finishing beef herds include: veterinary care, fuel, repairs, hired labor, and trucking. Although these costs are significant in the function of Minnesota beef operations, the practice of backgrounding could provide opportunity to increase feed efficiency while decreasing total corn consumption.

Growth

Growth for a meat animal is characterized as an increase in size or mass of bone, skeletal muscle, or adipose tissue (Allen et al., 1979). There are two types of growth in the living animal, hyperplasia and hypertrophy. Hyperplasia is an increase in cell number, while hypertrophy is an increase in cell size (Allen et al., 1979). Cattle will experience both hyperplasia and hypertrophy throughout their various growing periods. Previous work proposed that hyperplasia and hypertrophy both occurred throughout the various growing periods of cattle (Di Marco et al., 1987). However, it is now accepted that hyperplasia occurs primarily early in life and hypertrophy occurs primarily later in life (Owens et al., 1993).

Even subtle changes in an animal's growth can directly impact its performance. One of the most useful measures of animal performance is average daily gain. Average daily gain is a direct reflection of the animal's ability to grow. Increasing the rate of the gain allows producers to raise more livestock within a given amount of time, which usually increases production efficiency. However, the composition of this gain, fat versus lean, can have a dramatic effect on profitability (Gerrand and Grant, 2003). Certain tissues grow and mature before others. Growth generally starts with bone, then muscle tissue, and finally adipose tissue (Gerrand and Grant, 2003). The development of each tissue can range throughout different locations on the animals' body. Fat, for example, generally deposits internally first, then intermuscularly, subcutaneously, and intramuscularly. Providing an animal with adequate nutrients during this progression is important in maintaining optimum growth rates (Owens et al., 1993). Muscle growth can be affected by predetermined factors, such as, genotype and age (Oddy et al., 2001), but can also be manipulated by nutrition (McGregor et al., 2012).

Grass Fed vs. Grain Fed

Historically, beef production in the United States has relied heavily on a forage-based system. However, beef production has transitioned into a heavily grain-based system. This change was due to the change in growth of the animal and the overall cost. Grain feeding rapidly increases the rate of gain of the animal while reducing the overall cost per unit of product. (Mathews and Johnson, 2013). Today, roughly 80% of beef produced in the United States comes from grain fed (conventional) cattle, with the other 20% coming from an alternative system, such as grass feeding.

Grass fed cattle are defined by the Grass Fed Small and Very Small Producer Program as cattle who have only consumed grass and forages, with the exception of milk, for the lifetime of the animal (USDA, 2016). The animal must also have continuous access to pasture during the growing season and cannot consume any grain. The animal can consume common feeds fed to cattle; such as, silage and haylage, as long as there is no grain within the feed (USDA, 2016). Grain fed cattle on the other hand have been given grain for the duration of their post weaned life. Comparatively, grass-fed beef has a higher price due to a longer feeding period, the amount of land that it takes to feed each animal, and the quality of forages that need to be grown on that land to provide the nutrients to finish cattle (Severe and Zobell, 2011). An alternative system, backgrounding, is currently investigated to consider how both grass and grain can be utilized to maximize production.

Backgrounding

Most commercial beef cattle are moved to a feedlot upon completion of the weaning or growing phase. However, it is becoming more common to extend the calves' weaning/growing phase by delaying the finishing phase and feeding a low energy diet for longer. Thus, the calves experience compensatory growth by prolonging skeletal and muscle growth and delaying the onset of fat deposition (Yambayamba and Price, 1991). Allowing more time for skeletal and muscle growth allows small and medium frame steers to reach a greater weight before depositing fat (Vaage et al., 1998). Owens et al. (1993) found that backgrounding lighter weight cattle will result in a more acceptable carcass weight, quality and lean yield. More specifically, backgrounding has been shown to increase lean tissue mass, while maintaining the same quality grades (Knoblich et al., 1997; Vaage et al., 1998; Klopfenstein et al., 2000). Backgrounding cattle requires the animal to be on feed for longer, but in turn can result in lower feed costs due to a lower percentage of grain utilized. On average, cattle will gain 45 to 181 kg during backgrounding. However, the amount of gain depends on the forages that are fed, the other ingredients in the ration, and the length of time that the animal is backgrounded (Comerford et al., 2001).

Compensatory Gain

Compensatory growth is a period of catch-up in which an animal's growth is accelerated, following a period of restricted development. This restricted development is most commonly due to reduced feed intake (Hornick et al., 2000). Compensatory gain is maximized when the length of the growth restriction is short and not severe. In cattle, the maximum length of growth restriction to provide maximum benefits is 3 months (Hornick et al., 2000). After this length of time, the amount of compensatory gain is decreased drastically. The age of the animal and the maturity of the animal at the time of feed restriction have a substantial impact on the amount of compensatory gain the animal is able to obtain.

Calves who go through a period of feed restriction are not likely to compensate for their nutritional set back. On the other hand, yearling cattle that are at least 300 kg can express compensatory growth and reach an ending weight similar to those of the same age and maturity that did not go through a period of feed restriction. Yearlings can exhibit compensatory growth with an additional gain of up to 1 kg/hd/day with no impact on meat quality (Jennings, 2014). Restricting intake during the growing period increases carcass leanness, increases feed efficiency, decreases rate of gain, and increases the time required for cattle to reach market weight (Plegge, 1986; Hicks et al., 1990; Murphy and Loerch, 1994).

Fox and Johnson (1972) and Rompala et al. (1985) found that cattle who experienced compensatory growth had a greater potential for lean tissue deposit. Similarly, Murphy and Loerch (1994) found that along with an increase in carcass lean, carcass water percentage also increased, while carcass fat percentage was decreased. They concluded that this increase in carcass lean mass and the decrease in fat content was due to the steers having reduced maintenance requirements.

Implants

Implants are a common way for producers to decrease production costs and increase efficiency. According to the USDA (2013), implanting cattle improves feed efficiency 8 to 12% and rate of gain 15 to 20%. Implants are small pellets containing hormones approved by the United States Food and Drug Administration (FDA). They are placed under the skin between the tip of the ear and the base of the back of the ear. Implants slowly release their active ingredients over a period of time (Lawton, 2013; USDA, 2013). By doing this, the implants increase the levels of somatotropin and insulin growth-factor 1 (IGF-1) within the animal, which in turn increases the secretion of growth hormone. An increase in growth hormone ultimately increases muscle growth (Lawton, 2013). Implants can also have negative effects, such as rectal and vaginal prolapses, buller steer syndrome, and decreased marbling scores and tenderness (USDA, 2013).

There are different implants that are approved for specific ages, sex and stages of production in cattle. No implants are approved for use in bulls in the United States. Regardless of age, sex and stage of production, about 90% of feedlot cattle are implanted at least once in their lifetime (USDA, 2013). Calves could potentially receive 4 to 6 implants throughout their lifetime if they are implanted on a regular basis until slaughter, however, steers and heifers are most commonly implanted 2 times (Lawton, 2013; USDA, 2013). The greatest gains are achieved when combination implants (estrogen and androgen) are used. Producers can expect gains of 6 to 14% when using combination implants. Lesser gains are achieved when estrogen only implants are used (Lawton, 2013). In general, implants will increase the size of a ribeye by 3 to 4% while decreasing marbling by 4% (Lawton, 2013). Implants will also result in a heavier carcass with similar amounts of back fat as carcasses that did not receive an implant (Lawton, 2013).

Most of the implants that have been on the market in recent years require a second implantation to reach maximum benefits. However, Wallace et al. (2008) found that on average cattle producers lose $1.78 per steer due to this re-implantation. Due to these losses, some producers will not re-implant their cattle and therefore will lose out on a portion of the benefit. To give the same effect as two implants while only having the cost associated with one, Revalor® XS is designed for feedlot cattle and provides two doses within one single implant (Merck, 2012).

Implanting with Revalor® XS, in comparison to Revalor® IS and Revalor® S implants, has shown no differences in DMI, BW, ADG, G:F, marbling score, 12^{th} rib fat thickness, LM area, or YG (Nichols et al., 2014). However, animals that were implanted with Revalor® XS had a lower proportion of USDA Select carcasses and a higher amount of low Choice carcasses than the other implants (Nichols et al., 2014). Contrarily, Prouty and Larson (2010) found that implanting with Synovex® Choice on day 0 and implanting with Synovex® Plus on day 70 resulted in a tendency for BW, ADG, G:F, and HCW to be improved over single implantation of Revalor® XS. These differences could be due to the different trenbolone acetate to estradiol ratios within these products. Revalor® XS, Revalor® IS, and Revalor® S all have a trenbolone acetate to estradiol ratios of 5:1, where the Synovex® Choice and Synovex® Plus implants have a ratio of 10:1. It has been found that a higher ratio of trenbolone acetate to estradiol will increase growth rates and feed conversion ratios (Herschler et al., 1995). It has also been found that there are no differences in carcasses from animals that were implanted with Revalor® XS, Synovex® One, or Synovex® Plus (McLaughlin et al., 2013).

Sensory Analysis

When consumers evaluate meat quality, the most important factors they evaluate are color, odor, flavor, texture, and toughness (Oddy et al., 2001). When buying meat, the consumer relies on appearance to determine if the steak, chop, or roast will be acceptable. However, once the steak is cooked, they care about the tenderness, juiciness, and flavor of the steak (Mancini, 2009). O'Quinn et al. (2018) found that overall palatability of beef is dependent equally on the acceptance of tenderness, juiciness, and flavor. Failure of just one of these factors will dramatically increase the likelihood of overall palatability failure, indicating that all three factors are of equal importance to overall palatability. Tenderness, juiciness, and flavor of beef can be influenced by both genetic and environmental factors. Species is the most important genetic factor and feed source is the most important environmental factor (Ford & Park, 1981; Shahidi & Rubin, 1986). Tenderness is one trait that can be influenced by species. For example, research has shown that meat from *Bos taurus* cattle was more tender than meat from *Bos indicus* cattle, regardless of the marbling score (Wheeler et al., 1994).

However, Killinger et al. (2004) found that consumers who purchase beef visually like the appearance of marbling and overall have a better eating experience of the beef when more marbling is present. This greater eating experience is associated with a premium that consumers will pay for a USDA Prime steak versus a USDA Choice steak. However, in Germany and Spain a higher degree of marbling is seen as a negative attribute of meat quality (Grunert, 1997).

Color

Color is the most important factor that consumers use when buying fresh meat (Verbeke et al., 2005; Ngapo et al., 2007; Gracia and De-Magistris, 2013). Consumers will use meat color to predict how desirable their eating experience will be (Banović et al., 2012), even though meat color does not always truly represent eating satisfaction. For example, consumers will perceive a purple or red color as a fresh and desirable steak, while they perceive a brown color as a steak with a lack of freshness (Carpenter et al., 2001). Although consumers will look at color as a primary indicator of meat quality, consumer perception of color varies internationally.

There are many factors that determine the color of meat. Some of the factors that can affect the pigment of the meat include animal genetics, ante mortem conditions, post mortem conditions, fundamental muscle chemistry, packaging, distribution, storage, display, and final preparation for consumption (Mancini and Hunt, 2005).

Feeding a higher forage diet will decrease L* values and ultimately result in a darker colored steak (Duckett et al., 2007). In addition to a darker colored steak, Yang et al. (2002) and Duckett et al. (2007) also found that beef cattle fed on pasture had lower a* values and were ultimately less red than steaks from beef cattle fed a concentrate diet. Yang et al. (2002) also found that these differences in redness on fresh steaks disappeared after the meat was aged.

Flavor

"Beef flavor consists of multiple attributes, including general categories of flavor aromatics, basic tastes, feeling factors and aftertastes as similarly seen for other foods" (Adhikari et al., 2011). Beef flavor and aroma can be complex to study since they are formed by hundreds of volatile compounds that can be altered through storage and cooking (Calkins and Hodgen, 2007). The *infraspinatus* muscle and the muscles of the rib and loin primals of similar maturity carcasses have the highest flavor desirability scores (McKeith et al., 1985).

Since flavor is complex to study, there have been multiple studies evaluating the different components of beef flavor (Johnson and Civille, 1986). Although it is important to consider all of the components of beef flavor that drive consumer acceptance, "overall flavor" is a broad descriptor commonly used early to determine if further evaluation is warranted. Multiple studies have considered "overall flavor" and how treatments affect this attribute (Carmack et al., 1997; Baublits et al., 2006; Rowe et al., 2009; Hayes et al., 2010). In 1996, Miller et al. found that dietary grain source fed to steers did not affect flavor. Studies have also compared the flavor of grain-fed and grass-fed beef. Data suggests that grain-fed beef is more favorable and has less off flavor than grass-fed beef

(Davis et al., 1981; Larick et al., 1987; Berry et al., 1988; Duckett et al., 2007; Maughan et al., 2012). A noted difference between grass-fed beef and grain-fed beef is the amount of collagen within the meat (Gagaoua et al., 2018).

Tenderness

Tenderness is one of the most important attributes when evaluating eating experience of beef. Consumers are willing to pay a premium price for a tender steak, and 78% of consumers studied would purchase steaks if they were guaranteed to be tender (Miller et al., 2001). Tenderness is the psychological response to physical-chemical stimuli caused by mastication (Bailey, 1964). Tenderness is assessed as soon as the first bite is taken from the sample. The amount of myofibrillar and connective tissue along with muscle location and cooking temperature of each sample will change the panelists' perception of the tenderness between samples (Cover et al., 1962). Although total collagen content can be increased in cattle fed on pasture (Archile-Contreras et al., 2010), research has shown that tenderness and Warner-Bratzler shear force values were not different in cattle fed concentrate diets or pasture diets (Duckett et al., 2007). In contrast, Martz (1996) found that beef shear force values increased in forage fed cattle when compared to grain fed cattle. It was also found that shear force values between grain fed and grass fed cattle become equal by aging the meat for 3 weeks. Although previous work has shown varying shear force values between cattle fed concentrate diets or pasture diets, sensory studies have shown higher tenderness ratings for cattle finished on grain than cattle finished on forage (Davis et al., 1981; Berry et al., 1988). However, Miller et al. (1996) found that dietary grain source fed to steers did not affect tenderness.

Juiciness

Juiciness of meat can be influenced by many pre-harvest factors, such as breed, finishing diet and market weight (Thompson, 2004). Juiciness can also be influenced by post-harvest factors, such as pH, aging, freezing and packaging (Kim, 2015). Even with all of the factors that affect juiciness of beef, consumers typically associate marbling with juiciness when purchasing fresh retail cuts. However, as intramuscular fat increases to 15 to 20 percent, panelists no longer see an increase in juiciness (Thompson, 2004).

Conclusion

Rising feed costs already account for up to 70% of production costs, which is why finding ways to maximize feed efficiency is essential in the future of the beef industry. Backgrounding cattle could potentially help producers by providing the same quality beef while utilizing less concentrate ingredients and, therefore, decreasing overall beef production costs.

Chapter 2

Effects of Backgrounding Crossbred Steers Implanted with Revalor XS on Carcass Characteristics and Fresh and Processed Beef Quality

Introduction

The United States is the largest producer of beef in the world – providing about 20% of the worlds beef (USDA, 2018). With the rapidly decreasing number of smaller farms and the rapidly increasing number of larger more specialized farms and having limited land and resources to sustain these large farms, there is a need to find cost effective ways to maximize production (USDA, 2017). Rising feed costs already account for up to 70% of total production costs of livestock (Gunn and Schwab, 2016). Corn is the biggest feed cost for finishing beef, averaging $167.31/head in 2017 (FINBIN, 2017). Backgrounding has been used as a management practice to increase feed efficiency and decrease feed costs by feeding an overall lower amount of concentrate ingredients.

Backgrounding extends the calves' weaning/growing phase by delaying the finishing phase and feeding a low energy diet for longer. By feeding a lower energy diet for longer, the calves are able to experience compensatory growth by prolonging skeletal and muscle growth and delaying the onset of fat deposition (Yambayamba and Price, 1991). Allowing more time for skeletal and muscle growth allows small and medium frame steers to reach a greater weight before depositing fat (Vaage et al., 1998). Owens et al. (1993) found that backgrounding lighter weight cattle will result in a more acceptable carcass weight, quality and lean yield. More specifically, backgrounding has been shown to increase lean tissue mass, while maintaining the same USDA Quality Grades (Knoblich et al., 1997; Vaage et al., 1998; Klopfenstein et al., 2000). Backgrounding cattle requires the animal to be on feed for longer, but in turn can result in lower feed costs due to a lower amount of grain fed if managed properly (Berger et al., 2011). On average, cattle will gain 45 to 181 kg while being backgrounded. However, the amount of gain depends on the forages that are fed, the other ingredients in the ration, and the length of time that the animal is backgrounded (Comerford et al., 2001).

Therefore, the objective of the current study is to determine the effects of feeding a backgrounding diet to crossbred steers implanted with Revalor® XS on carcass characteristics and fresh and processed beef quality.

Materials and Methods

Dietary Treatments

All experimental procedures were approved by the University of Minnesota Animal Care and Use Committee (1709-35150A). Animals were housed and fed at the University of Minnesota Beef Research and Education Complex (Rosemount Research and Outreach Center) located in Rosemount, Minnesota, USA.

Ninety-five crossbred steers (initial body weight: 329.5 ± 16 kg) were randomly assigned to one of fifteen pens. Each pen was randomly assigned to one of two dietary treatments (Table 1). Dietary treatments included a traditional high energy (HigE) finishing diet (n = 7) or a moderate energy (ModE) backgrounding diet (n = 8). Cattle on HigE were fed a high energy finishing diet for all 193 d; those fed ModE were fed the moderate energy diet for 63 d followed by feeding the HigE diet for the last 130 d. Both diets were formulated on a dry matter basis (%DM). The HigE diet was composed of 38.3% corn silage, 17.4% high moisture corn, 20.5% dried distillers grains and solubles (DDGS), 18.2% dry rolled corn, and 5.7% liquid supplement. The ModE diet was composed of 9.9% corn silage, 59.0% high moisture corn, 13.2% dried distillers grains and solubles (DDGS), 14.0% dry rolled corn, and 3.9% liquid supplement. The vitamin and mineral supplement that was fed to all cattle contained Rumensin-90 at 400g/ton. All steers received Revalor®-XS on d 1.

Carcass Data Collection

After 193 days on feed (DOF) all animals were transported to a commercial abattoir (Iowa Premium Beef., Tama, IA) and were humanely harvested. Carcasses were evaluated for hot carcass weight (HCW), 12^{th} rib backfat (BF), ribeye area (REA), marbling score, USDA Yield Grade, USDA Quality Grade and percent kidney, pelvic, and heart fat (KPH) 48 h postmortem. USDA Yield and Quality grades were evaluated by a USDA grader. Two steers were randomly chosen from each pen for further evaluation of fresh and processed beef. Strip loins (IMPS #180) and shoulder clods (IMPS #114) were fabricated from the right side of each carcass and identified by numbers using food grade ink. The strip loins and shoulder clods were vacuum sealed, boxed, and held for 24 hours in accordance with the mandatory hold period practiced by the commercial abattoir.

Strip loins and shoulder clods were transported to the Andrew Boss Lab of Meat Science (ABLMS) on the University of Minnesota, St. Paul campus. All seals were checked on the packages and resealed if necessary. Shoulder clods were frozen at 80 hours postmortem in a blast freezer at -20°C and stored until further evaluation. Strip loins were processed at 90 hours postmortem.

Strip Loin Preparation and Backfat Color

Strip loins were first evaluated for vacuum purge loss and objective backfat color. Vacuum sealed strip loins were weighed, vacuum sealed bags were removed, and strip loins and vacuum bags were patted dry with a paper towel (Bounty® paper towels, Procter & Gamble Company, Cincinnati, OH). The dried strip loins and vacuum bags were reweighed to calculate vacuum purge loss.

Vacuum Purge Loss (VPL) % = [(initial weight – dry weight – package weight) / initial weight] x 100

Backfat color was measured by objective L*, a*, and b* measurements at three locations on each strip loin using a spectrophotometer (HunterLab Miniscan EZ, Hunter Associates Laboratory Inc., Reston, VA). The strip loins were then serially cut, using an automatic slicer (MHS Schneidetechnik GMBH, Abstatt, Germany), into eight 2.54 cm steaks from the anterior end of each strip loin. The first and second steaks serially were evaluated for drip loss, the third and fourth steaks for retail shelf life color analysis, the fifth and sixth steaks for cook loss and Warner-Bratzler shear force (WBSF), and the seventh and eighth steaks for sensory analysis. The two strip steaks that were designated for drip loss were weighed and suspended in an isolated environment at 2°C. After 24 hours, the steaks were reweighed to calculate drip loss percentage.

Drip Loss (DL) % = [(initial weight – final weight) / initial weight] x 100

The remaining strip loin was vacuum packaged, frozen and stored at -20°C.

Warner-Bratzler Shear Force (WBSF)

Two strip steaks were weighed using a digital scale (A & D company, Limited, San Jose, California), wrapped in aluminum foil, and cooked (Whirlpool RF263CXTB, Benton Harbor, Michigan) at 177°C to an internal temperature of 71°C. Temperature was measured using a temperature probe (Thermoworks Super-Fast Thermopen, American Fork, Utah) at the geometric center of the steak. Foil was then removed and the steaks were cooled to room temperature, patted dry, and re-weighed to calculate cook loss percentage.

$$\text{Cook Loss (CL) \%} = [(\text{raw weight} - \text{cooked weight}) / \text{raw weight}] \times 100$$

The steaks were then refrigerated for 24 hours at 2°C, tempered to room temperature (25°C) for one hour and trimmed to include only the *longissimus dorsi* muscle. Six cores (1.27 cm in diameter) were removed from the steaks in a parallel angle to the muscle fiber direction within the steak using a hand corer. Each core was then sheared perpendicular to the fiber direction using a texture analyzer with a WBSF attachment set to a test speed of 100 mm/min (Shimatzu Texture Analyzer, Kyoto, Japan). The average of all six cores was taken as a representation of the tenderness of the entire loin.

Fresh Steak Retail Shelf Life

Two steaks were placed onto polystyrene trays and overwrapped with polyvinylchloride (PVC) film and stored under cool white florescent lights (Sylvania H968, 100w, 2, 640 LUX) at 2°C for eight days. Objective L*, a*, and b* values were taken every 24 hours at three locations on each steak using a spectrophotometer (HunterLab Miniscan EZ, Hunter Associates Laboratory Inc., Reston, VA).

In addition to objective color values, a trained human panel (n = 8) was used to evaluate subjective scores for lean color, surface discoloration, and overall desirability of the two steaks based on the American Meat Science Association (AMSA) 2012 guidelines for meat color measurement. Panelists evaluated the samples every 24 hours for eight days. Lean color was scored on a scale of 1 to 8 with 1 being extremely brown and 8 being extremely bright, cherry red. Surface discoloration was scored on a scale of 1 to 11 with 1 being 91-100% discoloration and 11 being 0% discoloration. Overall desirability was scored on a scale of 1 to 8 with 1 being extremely undesirable and 8 being extremely desirable.

Steak Sensory Evaluation

One hundred and twenty one panelists were recruited by the University of Minnesota Food Science and Nutrition Sensory Center in St. Paul, Minnesota to participate in steak sensory evaluation. Panelists were at least 18 years old, had no food allergies or sensitivities, and had consumed cook beef steak within the last month. The University of Minnesota Institutional Review Board approved the procedures used for recruiting and utilizing human subjects for consumer panel evaluation of sensory attributes. Participants were compensated for their time.

Two steaks per steer were thawed at 2°C for 48 hours, individually wrapped in aluminum foil, and cooked to an internal temperature of 71°C using a standard electric range (General Electric JBP23DR3BB, Louisville, Kentucky) heated to 177°C. Temperature was measured using a temperature probe (Thermoworks Super-Fast

Thermopen, American Fork, Utah) at the geometric center of the steak. Steaks were then trimmed to include only the *longissimus dorsi* muscle. The *longissimus dorsi* muscle was then cut into cubes (1.27 cm x 1.27 cm x 2.54 cm) using a sensory sample sizer for steaks (AMSA, 2015). Once cubed, the samples were placed into an electric warmer (Nostalgia Products Group, LLC, BCD-992, Green Bay, Wisconsin) to keep the samples warm prior to distribution to panelists. Samples were stored in the warmer for no longer than 1 hour to avoid the samples drying out.

Each panelist was given two pieces of steak per sample in lidded 2 oz. plastic soufflé cups that were placed into insulated foam trays to help maintain sample temperature throughout the panelists' evaluation period. The samples served to participants were balanced for order and carryover effects. Participants were asked to evaluate the first sample for overall liking, flavor liking and texture liking. Participants were then asked to consume the second sample and rate the toughness, juiciness, and off flavor intensity. A 120 point Labeled Affective Magnitude (LAM) scale was utilized for the liking ratings, with the far left end labeled as *greatest imaginable disliking* and the far right end labeled as *greatest imaginable liking*. A 20 point line scale was utilized for the intensity ratings, with the far left end labeled as *none* and the far right ends labeled as *extremely intense* for off flavor, *extremely tough* for toughness, and *extremely juicy* for juiciness.

Shoulder Clod Preparation and Ground Beef Retail Shelf Life

Shoulder clods were thawed at 2°C for 7 days, then ground twice (Hobart 4156, Hobart Corporation, Troy, OH) through a 0.375 cm plate. Two samples of ground beef (227 g) per clod were utilized for ground beef retail shelf life. Ground beef samples were placed on polystyrene trays with polyvinylchloride (PVC) overwrap and stored under cool white florescent lights (Sylvania H968, 100w, 2, 640 LUX) at 2°C for eight days. Objective L*, a*, and b* values were taken every 24 hours at three locations on each sample using a spectrophotometer (HunterLab Miniscan EZ, Hunter Associates Laboratory Inc., Reston, VA).

In addition to objective color values, a trained panel (n = 10) evaluated subjective scores for lean color, surface discoloration, and overall desirability of the samples based on the American Meat Science Association (AMSA) 2012 guidelines for meat color measurement. Panelists evaluated the samples daily for eight days. Lean color was scored on a scale of 1 to 8 with 1 being extremely brown and 8 being extremely bright, cherry red. Surface discoloration was scored on a scale of 1 to 11 with 1 being 91-100% discoloration and 11 being 0% discoloration. Overall desirability was scored on a scale of 1 to 8 with 1 being extremely undesirable and 8 being extremely desirable.

Bologna Preparation

Random samples of ground clod from 3 animals per treatment were combined to create a 11.34 kg meat block that was mixed with a bologna seasoning blend and 1.13 kg ice. The mixture was then emulsified using a bowl chopper (Alipina, PB 80-890-II Gossau S G Switzerland, Speed setting 2, 3-knife head with Alipina tangential form blades) until batter reached 10°C. The batter was then stuffed into inedible collagen casings (Bologna 10.8 cm Walsrober Casings, Mar/Co Sales, Burnsville, MN) using a vacuum stuffer (Handtmann VF-608, Albert Handtmann Maschimen Fabrik GmbH & Co., Biberach, Germany). The stuffer was rinsed after each batch and was sanitized between treatments to prevent cross contamination of samples and treatments. Stuffed bologna links were hung on a standard smokehouse truck, placed into a commercial smokehouse (ALKAR 1000 Food Processing Oven, ALKAR RapidPak-Inc., Lodi, Wisconsin), and cooked to an internal temperature of 65.5°C. Temperature was measured using a thermocouple placed into the geometric center of the bologna link. Bologna was then removed from the smoke house, cooled at 2°C for 24 hours, and sliced using a deli slicer (Berkel Corporation 909, Laporte, Indiana) to a thickness of 4 mm.

Bologna Retail Shelf Life

Two slices of bologna from each link were utilized for retail shelf life evaluation. Slices were individually placed onto polystyrene trays, vacuum packaged (3 ml standard barrier, Bunzl PD, North Kansas City, MO), and stored at 2°C for ten days under cool white florescent lights (Sylvania H968, 100 w, 2, 640 LUX). Objective L*, a*, and b* values were taken every 24 hours at three locations on each sample using a spectrophotometer (HunterLab Miniscan EZ, Hunter Associates Laboratory Inc., Reston, VA).

In addition to objective color evaluation, a trained human panel (n = 10) was used to evaluate subjective scores for lean color, surface discoloration, and overall desirability of the samples based on the American Meat Science Association (AMSA) 2012 guidelines for meat color measurement. Panelists evaluated the samples every 24 hours for eight days. Lean color was scored on a scale of 1 to 8 with 1 being extremely dark red or brown and 8 being a light pinkish cured color. Surface discoloration was scored on a scale of 1 to 11 with 1 being 91-100% discoloration and 11 being 0% discoloration. Overall desirability was scored on a scale of 1 to 8 with 1 being extremely undesirable and 8 being extremely desirable.

Bologna Sensory Evaluation

One hundred and eight panelists were recruited by the University of Minnesota Food Science and Nutrition Sensory Center to participate in bologna sensory evaluation. Panelists were at least 18 years old, had no food allergies or sensitivities, and had consumed bologna or other beef products at least once per month. The University of Minnesota Institutional Review Board approved the procedures used for recruiting and utilizing human subjects for consumer panel evaluation of sensory attributes. Participants were compensated for their time.

Slices of bologna were divided into eight pieces and stored in refrigerated conditions until they were served to panelists. Each panelist was given two pieces of bologna per sample in lidded 60 ml plastic soufflé cups. The samples served to participants were balanced for order and carryover effects. Participants were asked to evaluate the first sample for overall liking, flavor liking and texture liking. Participants were then asked to consume the second sample and rate the toughness, juiciness, and off flavor intensity. A 120 point Labeled Affective Magnitude (LAM) scale was utilized for the liking ratings, with the far left end labeled as *greatest imaginable disliking* and the far right end labeled as *greatest imaginable liking*. A 20 point line scale was utilized for the intensity ratings, with the far left end labeled as *none* and the far right ends labeled as *extremely intense* for off flavor, *extremely tough* for toughness, and *extremely juicy* for juiciness.

Statistical Analysis

Carcass data were analyzed using the PROC GLIMMIX procedure of SAS (SAS Inst, Inc., Cary, NC. Version 9.4). Treatment was included in the model as a fixed effect and pen was included as a random effect. Initial body weight was used as a covariate for hot carcass weight (HCW). Pen was the experimental unit.

Fresh and processed beef quality data was analyzed using the PROC MIXED procedure of SAS (SAS Inst, Inc., Cary, NC. Version 9.4). Treatment was included in the model as a fixed effect and pen was included as a random effect. For retail shelf life color evaluation, treatment, day, and treatment by day interactions were included as fixed effects and day was evaluated as a repeated measure.

Sensory data was analyzed using the PROC MIXED procedure of SAS (SAS Inst, Inc., Cary, NC. Version 9.4). Treatment was included in the model as a fixed effect and panelist was included in the model as a random effect.

Significance was determined at an alpha value of 0.05 or below, and an alpha value less than 0.1 indicated a trend within the data. For data with a significant P- value, ANOVA and corrections for multiple comparisons were evaluated using the PDIFF function within LSMEANS.

Results and Discussion

Carcass Data

There was no treatment effect for hot carcass weight (P = 0.16), 12^{th} rib backfat (P = 0.51), ribeye area (P = 0.83), USDA Yield Grade (P = 0.44), USDA Quality Grade (P = 0.06) or kidney, pelvic, and heart fat (P = 0.85). However, marbling was higher for HigE cattle (P = 0.02; Table 2). Similarly, previous studies have found that backgrounding cattle did not impact hot carcass weight (Wright and Russel, 1991; Knoblich et al., 1997; McGregor et al., 2012). In addition, Knoblich et al. (1997) saw no differences in ribeye area or USDA Quality Grade, but in contrast did see a decrease in 12^{th} rib backfat, KPH, and USDA Yield Grade in cattle that were backgrounded, compared to traditionally finished beef cattle.

Backfat Color Evaluation

Backfat a* (P = 0.43) and b* (P = 0.18) values did not differ between treatments, however, L* values (P = 0.06) tended to be higher for HigE cattle (Table 3). In contrast, Realini et al. (2004) found that pasture finished cattle had higher L* values than cattle that were finished with concentrate and supplemented with vitamin E. Since all of the cattle in the current study were supplemented with the required vitamins, it is possible that the differences in L* could be due to moisture. The main concern when evaluating backfat color of beef cattle fed different dietary treatments is the yellowness that can develop from feeding non-concentrate ingredients. However, these cattle did not develop any yellowness (b*) to their fat from the lower concentrate backgrounding because of the short amount of time that the dietary treatments differed. Also, having a longer period of common diets after treatment could have driven fat color to a more common color between the two treatments.

Moisture Loss

No moisture loss attributes differed between treatments for purge loss (P = 0.40), drip loss (P = 0.41) or cook loss (P = 0.71; Table 4). McGregor et al. (2012) also found that drip loss was not affected by dietary treatment, but in contrast, found that cook loss was affected by dietary treatments. However, similarly, Kerth et al. (2007) found that cook loss was not impacted by dietary treatment. It was expected that no moisture loss attributes would differ between treatments due to no evidence of a change in pH between samples.

Warner-Bratzler Shear Force (WBSF)

Warner-Bratzler shear force values did not differ between treatments (P = 0.72; Table 4). Increasing the rate of growth prior to slaughter has been shown to increase beef tenderness (Aberle et al., 1981; Purchas et al., 2002). However, (Muir et al., 2001), in agreement with the current study, suggested that moderate frame cattle experiencing compensatory gain after a period of restriction will have no effects on meat tenderness.

Fresh Steak Retail Shelf Life

The subjective panel could not tell a difference in color (P = 0.11; Figure 1), desirability (P = 0.10; Figure 2), or discoloration (P = 0.21; Figure 3) between the two dietary treatments. Objective color score also did not differ between the two treatments: L* (P = 0.39; Figure 4), a* (P = 0.55; Figure 5), and b* (P = 0.68; Figure 6). McGregor et al. (2012) similarly found that backgrounding had no effect on L* or a* values, but in contrast found that b* values were lower for cattle that were backgrounded compared to those that were traditionally fed grain. It has also been shown that pasture fed cattle will have a greater color stability than cattle fed grain based diets (Lanari et al., 2002).

Steak Sensory Evaluation

There were no treatment effects for any of the steak subjective sensory attributes evaluated, including overall liking (P = 0.85), flavor liking (P = 0.78), texture liking (P = 0.55), toughness (P = 0.45), juiciness (P = 0.76), or off-flavor (P = 0.40; Table 5). No differences found in toughness is in agreement with the Warner-Bratzler shear force results. Hedrick et al. (1983) also found there to be no sensory differences in beef from cattle that were fed grain for longer periods of time versus shorter periods of time. Melton et al. (1982) found that beef flavor changes very little if cattle are finished on corn for longer than 80 to 90 days. Since the cattle that were backgrounded in the current study were finished on corn for slightly less than 80 days, this could account for lack of differences between dietary treatments.

Ground Beef Retail Shelf Life

Ground beef subjective color (P = 0.23; Figure 7), desirability (P = 0.32; Figure 8) and discoloration (P = 0.29; Figure 9) did not differ between treatments. Ground beef objective color scores did not differ between treatments for L* (P = 0.41; Figure 10), a* (P = 0.51; Figure 11), b* (P = 0.49; Figure 12). Similarly, (Realini et al., 2004) found that finishing diet had no impact on L*, a* or b* values of ground beef.

Bologna Retail Shelf Life

There were no differences in subjective color analysis for bologna color (P = 0.78; Figure 13), desirability (P = 0.58; Figure 14), and discoloration (P = 0.61; Figure 15). Objective L* (P = 0.18; Figure 16), a* (P = 0.98; Figure 17), and b* (P = 0.99; Figure 18) values did not differ between treatments. These results were expected as color loss in bologna is largely accelerated by lipid oxidation (Erdman and Watts, 1957) and treatments did not affect composition or quality of the fat due to the same finishing diet that was fed for remaining 130 days of the finishing period. Although there are very few studies that have evaluated how dietary treatments affect processed meat color, previous work has been done on various feed additives, such as Vitamin E, and how they affect the color stability of fresh products. For example, Ripoll et al. (2013) found that feeding lambs Vitamin E for a short period before slaughter decreased lipid oxidation of the meat. Similarly, Arnold et al. (1993) found that shelf life was extended 2 to 5 days when Vitamin E was fed for 252 days prior to slaughter in Holstein and beef breed steers.

Bologna Sensory Evaluation

Sensory analysis for bologna found no differences in overall liking (P = 0.21), flavor liking (P = 0.36), texture liking (P = 0.49), toughness (P = 0.16), juiciness (P = 0.63), or off-flavor (P = 0.87; Table 6). Since bologna is an emulsified product and the human visual panel detected no visible differences in bologna during shelf life, it was assumed likely that there would be no sensory differences between the dietary treatments. Although there are very few studies considering how dietary treatments affect the sensory properties of processed beef, previous work has been done on various feed additives, such as Vitamin E, and how they affect the tenderness, juiciness, meat flavor intensity and off-flavor intensity of fresh beef (Arnold et al., 1993).

Conclusion

Feeding a backgrounding diet before finishing can lead to similar carcass characteristics with a lower reliance on concentrate feed ingredients. Backgrounded cattle also have similar fresh and processed beef qualities but could be compromised at the retail display case with marbling scores being higher for cattle that were not backgrounded.

Table 1. Dietary treatment composition in percent dry matter (DM) of cattle fed different dietary energy during backgrounding

	Treatment[1]	
Item	ModE	HigE
Ingredient, % DM basis		
Corn silage	38.3	9.9
High moisture corn	17.4	59.0
Dried distillers grains w/solubles	20.5	13.2
Dry rolled corn	18.2	14.0
Liquid supplement*	5.7	3.9
Nutrient composition		
DM, %	52.08	64.51
NDF, %	22.27	13.15
Fat, %	4.09	3.94
Crude protein, %	15.34	13.85
NEg, Mcal/kg	1.28	1.41

[1]ModE = moderate energy diet fed for initial 63 d; HigE = high energy diet fed during initial 63 d and finishing phase.

*Contains Rumensin-90 at 400g/ton (Rumensin, Elanco Animal Health, Greenfield, IN)

Table 2. Beef carcass data of cattle fed different dietary energy during backgrounding

	Treatment*			
	ModE	HigE	SEM	P-Value
Hot Carcass Wt., kg	384	376	5.43	0.163
REA, sq. cm	85.81	85.29	2.26	0.825
12th Rib Backfat, cm	1.72	1.78	0.10	0.511
Yield Grade[1]	3.1	3.0	0.10	0.442
Quality Grade[2]	2.1	2.4	0.17	0.056
Marbling Score[3]	440[a]	486[b]	19.69	0.022

[ab] Different letters within each row denote significant differences ($P < 0.05$)

[1]Yield Grade: 1 to 5 where 1 = high yielding carcasses and 5 = low yielding carcasses

[2]Quality Grade: 1 = Select, 2 = Low Choice, 3 = Average Choice, 4 = High Choice, 5 = Prime

[3]Marbling Score: 300 = Slight, 400 = Small, 500 = Modest, 600 =Moderate, 700 = Slightly Abundant, 800 = Moderately Abundant, 900 = Abundant

*ModE = moderate energy diet fed for initial 63 d; HigE = high energy diet fed during initial 63 d and finishing phase.

Table 3. Twelfth rib fat color of cattle fed different dietary energy during backgrounding

	Treatment[1]			
	ModE	HigE	SEM	P-Value
L*	64.95	72.15	3.43	0.062
a*	5.62	4.79	1.02	0.434
b*	16.07	17.52	1.00	0.176

[ab] Different letters within each row denote significant differences ($P < 0.05$)

[1]ModE = moderate energy diet fed for initial 63 d; HigE = high energy diet fed during initial 63 d and finishing phase.

Table 4. Vacuum purge, drip loss, cook loss, and Warner-Bratzler Shear Force (WBSF) of cattle fed different dietary energy during backgrounding

	Treatment*			
	ModE	HigE	SEM	P-Value
Purge Loss, %	0.95	1.19	0.28	0.402
Drip Loss, %	0.60	0.73	0.15	0.406
Cook Loss, %	25.51	25.03	1.24	0.707
WBSF, kgf	1.53	1.56	0.07	0.722

[ab] Different letters within each row denote significant differences ($P < 0.05$)

*ModE = moderate energy diet fed for initial 63 d; HigE = high energy diet fed during initial 63 d and finishing phase.

Table 5. Fresh steak sensory characteristics of cattle fed different dietary energy during backgrounding

	Treatment*			
	ModE	HigE	SEM	P-Value
Overall Liking	74.81	75.24	2.22	0.847
Flavor Liking	75.98	75.30	2.42	0.779
Texture Liking	73.89	75.47	2.64	0.550
Toughness	8.73	8.31	0.56	0.453
Juiciness	7.24	7.40	0.54	0.761
Off-flavor	4.95	5.50	0.64	0.398

[ab] Different letters within each row denote significant differences ($P < 0.05$)

*ModE = moderate energy diet fed for initial 63 d; HigE = high energy diet fed during initial 63 d and finishing phase.

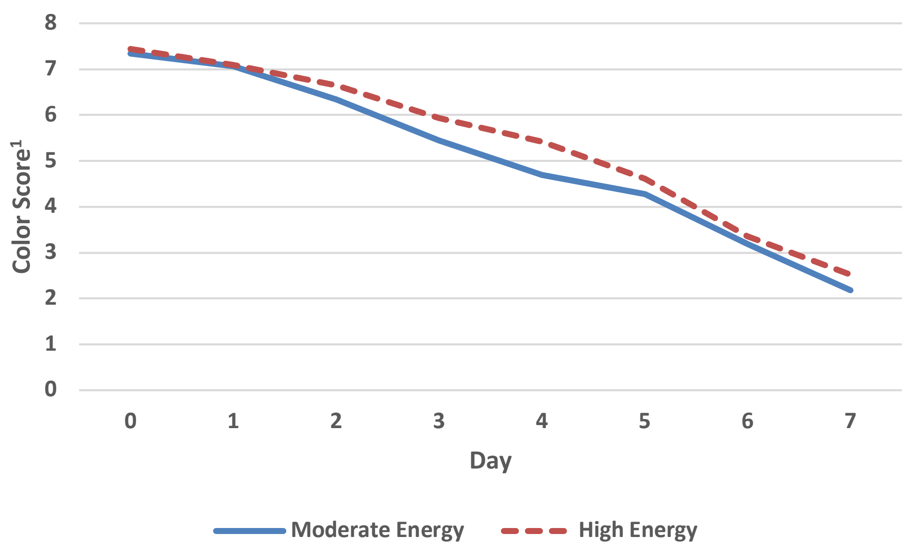
Table 6. Bologna sensory characteristics of cattle fed different dietary energy during backgrounding

	Treatment*			
	ModE	HigE	SEM	P-Value
Overall Liking	75.59	77.48	1.50	0.208
Flavor Liking	75.15	76.67	1.66	0.362
Texture Liking	75.24	76.33	1.58	0.488
Toughness	5.87	5.27	0.42	0.155
Juiciness	6.80	6.61	0.41	0.630
Off-flavor	4.57	4.49	0.45	0.868

[ab] Different letters within each row denote significant differences ($P < 0.05$)

*ModE = moderate energy diet fed for initial 63 d; HigE = high energy diet fed during initial 63 d and finishing phase.

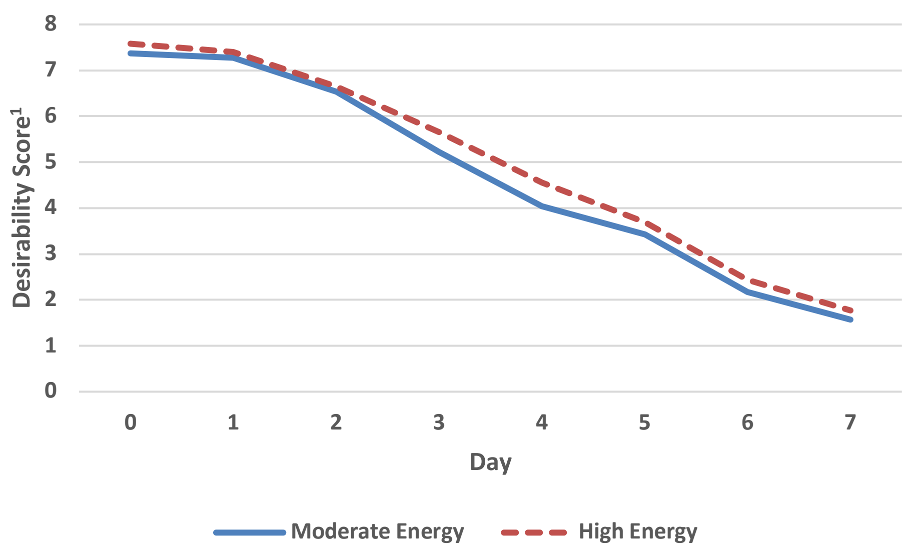
Figure 1. Lean color scores of fresh steaks from cattle fed different dietary energy during backgrounding



*Moderate energy diet fed for initial 63 d; high energy diet fed during initial 63 d and finishing phase.

[1]Color Score: 1 = Extremely Brown, 2 = Very Brown or Green, 3 = Moderately Brown or Green, 4 = Slightly Brown or Green, 5 = Slightly Bright Cherry Red, 6 = Moderately Bright Cherry Red, 7 = Very Bright Cherry Red, 8 = Extremely Bright Cherry Red

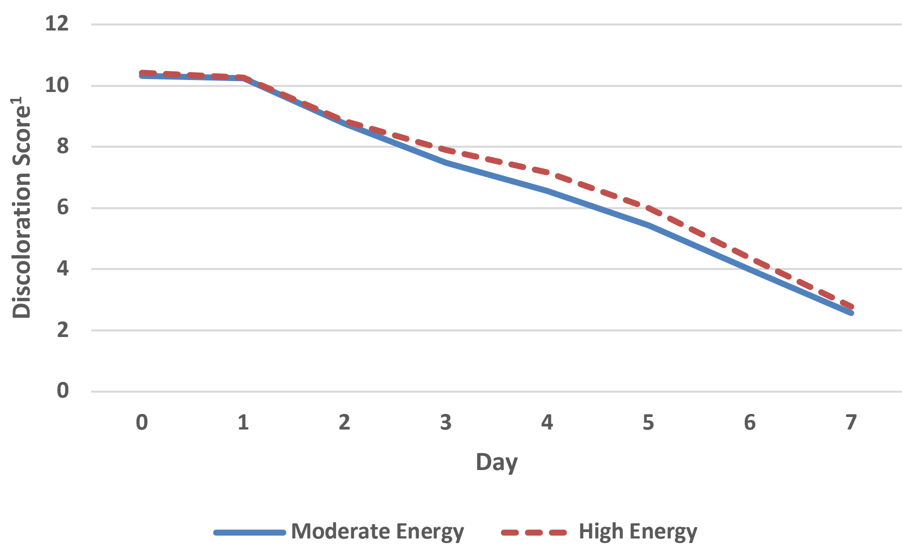
Figure 2. Desirability scores of fresh steaks from cattle fed different dietary energy during backgrounding



*Moderate energy diet fed for initial 63 d; high energy diet fed during initial 63 d and finishing phase.

[1]Desirability Score: 1 = Extremely Undesirable, 2 = Very Undesirable, 3 = Moderately Undesirable, 4 = Slightly Undesirable, 5 = Slightly Desirable, 6 = Moderately Desirable, 7 = Very Desirable, 8 = Extremely Desirable

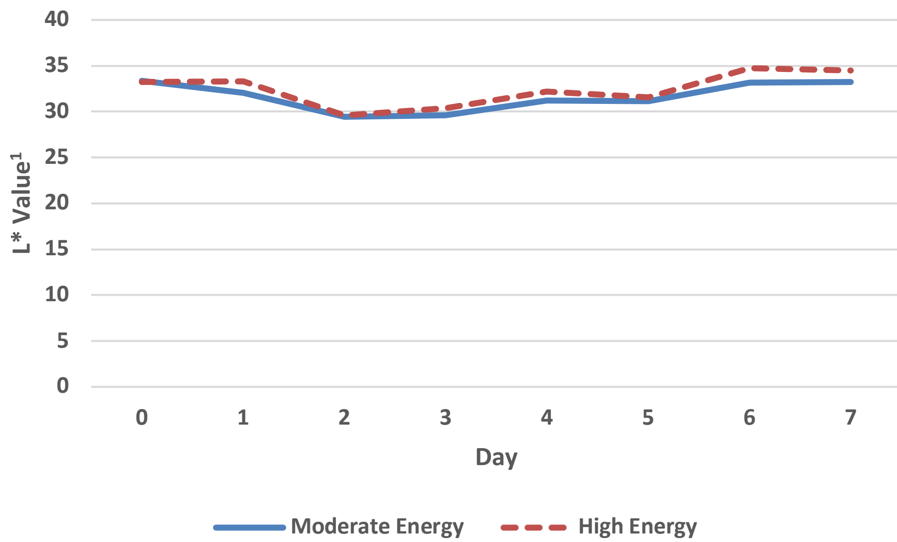
Figure 3. Discoloration scores of fresh steaks from cattle fed different dietary energy during backgrounding



*Moderate energy diet fed for initial 63 d; high energy diet fed during initial 63 d and finishing phase.

[1]Discoloration Score: 1 = 91 to 100% Discolored, 2 = 81 to 90% Discolored, 3 = 71 to 80% Discolored, 4 = 61 to 70% Discolored, 5 = 51 to 60% Discolored, 6 = 41 to 50% Discolored, 7 = 31 to 40% Discolored, 8 = 21 to 30% Discolored, 9 = 11 to 20% Discolored, 10 = 1 to 10% Discolored, 11 = 0% Discolored

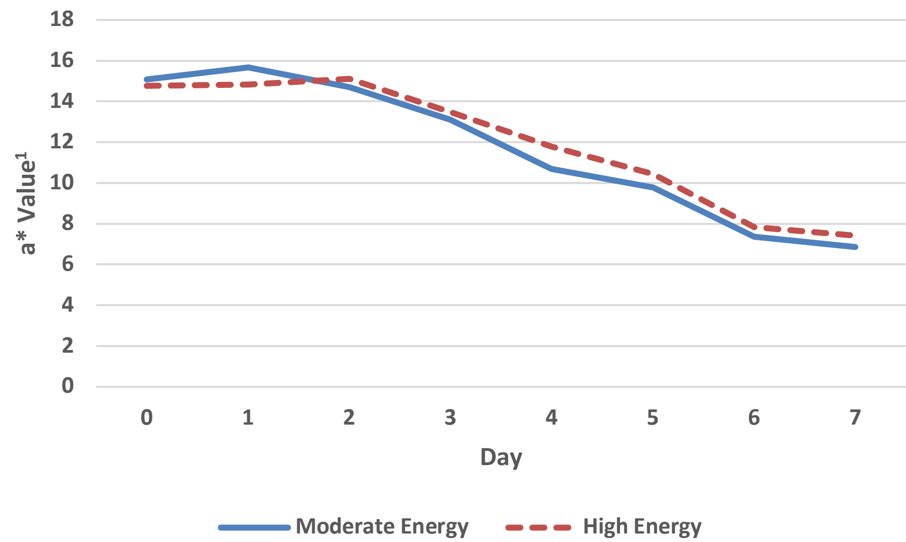
Figure 4. Lightness (L*) values of fresh steaks from cattle fed different dietary energy during backgrounding



*Moderate energy diet fed for initial 63 d; high energy diet fed during initial 63 d and finishing phase.

[1]L* Value: 0 = Black, 100 = White

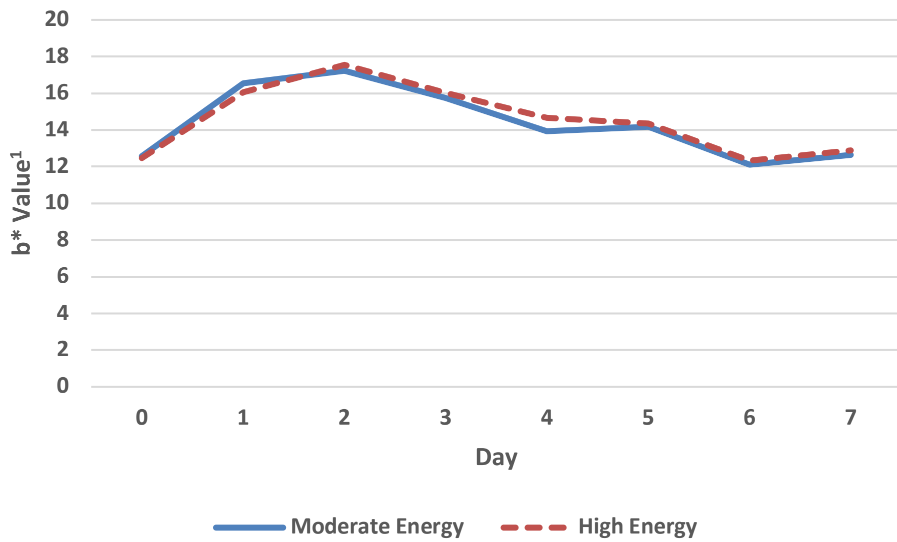
Figure 5. Redness (a*) values of fresh steaks from cattle fed different dietary energy during backgrounding



*Moderate energy diet fed for initial 63 d; high energy diet fed during initial 63 d and finishing phase.

[1]a* Value: -a = Green, +a = Red

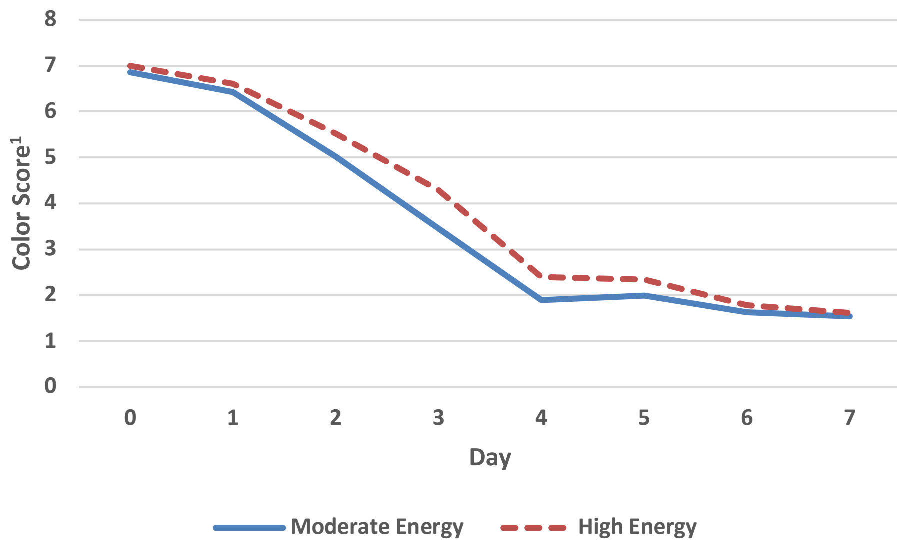
Figure 6. Yellowness (b*) values of fresh steaks from cattle fed different dietary energy during backgrounding



*Moderate energy diet fed for initial 63 d; high energy diet fed during initial 63 d and finishing phase.

[1]b* Value: -a = Blue, +a = Yellow

Figure 7. Lean color scores of ground beef from cattle fed different dietary energy during backgrounding

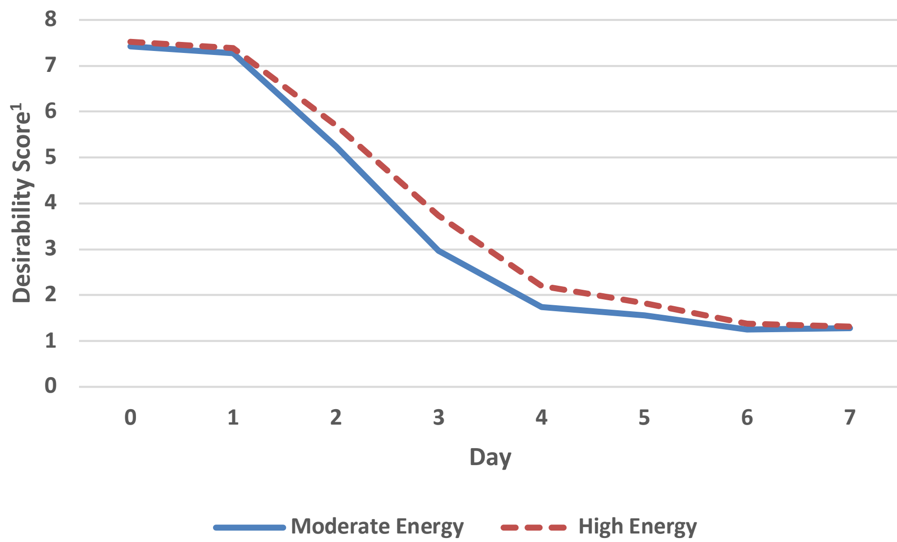


*Moderate energy diet fed for initial 63 d; high energy diet fed during initial 63 d and finishing phase.

[1]Color Score: 1 = Extremely Brown, 2 = Very Brown or Green, 3 = Moderately Brown or Green, 4 = Slightly Brown or Green, 5 = Slightly Bright Cherry Red, 6 = Moderately Bright Cherry Red, 7 = Very Bright Cherry Red, 8 = Extremely Bright Cherry Red

[2]Characteristics indexed in Appendix B

Figure 8. Desirability scores of ground beef from cattle fed different dietary energy during backgrounding

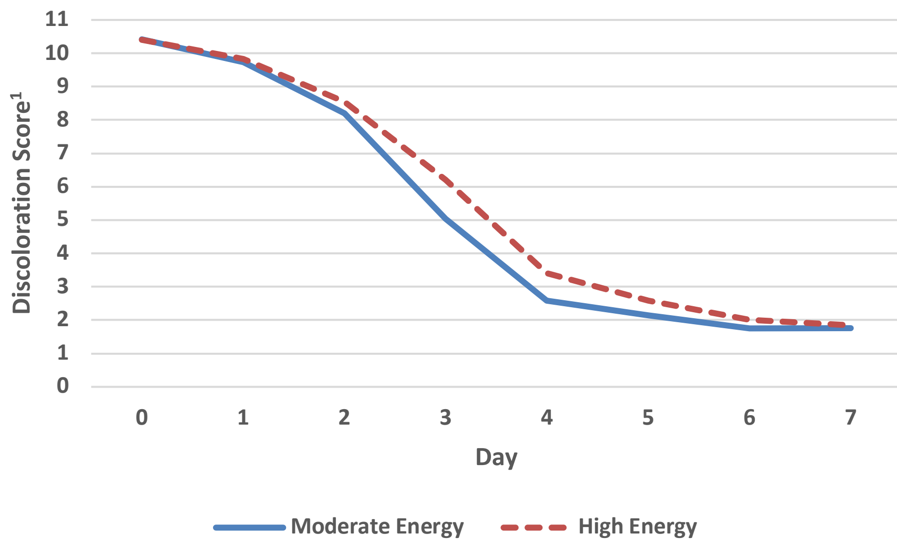


*Moderate energy diet fed for initial 63 d; high energy diet fed during initial 63 d and finishing phase.

[1]Desirability Score: 1 = Extremely Undesirable, 2 = Very Undesirable, 3 = Moderately Undesirable, 4 = Slightly Undesirable, 5 = Slightly Desirable, 6 = Moderately Desirable, 7 = Very Desirable, 8 = Extremely Desirable

[2]Characteristics indexed in Appendix D

Figure 9. Discoloration scores of ground beef from cattle fed different dietary energy during backgrounding

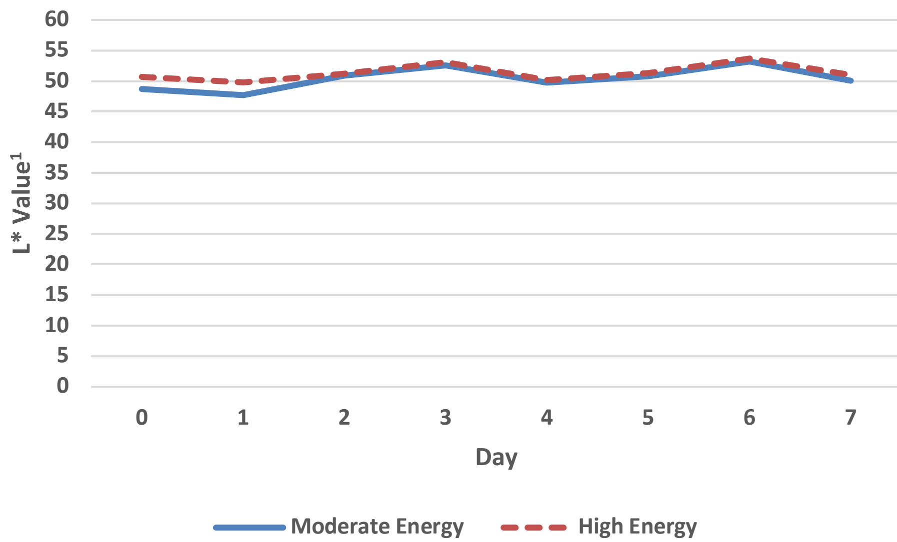


*Moderate energy diet fed for initial 63 d; high energy diet fed during initial 63 d and finishing phase.

[1]Discoloration Score: 1 = 91 to 100% Discolored, 2 = 81 to 90% Discolored, 3 = 71 to 80% Discolored, 4 = 61 to 70% Discolored, 5 = 51 to 60% Discolored, 6 = 41 to 50% Discolored, 7 = 31 to 40% Discolored, 8 = 21 to 30% Discolored, 9 = 11 to 20% Discolored, 10 = 1 to 10% Discolored, 11 = 0% Discolored

[2]Characteristics indexed in Appendix E

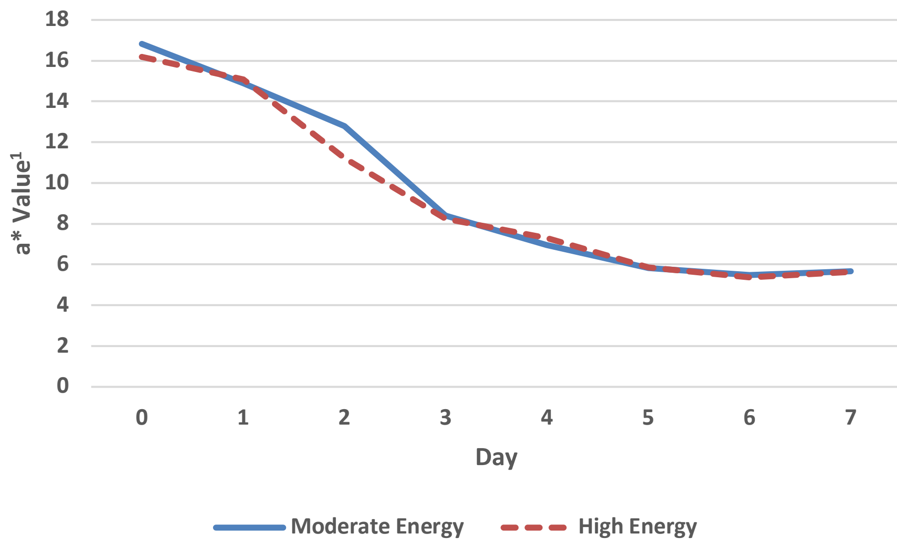
Figure 10. Lightness (L*) values of ground beef from cattle fed different dietary energy during backgrounding



*Moderate energy diet fed for initial 63 d; high energy diet fed during initial 63 d and finishing phase.

[1]L* Value: 0 = Black, 100 = White

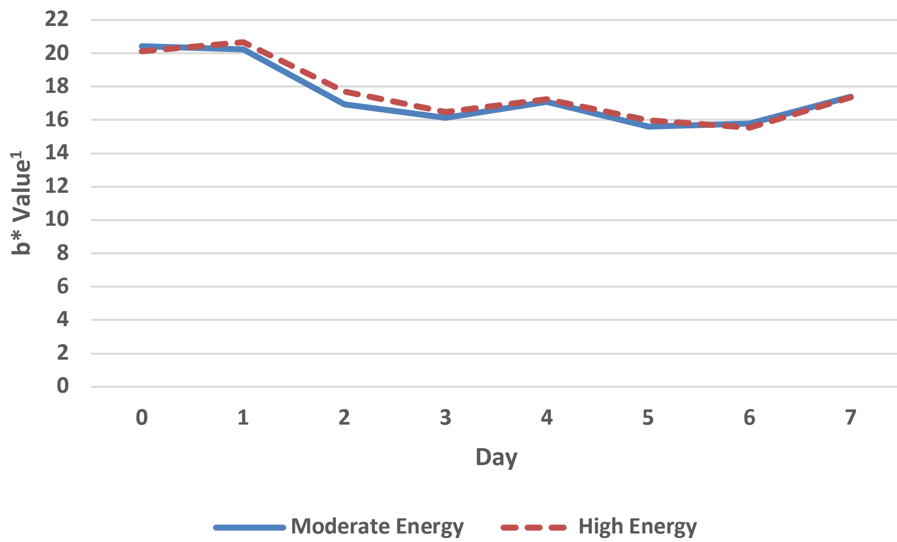
Figure 11. Redness (a*) values of ground beef from cattle fed different dietary energy during backgrounding



*Moderate energy diet fed for initial 63 d; high energy diet fed during initial 63 d and finishing phase.

[1]a* Value: -a = Green, +a = Red

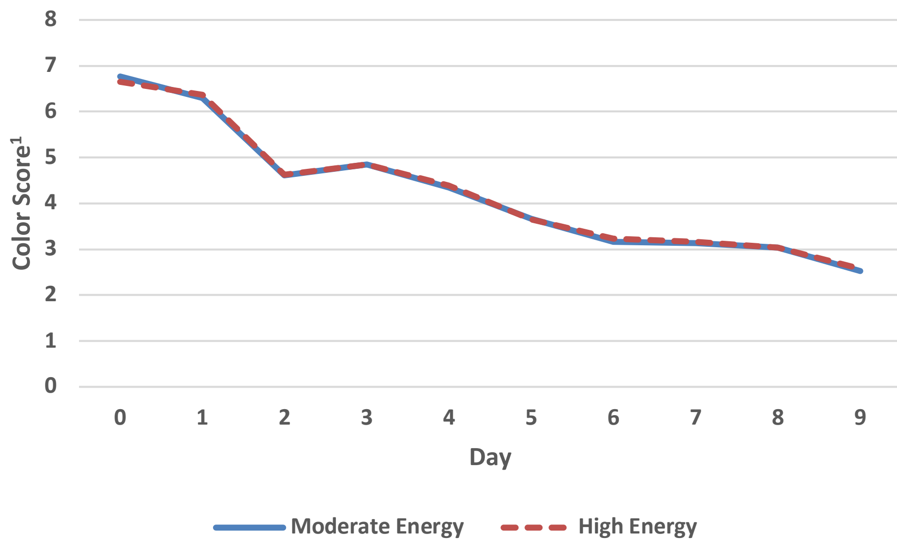
Figure 12. Yellowness (b*) values of ground beef from cattle fed different dietary energy during backgrounding



*Moderate energy diet fed for initial 63 d; high energy diet fed during initial 63 d and finishing phase.

[1]b* Value: -a = Blue, +a = Yellow

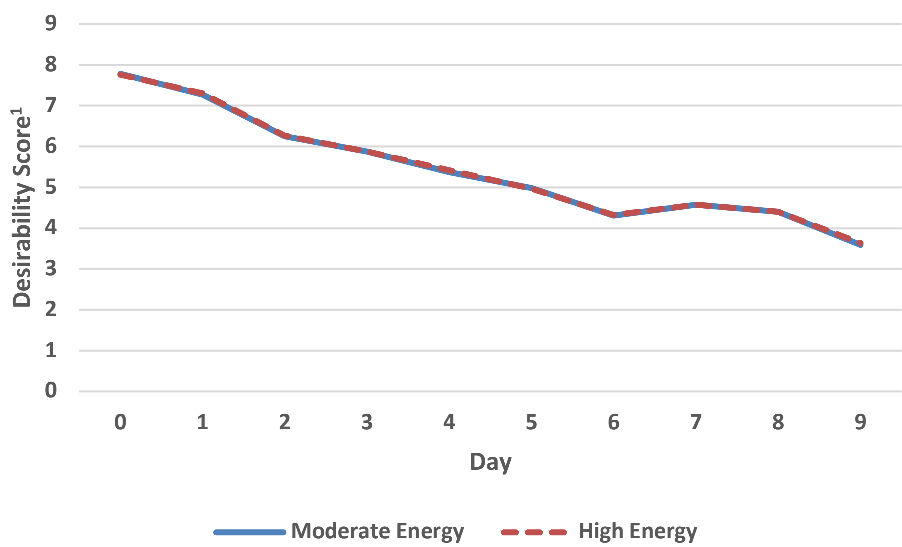
Figure 13. Lean color scores of bologna from cattle fed different dietary energy during backgrounding



*Moderate energy diet fed for initial 63 d; high energy diet fed during initial 63 d and finishing phase.

[1]Color Score: 1 = Very Dark Red Cured Color, 2 = Moderately Dark Red Cured Color, 3 = Slightly Dark Red Cured Color, 4 = Reddish-Pink Cured Color, 5 = Pinkish-Red Cured Color, 6 = Slight Pinkish Red Cured Color, 7 = Pinkish Cured Color, 8 = Light Pinkish Cured Color

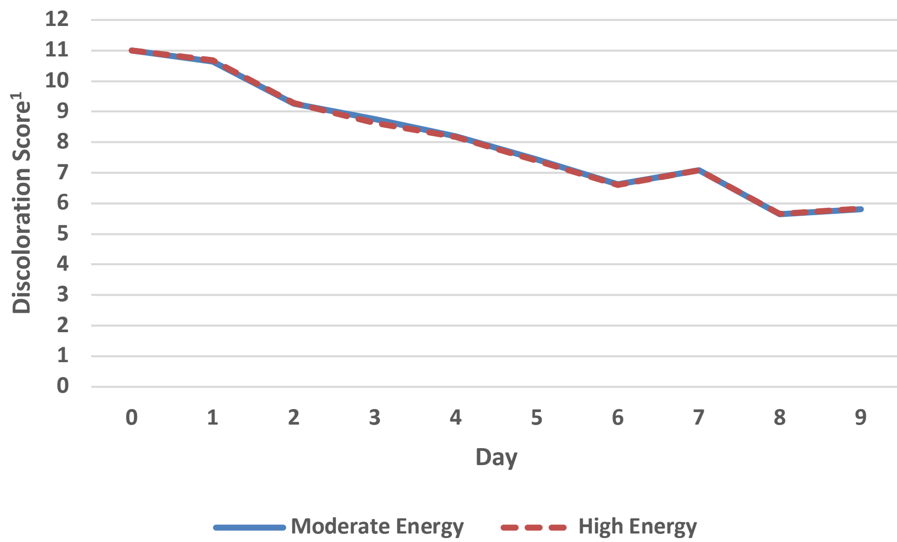
Figure 14. Desirability scores of bologna from cattle fed different dietary energy during backgrounding



*Moderate energy diet fed for initial 63 d; high energy diet fed during initial 63 d and finishing phase.

[1]Desirability Score: 1 = Extremely Undesirable, 2 = Very Undesirable, 3 = Moderately Undesirable, 4 = Slightly Undesirable, 5 = Slightly Desirable, 6 = Moderately Desirable, 7 = Very Desirable, 8 = Extremely Desirable

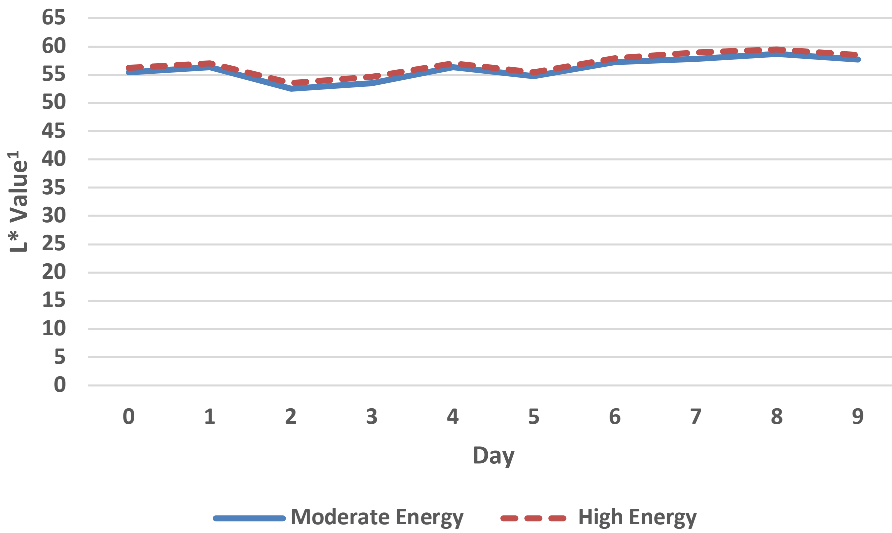
Figure 15. Discoloration scores of bologna from cattle fed different dietary energy during backgrounding



*Moderate energy diet fed for initial 63 d; high energy diet fed during initial 63 d and finishing phase.

[1]Discoloration Score: 1 = 91 to 100% Discolored, 2 = 81 to 90% Discolored, 3 = 71 to 80% Discolored, 4 = 61 to 70% Discolored, 5 = 51 to 60% Discolored, 6 = 41 to 50% Discolored, 7 = 31 to 40% Discolored, 8 = 21 to 30% Discolored, 9 = 11 to 20% Discolored, 10 = 1 to 10% Discolored, 11 = 0% Discolored

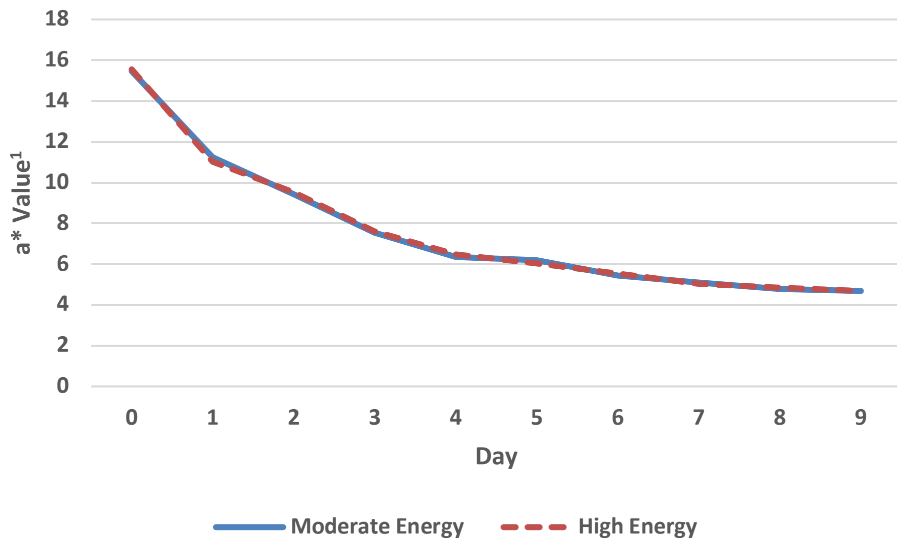
Figure 16. Lightness (L*) values of bologna from cattle fed different dietary energy during backgrounding



*Moderate energy diet fed for initial 63 d; high energy diet fed during initial 63 d and finishing phase.

[1]L* Value: 0 = Black, 100 = White

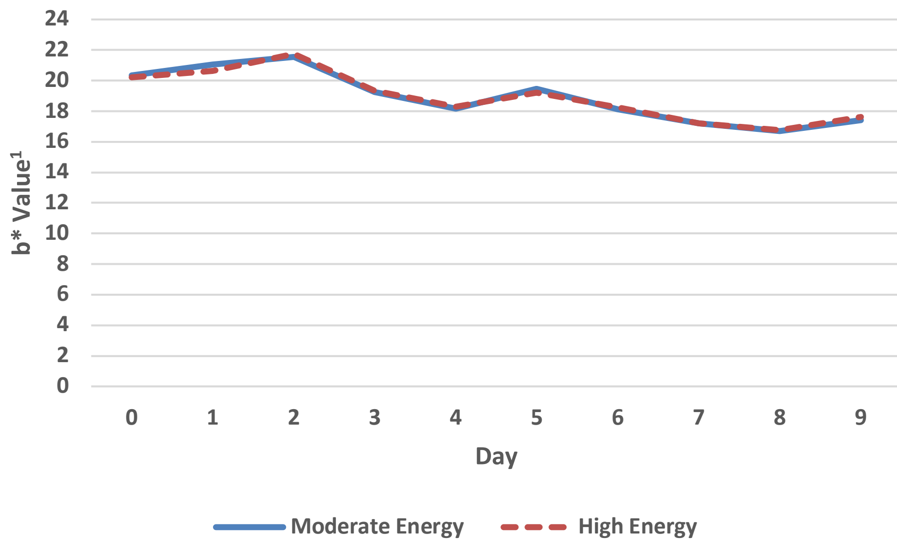
Figure 17. Redness (a*) values of bologna from cattle fed different dietary energy during backgrounding



*Moderate energy diet fed for initial 63 d; high energy diet fed during initial 63 d and finishing phase.

[1]a* Value: -a = Green, +a = Red

Figure 18. Yellowness (b*) values of bologna from cattle fed different dietary energy during backgrounding



*Moderate energy diet fed for initial 63 d; high energy diet fed during initial 63 d and finishing phase.

[1]b* Value: -a = Blue, +a = Yellow

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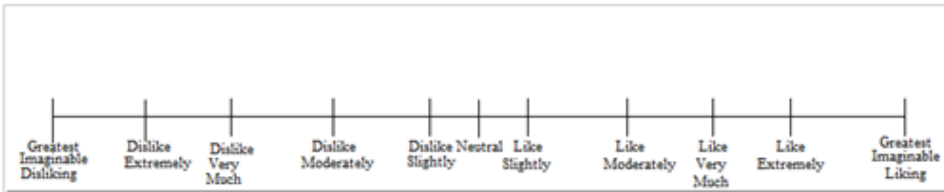
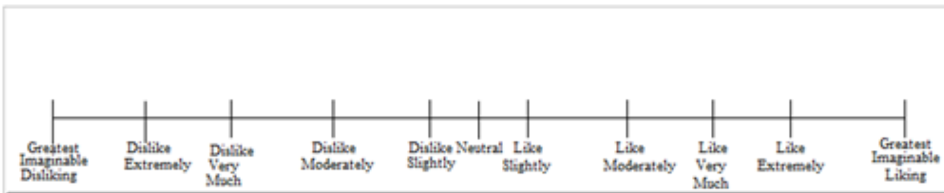
Appendix A

Fresh Steak and Bologna Sensory Scales

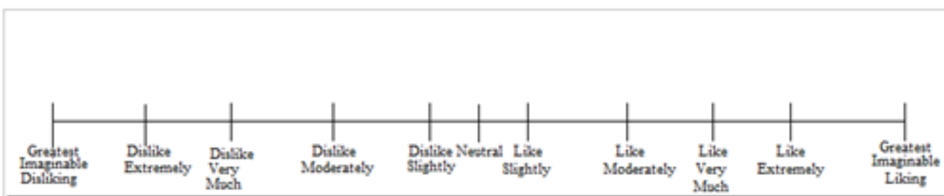
Overall Liking



Flavor Liking



Texture Liking

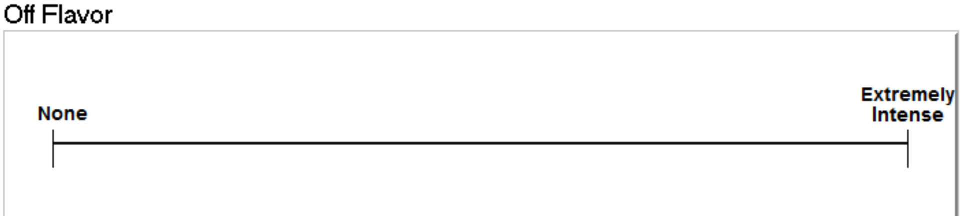


Reference Caption	***Point Value***
Greatest Imaginable Disliking	0
Dislike Extremely	13
Dislike Very Much	25
Dislike Moderately	39.5
Dislike Slightly	53
Neutral	60
Like Slightly	67
Like Moderately	81
Like Very Much	93
Like Extremely	104
Greatest Imaginable Liking	120

Toughness

Juciness

Off Flavor



Appendix B

Visual Color Scale for Fresh Steak and Ground Beef

Reference Caption	***Point Value***
Extremely Brown	1
Very Brown or Green	2
Moderately Brown or Green	3
Slightly Brown or Green	4
Slightly Bright Cherry Red	5
Moderately Bright Cherry Red	6
Very Bright Cherry Red	7
Extremely Bright Cherry Red	8

Appendix C

Visual Color Scale for Bologna

Reference Caption	***Point Value***
Very Dark Red Cured Color	1
Moderately Dark Red Cured Color	2
Slightly Dark Red Cured Color	3
Reddish-Pink Cured Color	4
Pinkish-Red Cured Color	5
Slight Pinkish-Red Cured Color	6
Pinkish Cured Color	7
Light Pinkish Cured Color	8

Appendix D

Visual Desirability Scale for Fresh Steak, Ground Beef, and Bologna

Reference Caption	***Point Value***
Extremely Undesirable	1
Very Undesirable	2
Moderately Undesirable	3
Slightly Undesirable	4
Slightly Desirable	5
Moderately Desirable	6
Very Desirable	7
Extremely Desirable	8

Appendix E

Visual Discoloration Scale for Fresh Steak, Ground Beef, and Bologna

Reference Caption	***Point Value***
91 to 100 % Discolored	1
81 to 90 % Discolored	2
71 to 80 % Discolored	3
61 to 70 % Discolored	4
51 to 60 % Discolored	5
41 to 50 % Discolored	6
31 to 40 % Discolored	7
21 to 30 % Discolored	8
11 to 20 % Discolored	9
1 to 10 % Discolored	10
0 % Discolored	11