GROWTH, PERFORMANCE AND QUALITY ATTRIBUTES OF STEERS SUPPLEMENTED WITH HIGH OLEIC SOYBEAN OIL

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by

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The undersigned, appointed by the dean of the Graduate School, have examined the thesis titled

GROWTH, PERFORMANCE AND QUALITY ATTRIBUTES OF STEERS SUPPLEMENTED WITH HIGH OLEIC SOYBEAN OIL

presented by William James Shirley,

a candidate for the degree of master of science,

and hereby certify that, in their opinion, it is worthy of acceptance.

Dr. Bryon R. Wiegand, Animal Sciences

Dr. Eric Bailey, Animal Sciences

Dr. Harley Naumann, Plant Sciences

DEDICATION

To my rodeo coach, Iola Else, thank you for believing and supporting me and so many other people with a love and passion that is truly immeasurable.

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GROWTH, PERFORMANCE AND QUALITY ATTRIBUTES OF STEERS SUPPLEMENTED WITH HIGH OLEIC SOYBEAN OIL

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ABSTRACT

Growing concerns with saturated fatty acids on human health has led to research being done to reduce saturated fatty acid levels in animal tissues. The objective of this study was to evaluate the effect of high oleic soybean oil on the performance, carcass composition and meat quaility of angus crossbred steers. 30 steers were sorted by weight using stratified sampling design into four pens, 2 being control and 2 being treatment. Control steers were fed a diet that included 3% regular soybean oil, while treatment steers were fed a diet with 3% high oleic soybean oil (HO). All animals were fed diets with soybean oil supplementation for a minimum of 63 days before harvest. After harvest, KPH weights and hot carcass weights were taken. Marbling score and longissimus dorsi area were assessed 48 hours after slaughter. Fat samples were taken from four different fat depots (subcutaneous, kidney, pelvic, heat (KPH), seam and intramuscular) and analyzed for fatty acids composition. PROC UNIVARIATE was ran and data more than three standard deviations from the mean was removed. Remaining data was analyzed using the PROC MIXED procedure of SAS 9.3. Greater DMI ($P<0.01$) was measured for cattle fed the HO diet and as a result DMI %BW was also significantly higher ($P<0.01$). However, the G:F was significantly less ($P= 0.05$) and the ending body weight had no difference.

Dietary treatment had no significant effect on any carcass characteristics except for the ribeye area (REA), which had a tendency to be smaller in the control diets (P=0.05). There were no significant differences in any of the fat depots with saturated and monounsaturated fatty acids except for intramuscular which had significantly less saturated fatty acids (P=0.03). Polyunsaturated and Omega-6 fatty acids were all significantly lower in the high oleic diets compared to the control (P<0.05). Results demonstrate that the high oleic oil did have a significant effect on the fatty acid profile of crossbred angus steers.

Chapter I

REVIEW OF LITERATURE

INTRODUCTION

The U.S. beef industry is unique to most other animal production systems due to it being relatively unintegrated. With an estimated 94.4 million head in the latest estimate by the USDA, cattle numbers have been on the increase the last couple of years (USDA NASS, 2018). Though inputs and cattle numbers continue to rise, beef prices have remained relatively constant due to many different factors, one of these being global consumption of beef.

Today's consumers are becoming more health conscientious as information about diets and its impact on human health become readily available. The overall meat consumption in the U.S. has not changed significantly in recent years. However, beef consumption has gone down compared to poultry which has gone up, and pork which has remained relatively constant (USDA ERS, 2017). Consumers were polled on their greatest concerns when it came to beef; price, cholesterol, artificial ingredients, convenience characteristics and caloric content all played a significant role in the negative perception of beef (Menkhaus et al., 1993). Though western civilizations consumption of beef has decreased, the world as a whole has increased disposable

income which has led to an increase in the purchase and consumption of more animal protein (Schulze-Ehlers and Anders, 2017). With growing global demand for protein, much research is being conducted to ensure consumers have a satisfying eating experiences when consuming meat products. Since one of the main concerns with beef is its perceived negative health effects, research is looking at developing a healthier product while maintaining quality attributes like tenderness, juiciness and flavor. Additionally, continued education for the public on meat quaility, handling and health benefits are done at the local, state and national levels.

U.S. Beef Industry

The U.S. beef industry is the largest beef producer in the world due to its considerable fed cattle numbers. An economic impact of $67.56 billion is estimated for both the cow and calf sector of the industry (USDA FAS, 2016). With an abundance of grain, more cattle can be finished allowing large numbers of high quaility beef to be produced. Though the U.S. is a large producer of beef, it is known as a net importer, which means it imports more product than it exports. Most of the beef imported into the U.S. is grass finished beef used for ground and other further processed products. The largest importer of beef into the U.S. is Australia, followed by New Zealand and Canada (USDA FAS, 2016). The estimated imports of beef into the U.S. is around 1.1 million tons compared to a total of 716,000 tons of exports in 2015 (USDA FAS, 2016).

There are two main sectors in the U.S. beef industry: cow calf and cattle feeding. The purpose of the cow calf sector is to raise calves that will eventually be placed into

the cattle feeding sector after weaning. The cow calf sector of the beef industry has remained largely unintegrated compared to other sources of animal protein and crop production (MacDonald et al., 2018). The average cattle herd in the United States is around 40 head, producing 49% of the industries cattle inventory. Almost all of these are family owned operations and are a source of additional income outside of off farm employment (USDA ERS, 2018).

The second main part of the cattle industry is the cattle feeding sector. The main goal of the feeding industry is to grow cattle to a point where they are placed on a grain-based diet and finished for slaughter. The majority of operations are comprised of less than 1,000 head but makeup a small number of the overall cattle fed (USDA ERS, 2018). Most cattle are in feedlots of 1,000 head or more with 40% of feedlots having 32,000 head or higher. The feedlot industry is beginning to change to a more vertically integrated system compared to the cow calf sector (USDA ERS, 2018).

EXPORT MARKETS

The U.S. has traditionally been one of the world leaders in beef exports and is currently the largest producer of beef in the world. Efficient production practices as well as the use and constant improvement of genetics has increased production over time. It is estimated that almost 51 million metric tons, or an increase of 3.1% of beef will be produced in 2019 (USDA FAS, 2018). Along with increased production, there is expected to be an increase of exports over 2019. Growing global demand will give rise to more opportunities for the U.S. to market its beef (USDA FAS, 2018). Increases

in household income in developing countries tends to be associated with an increase in meat consumption (Speedy, 2003). Therefore, as the global population and average income increases, global production and consumption of meat as a protein source is expected to rise (Speedy, 2003). Currently the three largest importers of beef are China, Japan and Hong Kong. While the main importers of U.S. beef are Japan, South Korea, Mexico, and Canada (USDA FAS, 2018).

U.S. Markets

There are four main ways for beef producers to market their finished product in the U.S.: they are conventional, natural, grass-feed and organic. Conventional is the most commonly used marketing strategy and is the traditional way most cattle are raised. The vast majority of the calves are born on pasture, weaned and finished in a feedlot (USDA ERS, 2018). During this process, cattle can be fed growth promotants and antibiotics can be used. To qualify for certified natural beef, three requirements must be met: (1) the product must be minimally processed, (2) the product cannot contain any artificial ingredients and (3) the product cannot contain any preservatives (Troxel, 2005). However, most certified natural products also have further regulations on antibiotics and growth promotants in order to be labeled under their branded product. There are no grass feed certifications under the USDA, but there is a reference that labels may use in their programs. This states that ruminants can only be fed grass or forage throughout their entire life (with exception to milk) and have access to pasture all the way through the finishing of the animal. (USDA AMS, 2018a). Like certified natural, many programs will have a set

of standards in order to qualify for their labeling. The last way to market beef is through the certified organic program. The certified organic program sets the rules and enforces the regulation of the program. In general, the land in which the cattle are raised, the cattle themselves, and any feed fed to the cattle have to all qualify as organic (USDA AMS, 2018b).

In combination with any of the above-mentioned programs, age and source verification can be added to increase the ability for reaching additional markets. Age and source verification tracts the calf from birth to slaughter and allows the consumer to determine when and where that calf was throughout its life. Many countries require age and source verification on the animal products they ship into their countries. The U.S. however, has not adopted a required age and source verification program (Pendell et al., 2013). One of the main reasons that there has not been a program put in place is due to the large number of small operations throughout the U.S. Many of these small operations do not see any of the direct benefits resulting from having an increased cost with an animal ID system (Schulz and Tonser, 2010, Tonser and Schroeder, 2006). Another reason that a verification program is being met with resistance is that most the beef produced is consumed domestically. In general, it has been found that most citizens do not demand verification therefore causing a pushback by many producers to adapt the program due to the added costs. As a result, the USDA developed and supports a voluntary age and source verification program. (Murphy et al., 2009).

CONSUMER DEMAND

Consumers are becoming increasingly aware of the safety and quality, as well as where and how their food is produced (Caswell, 1998). Bovine spongiform encephalopathy (BSE), recent E. Coli outbreaks and growing concerns with genetically modified organisms (GMO's) have all attributed to consumer concerns. To many consumers the source and the process used to produce beef is not apparent. Selections are based on experience, from consumption, or visual inspection of the product (Umberger et al., 2003). If additional production information such as origin, organic or all natural is available, it also can influence the consumer's decision (Caswell and Mojduszka, 1996). Therefore, consumers have both intrinsic and extrinsic quality cues effecting their decisions. Intrinsic quality ques include the cut, color and fat content. Extrinsic cues include things such price, origin and production means (Grunert et al., 2004).

Beef is considered and widely accepted as a healthy and nutritious food, but in recent years some negative health impacts have over shadowed the positives (Scollan et al., 2006). Many of the negative side effects have to do with the saturated fat levels found in beef adipose tissue. As a result, the meat industry has worked to produce leaner animals (Higgs, 2000). Lower quality grades (lower intramuscular fat) are associated with less desirable eating experience (Smith et al., 1984). While consumers have pushed for leaner and healthier products, quality associated with well marbled meat is still demanded (Colmenero, 2000).

BEEF QUALITY

To measure the quality and change of the U.S. beef herd, periodic quality audits have been conducted. Recent audits have looked at things from bruising to quality and yield measurements at various slaughter houses throughout the U.S. In general, there has been an increase in the overall quality and size of the cattle being produced in the U.S. (Eastwood et al., 2016). The increase is due to improved genetics and the overall growth of the frame size of cattle in the U.S. Along with improved quality, there has been an overall decrease in the incidences of bruises and condemnations of the cattle (Eastwood et al., 2016). This shows that along with the improvement of our cattle, there is also an advancement in the way we handle and feed our cattle resulting in a better product. Data shows that the overall quality of our animals and practices are getting better, but there is still room for improvement.

Maturity and quality grade are the two main factors that influence the overall quality grade of a carcass. Quality is measured using a visual representation of the marbling found on the longissimus dorsi surface of the 13^{th} rib while the maturity is determined by the ossification levels found on vertebrate. The basis of this measurement was a study by Smith et al. (1984) that showed as marbling increased, the likelihood that the steaks became more palatable increased. Smith et al. (1986) later showed that as the maturity of the animal increased, the tenderness and the overall palpability of rib steaks decreased. Cattle are typically bought on a combination of quality and yield grade (grid pricing). However, consumers only have the quality grade available to them to influence their purchasing decisions.

It is widely accepted that the quaility of eating beef is based off a combination of tenderness, juiciness and flavor. Quality can be affected by both ante- and postmortem handling. In a study done by Lahuckey et al. (1998), stress levels were shown to cause higher pH, increased water holding capacity and a decreased shear force. These increased levels can be indicators of DFD, or dark firm and dry, in beef. DFD is a result of glycogen depletion before the conversion of muscle to meat that results in a higher pH. This causes the muscle to bind to more free water leading to the increased light absorption and a darker color (Scanga et al., 1998). Consumers preferred the appearance, flavor and overall acceptability of normal steaks (pH 5.0-5.6) compared to DFD (Vilijoen et al., 2002). After the animal has been slaughtered, things such as suspension, chilling rate and hanging time all impact the quality of beef (Joseph et al, 1977).

FATTY ACIDS AND HEALTH

With the recent outbreak of obesity in many developed countries, growing concerns have arisen about the fat in our diets. While the public's overall perception of fats is negative, there is a great deal of research to show that there are numerous fatty acids that are beneficial for human health (Williams, 2000). The basic make up of fatty acids is a carbon chain tail attached to a carboxyl head. There are many types of fatty acids that all play various roles in human health.

Saturated fatty acids are fatty acids with no double bonds. Due to having no double bonds, saturated fatty acids fit closely together causing saturated fats to be solid at room temperature. High levels of saturated fats in a diet have been associated with an increase

in blood cholesterol concentrations (Hegsted et al., 1965) (Keys et al. 1965). However, only specific kinds of saturated fatty acids such as lauric, myristic and palmitic cause negative side effects such as increased lipoprotein levels (Bonanome, Grundy, 1988). Due to the adverse effects of saturated fats, the American Heart Association recommends that saturated fats make up less than 7% of a total diet (Lichtenstein et al., 2006).

There are two different kinds of unsaturated fatty acids, monounsaturated and polyunsaturated fatty acids. Monounsaturated fatty acids have one double bond in their carbon tail, while polyunsaturated have more than one. Both mono- and polyunsaturated fatty acids are known to have cholesterol lowering properties (Mattson and Grundy, 1985). There is some belief among the public that polyunsaturated fatty acids are more effective than monosaturated fatty acids. However, Mensink and Katan (1989) found that monounsaturated and polyunsaturated were both effective in reducing lipid cholesterol at similar levels. Due to the positive health attributes of both fatty acids, considerable time and attention has been put into replacing saturated fatty acids with unsaturated fatty acids.

There are two main types of polyunsaturated fatty acids: omega-3 (n-3) and omega-6 (n-6) fatty acids. One of the main sources of omega-3 fatty acids is seafood, but it can also be found in various seeds, nuts and vegetables as well (Meyer et al., 2003). Omega-6 fatty acids are found in most products containing fat from animals as well as in many cereal based products and vegetables (Meyer et al. 2003). Humans were believed to have evolved on a ratio of 1:1 or 2:1 of n-6 to n-3 fatty acids (Eaton et al., 1998) (Simpolus, 1991). Today's diets have a much more skewed ratio, anywhere from 20:1 to 50:1 of n-6 to n-3. Mammals lack the omega-3 desaturase which causes them to not be able to convert omega-6 to omega-3. This results in an abundance of n-6 products masking the benefits of n-3

(Schmitz and Ecker 2008). This skewed ratio of n-6 to n-3 has been associated with many health risks including cardiovascular disease, arthritis, depression and possibly cancer (Siscovick et al., 1995) (Geusens et al. 1994) (Jazayeri et al. 2008) (Simonsen et al. 1998).

Trans fatty acids are synthetic unsaturated fatty acids that are typically formed from the partial hydrogenation of vegetable oils. Food industries use this method of partially hydrogenating vegetable oils for added benefits in shelf life, frying and enhanced palability in some foods (Mozaffarian et al., 2006). Trans fats are also found in ruminant animal fat due to the biohydrogenation of other fats from their feedstuffs in the rumen (Reiser, 1951) (Shorland et al., 1955). Trans fatty acids produced by the rumen tend to be predominantly vaccenic acid (18:1 *trans*-11) and differ greatly compared to trans fatty acids produced by vegetable biohydrogenation, which tend to be elaidic acid (18:1 *trans*-9) (Wolff et al. 1998). Both are believed to have negative effects on cholesterol levels. Mensink and Katan (1990) found that trans fatty acids raise low-density lipid protein levels (LDL) and lower high-density lipid protein levels (HDL). LDL cells commonly referred to as "bad cholesterol" by the public are used in the body to transfer fat molecules in the extracellular water. HDL transfers both LDL and fats to the liver where they are metabolized by the liver. The combination of raising LDL and lowering HDL is why the American Heart Association recommends that trans-fat make of less than 1% of the energy in a healthy diet (Lichtenstein et al., 2006).

FATTY ACIDS AND MEAT QUALITY

Fatty acids have large effects on many different factors in meat quality. The compositions of saturated and unsaturated, and their different chemical properties, result in these differences. There are three main things that fatty acids affect in meat quaility. They are fat tissue firmness, shelf life and flavor.

In general, as saturation decreases, melting point decreases. This is due to the chemical properties of the fat allowing the molecules to pack closely together causing them to be solid at room temperature. Saturated fats have no double bonds. Double bonds cause a bend in the molecule and result in molecules not fitting closely together, causing them to be less firm. Ruminants tend to have a more saturated fatty acid profile compared to monogastrics (Enser et al., 1996). Therefore, their fat tends to be harder at room temperature. A study done by St. John et al. (1987) found that as unsaturation increased in the fat depots of both pigs and cattle, increases in oiliness and decreases in fat firmness were observed. The saturation of fatty acids can change throughout an animal's life. Fed beef cattle tend to have a more unsaturated profile of fatty acids during their fattening phase compared to later in life (Leat, 2009). There has been much research done to try and affect the fatty acid profiles of ruminants, but ruminal hydrogenation makes it more difficult for the fatty acid profile to be changed. Molecular structure also causes differences in melting temperature. Trans fatty acids have a higher melting point than cis-isomers and branched chain fatty acids have a lower melting point compared to straight chain fatty acids with the same number of carbons (Enser, 1984).

Lipid oxidation in beef is one of the major factors in the degradation of meat quality (Gray et al. 1996). Oxidation of lipids, especially unsaturated lipids, results in rancidity of the meat as display time increases (Vatansever et al., 2000). In addition, toxic byproducts as well as the loss of nutritional value can occur (Pearson et. al. 1983). It has also been proposed that lipid oxidation can promote myoglobin oxidation (Lin and Hultin 1977), or be closely associated with it (Mercier et al. 1995). This mechanism is due to the free radicals that are produced during lipid oxidation. Oxidized lipids decompose heme pigments and cause oxymyoglobin to be converted to metmyoglobin, which results in the brown color that is not desired by consumers (Haurowitz et al. 1941). In order to combat this, both synthetic and naturally found antioxidants such as BHT and rosemary are used (Formanek et al., 2001).

Flavor is another very important factor in a consumer's eating experience. Many factors influence meat flavor, but they can all be categorized into either water-soluble or lipids. Before cooking, meat has a bloody taste and little to no aroma. The taste and smell desired from meat are species specific and occur after cooking (Macy et al. 1964) (Kramlich and Pearson, 1960). This is due to the autoxidation of lipids. Cooking causes Maillard reactions which results in triglycerides and phospholipids, found in cell walls, to be converted to volatiles which results in specific tastes and aromas (Mottram, 1985). There are several hundred known volatile compounds derived from lipid degradation during the cooking of meat. Some of these include unsaturated aldehydes, alcohols and ketones. Aldehydes are thought to have the most effect on flavor due to them having very low odor thresholds and are also thought to be one of the major causes in the formation of the flavor of beef (Elmore et al, 1999). Campo et al. (2003) also found that the aroma of

cooked meat is a result of interaction between fatty acids and Maillard reaction products. Some of these products include cysteine and ribose.

MANIPULATING FATTY ACIDS

One of the major sources of fat in the modern diet comes from animal byproducts. With a growing concern of the relationship between cardiovascular disease and saturated fat in diets, much thought has been given to changing the fatty acids profile of livestock. In monogastrics, Kouba et al (2003) found that the n-6: n-3 ratio of fatty acids in pigs could be changed from 7.6 to 3.9 in twenty days between two different experimental groups of pigs. Changing the fatty acid profile of ruminants is much more difficult due the biohydrogenation that takes place in the rumen. One solution to the problem is feeding and finishing ruminants on a grass or forage diet. In general, when cattle are finished on grass, the total amount of fat goes down. Unexpectedly, results for saturated fats are inconsistent between studies. However, myristic (C14:0) and palmitic (C16:0) fatty acids tend to be higher in cattle finished on grain diets (Alfaia, et al., 2009) (Leheska, et al., 2008) (Ponnampalam, et al., 2006) (Nuernberg, et al., 2005). These fatty acids are associated with the negative effects on cholesterol serum levels. There are some off flavors associated with grass fed beef due to the change in the fatty acid composition (Larick and Turner, 1990). The increase in alpha-linolenic (18:3), which is higher in forages than cereal grains, is believed to cause the change in volatile compounds after cooking. Sitz et al (2005) found that overall acceptance of grain finished steaks was much higher compared

to grass finished steaks. This shows that the U.S. consumer is accustomed to and prefer the taste of grain finished beef.

Another way to manipulate the fatty acid profile of cattle is to feed certain fats and oils with specific fatty acids, or desired ratios of n-3 and n-6 fatty acids. In a study done by Scollan et al. (2007), cattle feed with whole linseed, fish oil and a combination of both increased some polyunsaturated fatty acids. The ratio of polyunsaturated to saturated did not change in the experiment. Fats and oils all have specific effects on ruminal activity and effect biohydrogenation depending on their fatty acid makeup. Scollan et al. (2001) found that whole linseed oil was biohydrogenated less than fish oil. This is believed to be in part due to protection from the seed coat. A feedlot trial found that fat supplementation compared with no fat supplementation resulted in a different proportion of oleic, linoleic, linoleinic, steric and palmitic acids (Brandt and Anderson, 1990). Also, different fat sources for feed affected the fatty acids ratios differently. There have been numerous studies done feeding vegetable oils to ruminants to try and change their fatty acid profile with varying success. Lipiarska et al. (2001) found that linseed and rapeseed oil cake resulted in a more unsaturated fatty acid profile and less total fat to a group of bulls. Beaulieu et al. (2002) feed a group of steers a diet with soybean oil and found that conjugated linoleic acid was not changed. Li et al., (2017) found decreases in saturated fatty acids as well as increases in oleic and linoleic fatty acids fed to cattle with whole linseeds. Bruns et al. (2015) and Barletta et al (2016) have reported increases in unsaturated fatty acids in milk when feeding whole raw or steam flaked soybeans. Overall, different fats are biohydrogenated and have different effects on ruminal activity. The source, amount, and the way the fat is fed all play a role.

HIGH OLEIC TRIALS

One example of an oil used to try and change the fatty acid profiles in livestock is high oleic soybean oil (18:1). It is also a healthy alternative to trans fatty acid vegetable oils for human consumption. Oleic oil is a monounsaturated fatty acid that is more resistant to oxidation compared to polyunsaturated fatty acids. In 2012, soybean oil accounted for over 64% of the vegetable oil consumed in the US (USDA ERS, 2012). In order to qualify as high oleic oil, the fatty acid make up must include 70% oleic acid (Huth et al., 2015). This monounsaturated fatty acid is a promising alternative for human consumption and research has begun to see if it can be used as a supplement in animal feed to try and change the fatty acid profile and quality of both meat and milk. In a study done by Lopes et al, (2016), dairy cattle fed high oleic soybean oil had increased mono-unsaturated and cis-9 18:1 fatty acids. Decreases in trans, polyunsaturated and conjugated linoleic fatty acids were also found in the milk fat. Holstein cows fed high oleic sunflower seeds resulted in lower unsaturated levels compared to control sunflower seeds (Casper et al., 1988). Felton and Kerley (2004) found an increased level of oleic acid found in loin samples from steers fed whole high oleic soybeans compared to control soybeans. In sheep, there were no detectable differences in growing traits with lambs fed high oleic soybean oil. There was a decreased a* value found in the longissimus dorsi muscle (Belon et al., 2018). Though there is some promise to altering fatty acid profiles, some studies such as one done by Hristov et al., (2005) found no detectable differences in fatty acid profiles of cattle fed oleic rich safflower oil compared to a control.

BIOHYDROGENATION

In most cases, fatty acids fed to ruminants become saturated in the rumen. This is believed to happen in a twostep process, lipolysis and biohydrogenation. In lipolysis, fatty acids are broken down from their fat structures by microbial lipases. The lipases break down the ester linkages by hydrolyzing them, causing a carboxyl group to be exposed (Garton et al., 1961; Dawson et al., 1977). The carboxyl group is then electronegative. This allows hydrogen to be bound to the carboxyl group causing a shift of electrons. Once this shift takes place, isomerization can occur, which allows the saturation of double bonds (Harfoot and Hazelwood, 1988).

There are few theories on why this occurs. One theory states that fatty acids are biohydrogenated into forms that are used in the membranes of certain lipids (Hazelwood and Dawson, 1979). This was discredited due to the fact that the believed bacteria performing this process make up a small proportion of the rumen biome. The second theory states that biohydrogenation takes place so that hydrogen gets disposed of to produce a reduced environment for certain bacteria (Lennarz, 1966). This theory was discredited by Harfoot and Hazelwood (1988) due to methanogenesis being a much more efficient process in removing hydrogen. The third and most accepted theory states that fatty acids are saturated in order to detoxify them against ruminal bacteria (Kemp and Lander, 1984). Unsaturated fatty acids are known to reduce microbial efficiency and fat fed at too high of levels is known to cause reduced intake and performance in cattle (Zinn et al. 1994). The mechanism behind this is due to the unsaturated fatty acids being absorbed into the cell membranes of certain microbial species in the rumen. This will eventually cause

disorganization of the phospholipids on the cell membrane enough to cause cell damage and death (Jenkins, 2002). The destruction of these bacteria can cause a shift in the biome of the rumen and alter its function and ability to ferment feedstuffs (Jenkins, 2002).

Cattle feedstuffs are primarily composed of 18:2 (linoleic) and 18:3 (alpha linolenic) fatty acids (Beef NRC, 2016). Diets that are forage based have more 18:3, while cereal grain-based diets have higher 18:2. Due to both of these fatty acids being unsaturated, the rumen biohydrogenates them towards 18:0 (steric acid) to minimize the toxic effects of unsaturated fatty acids. Polyunsaturated fatty acids are more toxic to biohydgrogenating bacteria than di- or monounsaturated fatty acids (Maia et al., 2010). As a result, as unsaturation increases, the more easily they are saturated by isomerases (Beam et al., 2000). There are many proposed pathways that lead to the formation of steric acid. However, the end result of steric acid is not always reached (Katz and Keeney, 1966). Products of biohydrogenation include different isomers of both linoleic (CLA's) and oleic fatty acids (Dawson and Kemp, 1970) (Shorland et al, 1957). It is believed that the various ruminal contents produce different enzymes (isomerases) that result in different cis and trans isomers (Yuraqecz et al., 1998). Isomerase activity can also be affected by the diet due to the change in pH that results in a microbial shift in the rumen. This leads to different biohydrogenation pathways depending on the pH (Leat et al. 1977). The concentration of oleic and alpha-linolenic fatty acids biohydrogenated in the rumen is around 86%, while linoleic is 82% (Jenkins and Bridges, 2007). The relationship between the total amount of fatty acids consumed and the loss of unsaturated fatty acids in the rumen is linear. Meaning, the higher amount a fatty acid is fed, the more it is going to escape the rumen and be absorbed in the small intestine (Beam et al., 2000). Out of 95% of the lipids

reaching the small intestine, 60% are transformed in the rumen and 35% are products from ruminal microorganisms (Jenkins, 1994).

To combat biohydrogenation, ruminal protection technologies have been used with varying success. There are two main ways to accomplish this: encapsulation of unsaturated fatty acids or alter the structure of desired fatty acids to prevent microbial actions (Beef NRC, 2016). In a comparison of 25 studies, Jenkins and Bridger (2007) found that ruminal loss was similar for alpha-linolenic and linoleic between treated and untreated and was about 15% improved for oleic.

DIGESTION AND ABSORPTION OF LIPIDS

After biohydrogenation of fatty acids occurs in the rumen, all the long chain fatty acids will then enter the small intestine usually as free fatty acids due to microbial lipolysis of triglycerides in the rumen (Garton, 1965). Other than being hydrogenated, long chain fatty acids from triglycerides are not degraded in the rumen and are not absorbed until they reach the small intestine (Garton, 1965). Only around 15-20% of dietary lipids are absorbed (Caple and Heath, 1975). There are also some lipids in the form of phospholipids that are from microbes in the rumen (Beef NRC, 2016). Once in the small intestine, bile salts released by the pancreas, cause the formation of micelles. These micelles are broken down by microvilli found on the walls of the small intestine. The free fatty acids are then taken up by the mucosal cells where they return to triglyceride form and are transported to the lymphatic system. The absorbed fatty acids form chylomicrons or fat droplets during the transition from the small intestine too the lymphatic system. After the chylomicrons

enter the lymphatic system, they enter the vascular system through the thoracic duct (Leat and Harrison, 1975) (Beef NRC, 2016).

FAT DEPOSITION

Deposition of fat in cattle takes place when energy intake is greater than energy expenditure (Mersmann, 1991). Adipose tissue is made up of 70-90% fat, 5-20% water and 5% connective tissue (Nurnberg et al. 1998). In general, adipose deposition for cattle occurs internally and moves externally as finishing and time increases (Buttler-Hogg and Wood, 1982). It is widely accepted that cattle have multiple fat depots. These include intermuscular (between muscles), intramuscular (between muscle fibers), visceral (kidney pelvic and heart), and subcutaneous (directly under the skin) (Aberle et al., 2012). Fat is typically deposited in the form of triglycerides into adipocytes to form adipose tissue. Triglycerides are molecules with a glycerol backbone and three fatty acid chain tails. Before fat can be deposited, fat cells mature from preadipocytes into mature adipocytes. As cattle grow, the total weight, number of cells, and the cell size of adipose tissue increases (Robelin, 1981). Growth in different depots occurred at different ages and different rates. Each depot followed the same path of hyperplasia (growing number of cells), then hypertrophy (filling of the cells). Subcutaneous is known to be the latest maturing but grew at the fastest rate. Costa et al., (2012) found that subcutaneous adipose tissue had a smaller number, but larger cells compared to visceral fat. In addition to different growth, after a certain level of fat deposition is reached, the fat ratio begins to become more unsaturated resulting in softer oilier fat in feedlot cattle (Leat, 1975) (Wood,

1984). Wiegand et al. (2011) found that pigs had different fatty acid contents in different fat depots when fed the same diet. Proving fat is deposited at different places throughout growth and also that fatty acid make-up is different in each of the depots.

Many factors influence fat deposition. As discussed earlier, the fatty acid profile can be changed by feeding various feedstuffs. After a certain age, adipose tissue begins to become more saturated and continues to do so as animals become older (Nürnberg et al., 1996). Gender also plays a role in fat deposition and saturation. Concentrations of PUFA are highest in males, followed by females and then male castrates (Malau-Aduli et al., 1998). Fat concentrations have also been found to be higher in females followed by castrates and then intact males (Lago et al. 2012) (Berg et al, 1979). Things such as feed additives affect fat deposition as well. β-agonists are known to increase muscle growth while decreasing fat in cattle (Moloney et al. 1994). With advancements in genetic technologies, genes have been found that affect adipose deposition. Wang et al., (2005) found that multiple genes were expressed between two breeds of cattle that effected marbling and fat deposition differences between the breeds, as well as individuals within the breed.

One of the main genes believed to affect the fatty acid profile of different fat depots is the stearoyl-CoA desaturase gene (SCD). The SCD gene causes an increase in Δ^9 desaturase (Chung et al., 2006). Δ^9 desaturase is an enzyme that is believed to be responsible for the conversion of saturated fatty acids into monounsaturated fatty acids during fat deposition (Smith et al., 2006). The expression of this gene and resulting enzymatic activity is higher in adipose compared to other tissues such as muscle (Chang et al., 1992) (Cameron et al., 1994). Expression of this gene is controlled by multiple means.

One of the main variables controlling expression of the SCD gene is age. Marin et al. (1999), found that expression of the gene is relatively stagnant until five months of age. At 5 months of age expression continually rises until around 12 months of age where it then peaks and begins to fall. The SCD gene is also affected by diet. Chung et al. (2006), found that cultured preadipocyte cells exposed to *trans*-10 and *cis*-12 conjugated linoleic acid (CLA) had nearly no expression of the SCD gene compared to *cis*-9 and *trans*-11 CLA had little effect on the gene expression except at high concentrations. *Trans*-10 and *cis*-12 CLA's also caused reduced lipid filling and a reduction of monounsaturated fatty acid deposition. Certain breeds, such as the American Waygu and Korean Hanwoo, also are more predisposed to express higher levels of the SCD gene resulting in higher levels of monounsaturated fatty acids in their fat depots compared to other breeds (Smith et al., 2006).

GROWTH AND PERFORMANCE

The overall growth and performance of cattle is the basis for any producer regardless of what sector they contribute to in the beef industry. When designing and testing different supplementation methods, careful consideration needs to be addressed on the effects of the supplement. In order to measure growth and performance, things such as gain to feed, dry matter intake and marbling score are all used to determine the resulting performance effects of a supplement. When supplementing fat, the main purpose is to increase the energy density of the feed, and more recently, to try to affect the fatty acid composition of the carcass. Increasing fat supplementation was measured to have a

quadratic effect with DMI decreasing until 8% fat levels were reached in the diet but increasing when fed at the 12% level (Zinn et al., 1994). As unsaturation and the amount long chain fatty acids increases in diets, decreases in DMI were found (Drackley et al., 1992). Inclusion of vegetable oil also has an effect in the amount and frequency of meals in cattle. Diets containing 10% vegetable oil caused smaller and more frequent meals resulting in no dry matter intake differences compared to a control (Heinriches et al.,1982). In a survey done by Vasconcelos and Galyean (2007), 71% of feedlots used added fat at an average of 3.1% of the diet. Diets containing up to 6% of fat supplementation were observed to have no negative effect on growth performance (Zinn and Jorquera, 2007). However, there is still some debate as to the acceptable range due to the average fat recommendation being around 7.6% of the diet (Vasconcelos and Galyean, 2007). There is a general acceptable range for fat supplementation, but if values exceed recommended levels, decreases in ADG, DM conversion and NE were measured (Zinn et al., 1994). Additionally, increasing the amount of days on soybean oil did not have any affect on carcass and performance measurements (Ludden et al., 2009).

Chapter II.

GROWTH, PERFORMANCE AND QUALITIY ATTRIBUTES OF STEERS SUPPLEMENTED WITH HIGH OLEIC SOYBEAN OIL

ABSTRACT

Growing concerns with saturated fatty acids on human health has led to research being done to reduce saturated fatty acid levels in animal tissues. The objective of this study was to evaluate the effect of high oleic soybean oil on the performance, carcass composition and meat quaility of angus crossbred steers. 30 steers were sorted by weight using stratified sampling design into four pens, 2 being control and 2 being treatment. Control steers were fed a diet that included 3% regular soybean oil, while treatment steers were fed a diet with 3% high oleic soybean oil (HO). All animals were fed diets with soybean oil supplementation for a minimum of 63 days before harvest. After harvest, KPH weights and hot carcass weights were taken. Marbling score and longissimus dorsi area were assessed 48 hours after slaughter. Fat samples were taken from four different fat depots (subcutaneous, kidney, pelvic, heat (KPH), seam and intramuscular) and analyzed for fatty acids composition. PROC UNIVARIATE was ran and data more than three standard deviations from the mean was removed. Remaining data was analyzed using the PROC MIXED procedure of SAS 9.3. Greater DMI ($P<0.01$) was measured for cattle fed the HO diet and as a result DMI %BW was also significantly higher ($P<0.01$). However, the G:F was significantly less ($P= 0.05$) and the ending body weight had no difference. Dietary treatment had no significant effect on any carcass characteristics except for the ribeye area (REA), which had a tendency to be smaller in the control diets ($P=0.05$). There

were no significant differences in any of the fat depots with saturated and monounsaturated fatty acids except for intramuscular which had significantly less saturated fatty acids ($P=0.03$). Polyunsaturated and Omega-6 fatty acids were all significantly lower in the high oleic diets compared to the control ($P<0.05$). Results demonstrate that the high oleic oil did have a significant effect on the fatty acid profile of crossbred angus steers.

INTRODUCTION

Increases in today's consumer's concern with their food and its effect on health, have resulted in research being conducted to improve the overall healthiness of many food products. Animal byproducts are known to be a large source of saturated fatty acids. Saturated fat is associated with increases in blood cholesterol concentration (Hegsted et al. 1965) and as a result the American Heart Association has recommended that saturated fats make up less than 7% of a diet (Lichtentein et al. 2006). Due to this, attempts have been made to replace saturated fatty acids with unsaturated fatty acids. Though unsaturated fatty acids are associated with many health benefits, meat quaility declines as unsaturation increases. One of the main causes in the loss of quality has to do with lipid oxidation and resulting rancidity (Vantansever et al., 2000). To combat both health issues and meat quality issues, oleic acid has been proposed as both a healthy alternative and are more resistant to oxidation compared to polyunsaturated fatty acids.

MATERIALS AND METHODS

The University Animal Care and Use Committee approved animal care and experimental protocols prior to the initiation of this experiment.

Experimental Procedure

In December of 2017, 30 crossbred angus steers at an average of 357 Kg, who were born and raised at The Beef Research and Teaching Farm (BRTF) in Columbia Missouri, were sorted into 4 pens, 2 being control and 2 being treatment, using stratified sampling. All the steers were AI calves sired by WR Journey (ORIgen © 2015) were born in the spring of 2017, weaned that fall, and placed in a feedlot pen at the BRTF. Both control and treatment calves were fed a standard corn-based finishing diet for the first 62 days (Table 2.1) and then were placed on a finishing diet with the inclusion of experimental (3% High Oleic Soybean Oil) or control diet (3% Commodity Soybean Oil) until slaughter (Table 2.2).

Feed samples were collected and sent to the University of Missouri Experiment Station Chemical Laboratories where a proximate feed analysis was done. Samples were collected biweekly for both the initial and finishing phases. Three random samples from each diet were ground and mixed before sending the laboratory for analysis.

The first weigh day after initial sorting occurred on day 34. Following this weigh date, 28 day weights were taken through day 118 (d=62, d=90, d=118). The inclusion of oil in the diet occurred on day 62 of the experiment. This allowed for a minimum of 63 days on feed with the inclusion of soybean oil before the first group of steers were

harvested. After day 118, the first group of 8 steers was sorted into individual pens and fed a standard amount of 22.02 kg of feed. Calves were chosen for slaughter based on backfat measurements conducted on weigh day 90. Final weights were calculated from the day before and day of slaughter. Consecutive groups of 8, 7 and 6 were chosen in the same fashion and slaughtered.

Slaughtering occurred at the University of Missouri Abattoir approximately 11.7 km away from the BRTF. Cattle were unloaded and allowed to rest in lairage with water and no feed until slaughtering occurred under USDA-FSIS inspection criteria. Upon opening of the carcass, kidney, pelvic and heart fat (KPH) was collected and weighed in order to later determine yield grade as well as a sample for fatty acid analysis. After visceral organs were removed, the carcass was split, hot carcass weight was collected, and then the halves were placed in the cooler.

Animals and Management

On the first weigh day, cattle were given a radio frequency identification tag (RFID;AllFlex, Dallas, TX) and 36 mg of Ralgrow (Merck Animal Health, Madison, NJ). Following processing, individuals were sorted into one of 4 pens that were 7.31 x 8.53 meters and had all concrete flooring. Half of each pen was covered to allow for protection from precipitation and sun while the remaining half was cover free. Cattle were provided ad libitum access to 2 Growsafe bunks (GrowSafe Systems, Airdrie, AB, Canada) and 1 automatic water per pen (Ritchie Industries Inc. Conrad, IA). Pens were bedded with sawdust and were cleaned approximately every two weeks. Feed was distributed at 0800

each morning with a truck-mounted mixer (Reel Auggie 3120, KUHN North America, Inc., Bordhead, WI).

One calf, number 7015, was treated for a jaw abscess during the study. The abscess was lanced, and the calf was given 35 mL of Liquamycin 200 (Zoetis Services LLC., U.S.). Calf number 7028 died during the study and an analysis done by the University of Missouri Veterinarian clinic concluded the steer died of bloat.

Carcass Breakdown

Carcasses were allowed to hang in the cooler until day 15 postmortem at 1±1°C. On day 15, halved carcasses were transported across the street to the University of Missouri Meat Lab for carcass breakdown. Seam, subcutaneous and intramuscular fat samples were collected for fatty acid analysis. Seam fat samples were collected from the center of the round, subcutaneous samples were collected at the 13th rib above the longissimus dorsi and a sample of the longissimus dorsi collected from the 13th rib was used for the intramuscular sample. The longissimus dorsi was also later used for fat and moisture analysis. All samples were packaged individually using Whirlpac® containers. All samples were collected on the left half of the carcass and were stored at -20±1°C until further fatty acid, fat and moisture measurements were taken.

Meat Quality Measurements

Approximately 48 hours postmortem, objective and subjective meat quality measurements were taken at the University of Missouri Abattoir. Chilled carcasses were ribbed between the 12th and 13th rib and allowed to bloom for 30 minutes. Ribeye area was

measured using a standard USDA ribeye grid. Back fat was measured using a UDSA yield grade ruler at the 12th rib approximately ¾ of the way up the longissimus dorsi muscle. Subjective marbling values were taken by trained personnel using USDA marbling cards.

Fat and Moisture

Determination of fat percentage was done in triplicate utilizing microwave drying and nuclear magnetic resonance as described in Dow et al. (2011) with a CEM SMART Trac rapid fat analysis system 5 (Matthews, NC, USA). Briefly, two CEM sample pads were heated and dried before 3.75 - 4.5 g of minced sample was smeared across one pad and topped with the remaining pad. Samples were dried using the CEM Moisture/Solids Analyzer, and moisture was determined on a dry weight basis. Following determination of moisture, sample pads were wrapped in TRAC paper, inserted into a CEM TRAC tube and placed into the CEM Rapid Fat Analyzer. Fat percentage of samples were then determined on a dry basis using NMR and was ultimately converted to a wet basis. Triplicate values were averaged to determine overall fat percentages for each sample.

Triglycerides

Blood samples collected from the morning of the kill day and were centrifugated at 1500 g and 4°C for 30 minutes with a Legend RT centrifuge (ThermoFisher Scientific, U.S). Individual serum samples were collected and placed in a freezer at -20°C. To determine triglyceride levels, Infinity (Fisher Diagnostics, Middletown, VA) triglycerides liquid stable reagent was used. First 5 ul of standard, control and sample were pipetted into a 96 well clear plate. 250 ul of reagent was then pipetted into each well using a

repeater. Pipetted samples were placed in an incubator at 37°C for 25 min. Samples were then read using a Synergy HT Microplate Reader (Biotek, Winooski, VT) at 500 nm and 660 nm. The reading from 660 nm was subtracted from 500nm for the final result and each sample was done in duplicate. Coefficient of variation (CV%), was calculated between control samples on two plates and between the duplicates of each sample. The CV% was 3% for the experimental samples. Steers 7007, 7032, 7051, and 7059 were all hemolyzed and results from these steers could be compromised.

Fatty Acid Analysis

The methodology utilized for fatty acid determination was an adaptation of the methods used by Folch et al. (1957) and Morrison and Smith (1964). Approximately 1 g of sample of ground longissimus dorsi and KPH, 1mg of subcutaneous and seam and 1mL of blood were placed in a glass tube and 5 mL of chloroform:methanol solution (CHCL3:CH3OH, 2:1, v/v) was added to the tube in order to extract lipids. 1 g of dried omasul fluid and 1 g of dried feed samples were also run for fatty acid analysis. Each sample was homogenized for 30 seconds using an Omni International 2000 homogenizer (Waterbury, CT, U.S.A.). The sample was then filtered through a sintered glass filter funnel fitted with a Whatman 2.4 cm GF/C filter and 8 mL a solution of 0.74% KCl was added to the tube. The sample sat for two hours to separate the phases and then the upper phase was removed and discarded. The lower phase was then transferred to a glass tube and evaporated to dryness with nitrogen gas in a heated water bath at 70oC using a Meyer N-Evap Analytical Evaporator (Organomation Associates Inc., Berlin, MA, U.S.A.). One mL of 0.5 N KOH in CH3OH was added to the sample and the tube was placed in a water

bath at 70°C for 10 min. Then, 1 mL of 14% boron trifluoride (BF3) in CH3OH was added to the tube, flushed with nitrogen, loosely capped and placed in a water bath at 70°C for 30 min. After 30 min, the sample was cooled to room temperature and 2 mL of HPLC grade hexane and 2 mL of saturated NaCl was added to the tube. Next, the upper layer was removed and placed in a glass tube with approximately 800 mg of Na2SO4 in order to remove moisture from the sample. Following this, 2 mL of hexane was added to the tube with saturated NaCl and once more, the upper layer was removed and placed in the same tube with Na2SO4. The liquid portion was then transferred to a scintillation vial which was placed in a water bath at 70°C and the sample was evaporated with nitrogen. A Varian 420 gas chromatograph (Varian, Pala Alto, CA, U.S.A.) was used to analyze fatty acid methyl esters; samples were injected onto a fused silica capillary column (SPTM – 2,560; 100 m x 0.25 mm x 0.2 µm film thickness; Supelco, Bellefonte, PA, U.S.A.). The temperature of the injector and of the flame-ionization detector was held constant at 240 and 260ºC, respectively. Helium was used as the carrier gas at a constant pressure of 37 psi and the oven was operated at 140ºC for 5 min (temperature programmed 2.5ºC/min to 240ºC and held for 16 min). Fatty acids were normalized which means that the area of each peak was represented as a percentage of the total area. An internal standard fatty acid methyl ester was used and all fatty acid values are expressed as the percentage of fatty acids detected.

Statistical Analysis

The study was done using a stratified sampling design with 2 dietary treatments. The individual steer was the unit of measure and the experimental unit. Each treatment had two replicates with pens of n=7 and n=8. All data was analyzed using PROC

UNIVARIATE and all data points three standard deviations from the mean were removed. The remaining data was run using PROC MIXED procedure of SAS 9.3. Significance was set at $P \leq 0.05$ with tendencies at $P \leq 0.10$.

RESULTS

Live Animal

Dietary treatment did not significantly affect initial body weight (P=0.81), average daily gain (P=0.81) or ending body weight (P=0.71). Dry matter intake was higher (P<0.01) for the high oleic diet (HO). As a result, dry matter intake as a % of body weight was also significant (P<0.01). Cattle fed the HO diet had a lower gain to feed ratio (P=0.05) compared to the control.

Carcass Composition

Dietary treatment had no effect on marbling score (P=0.45), quality grade (P=0.47), hot carcass weight (P=0.88), KPH % (P=0.45), dressing % (P=0.38), fat % (P=0.36), preliminary yield grade (P=0.25) triglycerides (P=0.61) and moisture (P=0.49). The one significant carcass characteristic between the two diets was that control fed steers had a smaller longissimus dorsi area (P=0.05). The smaller longissimus dorsi area resulted in a tendency for the control fed steers to have numerically lower yield grades (P=0.06).

Fatty Acid Composition

There were no differences among oleic acid in any of the depots (P=0.93 for sub q., P=0.20 for IM, P=0.71 for KPH and P=0.21 for seam). The saturated fatty acids were

not significant for subcutaneous fat (sub q.), KPH and seam depots (P=0.34 for sub q., P=0.61 for IM and P=0.46 for seam). However, HO fed steers had a lower intramuscular saturated fatty acid total (P=0.03). Monounsaturated fatty acids were not significant in any of the fat depots (P=.80 for sub q., P=0.20 for IM, P=0.54 for KPH and P=0.41 for seam). Polyunsaturated fatty acid totals were lower in all of the HO diets (P= <0.01 for sub q., IM and KPH. P=.01 for seam). Omega-3's were not significantly different in any of the depots except intramuscular (P=0.69 for sub q., P=0.47 for KPH, P=0.99). The intramuscular depot had higher omega-3's compared to the control (P=<0.01). All four depots had lower omega-6's in the high oleic diet compared to the control (P <0.01 for all four depots). In the feed samples, oleic acid was higher (P <0.01) for the HO diet compared to the control. In the abomasal contents, there was a tendency for the HO diet to have higher oleic acid (P=0.09).

DISCUSSION

In most studies, high oleic feeds have not resulted in any altered carcass characteristics which was consistent with results seen in this study. Felton and Kerley (2004) found no statistical differences among any carcass measurements (HCW, longissimus dorsi area, backfat, marbling score, KPH%, yield grade initial and yield grade calculated) except for dressing percentage (P=0.01) in cattle fed high oleic soybeans compared to a standard. In our data, there was a numerical decrease in the dressing percentage of HO cattle however, it was not significant (P=0.11). Hristov et al. (2005) also found no statistical differences when comparing cattle fed high oleic safflower oil

compared to high linoleic safflower oil in hot carcass weight, backfat and longissimus dorsi area. Belon et al., (2018) found no significant differences in hot carcass weight, cold carcass weight, and dressing percentage ($P > 0.05$) of market lambs fed high oleic soybean oil compared to a control soybean oil. The rib eye area of our control fed steers was significantly smaller compared to our HO steers ($P=0.05$). Though significance was not seen in other studies, numerically smaller rib eyes were seen in both Felton and Kerley (2004) and Hristov et al. (2005) in high oleic diets.

Feeding fat often decreases dry matter intake however, Zinn et al. (1994) concluded that there was a quadratic effect ($P<0$ .01) with levels of fat supplementation and DM intake. DMI decreased until 8% fat was reached, while fat fed at 12% resulted in an increase in DMI in beef cattle. Decreased ruminal digestion dropped linearly with the Zinn et al. study, therefore resulting in a higher DM intake to meet a reduced DM conversion found in the high fat supplementation diets. The fat levels in our diets were low (7.07 in HO diets and 5.65 in control) however, increased intakes were found in our diets with the average dry matter intake being larger (13.13 and 14.91 for diets including soybean oil) compared to 11.76 for the average of the diets not containing soybean oil. Though diets with the inclusion of soybean oil were fed after diets without any oil, DMI depressions were expected in the finishing phase of our experiment. This did not happen in our study and is possibly due to reduced DM conversion found in some supplemental fat diets.

In our study, HO diets had significantly higher intakes ($P <0.01$) compared to control. As a result, DMI as a percent of body weight was also higher ($P <0.01$). Similar results were seen in Lopes et al. (2016) where dairy cows fed Plenish® (high oleic soybean meal) diets tended to increase DMI ($P = 0.09$) compared to a control soybean meal diet,

without effecting milk yields. Numerical increases in DMI in high oleic diets compared to a control were also seen in Felton and Kerley (2004) in beef cattle and Casper et al. (1988) in dairy cattle, though none of them were significant. Our results also indicated there was a decreased gain to feed found in HO diets (P=0.05) compared to control. A study by Lopes et al. (2016), showed a decrease in feed efficiency in HO diets compared to a control in dairy cattle ($P < 0.001$). Though DMI increases were measured in both studies, there was no added performance resulting in a decrease in efficiency. Increases in dry matter intake of high oleic fed diets might indicate an increase in palatability or possibly a higher ruminal flow for diets containing high oleic soybean feedstuffs compared to standard soybean feedstuffs.

As expected, our HO diet feed samples did have higher 18:1n9c as a percentage of the total fatty acids detected compared to the control diet ($P<0.01$). The control diet had higher concentration of 18:2 ($P<0.01$) which was anticipated due to grain-based diets typically having high values of 18:2 compared to forage-based diets (Beef NRC, 2016). Though the oleic was measured to be significantly higher in treatment diets, abomasal contents only showed a tendency towards higher 18:1n9c (P=0.09). However, there was significantly less 16:0 in the abomasal contents of the HO diet. 18:1n9t was also significantly lower in HO (P=0.04) abomasal contents, indicating that most of the oleic acid was biohydrogenated in the rumen to 18:0, or other isomers were produced and not measured. The reduced 16:0 content in the high oleic diets was believed to be a result of a having a smaller proportion of 16:0 in the feed contents.

Though not shown in a table, fatty acids were seen to vary significantly between the different fat depots. These results are consistent with what has been found including a

study done by Wiegand et al. (2011) with pigs and Felton and Kerley (2004) with cattle. Monounsaturated fatty acids were not statistically significant in any of our fat depots though they were numerically higher in all the depots except subcutaneous fat. Casper et al. (1988) also found no increases in monounsaturated fatty acids in milk composition of dairy cows fed high oleic sunflowers compared to a control. This was inconsistent with the Felton and Kerley (2004) study which found significantly more monounsaturated fatty acids in both subcutaneous and intramuscular fat depots.

Polyunsaturated fatty acids were also found to be less in all four of our fat depots in the HO diets. This was also found in Felton and Kerley (2004) with all fat depots measured. Approximately 86% of linoleic and 82% on linoleic is biohydrogenated in the rumen (Jenkins and Bridges, 2007). The exact proportion of biohydrogenation is not known with our compiled data though high levels of saturation are also believed to have occurred in our study.

Saturated fatty acids were also not reduced in this study except for in intramuscular fat in the treatment group ($P=0.03$). The main factor for the reduction of saturated fatty acids is the reduction of 16:0 in the intramuscular fat depots of HO fed cattle. In milk fatty acid profiles in dairy cattle, Casper et al. (1988) showed significantly higher saturated fatty acids and lower unsaturated fatty acids when comparing the high oleic sunflower meal to control sunflower meal. Lopes et al, (2016) found there was no reduction in total saturation as seen in this study however, there was a tendency for a reduction of 16:0 in the milk fatty acid composition when feeding high oleic soybean meal. They as well had a reduction of 16:0 in their high oleic feed indicating this might have been the reason for there to be a tendency for a smaller proportion of 16:0.

While there is a high level of saturated fatty acids in the abomasal contents of both diets, monounsaturated fatty acids still make up the largest proportion of fatty acids in all depots for both diets. Δ^9 desaturase is believed to be the responsible enzyme for this. Δ^9 desaturase is responsible for the conversion of saturated fatty acids into monounsaturated fatty acids during fat deposition (Smith et al., 2006). Similar results were seen in our fat samples. Therefore, Δ^9 desaturase was believed to not be inhibited with either the high oleic or control oil diets due to the high proportion of monounsaturated fatty acids recorded in all our depots.

CONCLUSION

High oleic soybean oil did have a significant effect on the fatty acid profile of angus cross steers. Though there was not an increase in monounsaturated fatty acids and a decrease in polyunsaturated fatty acids, there was a decrease in the proportion of saturated fatty acids in the intramuscular depots. The primary reduction of saturation was due to reduced 16:0. Saturated short chain fatty acids are believed to be the most detrimental to lipoprotein levels and the reduction of 16:0 could be beneficial to human cardiovascular health. Results from the abomasal contents reinforce that saturation of unsaturated fatty acids occurs and that Δ^9 desaturase likely converts saturated fatty acids into monounsaturated fatty acids during fat deposition. Further high oleic research in ruminants will need to look at biohydrogenation and potentially ruminally protected soybean oil to try and increase the levels monounsaturated fatty acids. However, it does appear high oleic soybean oil has the potential to reduce the levels of 16:0 in intramuscular fat from angus

cross steers and reduce the negative health impacts associated with saturated fatty acids in beef.

Table 2.1. Dietary nutrient composition of feed for adjusting period of steers fed diets with the inclusion of soybean oil

Ingredient (%DM)	Control
Corn	50.68
Dried Distillers Grains with Solubles	22.39
Brome Hay	7.93
AminoPlus[1]	8.30
Premix	
Ground Corn	8.71
Limestone	1.31
Mag Oxide	0.20
Vit E[3]	0.10
Urea	0.10
Salt	0.10
RTM[4]	0.09
Vit AD&E[5]	0.05
AjiPro[6]	0.04
Rumensin 90[7]	0.01
Nutrient Composition	
DM, %	88.01
CP, % DM	17.66
Crude Fat, % DM	4.28
Ash %	5.78

[1]AminoPlus; Ag Processing Inc., Omaha, NE
[2] Vitamin E= 20,000 IU/kg
[3]Trace Mineral Premix= 24% (Min) Ca, 3.0% Zn, 2.5% Fe, 2.0% Mn, 1.0% Cu, 100 ppm Co, 500 ppm I, 100 ppm, Se)
[4] ADE= 8,800,000 IU/kg Vitamin A, 1,100 IU/kg Vitamin E, 1,760,000 IU/kg Vitamin D
[5]AjiPro-L; Ajinomoto, Chicago, IL
[6]Rumensin 90; Elanco Animal Health, Greenfield, IN

Table 2.2 Dietary nutrient composition of feed for the finishing phase of steers fed diets with the inclusion of soybean oil

Ingredient (%DM)	High Oleic	Control
Corn, Whole Shelled	56.05	56.05
Dried Distillers Grains with Solubles	14.13	14.13
AminoPlus[1]	9.28	9.28
Brome Hay	7.71	7.71
Oil[2]	3.02	3.02
Premix		
Ground Corn	7.99	7.99
Limestone	1.20	1.20
Mag Oxide	0.19	0.19
Salt	0.10	0.10
Vit E[3]	0.09	0.09
Urea	0.09	0.09
RTM[4]	0.08	0.08
Vit AD&E[5]	0.04	0.04
AjiPro[6]	0.04	0.04
Rumensin 90[7]	0.01	0.01
Nutrient Composition		
DM, %	88.13	88.28
CP, %DM	15.38	15.17
Crude Fat, % DM	7.07	5.65
Ash %	5.31	5.22

[1]AminoPlus; Ag Processing Inc., Omaha, NE
[2]Oil= high oleic soybean oil (HO), standard soybean oil (control)
[3] Vitamin E= 20,000 IU/kg
[4]Trace Mineral Premix= 24% (Min) Ca, 3.0% Zn, 2.5% Fe, 2.0% Mn, 1.0% Cu, 100 ppm Co, 500 ppm I, 100 ppm, Se)
[5]ADE= 8,800,000 IU/kg Vitamin A, 1,100 IU/kg Vitamin E, 1,760,000 IU/kg Vitamin D
[6]AjiPro-L; Ajinomoto, Chicago, IL
[7]Rumensin 90; Elanco Animal Health, Greenfield, IN

Table 2.3. Adjusting period of growth and performance traits of steers fed diets with the inclusion of soybean oil

	Treatment			
Item	Control	High Oleic	SEM	P-Value
IBW, kg[1]	356.75	356.51	6.485	0.99
DMI, kg	11.57	11.94	0.184	0.32
DMI, %BW[2]	2.74	2.83	0.045	0.34
ADG, kg	2.12	2.19	0.038	0.41
G:F	0.18	0.18	0.004	0.48
EBW, kg[3]	488.18	492.01	7.752	0.81

[1] IBW = Initial BW

[2] DMI, %BW = Calculated DMI as a percent of calculated midpoint BW

[3] EBW = End BW for growth period

Table 2.4. Finishing phase of growth and performance traits of steers fed diets with the inclusion of soybean oil

	Treatment			
Item	Control	High Oleic	SEM	P-Value
IBW, kg[1]	488.18	492.01	7.752	0.81
DMI, kg	13.13	14.91	0.284	<0.01
DMI, % BW[2]	2.46	2.77	0.051	<0.01
ADG, kg	1.67	1.69	0.044	0.81
G:F	0.13	0.12	0.006	0.05
EBW, kg[3]	581.70	587.72	7.989	0.71

[1] IBW = Initial BW
[2] DMI, %BW = Calculated DMI as a percent of calculated midpoint BW
[3] EBW = End BW for growth period

Table 2.5. Carcass characteristics, blood triglyceride %, fat and moisture values of longissimus dorsi muscle from the 12th rib of steers fed diets with the inclusion of soybean oil

	Treatment			
Item	Control	High Oleic	SEM	P-Value
Triglycerides %	41.33	42.54	0.189	0.61
HCW, kg	358.24	356.89	4.767	0.88
REA[1], cm^2	36.03	37.67	0.668	0.05
PYG[2]	3.28	3.20	0.046	0.25
YG[3]	2.77	2.47	0.080	0.06
MARB[4]	543.01	556.57	16.215	0.45
Quality Grade[5]	196.49	194.65	5.399	0.47
KPH %[6]	2.35	2.34	0.083	0.45
Dressing %	59.98	59.67	0.171	0.38
Fat %	6.50	6.04	0.189	0.36
Moisture %	64.47	70.04	0.387	0.49

[1]REA = LM area
[2] PYG= Calculated Preliminary Yield Grade
[3] YG = Calculated USDA Yield Grade
[4]MARB = Marbling score
[5]Quality Grade = Calculated USDA Quality Grade
[6] Kidney, Pelvic and Heart fat

Table 2.8. Fatty acid profiles of feed and abomasal contents of steers fed diets with the inclusion of soybean oil[1]

	Treatment			
Item	Control	High Oleic	SEM	P-Value
Feed				
16:0	13.71	11.30	0.586	<0.01
18:0	3.22	3.48	0.148	0.02
18:1n9c	27.46	50.43	3.783	<0.01
18:2n6c	51.15	30.76	3.487	<0.01
Abomasal				
16:0	16.81	15.30	0.305	0.01
18:0	32.88	28.73	1.527	0.18
18:1n9t	2.96	2.14	0.197	0.04
18:1n9c	24.30	28.68	0.730	0.09

[1]Values are percentage of total fatty acids detected

Table 2.7. Fatty acid profiles of carcass fat depots from steers fed diets with the inclusion of soybean oil in the diet[1]

Item	Treatment		SEM	P-Value (trmt)
	Control	High Oleic		
Sub Q.				
16:0	25.08	25.26	0.146	0.77
18:0	12.93	13.61	0.134	0.22
18:1n9c	44.73	44.81	0.209	0.93
18:2n6c	2.74	2.32	0.031	<0.01
SFA[2]	43.67	44.56	0.225	0.34
MUFA[3]	51.95	51.61	0.324	0.80
PUFA[4]	3.90	3.18	0.039	<0.01
O_3[5]	0.20	0.21	0.006	0.69
O_6 [6]	3.49	2.88	0.035	<0.01
IM				
16:0	28.09	26.47	0.146	0.01
18:0	13.00	13.18	0.134	0.75
18:1n9c	41.71	42.83	0.209	0.20
18:2n6c	3.25	2.84	0.031	<0.01
SFA[2]	46.94	44.89	0.225	0.03
MUFA[3]	48.81	50.50	0.324	0.21
PUFA[4]	3.96	3.47	0.039	<0.01
O_3[5]	0.09	0.20	0.006	<0.01
O_6[6]	3.63	3.09	0.035	<0.01
KPH				
16:0	34.92	35.25	0.146	0.71
18:0	25.07	24.65	0.134	0.45
18:1n9c	34.92	35.25	0.209	0.71
18:2n6c	2.76	2.32	0.031	<0.01
SFA[2]	56.48	56.01	0.225	0.61
MUFA[3]	39.15	39.72	0.324	0.54
PUFA[4]	3.43	2.80	0.039	<0.01
O_3[5]	0.06	0.08	0.006	0.47
O_6[6]	3.22	2.59	0.035	<0.01
Seam				
16:0	24.51	23.93	0.146	0.35
18:0	17.24	17.24	0.134	0.99
18:1n9c	41.37	42.46	0.209	0.21
18:2n6c	2.88	2.47	0.031	<0.01

SFA[2]	47.87	47.19	0.225	0.46
MUFA[3]	47.69	48.80	0.324	0.41
PUFA[4]	3.55	3.12	0.039	0.01
O_3[5]	0.09	0.09	0.006	0.99
O_6[6]	3.36	2.93	0.035	<0.01

[1]Values are percentage of total fatty acids detected
[2]Saturated fatty acids
[3]Monounsaturated fatty acids
[4]Polyunsaturated fatty acids
[5]Omega 3 fatty acids
[6]Omega 6 fatty acids

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