EFFECTS OF ROUGHAGE SOURCE AND EXERCISE DURING RECEIVING AND CORN PROCESSING METHOD DURING FINISHING ON THE HEALTH, PERFORMANCE, AND CARCASS CHARACTERISTICS OF BEEF STEERS

By

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"With God all things are possible" --Matthew 19:23-30

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Abstract: The effects of roughage source and exercise on the health and performance of receiving calves were evaluated using 94 steers (initial BW = 250). Steers were allocated by BW to 1 of 4 treatments: (HAY) 30% hay DM or (HULLS) 15% cottonseed hulls and 15% soybean hulls DM and (EX) 529 m of exercise or (NEX) no exercise. There were no differences in BW or ADG ($P \geq 0.15$) during the 56 d experiment. However, HULLS had reduced DMI from d 29-42, 43-56, and 0-56 ($P \leq 0.04$). Throughout the experiment, G:F was increased for HULLS ($P < 0.001$) and EX ($P = 0.02$). On d 56, there was an interaction for both fecal score (FS) and fecal pH (FpH) with HAY + NEX having decreased FS and FpH ($P < 0.01$ and $P = 0.05$, respectively). There were no differences ($P \geq 0.26$) among treatments for clinical health signs excluding severity scores. An interaction ($P = 0.02$) for severity score was present with HULLS + EX having increased severity scores. A second experiment, evaluated the effects of corn processing on feedlot performance and carcass characteristics. Eighty-four steers were fed 1 of 2 diets: steam-flaked corn (SFC) or crimped corn (CC). There were no differences in BW ($P \geq 0.15$) or ADG ($P \geq 0.15$) during the 156 d finishing experiment. Crimped corn calves had an increased DMI on d 0-56, 57-125, and 0-156 ($P < 0.01$). Flaked corn calves were more efficient ($P = 0.04$) on d 57-125. There were no differences ($P \geq 0.11$) on carcass characteristics between treatments.

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NOMENCLATURE

ADF	acid detergent fiber
ADG	average daily gain
BRD	bovine respiratory disease
BW	body weight
CC	crimped corn
CSH	cottonseed hulls
DM	dry matter
DMI	dry matter intake
DP	dressing percent
EX	exercise
FDA	Food and Drug Administration
F:G	dry matter intake:average daily gain
FS	fecal score
FSC	fecal score change
FpH	fecal pH
FpHC	fecal pH change
G:F	average daily gain:dry matter intake
HAY	30% prairie hay
HCW	hot carcass weight

HULLS	15% CSH and 15% SBH
KPH	kidney, pelvic, and heart fat
NDF	neutral detergent fiber
NE_g	net energy for gain
NE_m	net energy for maintenance
NEX	no exercise
NRC	National Research Council
SBH	soybean hulls
SEM	standard error of the mean
SFC	steam-flaked corn
TDN	total digestible nutrients
TMR	total mixed ration
USDA	United States Department of Agriculture
VFA	volatile fatty acid
WDGS	wet distillers grains plus solubles
WSBRC	Willard Sparks Beef Research Center
YG	yield grade

CHAPTER I

REVIEW OF LITERATURE

Welfare concerns with confinement

Awareness of quality of life for animals has become a primary concern for consumers (Lyles and Calvo-Lorenzo, 2014). A telephone survey was completed regarding consumer interest and concern with animal welfare where 1,019 people responded throughout the US (Prickett, 2008). The survey contained 49 questions with topics ranging from concerns about living conditions of animals to the cost of meat. The majority of respondents concluded that animal welfare is of greater importance compared to low meat prices. Additionally, respondents concluded that production practices should allow animals to behave as if animals were in a natural environment. An example would be access to the outdoors for animals to exhibit normal behaviors (Prickett, 2008). Consumer concern about animal welfare can be defined by 3 different parameters including: health, natural behavior, and positive affective state (Fraser, 2008). Positive affective state is defined by how animals experience positive emotions while interacting with other animals and surroundings (Czycholl et al., 2015). An additional animal welfare concern is whether animals are receiving adequate exercise as animal confinement is a concern expressed multiple times by consumers. According to consumers, the generally accepted definition of confinement is prohibiting animals from the outdoors and exhibiting natural behaviors (Prickett, 2008). This view can be perceived in the poultry industry regarding free-range chickens (Buller and Roe, 2012). Similarly, confinement has been recently discussed in the swine industry concerning gestation crates (Tonsor et al., 2009).

Currently, the government does not regulate stocking density in feedlots. However, there are recommendations that should be followed for animal well-being. There are recommendations for bunk space per animal of 0.76 m within feedlot pens (Ray and Roubicek, 1971). If bunk space is limited, aggressive behavior can be expressed during feeding. If cattle are removed from feedlot pens and allowed time to exercise this could alleviate some of these aggressive behaviors.

The industry confines livestock in order to advance production and assist in the animal well-being. Producers utilize farrowing crates and battery cages to alleviate issues due to natural social hierarchy and decrease aggressive behaviors. When swine are group fed in a trough a hierarchy is established which can result in aggressive behavior. An experiment conducted by Blackshaw and McVeigh (1984) compared group-housed sows, stalled sows, and neck-tethered sows and concluded that grouped sows had signs of increased aggression compared to the other 2 housing mechanisms. Another advantage to individual crates is the regulation of food consumption, allowing for a more accurate use of feed. Croney and Millman (2007) stated that gestation stalls for sows are utilized to prevent other potential harmful behaviors such as overeating. The perception consumers have regarding animal confinement causes consumers to question how meat is produced (Buller and Roe, 2012). These authors assessed that consumers would prefer to see production labels such as ‘free-range’ or ‘natural’ when purchasing egg or animal products.

Cattle producers are seeking alternative production practices in order to ease consumer concerns regarding animal welfare. A few examples of alternative methods that have been suggested are essential oils and grass fed, Certified Organic, American Humane Certified, Animal Welfare Approved, Certified Humane, and No Hormones Administered/ No Antibiotics Added. These alternative practices allow producers to generate increased revenue compared to conventionally fed cattle because of the consumer’s idea of a “natural” product being produced. Exercise is an alternative method that has the potential of benefiting both the cattle and the consumer. Exercising cattle could potentially alleviate consumer concerns about confinement by allowing cattle access to a more open space.

Concerns with antimicrobial use

Another major consumer concern is the use of antibiotics or antimicrobials in meat production. Antimicrobials are administered for different reasons. The reasons include, but are not limited to treating clinical diseases, preventing diseases, and controlling common disease events (McEwen and Fedorka-Cray, 2002). When an antimicrobial is administered to an animal there is a “withdrawal” period before the animal can be harvested. This withdrawal period allows time for the animal to fully metabolize the administered drugs. When all withdrawal guidelines are followed, antibiotic residue left in the meat for human consumption is below USDA requirements.

The USDA publishes an annual report regarding carcass data and antibiotic residue (USDA, 2012). In the 2012 report, 211,733 samples were tested and only 1,632 tested positive for residue (0.80%) (USDA, 2012). When violations are found within the abattoir, the carcass is condemned and will not enter the food chain.

Nevertheless, consumers want to see a decrease in antibiotic use in livestock species due to concerns of potential residue remaining in the meat (Lagerkvist and Hess, 2010). Bacteria or microbes are becoming increasingly resistant to antimicrobials; which consumers believe is a side effect of the antibiotic residue in the meat being transferred from animal to human (Teuber, 2001).

Due to these consumers, the government has regulated the use of antibiotics. One example of this regulation, is the Veterinary Feed Directive (VFD) which came into effect on January 1, 2017 (FDA, 2017). The VFD gives the government the ability to regulate the use of antibiotics in feed. The cattle industry is greatly impacted by the VFD because antibiotics are commonly administered in the feed to improve calf health and prevent bacterial infections. Under the new regulations, producers need a VFD from a veterinarian to incorporate antibiotics in feed. Previously, producers could buy these supplements without restriction. The VFD requires producers to obtain documentation that tracks the class and amount of antibiotics are administered (FDA, 2017). The VFD and other regulations, have encouraged producers to develop alternative methods to enhance animal well-being.

Stress

Calves typically experience a substantial amount of stress following weaning. Calves are typically separated from dams at 6 to 7 months of age (Hickey et al., 2003 and Price et al., 2003). At weaning, calves are commonly sent straight to an auction market to be sold. Once sold, calves are shipped which creates an additional stressor. According to Cernicchiaro et al. (2012), when calves are weaned, sold, and transported long distances it results in increased morbidity and mortality rates for feedlots. The stress cattle experience during these times can be attributed to co-mingling, new social hierarchy, and new pathogens, among other things. Furthermore, these stressed cattle are considered high-risk for health issues due to mismanagement and the increase in stress endured over a short period of time. One of the most significant health issues affecting cattle is Bovine Respiratory Disease (BRD). This viral and bacterial disease, affects the lungs by causing pneumonia, is the number one cause for increased morbidity and mortality rates in feedlots. In 2013, BRD morbidity and mortality was the greatest economic loss for producers totaling greater than $2 billion (Powell, 2013). In addition, Edwards (1996) reported that BRD is responsible for approximately 75% of feedlot morbidity and 50% for mortality.

In an assessment completed by Grandin (1997), physical stress or fear stress, can be increased with human interaction. Increased handling and interaction could be an added stressor to calves when arriving at a feedlot. Prior to weaning, calves commonly have limited interaction with humans. For example, cattle that are born in swampy areas, such as Florida and Louisiana, do not experience frequent interactions with humans. Due to the swampy terrain, producers utilize helicopters to bring cattle in for weaning instead of by foot or horse. By allowing cattle and humans to interact before a stressful situation, the overall health of the animal could be improved because of the decrease in physical stress. Jago et al. (1999), stated ($P < 0.05$) that simultaneously feeding and handling cattle decreases stress levels. Forty Danish Friesian calves were used in this experiment and were removed immediately after birth from the mothers. Calves were assigned to 1 of 4 treatments: (1) fed by humans and handled (stroked), (2) fed by humans, but not handled, (3) fed without visual contact with humans and handled, and (4) fed without visual contact with humans and not handled. The researchers concluded that the interaction between human and calf during feeding decreased the calves' fear of the stockman. An overview of stress during handling and transportation by Grandin (1997) concluded that handling cattle multiple times prior to processing decreased cortisol levels resulting in more relaxed calves.

Physiological changes during exercise

Cortisol, a stress hormone, can either be positive or negative depending on the amount released within the body. According to Anderson et al. (1991), cortisol is an acceptable marker to consider when assessing stress response as when stress is induced, cortisol levels increase. When these stressful situations occur adrenaline is increased within the animal. This results in different behaviors including a fight or flight reaction, a decrease in appetite, an increase in respiratory rate, and an elevated heart rate (Grandin, 1989).

During exercise, the release of the cortisol is also increased (Kuhlmann et al., 1985). An experiment conducted by Hill et al. (2014) examined cortisol levels when humans were exercised for 30 minutes at an intensity of 40, 60, or 80% of the maximal oxygen uptake. The researchers concluded that cortisol levels increased when exercised at 60 and 80% of the maximal oxygen uptake. In contrast, the low intensity exercise did not increase cortisol levels. The authors concluded that low intensity exercise actually decreased circulating cortisol levels. Small amounts of exercise could potentially decrease cortisol levels that results from stressful situations.

Exercise and health

Exercise is beneficial for both humans and livestock because it improves physiological well-being while reducing stress, anxiety, and depression (Salmon, 2000). More specifically, the swine industry has noticed improvements with exercise on health parameters. An experiment subjected 8 female miniature pigs to treadmill exercise daily (Delp et al., 2001). This research experiment demonstrated that blood flow to the brain increases when exercise is induced. However, there has been limited research completed in the cattle industry to see if exercise improves the health of feedlot calves.

Gustafson (1993) conducted an experiment in which calves were exercised to improve health status. Twenty-eight heifers were subjected to 1 of 2 treatments, non-exercised or walking once daily for a year. The researchers concluded that exercised heifers decreased total veterinarian visits or had an improved health status. The non-exercised calves had numerically higher paresis, retained placentas, endometritis, mastitis, diarrhea, bloat, leg disorders, and laminitis visits. This research provided evidence that exercise could have a positive effect on the health of calves (Gustafson 1993). It should be noted that the experiment did not specifically address BRD.

Bovine respiratory disease is ultimately caused by viral or bacterial pathogens infecting the lungs of calves. Cattle respire or breathe 26-50 times per minute under normal conditions (Ruiz, 2016). When comparing this to other species of similar BW, cattle have increased rates of reparation (Wood, 2013). This increase in oxygen intake, however, does not allow cattle to fully utilize lung capacity. During exercise, oxygen intake is increased which leads to increased blood flow. A review completed by Mairbaurl (2013), explained how exercise can increase oxygen demand in skeletal muscle which then can increase muscle blood flow by increasing cardiac output. With increased blood flow, cell growth is promoted and organ function is improved (Fellman, 2011). Increased blood flow could potential benefit calves by aiding in the response to bacterial infections by increasing oxygen and blood flow to tissues.

Exercise and performance

Limited research has been conducted with exercise in feedlots. However, Gerlach (2014) completed 2 different experiments in which performance and carcass characteristics were examined with exercise. In the first experiment, calves were subjected to exercise 3 times a wk by being removed from pens and walked. Results concluded a decrease in BW and ADG for the exercised calves. However, in the second experiment 420 steers were allocated to 1 of 4 treatments including: (1) no exercise, (2) exercised 3 times per wk for the first 10 wk of finishing, (3) exercised 3 times per wk for the final 7 wk of finishing, or (4) exercised 3 times a wk for the duration of the 116 d finishing period. Gerlach (2014) concluded that there was no difference in BW, ADG, or G:F among the 4 treatments. However, on d 116 cattle that were not exercised were numerically heavier in BW compared to the other treatments. The author concluded that further research assessing these treatments needs to be conducted because of the contradicting values in performance.

Due to the limited published research on cattle, other species were assessed regarding exercise and performance. Sheep are similar to cattle in both physiology and digestive system which make sheep applicable when assessing the results of exercise on performance. Aalhus and Price (1990) completed an experiment using 8 Suffolk-cross ram lambs. Lambs were allocated to non-exercise or an exercise course. This course was an oval shaped track that was approximately 15 m long with 4 platform jumps. Lambs were exercised 5 times a week for 8 weeks. The results of this experiment demonstrated no differences between exercised and non-exercised sheep on DMI, BW, or ADG. These results indicated that there was no benefit to performance with exercise.

In the swine industry, exercise has been used to combat confinement issues. Weiss et al. (1975) used 56 growing and finishing swine to determine if treadmill exercise affected performance and carcass characteristics. The researchers concluded that treadmill exercise did not have an effect on ADG or G:F compared to the control or no exercise swine. Other species have been investigated with regards to exercise, but have not reported data on further performance with ADG or G:F.

Roughages

Forage is the most common natural feed that cattle consume. However, cattle do not grow as quickly on a forage-based diet compared to a grain-based diet. In feedlots, cattle are fed a concentrate diet to ensure efficient growth and weight gain. According to Galyean and Defoor (2003), roughages have been included in feedlot diets with the primary goal of optimizing DMI for an increase in ADG and G:F while reducing digestive problems, such as acidosis.

Khan et al. (2011) conducted an experiment that examined calves consuming varied levels of milk and different levels of chopped hay. The research concluded that increasing chopped hay aided in the physical development of the reticulorumen. Once cattle are weaned, sold and shipped, allowing access to roughage encourages feed intake (Lofgreen et al., 1981). Lofgreen et al. (1981) concluded that calves fed increased roughages upon arrival at the feedlot tended to have fewer total sick days. A diet with roughage also assists cattle with rumination by allowing regurgitation of feed to decrease particle size and surface area (Welch, 1982).

Roughages provide a scratch factor to stimulate rumen microbial synthesis. When born, calves do not have a complete rumen which does not allow forage digest to the full extent. Calves are predominantly psuedoruminants until there is decreased milk intake and increased roughage intake to assist with villi and protozoa growth in the rumen (Warner et al. 1956). Calves begin to consume forages which stimulates microbe and papilla growth which aids in the digestion of cellulose within roughages.

Ruminants produce volatile fatty acids (VFA) for a main energy source (Allen et al., 1997). Three major VFA produced in the rumen are propionate, acetate and butyrate. Rumen microbes break down feedstuffs and VFA allowing for rumen development (Lengemann and Allen, 1955). These VFA assist with the development of the rumen and are originated from particles such as roughage and grain. An experiment conducted by Tamate et al. (1962) concluded that forage consumption improved the muscular development within the rumen due to the large particle size and bulk content of the forages.

Rust and Owens (1981) evaluated different roughages commonly fed in feedlot diets. Six roughage sources were evaluated on digestion in this experiment: cottonseed hulls, prairie hay, alfalfa hay, sorghum plant silage, and 2 varieties of corn plant silage (with or without the corn). Within this experiment 24 Hereford-Angus steers were utilized. The researchers concluded that there was no difference between roughage sources on digestibility of starch.

A survey completed by Samuelson et al. (2016) asked a total of 101 questions ranging from general cattle management questions to roughages used in feedlot diets. The researchers concluded that the most common roughage feeds in receiving diets were alfalfa hay (58.3%), cottonseed hulls (8.33%), corn silage (4.17%), or corn stalks (4.17%). The remaining of (25%) roughages used were not included in the survey (Samuelson et al. 2016).

Roughage processing

Grinding hay decreases particle size which decreases the amount of time the forage stays in the rumen. When hay is ground it passes through the reticulo-rumen faster than long stem hay or hay that has not been ground (Blaxter et al., 1959; King et al., 1962; Meyer et al., 1959; and Rodrigue and Allen, 1960). The finer the roughage is ground, the greater the rate of passage to the abomasum. This may allow for a more efficient animal because of the decrease in rumination and regurgitation.

Ground hay, when provided in a TMR, decreases the opportunity for cattle to sort out particles. In addition, the TMR helps control the amount of roughage included in a diet at a feedlot while making the diet more uniform. Grinding hay can decrease wastage by sorting.

An experiment completed by Weiss et al. (2017) compared corn stalk roughage inclusion and grind size on digestibility and DMI of cannulated steers. Roughage inclusions were at 5 and 10% in the diet and ground through a 7.6-cm screen once (long grind, LG) or twice (short grind, SG). Weiss et al. (2017) did not find a difference in DMI however, the researchers did notice that rumination time increased ($P < 0.01$) in the diets containing the LG corn stalks. This could potentially affect G:F in a feedlot due to the increase of rumination time and energy expended to masticate the feed.

Cottonseed hulls

Cottonseed hulls (CSH), the outer layer of the cottonseed, are a bulky roughage. Cottonseed hulls are a byproduct of whole cottonseed once the oil is extracted (Jurgens and Bregendahl, 2007). Cottonseed hulls can be utilized as a roughage source when feeding beef cattle due to the high fiber component, approximately 48% (NRC, 1984). Cottonseed hulls are also known to be very palatable to receiving calves by stimulating intake (Blasi and Drouillard, 2002).

Soybean hulls

Similarly, soybean hulls (SBH) are the outer layer of the soybean that is left after processing. In 3 separate experiments conducted by Hsu et al. (1987) wet corn fiber, SBH, CSH, and oat hulls were examined as a roughage sources. The first experiment, in situ samples were incubated in 2 ruminal-cannulated calves. The researchers concluded that wet corn fiber and SBH had increased rates of DM digestibility and greater rates of disappearance (Hsu et al., 1987). The second lamb feedlot experiment compared wet corn fiber and SBH to corn that was supplemented with fescue hay. One hundred and eight male and female lambs were used in the experiment. The sheep consuming the SBH diet had the greatest CP digestion. A feedlot experiment was completed comparing wet corn fiber and SBH at supplemental levels of 25 and 50% DM basis. The researchers concluded that steers fed the SBH diet had similar ADG, but increased DMI and G:F compared to the corn diet (Hsu et al., 1987). These results suggest that SBH are a highly digestible feedstuff. The high digestibility has lead researchers to question if SBH could replace corn in diets. Multiple experiments have been conducted observing this more specifically. An experiment completed by Martin and Hibberd (1990) using 12 cannulated Hereford cattle evaluated different levels of SBH available for calves grazing native forage in Oklahoma. Martin and Hibberd (1990) concluded that SBH could be supplemented to calves grazing native forage, similar to corn. Multiple experiments have been conducted that demonstrates that SBH are comparable to corn when cattle are grazed on forages (Blasi et al., 2000).

Roughages and health

Calves are removed from forage based diets in order to be sent to the feedlot. At the feedlot, forages are fed to encourage calves to come to the feed bunk. Including hay in the diet assists in the prevention of bloat in feedlot cattle. Once cattle are received at the feedlot, it is common to include a roughage source of 30% or greater on a DM basis (Samuelson et al., 2016). The roughage included in a TMR diet aids the microbial population in the transition to a high concentrate finishing diet. This process makes the cattle more efficient and prevents digestive upsets in a feedlot. Proper nutrition and bunk management, both of which stimulate feed intake, can decrease morbidity and mortality while improving performance.

With high starch diets cattle are more susceptible to acidosis (Owens et al., 1998). Including roughages in the diet decreases eating rate and meal size, however, it also increases chewing time and saliva production. Increased saliva production allows for an increase in buffering capacity and aids in maintaining a desirable ruminal pH. As mentioned previously, roughage is important in rumen development. Warner et al. (1956) assessed the difference between milk, hay, and grain on rumen development. Five groups of calves were used in this experiment including: (1) milk, (2) grain, (3) hay, (4) hay and grain, and (5) newborns. Calves were fed the respective diets and sent to slaughter to determine papillae growth within the rumen. The calves fed the hay diet had an increase in total rumen and omasum capacity compared to the grain and milk fed calves. Additionally, the newborn calves exhibited a smooth epithelium with no papillae present. The hay or grain calves had 1 cm papillae growth at 4 weeks of age.

Fecal characteristics with roughages

The experiment by Rust and Owens (1981) compared 6 roughage sources in cattle diets while 2 of those roughages including CSH and prairie hay. The researchers concluded that fecal pH did not differ between these 2 roughages. Another experiment compared feeding alfalfa hay or CSH on fecal pH (Gill and Owens, 1981). Once the calves were placed on the diets, fecal pH was compared on d 20 and d 115. The authors concluded that pH was not different between the 2 diets. Furthermore, an experiment by Doescher (2010) with 64 Holstein calves fed (1) no CSH, (2) 10% CSH, (3) 15% CSH, or (4) 20% CSH assessed fecal characteristics. Fecal scores were assessed by 1 = normal, 2 = soft, 3 = runny, or 4 = watery. Fecal score was decreased (more water like) for calves fed the no CSH compared to the other diets.

Corn processing

When cattle are finished in a feedlot, calves are fed high concentrate diets. Feedlot diets consist of up to 80 – 90% cereal grains and the chief dietary component is starch. Due to fluctuating market prices, it is critical for cattle to efficiently utilize the starch that is available in the diet. Increasing starch utilization can be accomplished through grain processing.

Corn processing started in the US with the invention of the simple hammermill in 1840 (Matsushima, 2006). The next advancement in grain processing occurred in 1930 with crimping and steam-flaking. In 1940, commercial cattle feeding became popular and producers determined that feed costs were the most expensive component of finishing cattle (Matsushima, 2006). This led to increased interest in the processing of grains to reduce feed cost. In 1962, Colorado State University conducted the first steam-flaking experiment. The steam-flaking of corn increased BW in feedlot cattle when compared to dry-rolled corn. Colorado State then completed another trial comparing flake densities. Results indicated that "thin flakes" are superior to "thick flakes" for cattle performance. Average daily gain was 4.3% greater in calves fed the thin flakes and those calves were 7.8% more efficient as well (Matsushima, 2006). This research raised questions regarding grain processing and how it can be utilized within a feedlot to benefit producers by decreasing feed costs.

There are 2 general grain processing methods: dry or wet processing. Steam-flaking and crimping fall under wet processing methods due to the exposure to steam. Multiple other corn processing methods have been introduced to feeding cattle. Some of these include but are not limited to: extruding, popping, high moisture-ensiling, reconstitution, and exploding (Matsushima, 2006). After the invention of steam-flaking, 12 different corn processing methods were explored for the next 40 plus years (Matsushima, 2006). Steam-flaking is still considered superior to other grain processing methods by the feedlot industry (Samuelson et al., 2016).

Starch availability and digestion

Several grains are used in feedlot diets, however, the most commonly utilized is corn (Samuelson et al., 2016). Corn has been deemed the most important concentrate in the US due to its palatability, availability, and richness in total digestible nutrients (Morrison, 1950). Corn is considered the standard grain by which other concentrates are compared. Corn is composed of approximately, 82.9% endosperm, 11.0% germ, 5.3% bran coat, and 0.8% tip cap on a DM basis (Bunge, 2015). Corn analyzes, 75.0% starch, 8.9% protein, 4.0% oil, 1.5% ash, 1.7% sugars, and 8.9% fiber (Bunge, 2015).

Corn is mainly composed of starch, which is composed of hydrogen bound amylose and amylopectin that will disentangle during gelatinization (Biliaderis, 1998). Most starch contains 20 – 35% amylose which is made up of linear chains of α-1,4-linked D-glucose with α-1,6 branch points. Starch is contained within the endosperm in 2 different forms: horny or floury. Floury endosperm is soft and easily to digest. However, horny endosperm is a crystalline structure and is bound tightly and more difficult for the animal to digest (Kikuchi et al., 1982). For animals to digest starch, the endosperm must be exposed directly to digestive enzymes. The endosperm of starches can be exposed by multiple techniques. One obvious technique is mastication. Ruminants can mechanically expose the endosperm through mastication. An experiment by Beauchemin et al. (1994) evaluated the effects of mastication on the physical breakdown of whole grains. Three Hereford calves were used to evaluate the chewing activity for corn, barley, and wheat. The researchers concluded that corn was more damaged with initial mastication, however, this could be attributed to the size of the corn kernel relative to barley and wheat. Processing grains prior to feeding reduces the time spent masticating feed. Grain processing exposes the endosperm allowing the rumen microbes to readily attach to the grain. Processing methods increase the energy availability for the animal while improving efficiency and rate of digestion.

When particle size is reduced, surface area increases. Smaller particles are fermented faster and more extensively in the rumen, unlike large particles that may increase the flow of starch to the small intestine for digestion. Owens et al. (1986) summarized that an increase in ruminal digestion results in a higher total tract digestibility. If larger particles are passed through the rumen into the small intestine these particles are poorly digested compared to smaller more masticated particles (Galyean et al., 1979; Anzola, 1987).

Starch digestion first occurs in the rumen where the microorganisms rely on a constant supply of nutrients to produce energy. Up to 40% of starch can escape fermentation in the rumen depending on the processing method (Orskov, 1986). Many factors can influence the digestion of starch including the grain sources, other diet components, grain processing method, and the rumen of the animal because of the fluctuations in ruminal pH and microbial population. Owens et al. (1986) concluded that more intensive grain processing decreases the amount of grain present in the small intestine, but processing increases digestion in both the rumen and the small intestine.

Steam-flaking

Steam-flaking is the most utilized grain processing method in commercial facilities. In the survey by Samuelson et al. (2016) steam-flaking was the most common grain processing method (70.8%) followed by high-moisture harvesting and storage (16.7%) and finally dry-rolling (12.5%). Steam-flaking requires time, temperature, and moisture, but can improve available net energy for maintenance and gain by 15 and 19% (Corona et al., 2005). In the flaking process, moisture, heat, and pressure are used to increase starch and protein digestion and availability (Theurer, 1986).

The steam-flaking process typically begins by tempering the grain in moisture for 1 to 24 hr prior to steaming (Heimann, 1999). Following this, the grain is steamed at atmospheric pressure in a steam cabinet at approximately 100°C for 20 to 40 min. Once the grain is steam-conditioned it is passed through 2 corrugated rollers and is flaked to a density of 0.309 to 0.4012 kg/L (Armbruster, 2006). The flakes are fed warm out of the flaking machine to the cattle in a TMR. Flake density can differ between feedlots, but research has shown that steam flaking to a bulk density of 0.26 kg/L and 0.36 kg/L is optimal when fed to finishing cattle (Brown et al., 2000).

Crimping

Crimping corn is not a common practice. Crimping can also be classified as steam-rolling. The main difference between steam-flaking and crimping (steam-rolling) is the amount on time spent in the steam chest (Richards and Hicks, 2007). The grain is also not subjected to the amount of pressure that flaking is once passed through the rollers, and the temperature is also decreased. Crimped grains are prepared by steaming the whole grain at a temperature of 82.22^0 C for 10-15 min. After softening in the steam chamber, the grain is passed through a roller mill. This process allows the grain to be opened because the heating process causes a gelatinization of the starch. Crimping creates cracks in the grain to allow the starch to be readily exposed for increased digestion.

Effects of corn processing on animal performance

The primary goal of grain processing is to efficiently increase animal performance while decreasing DMI. Feeding SFC improves efficiency by about 16% compared to dry-rolled corn (Zinn et al., 1998). A review about grain source and processing was completed by Owens et al. (1997) in which he concluded that steam-flaked and steam-rolled grains differ on the extent of processing. However, there was no research in the review comparing the 2 processing methods. The authors concluded that efficiency can be improved by 12% when SFC was fed, compared to dry-rolled corn, while DMI decreased by 11.6%. However, ADG did not differ between the 2 processing methods.

While limited research is published concerning the feeding of crimped corn to feedlot cattle, multiple experiments have been completed with Holstein cows. In one experiment, 32 lactating Holstein cows were fed 1 of 4 diets (Yu et al., 1997). These diets were: (1) SFC with Aspergillus oryzae, (2) SFC without Aspergillus oryzae, (3) steam-rolled corn with Aspergillus oryzae, (4) steam-rolled corn without Aspergillus oryzae. Aspergillus oryzae was included or not included in the diet to determine if there could be an increase in milk production. In this experiment, the steam-rolled corn was processed similar to CC. Cows fed steam-rolled corn had an increased DMI compared to the SFC fed cows. However, these are the only performance parameters the researchers assessed. The second experiment was conducted with 12 Holstein cows that were fed diets containing finely ground corn (580 g/L), coarsely ground corn (618 g/L), SFC at a low density (309 g/L), SFC at a medium density (361 g/L), and steam-rolled corn (490 g/L; Yu et al., 1998). Dry matter intake was decreased in the cows fed the finely ground corn compared to the other corn processing methods. The 2 experiments reported similar results when comparing SFC to steam-rolled corn.

An experiment completed by Barajas and Zinn (1998) compared dry-rolled and SFC on finishing cattle. With this experiment, 80 heifers were used to determine feedlot performance and carcass characteristics. The researchers concluded that grain processing had no effect on BW and ADG. However, steam-flaking reduced DMI compared to dry-rolled. Due to this, feed efficiency was increased in heifers that were fed the SFC diet. More recently, these results were replicated in an experiment conducted by Buttrey et al. (2012). Two hundred sixty-four heifers were fed 4 different diets. These diets included: (1) SFC with 0% wet distillers grains plus solubles (WDGS), (2) SFC with 25% WDGS,

(3) dry-rolled corn with 0% WDGS, or (4) dry-rolled corn with 25% WDGS. The experiment had similar results as Barajas and Zinn in that heifers were not different in final BW and ADG. However, the heifers that were fed SFC were more efficient than those fed the dry-rolled corn.

Effects of corn processing on carcass characteristics

Zinn (1990) completed 2 experiments comparing the flake densities of corn. This could be relevant for comparing to crimping at an increased flake density. The first was a digestibly experiment and the second focused on feedlot performance. Seventy-two steers were fed 1 of 3 flake densities: 0.30, 0.36, or 0.42 kg/L. Zinn (1990) concluded flaking density had no effect on carcass merit since there were no differences in HCW, DP, ribeye area, fat thickness, KPH, marbling score, or YG.

The experiment by Barajas and Zinn (1998) previously mentioned, also assessed carcass characteristics. The researchers concluded no difference in fat thickness, HCW, DP, ribeye area, or carcass yield between dry-rolled corn and SFC. However, KPH fat was increased for the calves fed the SFC. In an experiment conducted by Corona et al. (2005) 120 steers were used and compare SFC, dry-rolled corn, ground corn, and whole corn processing mehtods. Dressing percentage was increased in the calves fed the SFC compared to the other processing methods.

Conclusions from the literature

Animal welfare has been receiving increased attention for many years from consumers and producers. Due to rising concerns from consumers, producers are pursuing alternative methods to aid in animal health and well-being. Exercise could potentially be beneficial as an alternative method. However, limited research has been completed assessing exercise as a benefit for receiving calf health and performance. Roughages stimulate the rumen environment to improve digestive health and aid in the transition to a high concentrate diet. In feedlot diets, feeding alfalfa is the most common form of roughage followed by CSH.

Finishing cattle consume high concentrate diets with increased starch, to provide increased energy. Grain processing increases starch availability allowing finishing cattle to be more efficient. The most commonly practiced grain processing is steam-flaking and the most common grain utilized is corn. However, limited research has been conducted comparing CC compared to SFC.

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CHAPTER II

EFFECTS OF EXERCISE AND ROUGHAGE SOURCE ON THE HEALTH AND PERFORMANCE OF RECEIVING BEEF CALVES

ABSTRACT

There has been increased interest in animal welfare, antimicrobial use, and confinement within the cattle industry from consumers. Exercise could be a potential benefit to animal health while alleviating some animal welfare concerns. Roughages stimulate the rumen environment to improve digestive health and aid in the transition to a high concentrate diet. The objectives of this experiment were to determine the effects of exercise and roughage source on receiving calf health and performance during a 56 d receiving period. Steers (n = 94; BW 250 ± 12 kg) were assigned to treatments in a randomized complete block design with a 2 × 2 factorial arrangement of treatments including: (HAY) 30% hay DM or (HULLS) 15% cottonseed hulls and 15% soybean hulls DM and (EX) 529 m of exercise or (NEX) no exercise with 5 pens/treatment. Every 14 d, BW were obtained and fecal samples were collected to determine fecal pH (FpH) and fecal score (FS; 5-point scale with 1 = solid to 5 = water-like). There were no differences in BW or ADG ($P \geq 0.15$). However, HULLS had reduced DMI from d 29-42, 43-56 and 0-56 ($P \leq 0.04$). There was a interaction for G:F from d 43-56 increased in

HULLS + EX (*P* = 0.01). The HULLS + EX had increased (*P* = 0.01) G:F on d 43-56. From d 0-56 the HULLS and EX calves were more efficient (*P* < 0.001 and *P* = 0.02, respectively). The HULLS had a greater FS on d 14 (*P* = 0.02) resulting in increased FS change (FSC) from d 0-14 (*P* = 0.01). A FSC interaction was present from d 15-28 (*P* = 0.02) and on d 28 FS had a tendency (*P* = 0.08) for HULLS to be increased. On d 56, there was an interaction for both FS and FpH with HAY + NEX having decreased FS and FpH (*P* < 0.01 and *P* = 0.05, respectively). This resulted in a tendency for an interaction for FSC (*P* = 0.09) and an interaction for FpH change (*P* = 0.04) overall. There were no differences (*P* ≥ 0.26) among treatments for clinical health signs excluding severity scores. An interaction (*P* = 0.02) for severity score was present with HULLS + EX having increased severity scores. When cottonseed hulls and soybean hulls were fed as the roughage source, calves gained weight more efficiently during the first 56 d on feed. Calves that were exercised were also more efficient during the 56 d receiving period. Further investigation is needed to determine the effects of exercise on clinical health and fecal characteristics.

Key words: calves, exercise, receiving calf health, roughage source

INTRODUCTION

Consumers are becoming more concerned about quality of life for animals (Lyles and Calvo-Lorenzo, 2014). These concerns can be defined by 3 parameters: health, natural behavior, and positive affective state (Fraser, 2008). Additional concerns include access to the outdoors, exercise, and the use of antibiotics, even when antibiotics are used for treating, preventing, and controlling clinical diseases (McEwen and Fedorka-Cray, 2002).

Forage is the most common natural feed that cattle consume. However, cattle do not grow as quickly on a forage-based diet due to a lack of energy necessary to maximize growth rate. In feedlots, cattle are fed a concentrate diet to promote efficient growth and weight gain. Roughages are included in feedlot diets primarily to optimize DMI for increased ADG and G:F while reducing digestive problems, such as acidosis. Roughages also aid in the transition to a high concentrate diet (Gaylean and Defoor, 2003). Tamate et al. (1962) reported that forage consumption improved the muscular development within the rumen due to the large particle size and bulk content of the forages.

In feedlot diets, a roughage source constituting 30% of the DM or greater is commonly included (Samuelson et al., 2016). Cottonseed hulls can be utilized as a roughage source due to the high fiber content at approximately 48% (NRC, 1984). Cottonseed hulls are very palatable to receiving calves and stimulate intake in young calves fed grain-based diets (Blasi and Drouillard, 2002).

Producers are seeking alternative methods to improve animal health and well-being, without the use of antibiotics, and exercise could potentially be an alternative while easing consumer concerns. However, limited research has been completed regarding exercise in feedlot settings. The objectives for this experiment were to determine the effects of exercise and roughage source on receiving calf health and performance during a 56 d receiving period.

MATERIALS AND METHODS

All procedures were approved by Oklahoma State University's Institutional Animal Care and Use Committee (Animal Care and Use Protocol AG-16-1).

Cattle description, initial processing, and body weights

In mid-August, 94 crossbred steers (BW at arrival = 250 ± 12 kg) were purchased at a livestock market in Holden, Missouri and transported (approximately 568 km) to the Willard Sparks Beef Research Center (WSBRC) at Oklahoma State University in Stillwater, OK. Calves arrived on d -8 and were commingled in holding pens with ad libitum access to water and prairie hay for approximately 4 h. Due to high temperatures, cattle were moved to small pens (4.57 × 15.24 m) with access to shade and sprinkled with water. In these pens, calves were still provided ad libitum access to water and prairie hay. The following morning d -7, calves were individually weighed, verified for sex, and administered a uniquely numbered ear tag in the left ear. Calves were administered clostridial bacterium/toxid (Vision 7; Merck Animal Health, DeSoto, KS), treated for parasites (Safeguard; Merck Animal Health, DeSoto, KS and Dectomax; Zoetis Animal

Health, Florham Park, NJ), and implanted (Component TE-IS with Tylan; Elanco Animal Health, Greenfield, IN).

Prior to the start of the experiment, calves were fed a common receiving diet for 7 d (Table 2.1; HAY). Throughout the experiment, calves were housed in 4.57 × 15.24 m pens that contained a 4.57 × 4.42 m concrete pad covered by a solid shade awning. The remainder of the pen was open-aired and soil surfaced. Each pen contained a 4.57 m concrete feed bunk and a concrete water tank (model J 360-F; Johnson Concrete, Hastings, NE) was shared between 2 adjacent pens. Calves were blocked by initial processing BW on d -7 and if calves received an antimicrobial prior to d 0 were placed into a single block. Twenty pens were utilized with 5 pens per treatment and 3 to 5 head per pen. Calves were weighed again on d 0 for initial BW and then on d 14, 28, 42 and 56.

Experimental treatments

Steers were assigned to treatments in a randomized complete block design with a 2 × 2 factorial arrangement of treatments. Factors were: 1) roughage source; 30% hay on a DM basis (HAY) or 15% cottonseed hulls (CSH) and 15% soybean hulls (SBH) on a DM basis (HULLS) 2) exercise; exercise (EX) or no exercise (NEX). Exercising of calves was also conducted at WSBRC in Stillwater, OK. Exercise consisted of walking 3 times per wk (Monday, Wednesday, and Friday) at approximately 0530 for a distance of 529 m. The average speed per pen was 3.59 km/h resulting in an average of 10 min of exercise. Exercise of calves was conducted with no verbal communication or driving aids in an attempt to minimize stress.

Feed and bunk management

Cattle were fed experimental diets ad libitum twice daily at 0630 and 1300 throughout the 56 d experiment. Diets were mixed and fed in a 2,377 or a 5,207-L, trailer mounted feed mixer (Roto-Mix 84-8 or Roto-Mix 184-4, Dodge City, KS). Feed remaining was weighed back as needed, before feeding on weighdays or due to weather events. Diet and ingredient samples were collected twice per wk and DM content of diets and dietary ingredients were determined. To determine DM content, diet samples and refusals were placed in a force-air oven at 60^{o}C for 48 h. Dried diet samples were ground through a 1 mm screen on a Wiley mill and were evenly composited by sample for nutrient analysis. Composited, dried samples were shipped to a commercial laboratory for nutrient analysis (Servitech; Dodge City, KS; Table 2.1).

Fecal samples

Fecal samples were obtained from individual animals on d 0, 14, 28, 42, and 56 via rectal palpation, fecal pH (FpH) was measured with a portable pH meter (Orion 611 pH millivolt; Thermo Electron Corporation; Beverly, MA). Fecal score (FS) was adapted from Ireland-Perry (1993) where fecal samples were evaluated by viewing and handling. Fecal samples were given a score from 1 to 5. Scores were characterized as: FS 1 (firm, hard and dry appearance; characteristic of a cow on dry hay), FS 2 (slightly less firm and hard, having the consistency of cookie dough), FS 3 (relatively soft and moist), FS 4 (loose, very moist and runny; consistency of pancake batter), FS 5 (very thin and watery, could not be captured in an open hand; consistency of orange juice). An ideal FS was considered a score of 3. Fecal pH change (FpHC) and FS change (FSC) were also measured. Change was determined by taking the later date subtracted from the earlier date measurement from individual animals, then the average change for the pen was calculated.

Animal health

Every morning, trained personnel visually monitored the calves for clinical signs of bovine respiratory disease (BRD). The trained personnel used a modified DART system (Step et al., 2008 and Wilson et al., 2015). The criteria used to pull calves for BRD included depression, abnormal appetite, respiratory signs, and temperature. Signs of depression included hanging of the head, sunken or glazed eyes, or difficultly standing or walking. Signs of abnormal appetite included animals going off feed, animals eating less than expected, lack of fill, or obvious decreased BW. Respiratory signs include labored or open mouthed breathing, extended head and neck, or audible noises when breathing. Severity scores: (1) mild, (2) moderate, (3) severe, or (4) moribund were assigned to the calves by the trained personal based on observed clinical signs. Calves that were given a severity score were pulled for further evaluation which included rectal temperature (GLA, M-500, GLA Electronics, San Luis Obispo, CA). Animals that were given a severity score of 1 or 2 were administered antibiotics only when rectal temperature was ≥ 40.0°C. Calves with a severity score of 3 or 4 were administered antibiotics regardless of rectal temperature.

Before any antimicrobials were administered, BW was obtained to determine the appropriate dosage. If calves were treated with an antimicrobial, BW, severity score, temperature, and amount of antimicrobial administered were recorded. The first antimicrobial treatment given was tilmicosin phosphate at 1.5 mL/45.4 kg of BW (Micotil 300; Elanco Animal Health, Greenfield, IN) on the left side of the neck. If tilmicosin phosphate was administered, flunixin meglumine injection (Prevail; MWI Veterinary Supply, Boise, ID) was also administered intravenously at 1 mL/45.4 kg of BW and vitamin B complex (Agri Laboratories, Ltd.; St. Joseph, MO) was administered intramuscularly at 1.5 mL/45.4 kg of BW. Before the second antimicrobial treatment could be administered, a 120-h post treatment interval was observed. If calves demonstrated signs of BRD for a second time, florfenicol (Nuflor; Merck Animal Health, Desoto, KS) was administered at 6 mL/45.4 kg of BW subcutaneously on the right side of the neck. Once florfenicol was administered, a 96-h post treatment interval was observed. If clinical signs were observed after this post treatment interval, a third antimicrobial treatment of ceftiofur crystalline free acid (Excede; Pfizer, New York, NY) was administered at 1.5 mL/45.4 kg of BW subcutaneously at the base of the left ear. If calves showed clinical signs of BRD after the third antimicrobial treatment and had lost BW during the 120-h post treatment interval, the calf was classified as a "chronic" and was removed from the experiment.

Calculations and statistical analysis

The experimental design was a completely randomized block with a 2 × 2 factorial arrangement of treatments. Data was analyzed using the PROC MIXED procedure of SAS Release (SAS Inst. Inc., Cary, NC). Weight block was included as a random effect and pen was the experimental unit. All BW measurements were calculated with a 2% shrink. Exercise, diet, and the exercise × diet interaction were included in the model. Due to the difference in FpH on d 0, d 0 FpH was used as a covariate in the model for all FpHC data. Significance was declared when $P \leq 0.05$ and tendencies were considered when $P > 0.05$ and ≤ 0.10.

RESULTS AND DISCUSSION

Live animal performance

Receiving performance data is presented in Table 2.1. There were no differences in BW ($P \geq 0.63$) or ADG ($P \geq 0.35$) due to exercise. These results are similar to Gerlach (2014) who determined exercise did not improve BW or ADG over 116 d finishing period. Additionally, Dune et al. (2005) completed an experiment using 48 crossbred steers that were exercised a distance of 1,113 m or were not exercised. Steers that were exercised daily had a decrease in BW and ADG (Dunne et al., 2005). This contradicts the results current experiment, however, the steers in the current experiment were exercised a shorter distance. Aalhus and Price (1990) completed an experiment with sheep that were subjected to a rigorous exercise course including jumps 5 times a wk for 56 d. The researchers observed no differences between exercised and non-exercised groups on final BW ($P = 0.16$) or ADG ($P = 0.28$). Results from the present experiment, are similar to those from Aalhus and Price (1990).

There were no differences in BW ($P \geq 0.61$) or ADG ($P \geq 0.24$) due to diet. An experiment conducted by Doescher (2010) used 64 Holstein calves that were fed 1 of 4 diets including: (1) no CSH (2) 10% CSH (3) 15% CSH (4) 20% CSH for 56 d. Doescher (2010) concluded no differences in BW between treatments, similar to results of the current experiment. An experiment conducted by Tricarico et al. (2007) used 162 steers fed a finishing diet containing either 12% alfalfa hay or 7% CSH. The researchers concluded that there was no difference in BW or ADG between the diets. These results are also similar to the current experiment in regard to BW and ADG. Hsu et al. (1987) completed 2 feedlot experiments comparing wet corn fiber and SBH at supplemental levels of 25 and 50% of diet DM. The first experiment included fescue silage and the second included corn silage as additional roughage sources. The researchers concluded that steers fed the SBH diet had similar ADG during the feeding period in both experiments (Hsu et al., 1987). These results are in agreement with the current experiment.

There were no differences ($P \geq 0.12$) in DMI with exercise, however DMI decreased for calves fed the HULLS diet on d 29-42 ($P = 0.04$), d 43-56 ($P < 0.01$), and overall from d 0-56 ($P = 0.01$). In contrast to the current experiment, Blasi et al. (2001) used 625 heifers comparing diets with alfalfa hay or a mixture of CSH and cottonseed meal. The heifers fed the cottonseed meal and CSH combination consumed more ($P <$

0.01) than the heifers fed the alfalfa based diet. While these results contradict those of the current experiment, it should be noted that alfalfa hay was used as a roughage source rather than prairie hay. The difference in roughage quality between alfalfa and prairie hay likely would influence DMI.

This difference in DMI subsequently affected G:F where a diet × exercise interaction for G:F (P = 0.010) was observed from d 43-56. The calves that were consuming HULLS + EX had the greatest G:F on d 43-56 compared to the other 3 treatments. From d 0-56 the HULLS (P < 0.001) and EX (P = 0.02) calves were more efficient. In the experiment by Blasi et al. (2001), the heifers consuming the alfalfa hay diet tended to be more efficient compared to the CSH and meal fed heifers. Furthermore, Bartle et al. (1994) utilized 503 steers evaluating 2 roughage sources, alfalfa hay and CSH. Both roughages were included at 3 levels within the diet: 0%, 20%, or 30%. The researchers concluded that the calves consuming the alfalfa diet consumed less feed resulting in more efficient calves. These results also contradict the results of the current experiment.

It should be noted that SBH and CSH are not nutritionally equivalent primarily due to the original grain composition. An experiment conducted at Kansas State University evaluated 230 steers on 3 different diets including; (1) 45% alfalfa and 20% prairie hay (2) 15% alfalfa (3) 92% SBH (Loest et al., 1998). Diet 1 was fed at 2.75% BW and diets 2 and 3 were fed at 1.5% and 2.25% BW, respectively. Calves fed the SBH and hay diets had similar gains, however, the SBH diet fed at 2.25% BW was numerically more efficient than the alfalfa and prairie hay combination diet (Loest et al., 1998). These results are similar to the current experiment with the HULLS diet being more efficient than the HAY fed calves.

Fecal characteristics

Fecal consistency is important when assessing the site and extent of digestion and fermentation of feedstuffs (Kononoff et al., 2002). Fecal examination can aid producers when assessing cattle health, performance, and behavior (Kononoff et al., 2002). Acidosis is a digestive disorder that can commonly occur when transitioning cattle to a high concentrate diets (Owens et al., 1998). Acidosis can be defined by a decrease in ruminal pH leading to a more loose fecal consistency. Evaluating feces is common when assessing cattle for digestive disorders. Fecal score, FSC, FpH, and FpHC data from the samples collected are shown in Table 2.3. There was an increased, more watery, FS on d 14 (P = 0.02) and a similar tend (P = 0.08) on d 28 for calves fed the HULLS diet. On d 42 the EX calves had a tendency (P = 0.06) for FS to be more firm. On d 56 there was an interaction ($P < 0.01$) with decreased FS in the HAY NEX calves compared to the other 3 treatments.

The difference in FS on d 14, resulted in an increased (P = 0.01) FSC between d 0-14 for the HULLS fed calves. A diet × exercise interaction (P = 0.02) was observed in FSC from d 15-28 with the HULLS + EX calves having the greatest FSC, HAY + NEX being the intermediate, HAY + EX calves and HULLS + NEX calves having the least FSC. Over the duration of the experiment, there was a tendency (P = 0.09) for an interaction on FSC with the change being the least in HAY + NEX calves and the greatest change in the HULLS + NEX. Fecal consistency (less firm) and decreased pH have been associated with low forage diets in lactating dairy cattle (Ireland-Perry et al., 1993). The results in this experiment are similar to Ireland-Perry et al. (1993) with the HAY diet having a more firm FS. An experiment using 56 Holstein calves compared a starter diet that included: (1) 0% CSH and 5.10% SBH or (2) 15% CSH and 4.40% SBH on a DM basis (Hill et al., 2009). The researchers compared fecal consistency with 1 being a normal fecal score and 4 being watery. They concluded that the calves fed the 0% CSH and 5.10% SBH diet had an increased or more loose fecal score (Hill et al., 2009). These results are similar to the current experiment on d 14 and 28 with HULLS calves having more loose FS. An experiment by Doescher (2010) used 64 Holstein calves that were fed 1 of 4 diets including: (1) no CSH (2) 10% CSH (3) 15% CSH (4) 20% CSH for 56 d and assessed fecal characteristics as: 1 = normal, 2 = soft, 3 = runny, or 4 = watery. Fecal score were decreased (more water like) for calves fed no CSH compared to the other diets.

At the beginning of the experiment (d 0) FpH was increased (*P* = 0.01) in the EX calves. To account this initial difference, FpH was included as a covariate when comparing subsequent FpH data. On d 56 there was a diet × exercise interaction (*P* = 0.05) for FpH with the HULLS + NEX calves having an increased FpH compared to the other 3 treatments. Fecal pH change, was similar prior to d 42, but a diet × exercise interaction occurred from d 43-56 (*P* = 0.02) and d 0-56 (*P* = 0.04). From d 43-56 the lowest (*P* = 0.02) FpHC was in the HAY + NEX calves compared to the other 3 treatments. Fecal pH change from d 0-56 was the greatest in the HAY + NEX calves and the least in the HULLS + NEX calves. Rust and Owens (1981) completed an experiment with 24 Hereford-Angus steers to comparing 6 roughage sources in cattle diets. Two of these 6 roughages included CSH and prairie hay. Fecal pH did not differ between these 2 roughages. Another experiment comparing alfalfa hay to CSH evaluated fecal pH on d 20 and d 115 (Gill and Owens, 1981). The authors concluded that pH was not different between diets fed. These results are similar to the results from this experiment. Limited research has been conducted regarding exercise on fecal characteristics in cattle. So further investigation is needed to determine the effects of exercise and FS and FpH.

Animal health

Animal health data is presented in Table 1.4. Across all treatments, the number of steers treated at least once for clinical signs of BRD was 33 calves (35 %, first treatment morbidity). Eleven calves (12 %) required multiple antimicrobial treatments during the 56 d receiving period. A total of 6 steers were euthanized or removed from the experiment. Out of those 6 steers, 2 were euthanized or removed due to BRD and the remaining 4 hd were removed or euthanized for other reasons not related to BRD. There was no diet × exercise interaction ($P \geq 0.30$) or difference in main effects ($P \geq 0.26$) for first treatment morbidity percentage, second treatment morbidity percentage, antimicrobials administered, or rectal temperature. There was a diet × exercise interaction ($P = 0.02$) for severity score with the HULLS + EX calves having the greatest severity scores. There has been limited research observing animal health, specifically BRD, with exercise. However, Gustafson (1993) assessed general health of calves and exercise related to reduced veterinary visits. Twenty-eight calves were used in this experiment and were subjected to no exercise or were exercised once daily. Gustafson (1993) concluded that the non-exercised calves had more visits to the veterinarian than the exercised calves. Even though this experiment had limited number of calves, it suggest there could be a benefit on health parameters with exercise, but not specifically on BRD incidence.

IMPLICATIONS

Cottonseed hulls, in combination with SBH, can be an effective roughage source for receiving cattle diets. When CSH and SBH were fed as a roughage source in the diet calves gained weight more efficiently during a 56 d receiving period. Limited research has been conducted regarding exercise and receiving calf performance and health in feedlot settings. However, this experiment suggests that routine exercise could potentially improve calf efficiency. There was no difference in receiving calf health due to exercise or roughage source. Further investigation is needed to determine the effects of exercise on clinical health and fecal characteristics.

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Table 2.1. Composition of experimental diets

Ingredient (% DM)	HAY	HULLS
Dry rolled corn	10.00	10.00
Sweet Bran[1]	54.80	54.80
Dry supplement B-273[2]	5.20	5.20
Prairie hay	30.00	--
Cottonseed hulls	--	15.00
Soybean hulls	--	15.00
Nutrient composition[3]		
Dry matter	71.99	70.79
NE_m, Mcal/kg	2.01	1.76
NE_g, Mcal/kg	1.34	1.15
TDN, %	82.10	74.30
Crude protein, %	17.40	18.57
Crude fiber, %	16.57	18.23
NDF, %	42.87	46.33
ADF, %	18.40	25.17
Calcium, %	0.83	0.77
Phosphorus, %	0.72	0.76
Magnesium, %	0.32	0.35
Potassium, %	1.23	1.33

[1]Wet corn gluten feed (Cargill, Dalhart, TX).

[2]Dry supplement B-273 was formulated to contain (% DM basis) 38.46% ground corn, 30.36% limestone, 21.04% wheat midds, 6.92% urea, 1.03% magnesium oxide, 0.618% zinc sulfate, 0.38% salt, 0.119% copper sulfate, 0.116% manganese oxide, 0.05% selenium premix (contained 0.6% Se), 0.311% vitamin A (30,000 IU/g), 0.085% vitamin E (500 IU/g), 0.317% Rumensin 90 (Elanco Animal Health, Indianapolis, IN), and 0.195% Tylan 40 (Elanco Animal Health).

[3]Feed samples were analyzed for nutrient composition by an independent laboratory (Servi-Tech Laboratories, Dodge City, KS).

Table 2.2. Effects of roughage source and exercise on BW, ADG, DMI, and G:F

	HAY[1]		HULLS[1]			*P*-value		
Item	EX	NEX	EX	NEX	SEM	Diet	Exercise	Diet × Exercise
BW[2], kg								
d 0	251	249	249	249	12.1	0.74	0.74	0.56
d 14	275	270	273	274	10.9	0.91	0.63	0.39
d 28	302	298	300	303	11.0	0.61	0.97	0.24
d 42	330	326	324	330	10.9	0.78	0.86	0.15
d 56	357	354	356	357	11.4	0.81	0.68	0.48
ADG[3], kg								
d 0-14	1.73	1.55	1.70	1.77	0.18	0.56	0.74	0.43
d 15-28	1.89	1.96	1.93	2.06	0.16	0.62	0.53	0.85
d 29-42	2.03	1.99	1.77	1.94	0.14	0.24	0.62	0.43
d 43-56	1.95	1.97	2.23	1.91	0.16	0.50	0.35	0.28
d 0-56	1.90	1.87	1.91	1.92	0.05	0.56	0.83	0.65
DMI[4], kg								
d 0-14	6.38	6.39	6.42	6.37	0.17	0.92	0.90	0.86
d 15-28	8.55	9.03	8.44	8.64	0.40	0.32	0.19	0.58
d 29-42	9.87	10.10	8.27	9.37	0.52	0.04	0.22	0.41
d 43-56	11.27	11.58	8.76	10.28	0.58	< 0.01	0.12	0.29
d 0-56	9.02	9.27	7.97	8.67	0.34	0.01	0.12	0.46
G:F[5]								
d 0-14	0.271	0.241	0.266	0.282	0.030	0.442	0.772	0.318
d 15-28	0.221	0.218	0.231	0.242	0.021	0.375	0.847	0.722
d 29-42	0.208	0.201	0.215	0.205	0.015	0.682	0.510	0.911
d 43-56	0.173[b]	0.169[b]	0.256[a]	0.186[b]	0.011	< 0.001	0.004	0.010
d 0-56	0.212	0.202	0.240	0.223	0.009	< 0.001	0.024	0.448

[1]HAY = diet containing 30% hay on a DM basis. HULLS = diet containing 15% soybean hulls and 15% cottonseed hulls on a DM basis.
[2]Treatment BW was the BW in kg with a calculated 2% shrink.
[3]Treatment ADG was calculated from the shrunk (2%) BW in kg and days on feed between the time periods.
[4]Treatment DMI was calculated by taking DMI kg for a pen for the period shown divided by the actual number of head days within each pen.
[5]Treatment G:F was calculated by taking pen ADG in kg divided by the pen average DMI in kg for the time period.
[a, b] Least squares means without a common superscript differ ($P \leq 0.05$).

Table 2.3. Effects of roughage source and exercise on fecal score, fecal score change, fecal pH, and fecal pH change

	HAY[1]		HULLS[1]			*P*-value		
Item	EX	NEX	EX	NEX	SEM	Diet	Exercise	Diet × Exercise
Fecal score[2]								
d 0	2.79	2.75	2.84	2.62	0.23	0.81	0.45	0.61
d 14	2.81	2.96	3.64	3.02	0.18	0.02	0.19	0.14
d 28	2.84	2.68	2.98	3.27	0.19	0.08	0.73	0.26
d 42	2.80	2.44	3.00	2.60	0.19	0.35	0.06	0.93
d 56	3.34[a]	2.88[b]	3.32[a]	3.36[a]	0.12	< 0.01	0.01	< 0.01
Fecal score change[3]								
d 0-14	-0.086	0.214	0.716	0.496	0.231	0.01	0.83	0.17
d 15-28	0.080[a]	-0.280[ab]	-0.656[b]	0.120[a]	0.210	0.16	0.81	0.02
d 29-42	-0.050	-0.234	0.032	-0.634	0.306	0.61	0.18	0.44
d 43-56	0.550	0.400	0.384	0.816	0.208	0.51	0.47	0.14
d 0-56	0.550[ab]	0.226[b]	0.480[ab]	0.906[a]	0.261	0.16	0.81	0.09
Fecal pH								
d 0	7.18	6.92	7.07	6.93	0.07	0.43	0.01	0.39
d 14	6.51	6.50	6.49	6.56	0.13	0.81	0.84	0.64
d 28	6.29	6.11	6.21	6.10	0.15	0.69	0.27	0.74
d 42	6.09	6.28	6.09	6.16	0.10	0.52	0.23	0.50
d 56	6.49[ab]	6.39[b]	6.44[ab]	6.51[a]	0.04	0.30	0.74	0.05
Fecal pH change[4]								
d 0-14	-0.516	-0.521	-0.550	-0.479	0.137	0.96	0.78	0.68
d 15-28	-0.170	-0.411	-0.278	-0.467	0.230	0.51	0.20	0.84
d 29-42	-0.133	0.134	-0.110	0.053	0.149	0.81	0.20	0.67
d 43-56	0.415[a]	0.079[b]	0.360[a]	0.353[a]	0.072	0.11	0.04	0.02
d 0-56	-0.537[ab]	-0.632[b]	-0.583[ab]	-0.522[a]	0.039	0.34	0.68	0.04

[1]HAY = diet containing 30% hay on a DM basis. HULLS = diet containing 15% soybean hulls and 15% cottonseed hulls on a DM basis.
[2]Fecal score adapted from Ireland-Perry (1993), higher score indicating more viscous "watery" consistency.
[3]The measurement from the later date was subtracted from the earlier date for each individual animal and then a pen average was calculated.
[4]The measurement from the later date was subtracted from the earlier date for each individual animal and then a pen average was calculated.
[a, b] Least squares means without a common superscript differ ($P \leq 0.05$).

Table 2.4. Effects of roughage source and exercise on clinical health

	HAY[1]		HULLS[1]			*P*-value		
Item	EX	NEX	EX	NEX	SEM	Diet	Exercise	Diet × Exercise
1st antimicrobial treatment[2], %	37.00	43.20	42.40	37.40	15.02	0.97	0.91	0.30
2nd antimicrobial treatment[3], %	20.00	0.00	25.00	40.00	8.66	0.63	0.36	--
Total antimicrobials[4], %	49.00	45.96	71.21	46.21	20.95	0.40	0.26	0.38
Rectal temperature[5], ºC	40.21	40.12	40.00	40.19	0.16	0.63	0.76	0.35
Severity score[6]	1.37[a]	1.86[ab]	1.99[b]	1.38[a]	0.32	0.75	0.76	0.02

[1]HAY = diet containing 30% hay on a DM basis. HULLS = diet containing 15% soybean hulls and 15% cottonseed hulls on a DM basis.
[2]1st antimicrobial treatment = % calves receiving an antimicrobial within a pen.
[3]2nd antimicrobial treatment = % of calves receiving a 2nd antimicrobial out of 1st treat.
[4]Total antimicrobials = total number of antimicrobials administered as a % of calves in a pen.
[5]Rectal temperature = Rectal temperature at the time of antimicrobial administration.
[6]Severity score = 1 (mild), 2 (moderate), 3 (severe), and 4 (moribund).
[a, b] Least squares means without a common superscript differ ($P \leq 0.05$).

CHAPTER III

EFFECT OF FEEDING STEAM-FLAKED CORN OR CRIMPED CORN ON FINISHING CATTLE PERFORMANCE AND CARCASS CHARACTERISTICS

ABSTRACT

Grain processing has been used in feedlots for decades to improve efficiency and decrease production cost, with steam-flaking being the most common grain processing method. Crimping is a similar process to steam-flaking except the grain is in the steam chest for a reduced amount of time. Crimping is not not common within the feedlot industry. The objective of this experiment was to determine the effects of corn processing on feedlot performance and carcass characteristics. Eighty-four crossbred steers (BW 379 ± 12 kg) were assigned to finishing diets containing either steam-flaked corn (SFC) or crimped corn (CC), in a randomized complete block design. Calves were blocked by BW with 9 pens/treatment and 5 head/pen. Body weights were obtained on d 0, 56, 125, and 156. All calves were fed ractopamine hydrocholride for the last 31 d. There was no difference in BW ($P \geq 0.15$) or ADG ($P \geq 0.15$) during the 156 d finishing experiment. The CC cattle had an increased DMI from d 0-56, 57-125, and 0-156 ($P <$ 0.001). Steam-flaked corn calves were more efficient ($P = 0.04$) from d 57-125. There was no difference ($P \geq 0.11$) in carcass characteristics among the experimental treatments. Steers fed CC had an increased DMI during the 156 d finishing period compared to the diet with SFC. Otherwise there were negligible differences between SFC and CC. Further investigation is needed to determine the effects of CC on performance and carcass characteristics.

Key words: corn processing, crimped corn, feedlot calves, steam-flaked corn

INTRODUCTION

Cattle finished in feedlots are fed high concentrate diets that consists of up to 90% cereal grains containing high levels of starch. While several grains are used in feedlot diets the most commonly utilized grain in the US is corn (Samuelson et al., 2016). Corn is fed due to its palatability, availability, and high total digestible nutrients (Morrison, 1950).

Grains included in feedlot diets are commonly processed to increase nutrient availably and improve feed efficiency. Grain processing exposes the endosperm allowing the rumen microbes improved access to the nutrients within the grain. For the animal, these processing methods increase available energy, efficiency, and rate of digestion. Smaller particles and more highly processed grains are fermented more rapidly and extensively in the rumen, which reduces the amount of starch that flows to the small intestine for digestion. Owens et al. (1986) summarized that increased ruminal digestion results in a greater total tract digestibility.

Feeding steam-flaked corn (SFC) improves efficiency by approximately 16% compared to dry-rolled corn (Zinn et al., 1998). Samuelson et al. (2016) completed a survey of feedlot nutritionists that concluded steam-flaking was the most common grain processing method (70.8%) followed by high-moisture harvesting (16.7%) and dry-rolling (12.5%). The main difference between steam-flaking and crimping (steam-rolling) is the amount on time spent in the steam chest (Richards and Hicks, 2007). Crimped corn (CC) is in the steam chest half the amount of time as steam-flaked corn. Crimping corn is not a common practice within the feedlot industry. As a result, limited research has been conducted comparing crimping directly to steam-flaking. Steam-flaking and steam-rolling (crimping) are considered to be high moisture grain processing methods.

Finishing cattle consume concentrate diets high in starch, to provide increased energy. Grain processing increases starch availability allowing finishing cattle to be more efficient. Limited research has been conducted comparing CC to SFC. The objective of this experiment was to determine the effects of feeding SFC or CC on the performance and carcass characteristics of feedlot cattle.

MATERIALS AND METHODS

All procedures were approved by Oklahoma State University's Institutional Animal Care and Use Committee (Animal Care and Use Protocol AG-16-1).

Cattle description, initial processing, and receiving period

Eighty-seven calves were received at Willard Sparks Beef Research Center in Stillwater, OK in mid-August. Calves were processed the following day and administered a clostridial bacterium/toxid (Vision 7; Merck Animal Health, DeSoto, KS), treated for parasites (Safeguard; Merck Animal Health, DeSoto, KS and Dectomax; Zoetis Animal Health, Florham Park, NJ), and implanted (Component TE-IS with Tylan; Elanco Animal Health, Greenfield, IN). Calves were also individually weighed, verified for sex, and administered a uniquely numbered ear tag that was placed in the left ear. Calves were placed in 5 head pens and fed a receiving diet for an 82 d receiving period (Table 3.1).

Finishing period and cattle management

Cattle were weighed on d -9 and implanted with 4 mg of estradiol and 20 mg of trenbolone acetate (Revalor XS; Merck Animal Health, DeSoto, KS). The BW from d -9 were utilized to allocate steers to finishing treatment. Steers were blocked by BW into 9 blocks with 5 calves per pen except for the heaviest weight block which had only 3 steers per pen. Pens were randomly assigned finishing diet treatments in which the grain component was SFC or CC. Treatment pens were 4.57 × 15.24 m in area with a 4.57 m cement bunk line and a solid shade awning. These pens contained a 4.57 × 4.42 m concrete pad and the remainder of the pen was soil surfaced. Concrete fence line water tanks (model J 360-F; Johnson Concrete, Hastings, NE) were shared between 2 adjacent pens. Steers were weighed on d 0, 56, 125, and 156.

Corn processing

The SFC was sourced from 2 locations during the experiment. For the first 56 d, the SFC was steamed at atmospheric pressure in a steam cabinet at 101°C for 20 min. After the grain was conditioned, it passed through corrugated rollers. After rolling, the SFC was placed on a concrete pad to dry prior to shipment. After d 56 the SFC was sourced from a different location for the remainder of the experiment where the corn was only steamed for 5 min. The CC was steamed at 82.22°C for 8-10 min and passed through corrugated rollers. The corn proceeded to pass through a cooling tower for 12 min. Processed grains were commercially sourced from different processors. The SFC from d 0-56 was sourced from Livestock Nutrition Center in Saginaw, TX and the SFC from d 57-156 was sourced form Nesika Energy in Scandia, KS. The CC was soured from Stillwater Milling Company in Stillwater, OK for the duration of the experiment.

Feed and bunk management

All pens were fed twice daily at approximately 0700 and 1300 h. Feed was mixed and delivered with a 274-12 Roto-Mix mixer wagon (Roto-Mix; Dodge City, KS) to the nearest 0.45 kg of that day's feed call. Steers were adapted to finishing diets using a 21 d, 2-ration blending protocol. Feed remaining was weighed back as needed, before feeding on weighdays or due to weather events. Diet and ingredient samples were collected once per wk and DM content of diets and dietary ingredients were determined. Samples were dried in a 60^{0}C forced air oven for 48 hr. Once dried, feed samples were ground through a 2-mm screen in a Wiley mill and composited by week for nutrient analysis. Composited dried samples were shipped to a commercial laboratory for nutrient analysis (Servi-Tech Inc.; Dodge City, KS; Tables 3.1 and 3.2). Steers were placed on ractopamine hydrochloride (Optaflexx, Elanco Animal Health, Greenfield, IN) fed at a rate of 300 mg per steer daily for the last 31 d on feed.

Corn prices

The average corn price for the experiment ($0.1327/kg) was obtained from USDA reports (USDA, 2017). On a DM basis, this calculated to $0.1508/kg. The cost for steam flaking was $0.0088/kg. The cost for crimping was $0.0167/kg. To determine the $/kg of each grain, the cost of the grain on a DM basis ($0.1508/kg) was multiplied by the percentage of DM of the grain in each processing method. Following this the processing cost was added in for each grain processing method. In this experiment, $/kg of SFC =

(\$0.1508/kg × 0.75) + \$0.0088/kg and the \$/kg of CC = (\$0.1508/kg × 0.87) + \$0.0167/kg.

Data collection, calculations, and statistical analysis

All steers were harvested on the same day at 2 different plants. The black hided steers (n = 76) were harvested at Creekstone Farms (Arkansas City, KS). All other steers (n = 8; 4 hd/treatment) were harvested at Cargill Meat Solutions (Dodge City, KS). A total of 3 steers did not complete the experiment. Trained personnel from Oklahoma State University, Cargill Meats Solutions, and Creekstone Farms obtained all carcass data. Measurements included HCW, DP, ribeye area, marbling score, fat thickness, YG, and the USDA percentage prime, choice, and select carcasses. Data were analyzed using the PROC MIXED procedure of SAS 9.4 (SAS Inst. Inc.; Cary, NC). Pen was the experimental unit and block included as a random effect. All BW measurements were calculated with a 4% shrink. Significance was declared when $P \leq 0.05$ and trends were considered when $P > 0.05$ and ≤ 0.10.

RESULTS AND DISCUSSION

Total and available starch

Grain samples were analyzed for total starch and starch availability on a DM basis at a commercial laboratory (Servi-Tech, Inc. Dodge City, KS). Total starch on a DM basis was analyzed at SFC (d 0-56) 81.4%, SFC (d 57-156) 75.6%, and CC 73.9%. Starch availability on a DM basis was analyzed at SFC (d 0-56) 63%, SFC (d 57-156) 18% and CC 14%.

Animal performance

Feedlot performance data are presented in Table 2.2. There were no difference in BW ($P \geq 0.15$) or ADG ($P \geq 0.15$) during the 156 d finishing experiment. The CC calves had numerically ($P = 0.29$) heavier final BW. Zinn (1990) conducted an experiment assessing different flake densities of corn on feedlot performance. The experiment used 72 steers that were SFC based diet consisting of flake densities of 0.30, 0.36, or 0.42 kg/L. There were no differences in performance between steers fed the different density flakes. However, the author did mention that the calves fed the lowest flake density tended to have lighter final BW and decreased in feed efficiency (Zinn, 1990). These results could be relevant to the current experiment when considering the similar processing methods, but differences in density and starch availability among the 2 treatments.

Owens et al. (1997) reviewed data from 164 grain processing experiments. Within this review, there was a comparison between whole, dry-rolled, or steam-rolled corn fed to finishing cattle. The authors concluded that steam-rolled corn resulted in numerically decreased ADG. These results are similar to the current experiment as SFC and CC calves had similar ADG during the 156 d finishing experiment.

Dry matter intake was increased ($P \leq 0.01$) in the CC calves from d 0-56, d 57-125, and d 0-156. Yu et al. (1997) conducted an experiment with 32 lactating Holstein cows comparing SFC and steam-rolled corn. The researchers noted that the cows consuming the steam rolled corn ate 5% more feed than those consuming the SFC. These results are similar to the current experiment with the CC calves consuming more feed. Another experiment used 160 Holstein cows fed 1 of 5 diets over a 56 d period (Yu et al. 1998). The diets included SFC at a low flake density (309 g/L), SFC at a medium density (361 g/L), steam rolled corn (490 g/L), finely ground corn (580 g/L), and coarsely ground corn (618 g/L). The authors concluded that DMI of the lactating dairy cattle was not different between the SFC and steam rolled diets. These results contradict the DMI results from the current experiment when comparing CC and SFC calves.

Calves fed SFC were more efficient ($P = 0.04$) from d 57-125. Owens et al. (1997) concluded that more extensive (steam flaking or steam rolling) gain processing resulted in cattle being more efficient compared to cattle fed dry-rolled or high-moisture corn. However, Owens (1997) did not differentiate the extent of processing between SFC or steam rolled corn. Further investigation is needed to adequately determine the effects of these 2 corn processing methods on cattle performance.

Carcass characteristics

Carcass characteristics are presented in Table 2.3. There were no differences between corn processing methods for any carcass variables. However, CC calves had being numerically heavier HCW ($P = 0.11$). The experiment by Zinn (1990) also assessed carcass characteristics. He did not find a difference for HCW, DP, ribeye area, fat thickness, KPH, marbling score, or YG with different flaked densities of corn. An experiment by Leibovich et al. (2009) compared 2 different corn processing methods (SFC or dry-rolled corn) and used 160 steers. In this experiment they measured DP, HCW, ribeye area, fat thickness, KPH, YG, and marbling score. Leibovich et al. (2009) concluded that SFC steers had increased YG and fat thickness. These results are similar to current experiment for most carcass characteristics. Leibovich et al. (2009) concluded that different corn processing could potentially have an effect on carcass characteristics which was not observed in the current experiment.

Economical costs

Economics were evaluated (but not statistically analyzed) based on current prices of the feeds used in the experiment. Ingredients were calculated as $/kg DM basis at the percentage included in the diet. Supplement $0.019, dried distillers grains $0.021, liquid supplement $0.013, prairie hay $0.008, Sweet Bran $0.016, SFC $0.075, and CC $0.091. The total cost for 1 kg of the rations on a DM basis was $0.152/kg for SFC and $0.168/kg for CC.

The SFC calves had an ADG of 1.62 and an average DMI of 10.4 kg resulting in a G:F of 0.156 or a feed:gain (F:G = 6.42). To determine the cost kg/gain the total cost for 1 kg of the SFC diet was multiplied by the F:G ratio for a total of $0.979/kg gain. The calves consuming the SFC diet had DMI of 10.4 kg resulting in the cost of feeding each steer $1.586/d.

The CC calves had an ADG of 1.66 and an average DMI of 11.1 kg resulting in a G:F of 0.151 (F:G = 6.69). To determine the cost kg/gain the total cost for 1 kg of the CC diet was multiplied by the F:G ratio for a total of $1.126/kg gain. The calves consuming the CC diet had DMI of 11.1 kg resulting in the cost of feeding each steer $1.869/d.

IMPLICATIONS

Calves fed CC consumed more DM than calves fed SFC. Otherwise calves fed CC and SFC exhibit similar performance. This difference in DMI has been observed in previous literature with Holstein cows. The feed cost and cost of gain was increased in calves fed the CC diet compared to calves fed the SFC diet. With limited research conducted comparing these 2 specific corn processing methods, additional research is needed to conclusively determine the effects of steam flaking or crimping on performance and carcass characteristics.

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Table 3.1. Composition of receiving diet

Ingredient (% DM)	HAY
Dry rolled corn	10.00
Sweet Bran[1]	54.80
Dry supplement B-273[2]	5.20
Prairie hay	30.00
Nutrient composition[3]	
Dry matter	71.99
NE_m, Mcal/kg	2.01
NE_g, Mcal/kg	1.34
TDN, %	82.10
Crude protein, %	17.40
Crude fiber, %	16.57
NDF, %	42.87
ADF, %	18.40
Calcium, %	0.83
Phosphorus, %	0.72
Magnesium, %	0.32
Potassium, %	1.23

[1]Wet corn gluten feed (Cargill, Dalhart, TX).

[2]Dry supplement B-273 was formulated to contain (% DM basis) 38.46% ground corn, 30.36% limestone, 21.04% wheat midds, 6.92% urea, 1.03% magnesium oxide, 0.618% zinc sulfate, 0.38% salt, 0.119% copper sulfate, 0.116% manganese oxide, 0.05% selenium premix (contained 0.6% Se), 0.311% vitamin A (30,000 IU/g), 0.085% vitamin E (500 IU/g), 0.317% Rumensin 90 (Elanco Animal Health, Indianapolis, IN), and 0.195% Tylan 40 (Elanco Animal Health).

[3]Feed samples were analyzed for nutrient composition by an independent laboratory (Servi-Tech Laboratories, Dodge City, KS).

Table 3.2. Composition of finishing experimental diets

Ingredient (% DM)	Flaked[1]	Crimped
Steam-flaked corn	61.50	--
Crimped corn	--	61.50
Sweet Bran[2]	11.00	11.00
Distillers grains	11.00	11.00
Prairie hay	8.00	8.00
Dry supplement B-273[3]	5.50	5.50
Liquid supplement[4]	3.00	3.00
Nutrient composition[5]		
Dry matter	80.62	80.81
NE_m, Mcal/kg	2.15	2.18
NE_g, Mcal/kg	1.48	1.50
TDN, %	86.87	87.53
Crude protein, %	14.18	14.40
Crude fiber, %	6.93	7.05
Crude fat, %	4.13	4.22
ADF, %	10.07	9.35
Calcium, %	0.73	0.79
Phosphorus, %	0.50	0.53
Potassium, %	0.84	0.87
Magnesium, %	0.23	0.24
Sulfur, %	0.22	0.24
Sodium, %	0.10	0.10

[1]SFC from d 0-56 was sourced from Livestock Nutrition Center in Saginaw, TX and the SFC from d 57-156 was sourced form Nesika Energy in Scandia, KS.

[2]Wet corn gluten feed (Cargill, Dalhart, TX).

[3]Dry supplement B-273 was formulated to contain (% DM basis) 38.46% ground corn, 30.36% limestone, 21.04% wheat midds, 6.92% urea, 1.03% magnesium oxide, 0.618% zinc sulfate, 0.38% salt, 0.119% copper sulfate, 0.116% manganese oxide, 0.05% selenium premix (contained 0.6% Se), 0.311% vitamin A (30,000 IU/g), 0.085% vitamin E (500 IU/g), 0.317% Rumensin 90 (Elanco Animal Health, Indianapolis, IN), and 0.195% Tylan 40 (Elanco Animal Health).

[4]Liquid supplement was formulated to contain (% DM basis) 45.86% cornsteep, 36.17% cane molasses, 6.00% hydrolyzed vegetable oil, 5.46% 80VOP/20 oil, 5.20% water, 1.23% urea (55% solution), and 0.10% xanthan gum.

[5]Feed samples were analyzed for nutrient composition by an independent laboratory (Servi-Tech Laboratories, Dodge City, KS).

Table 3.3. Effects of corn processing on BW, ADG, DMI, and G:F

	Corn processing method			
Item	Flaked	Crimped	SEM	*P*-value
BW[1], kg				
d 0	377	380	11.45	0.19
d 56	470	479	12.47	0.15
d 125	578	584	14.46	0.43
d 156	629	639	16.63	0.29
ADG[2], kg				
d 0-56	1.65	1.77	0.06	0.15
d 57-125	1.59	1.54	0.06	0.50
d 126-156	1.66	1.78	0.11	0.41
d 0-156	1.62	1.66	0.05	0.43
DMI[3], kg				
d 0-56	10.3	11.2	0.32	< 0.01
d 57-125	10.4	11.0	0.35	< 0.01
d 126-156	10.5	10.9	0.45	0.26
d 0-156	10.4	11.1	0.33	< 0.01
G:F				
d 0-56	0.162	0.158	0.005	0.62
d 57-125	0.153	0.141	0.004	0.04
d 126-156	0.156	0.163	0.007	0.48
d 0-156	0.156	0.151	0.003	0.12

[1]Treatment BW was the BW in kg with a calculated 4% shrink.

[2]Treatment ADG was calculated from the shrunk (4%) BW in kg and days on feed between the time periods.

[3]Treatment DMI was calculated by taking DMI in kg for a pen for the period shown divided by the actual number of head days within each pen.

[4]Treatment G:F was calculated by taking pen ADG in kg divided by the pen average DMI in kg for the time period.

Table 3.4. Effects of corn processing on carcass characteristics

	Corn processing method			
Item	Flaked	Crimped	SEM	*P*-value
HCW, kg	402	411	10.20	0.11
Dressing percentage[1], %	63.9	64.4	0.32	0.20
Fat thickness[2], cm	1.36	1.37	0.07	0.86
Ribeye area[3], cm^2	91.7	91.4	1.56	0.85
Marbling score[4]	453	463	12.1	0.53
Yield grade[5]	3.12	3.17	0.11	0.64
Prime[6], %	7.22	14.78	4.47	0.21
Choice[7], %	90.6	83.0	4.34	0.21
Select[8], %	2.22	2.22	2.22	1.00

[1]Calculated by dividing the HCW by the shrunk live weight.

[2]Meaurement of the thickness of external fat on the carcass between the 12^{th} and 13^{th} ribs.

[3]Total area of the *longissimus dorsi* between the 12^{th} and 13^{th} ribs.

[4]Marbling scores: 400 = $small^{00}$, 500 = $Modest^{00}$.

[5]Calculated from HCW, ribeye area, fat thickness, and KPH.

[6]Percentage of calves with USDA prime carcasses within each pen.

[7]Percentage of calves with USDA choice carcasses within each pen.

[8]Percentage of calves with USDA select carcasses within each pen.

VITA

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Candidate for the Degree of

Master of Science

Thesis: EFFECTS OF ROUGHAGE SOURCE AND EXERCISE DURING RECEIVING AND CORN PROCESSING METHOD DURING FINISHING ON THE HEALTH, PERFORMANCE, AND CARCASS CHARACTERISTICS OF BEEF STEERS

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