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Performance, carcass traits and fatty acid profiles of yearling beef cattle supplemented with self-fed byproducts on pasture

by

Daniel D. Kiesling

A thesis submitted to the graduate faculty

in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Major: Animal Science

Program of Study Committee:
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Ames, Iowa
2013

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ABSTRACT

Due to rising costs of conventional feedstuffs, more focus has been put on feeding byproduct feedstuffs, which include coproducts of ethanol production or further processing of grains. The effects of using these feedstuffs on live animal performance, carcass traits and the economic benefits are still under investigation. Beef from grass-fed cattle have elevated levels of *cis-9, trans-11* conjugated linoleic acid (CLA) and is currently receiving premiums at the retailer level because of CLA's supposed health benefits. The objective of this study was to investigate the effects of finishing yearling cattle on pasture utilizing a combination of self-fed byproducts and corn on performance, carcass traits and fatty acid profiles; specifically CLA. During the 2007 (year 1) and 2008 (year 2) grazing periods, 162 head of beef steers were finished with self-fed byproducts on cool-season grass pastures. The yearling steers were continuously stocked at the Neely-Kinyon Farm in southwest Iowa near Greenfield on cool-season grasses at a stocking rate of 5.6 head/hectare. Half of the cattle within each supplement treatment were implanted (Synovex®-S) and half were not. Cattle had access to either soyhulls-dried distillers grains with solubles (DDGS) (Supplement 1) or ground corn-DDGS (Supplement 2) that were offered as a meal through self-feeders. Both supplements were composed of equal parts DDGS-soyhulls or DDGS-corn along with a mineral balancer that included Rumensin®. Main effects of supplement (Supplement 1 vs. Supplement 2), implant status (yes vs. no) and year (2007 vs. 2008) were investigated for live animal performance and carcass traits. Supplement did not affect total lipid values (3.81 vs. 4.63 mg/ g muscle, for supplement 1 vs. supplement 2 respectively, P =0.0630). Conjugated linoleic acid concentrations were increased in cattle fed supplement 1 (0.6338 vs. 0.4555 mg/ g muscle, P <0.0001). Omega-3 fatty acids, a group of essential fatty acids that are found in

foods and sought after by health conscious consumers were increased in cattle fed supplement 1 (1.428 vs. 0.9700 mg/g muscle, $P = 0.0012$) compared to supplement 2. Subsequently, the omega-3: omega-6 fatty acids ratio was increased in cattle fed supplement 1 (0.1998 vs. 0.1167 mg/g muscle, $P < 0.0001$). Live cattle performance and carcass traits were not affected by supplement. As expected, implanted cattle outgained non-implanted over the entire finishing period (1.59 vs. 1.44 kg/d, $P = 0.0075$). This treatment led to implanted cattle being heavier at harvest (600 vs. 579 kg, $P = 0.0002$) and subsequently having heavier carcasses (374 vs. 363 kg, $P < 0.0012$) compared to non-implanted cattle. Ribeye areas were also greater (84.19 vs. 81.94 cm^2, $P = 0.045$) for implanted cattle compared to non-implanted cattle; which was likely due to the heavier carcass weights of implanted cattle. Several performance variables differed between year 1 (2007) and year 2 (2008). These differences were attributed primarily genetic makeup of cattle, initial weights of cattle (375 vs. 432 kg, year 1 vs. year 2 respectively, $P < 0.0001$), time of year when cattle were harvested (late August vs. early September) and grading technology (manual vs. computer). In conclusion, pasture rearing cattle, when given access to self-fed byproducts, can be a viable option for producers looking for alternative production methods while using cheaper feedstuff that are currently available. Some considerations should be made by the feeder in regards to time of year when marketing cattle and the cattle's genetics. This system of production offers an opportunity for producers to increase income from non-tillable, erodible acres. This system should also allow for smaller scale producers to utilize resources to be competitive in the market place, especially if they can capitalize on value-added premiums for the enhanced fatty acid composition.

CHAPTER 1. GENERAL INTRODUCTION

THESIS ORGANIZATION

This thesis is organized as an introduction to the research and related literature review followed by a brief description of the hypothesis for developing this research and its objectives. A manuscript for submission to the Journal of Animal Science follows the literature review and introduction of research. Following the manuscript are a general conclusion, appendices of additional information and acknowledgements.

INTRODUCTION

Due to rising cost of conventional feedstuffs, caused by adverse weather patterns and competition for feed grains used for biofuels; producers are looking for alternative feedstuffs to lower costs of beef cattle production. These alternatives can include: 1) feeding coproducts or byproducts from the processing of feed grains for biofuels; 2) feeding coproducts or byproducts from processing of feed grains or seeds for meal or oil; or 3) utilizing non-tillable acres for pasture with supplementation of coproducts or byproducts.

One source of cheaper feedstuffs is byproducts of alternative energy production. The Environmental Protection Agency (EPA) passed the Energy Policy Act in 2005, implementing the Renewable Fuel Standard (RFS) (EPA, 2011). The RFS set up regulations that transportation fuel would contain a minimum volume of renewable fuel. The original RFS program established that 7.5 billion gallons of renewable fuel was to be blended into gasoline by 2012. The RFS program was expanded in 2007 under the Energy Independence and Security Act. The act added diesel fuel to be blended with renewable fuel and increased the volume of renewable fuel to be blended to transportation fuel to 36 billion gallons by 2022 (EPA, 2011).

Byproducts of ethanol production, such as wet and dried distillers grains, are readily available in the Midwest. As of 2010, in the state of Iowa and its neighboring states, there were 99 ethanol plants in operation (RFA, 2010). Feeding these byproducts could be one way that producers could potentially lower feed costs. When corn prices were highly volatile in 2008, dried distillers grains (DDGS) were $0.02 - $0.03 cheaper per pound than corn (USDA-AMS). In a study by Busby et al. (2009), cattle that were finished on pasture with a corn-DDGS supplement had lower cost of gains than cattle finished in a conventional feedlot ($89.25/cwt. vs. $90.25/cwt.). This decreased cost of gain resulted in greater profit per head for the pasture with supplementation group ($12.02 vs. -$32.75).

Soybean hulls (SH) are a byproduct of the processing of soybeans for oil and meal production and consist primarily of the outer covering of the soybean. Soybean hulls have been recognized as consistent source of readily available energy in forage-based diets in growing and finishing diets (ASA, 1998). Allison and Poore (1993) concluded that SH have similar feeding values as corn in a forage-based diet. Economically, SH were as much as $0.05/lb. cheaper than corn in that volatile season of 2008 (USDA-AMS). The availability of both DDGS and SH in the Midwest offers great potential for cattle feeders looking to lower production costs and increase profit.

Ruminant food products are a primary source of conjugated linoleic acid (CLA). Strategies to increase CLA levels found in milk and meat products have been investigated extensively over the past twenty years (Bauman et al., 2003). Strategies studied to increase CLA content have included altering forage to concentrate ratios, oilseed supplementation, effects of forage quality and investigating breed or gender effect (Bauman et al., 2000).

The two major sources of CLA in the ruminant are biohydrogenation in the rumen and endogenous synthesis; primarily in adipose tissue (Bauman, 2000). Conjugated linoleic acid has been shown to have many health benefits including reduction in tumor development or growth, protection of arterial walls from plaque formation, alterations in circulating lipoproteins and cholesterol, enhancing the immune system, and altered fat partitioning (McGuire and McGuire, 2000). Foods enriched with CLA are being sold at a premium because of these potential health benefits (McGuire and McGuire, 2000). The opportunity of receiving these premiums could make producers re-evaluate their production system to produce CLA-enriched beef that is in higher demand.

CHAPTER 2. REVIEW OF LITERATURE

DRIED DISTILLERS GRAINS WITH SOLUBLES

Processing and Nutritional Value

The quantity of corn milling coproducts has increased dramatically due to the increase of ethanol production (Erickson et al., 2007). Distillers grains (DG), both in the dry or wet form offer options when developing feeding rations for finishing cattle. Dry milling of corn for ethanol production is a process that involves grinding of the corn (or other starch source), fermentation, the conversion of starch to ethanol and CO_2. Corn grain is approximately two-thirds starch and that starch is fermented into ethanol, leaving the remaining one-third available as a feed source. Because of this process, the nutrients that remain are concentrated 3-fold (Erickson et al., 2007). Distillers grains with solubles contain the bran, which is high in fiber, along with the germ which is high in fat and protein (Depenbusch et al., 2007). Distillers solubles have been found to be a good source of protein (25% DM) as well as being high in fat (20% DM) and have become popular as a liquid feed supplement, replacing molasses when prices have become high (Erickson et al., 2007)

Dried distillers grains with solubles are approximately 80% distillers grains and 20% solubles; however that ratio can vary from plant to plant (Erickson et al, 2007). Based on that ratio, samples from three ethanol plants in Nebraska, Iowa and Texas were found to average 90.4% DM, 33.9% CP, and 0.82 Mcal NEg/lb and as more solubles were added, fat increased (Erickson et al., 2007). Despite nutrient compositions for DDGS found from previous studies, analysis is recommended to ensure accurate nutrient content. Dried coproducts have been shown to have a lower feeding value when compared to wet coproducts due to the drying process (Firkins et al,, 1985). Nutrients are heat damaged during the process; therefore

the lower feeding values (ASA, 1998). Despite the lower feeding value, DDGS are recognized for being high in readily available digestible fiber, protein and phosphorus (Loy et al., 2007). Protein is the first nutrient to be replaced when DGS are added to the cattle's diet (Depenbusch et al., 2007). As inclusion levels increase and protein requirements are met, DGS can then be utilized as an energy source (Loy et al., 2007). Two effects can control variation of feeding value from load to load; processing and quality control. United States Department of Agriculture (USDA) weekly ethanol processing values currently indicate DDGS represents approximately 12-13% of the gross revenue from a bushel of processed corn (USDA-AMS, 2012). Ethanol plants that have seen the value in selling byproducts to livestock producers have made it a priority to produce a consistent feed product and have modified their processing procedures to ensure that consistency (Erickson et al., 2007).

Live Animal Performance

Including DDGS in finishing diets have shown a trend towards increased performance. Firkins et al., (1985) investigated the performance of Charolais steers fed corn silage and soybean meal (SBM) as the control diet and replaced the SBM with 34.9% dried corn gluten feed (DCGF), 34.9% wet corn gluten feed (WCGF) or 17.4% dried distillers grains (DDG). When comparing the control and DDG diets, feed intake was similar for both groups. However, feed efficiency was improved for the cattle on the DDG diet (5.71 vs. 6.86 kg feed/ kg gain, $P < 0.05$). This increased feed efficiency was caused by the increased average daily gain observed in the steers feed the DDG diet (1.57 vs. 1.24 kg/d, $P < 0.05$).

Depenbusch et al., (2007) also showed that DDGS are a suitable source for protein substitution in a feedlot setting. The control diet consisted of steam-flaked corn, soybean meal and alfalfa hay (81.1%, 4.2% and 6.0% of dry matter, respectively) along with

concentrated separator byproduct, urea, limestone, and mineral supplement. Cattle on the experimental diet had DDGS added at a 15% inclusion rate in lieu of the soybean meal. Results showed that cattle fed the DDGS diet had similar gains (1.45 vs. 1.44 kg/d, respectively), dry matter intakes (9.48 vs. 9.34 kg/d, respectively) and feed conversions (2.97 vs. 2.94 kg feed/kg gain, respectively). The authors concluded that DDGS is a comparable substitute for soybean meal (Depenbusch et al., 2007).

Supplementing High Forage Diets

It has long been known that supplementing grazing cattle is an effective strategy to increase average daily gain (Pordomingo et al., 1991). This strategy is typically done when forage is of low-medium quality or during dormant growing seasons. When forage is high quality, it is often low in available energy relative to available protein (Pordomingo et al., 1991). It has also been found that supplementing energy rather than protein results in more favorable responses for body weight gains (Martinez- Perez et al., 2010). Previously, cereal grains were used for supplementation during grazing (Erickson et al., 2007). As mentioned earlier, due to the proliferation of ethanol plants and the decreasing availability of those cereal grains, DDGS have been investigated as a potential substitute for supplementing grazing cattle (Erickson et al., 2007).

One reason DDGS could be used is that the starch removed during the processing allows for greater fiber utilization and could increase forage intake (Depenbusch et al., 2007). Another positive aspect of supplementing DDGS is lowered incidences of acidosis and other digestive disorders (Stock and Britton, 1993). Roughages are often included in feedlot diets to maintain intake and control acidosis; utilizing DDGS can decrease the need for additional roughages from conventional levels used in feedlot diets (Stock and Britton, 1993).

Martinez-Perez et al., (2010) supplemented crossbred steers grazing native range grass in the Southern Plains with DDGS at 0.0, 0.20, 0.40 and 0.60 % of the steers' initial body weight once a day. As supplementation level increased, average daily gain also increased linearly (0.64, 0.75, 0.80, and 0.86 kg/d, $P = 0.01$ for supplement fed at 0, 0.2, 0.4, 0.6 % of BW, respectively).

Similar results were found by Corrigan et al., (2009) when dried distillers grains (DDG) were supplemented at an increasing level to a basal diet of alfalfa hay, brome hay and vitamin supplement fed at 95% ad libitum. Total daily dry matter intake (DMI) increased linearly as supplementation levels increased (7.64, 8.20, 8.60, and 8.69 kg/d, $P < 0.01$ for supplement fed at 0.25, 0.50, 0.75, and 1.00% of BW, respectively). However, Corrigan et al., (2009) did not find a linear increase in average daily gain (1.17, 1.08, 1.30, and 1.26 kg/d $P = 0.01$ for supplement fed at 0.25, 0.50, 0.75, and 1.00% of BW, respectively). Feed efficiency (kg gain/kg feed) was not increased ($P = 0.50$) with increasing levels of supplementation.

Martinez-Perez et al., (2010a) found that total crude protein (CP) intake increased (1.04, 1.18, and 1.39 kg/d and $P < 0.01$ for supplement fed at 0, 0.2, and 0.4% of BW, respectively). The study found that supplementation over 0.4% of BW, decreased CP intake (1.36 kg/d for supplement fed at 0.6% BW, $P < 0.01$). Also, digestibility of CP, organic matter (OM), and neutral detergent fiber (NDF) also increased ($P < 0.01$) with increasing level of DDGS supplement. Similar results have been observed in studies by Loy et al., (2007) and Leupp et al., (2009) where DDGS supplementation increased ($P < 0.01$) intake of OM, NDF, CP and ether extract (EE). This effect is most likely due to the greater CP and EE

content of DDGS and that the DDGS were more digestible than the forage that was being grazed (Martinez- Perez et al., 2010).

SOYBEAN HULLS

Processing and Nutritional Value

Soybean hulls are a by-product of processing soybeans for the production of soybean meal (SBM) or oil (SO). Soybeans are graded, cleaned, and cracked with a roller to break the bean into smaller pieces; allowing for removal of hulls, but still limiting the amount of fines. A second dehulling process step is performed, removing the hulls from the soybean meats that are passed on to be made into soybean meal. Hulls are then toasted to eliminate urease activity and ground to the desired particle size. (ASA, 1998)

Typically, SBM made for swine and poultry diets are completely dehulled because monogastric species cannot utilize the fiber. Soybean meal manufactured for ruminant species can have greater hull content. “Average” nutritional values for SH have been reported (9.4% CP, 74% NDF, 2.5% EE, 77% TDN, 0.37 Mcal/kg NE_m, and 0.24 Mcal/kg NE_g; dry matter basis), however it is strongly recommended that producers have SH analyzed for accurate nutritional content when incorporating into feed rations (Blasi et al., 2000).

Utilization of soyhulls in different finishing diets

Soybean hulls are available whole, as pellets (whole and ground) or ground. Feeding SH in the whole or ground form does not affect live animal performance when comparing either form. Anderson et al. (1988) conducted a series of trials investigating the effects of supplementing rolled corn, whole SH and ground SH to steers and spayed heifers grazing smooth bromegrass and were supplemented 1.36 kg/h/d DM. The first trial compared steers receiving no supplement, whole SH, or rolled corn. Cattle gained similarly (1.04, 1.14, and

1.13 kg/d, $P = 0.15$, for no supplement, whole SH, and rolled corn, respectively) across supplementation treatments. In the second trial, steers and spayed heifers received no supplement, rolled corn, ground SH or whole SH. Average daily gains were greater for cattle receiving supplement (0.60 vs. 0.75, 0.77, and 0.78 kg/d, $P < 0.05$ for no supplement vs. rolled corn, ground SH, and whole SH, respectively) and similar among supplement types.

The form of SH fed to cattle has also been found not to have an effect on average daily gain (ADG) or dry matter intake (DMI). Drouillard and Klopfenstein (1988) supplemented pelleted, whole SH or pelleted, ground SH at 2.72 kg/hd/d with brome grass/alfalfa hay fed ad libitum to steers. Forage DMI (6.76 and 6.94 kg/hd/d, $P < 0.32$ for pelleted, whole and pelleted, ground SH, respectively) and ADG (0.93 and 0.96 kg/d, $P < 0.18$, for pelleted, whole and pelleted, ground SH, respectively) were similar. Feed: gain ratio (forage DMI: ADG) (3.32 kg vs. 3.26 kg, $P < 0.72$, for pelleted, whole and pelleted ground SH, respectively) was also similar for both groups.

These studies concluded that in a forage-based diet, SH have a feeding value similar to corn resulting in similar performance and gains. However, when SH replace corn or other cereal grains in concentrate diets, feeding value decreases. Ludden et al., (1995) fed SH at 0, 20, 40, or 60% of diet DM in a basal diet of cracked corn, protein supplement and ground corn cobs. Replacing corn with SH decreased average daily gain (1.40, 1.39, 1.30, 1.19 kg/d, $P < 0.03$ for 0, 20, 40 and 60% SH diet DM, respectively) and gain efficiency (0.143, 0.128, 0.115, 0.107 kg BW gain/kg feed, $P < 0.01$ for 0, 20, 40 and 60% SH diet DM, respectively). Wether lambs underwent a similar trial to determine digestibility (Ludden et al., 1995). Dry matter intake increased ($P < 0.001$) linearly with increasing levels of SH as did neutral-detergent fiber (NDF) intake ($P < 0.001$). Digestible energy decreased ($P < 0.001$) linearly

with increasing levels of SH. The authors estimated the feed value of SH to be 74-80% of corn if used high concentrate-based diets.

The utilization of SH in finishing diets is practical, especially in high forage based diets and research suggests that SH improve performance more in forage-based diets compared to inclusion in concentrate-based diets (Blasi et al., 2000). As with all alternative feed sources, usage should be dictated by cost, realizing that SH does not have the same feeding value in high-concentrate versus high-roughage diets.

CIS-9, *TRANS*-11 CONJUGATED LINOLEIC ACID

Chemistry of CLA

Conjugated linoleic acids (CLA) are a mixture of positional and geometric isomers of octadecadienoic acid with conjugated double bonds. Many isomers that differ in the position and configuration of the double bonds are possible. Parodi (1977) demonstrated that the *cis*-9, *trans*-11 formation is the most predominate isomer in ruminant animal products (meat and milk). Because the *cis*-9, *trans*-11 form of CLA is the naturally occurring product found in these products, this isomer was identified as *rumenic acid* (Kramer et al., 1998). Conjugated linoleic acid is not a normal constituent of feed fed to ruminants and is a product of two sources: ruminal biohydrogenation of linoleic acid ($C_{18:2}$) and different forms of linolenic acid ($C_{18:3}$); and endogenous synthesis by animal's tissues from *trans*-11 octadecadienoic acid (Bauman et al., 1999). Biohydrogenation occurs in the rumen and endogenous synthesis occurs in the animal's tissues; mainly adipose tissue. These two processes will be described later in this section.

Most research investigating CLA content in ruminant products has been done in milk fat (Bauman et al., 1999). In contrast, there is much less data on CLA content in other tissues

of the ruminant, primarily adipose tissue. Previous research shows that there are similarities in how CLA is enriched in milk fat and other adipose tissue (Griinari and Bauman, 1999). Seventy to ninety percent of total CLA found in milk fat is the *cis*-9, *trans*-11 isomer. While *cis*-9, *trans*-11 is the predominant isomer found in ruminant fat, it is found in lower concentration in beef fat (Bauman et al., 1999). One other prevalent form of CLA is *trans*-7, *cis*-9 which has a concentration ranging from 3-16% of total CLA in ruminant fat (Bauman et al., 2003). Advanced analysis methods have shown that many isomer forms of CLA have been found in ruminant fat, but are usually at less than 0.5%. These isomers have double bonds usually between the tenth and fourteenth carbon and come in an assortment of configurations- *cis*-*trans*, *cis*-*cis* or *trans*-*trans*. For this paper, we will focus on the *cis*-9, *trans*-11 form.

Potential benefits of CLA on human health

There have been many reviews (Belury, 2002; McGuire and McGuire, 2000; Stankus, 2008) that state CLA could have many potential health benefits. Because of these potential benefits, ruminant animal food products are now being viewed as a "functional food." This term was defined by the National Academy of Science as "any food or food ingredient that may provide a health benefit beyond the traditional nutrients it contains" (NRC, 1994). Benefits of CLA include reduction in tumor development or growth, protection of arterial walls from plaque formation, alterations in circulating lipoproteins and cholesterol, enhancing the immune system, and altered fat partitioning (McGuire and McGuire, 2000). Additional research is being and still needs to be conducted to determine which isomers of CLA are specifically responsible for these positive effects.

Initially, Pariza (1979) found that CLA can inhibit carcinogenesis by modulating

mutagenesis. Since then, studies from several authors (Hubbard et al., 2000; Ip et al., 1999; Scimeca et al., 1994; Visonneau et al., 1997) have examined how CLA can inhibit tumor formation in rats and mice. These studies suggest that there is strong evidence to support the conclusion made by the National Academy of Science, that "…conjugated linoleic acid (CLA) is the only fatty acid shown unequivocally to inhibit carcinogenesis in experimental animals" (NRC, 1996).

Studies linking CLA and atherosclerosis have also been conducted (Lee et al., 1994; Nicolosi et al., 1997) showing that providing dietary CLA reduced circulating blood cholesterol levels and reduced plaque formation. These results were again shown in laboratory animals (i.e. rabbits and hamsters) (McGuire and McGuire, 2000). These results have been contradicted in a more recent study by Munday et al., (1999), where increased fatty streaking of the aorta was observed in hamsters fed CLA. The results of all of these studies still necessitates the need for further investigation of CLA and its effects on atherosclerosis in humans.

Other positive effects of CLA have been shown in the last 10-15 years on nutrient partitioning in mice, chickens and pigs, such as: reduced weight loss, decreased adipose tissue accretion coupled with increased lean growth and increased metabolic rate (McGuire and McGuire, 2000). The sources of CLA in these studies were commercial mixtures of several different isomers and it is still not clear which isomer is specifically responsible for these results. Furthermore, studies have looked at the anti-diabetic effects, enhanced immune response and influenced bone formation and reabsorption caused by CLA (McGuire and McGuire, 2000). These initial studies provide enthusiasm for the continued research of CLA isomers and their effects on the positive health benefits for humans. It cannot be stated

enough though that further research needs to conducted in humans to examine these effects and realize which isomers are responsible for what positive effects and if some isomers have negative effects .

Biosynthesis

Studies have shown that there are two sources of CLA in ruminants; ruminal biohydrogenation (BH) and endogenous synthesis in the tissues (Bauman et al., 1999, Palmquist et al., 2005, Jenkins et al., 2008). Results have shown that endogenous synthesis is the major source for CLA in milk and meat (Palmquist et al., 2005). In a number of studies, CLA in milk fat from endogenous synthesis ranged from 64-97% (Griinari et al., 2001, Corl et al., 2001, Kay et al., 2004, Lock and Garnsworthy, 2002, Piperova et al., 2002, Shingfield et al., 2003). It is more difficult to gauge endogenous synthesis of CLA in growing ruminants. Palmquist et al. (2004) used mathematical modeling to estimate that 45-95% of rumenic acid in muscle and adipose tissues of growing lambs was endogenously synthesized.

Biohydrogenation

A major influence on the fatty acid composition of ruminant products is ruminal fatty acid metabolism of unsaturated fatty acids including linoleic acid and α-linolenic acid from dietary sources (Jenkins et al., 2008). The process of transforming polyunsaturated fatty acids (PUFA) to saturated fatty acids (SFA) is known as ruminal biohydrogenation (BH).

The main dietary lipids entering the rumen are triglycerides, phospholipids, glycolipids and galactolipids (Jenkins et al., 2008). The major fatty acids entering the rumen are the unsaturated fatty acids linoleic and linolenic acid. Microbial lipases break-down lipids entering the rumen through lipolysis. Ester linkages in the complex lipids are hydrolyzed by these microbial lipases. Only after lipolysis occurs, can BH occur; converting unsaturated

fatty acids to saturated fatty acids. This specific requirement for BH to occur makes lipolysis a rate limiting step (Palmquist et al., 2005). Other requirements for BH to occur are that these fatty acids are unesterified and have a free carboxyl group (Harfoot and Hazelwood, 1988). Biosynthesis of CLA is a result of isomerization of the PUFA's mentioned earlier and is another critical process that occurs during BH. *Trans*-vaccenic acid (*trans*-11 $C_{18:1}$), CLA and other isomers are intermediates in the ruminal BH pathway in which stearic acid ($C_{18:0}$) is the primary end product (Palmquist et al., 2005).

Rumen bacteria are largely responsible for the biohydrogenation of PUFA. Studies established evidence of BH in the rumen in the1930's (Harfoot and Hazelwood, 1988). Through the 1950's and 1960's *in vivo* and *in vitro* studies focused on bacteria and the hydrogenation of forage lipids that occurred in the rumen (Harfoot and Hazelwood, 1988). Early on, *Butyrivibrio fibrisolvens* was the only known bacterium that was capable of BH. As this was further studied, a wide range of bacterial species were found to play a role in BH. However, no single species has been found to catalyze the complete process. In 1984, Kemp and Lander divided the bacterial species into two groups based on their reactions and endproducts. Group A bacteria are able to hydrogenate linoleic acid and α-linolenic and *trans*-vaccenic acid (TVA) is the major endproduct. These bacteria include strains of *B. fibrisolvens*, *Ruminococcus,* and *Eubacterium*. Strains of *Fusocillus* are the majority of the Group B bacteria which utilize TVA as a substrate and produce stearic acid as the major endproduct. (Bauman et al., 1999)

It is well established that bacteria are not the only components of the rumen microbe environment. Ciliate protozoa can account for up to half of the rumen microbes (Williams and Coleman, 1992) and it has been known for years that protozoal lipids contain more

unsaturated fatty acids than the bacterial fraction (Katz and Keeney, 1966; Harfoot and Hazelwood, 1997). This microbial population could represent an important source for incorporation of PUFA, CLA and TVA into meat and milk. It was concluded by Wright (1959, 1960) that protozoa and bacteria were involved in BH, and later suggested that protozoa were not necessary for BH to occur; having only a minor contribution to the process (Jenkins et al., 2008). Anaerobic fungi, another population in the rumen microbe ecosystem, have a relatively high $C_{18:1}$ composition. When linoleic and linolenic acid were incubated with *Piromonas communis*, formation of CLA isomers and conjugated products including *cis*-9, *trans*-11 CLA, was a result. However, the production of any CLA was very little and not considered a major factor in the BH process (Jenkins et al., 2008).

Endogenous synthesis of CLA

While many assume *cis*-9, *trans*-11 CLA is an endproduct of ruminal biohydrogenation, it is only an intermediate in the pathway of the major endproduct; stearic acid (Griinari and Bauman, 1999). Before complete biohydrogenation occurs, several conjugated dienes, including CLA and TVA escape from the rumen.

As mentioned previously, studies have shown that it is endogenous synthesis, not ruminal biohydrogenation is the major source of *cis*-9, *trans*-11 CLA in milk fat (Bauman et al., 2003). Because the low amount of CLA produced in the rumen could not account for levels present in the milk products, researchers hypothesized that synthesis had to be occurring elsewhere in the body (Bauman et al., 2003). This source needed to be found and explored. Based on work done by Holman and Mahfouz (1981) and Pollard et al. (1980), it was hypothesized CLA was being synthesized from TVA, by delta-9 desaturase (Parodi, 1994). Later, it was proposed that endogenous synthesis was occurring in the mammary

gland (Griinari and Bauman, 1999). These hypotheses were made from the close linear relationship Bartlett and Chapman (1961) showed between TVA and dienes that were conjugated in butter samples. Griinari et al. (2000) infused TVA abomasally into dairy cows, resulting in a 31% increase in milk fat CLA. Additionally, when inhibitors of delta-nine desaturase; sterculic acid and malvalic acid were infused in sterculic oil, CLA concentration was decreased by 45%.

The delta-nine desaturase system is a system of enzymes that includes NADH-cytochrome b5 reductase, cytochrome b5, acyl-coenzyme A (acyl-CoA) and the terminal delta-9 desaturase (Ntambi, 1995). While stearoyl- CoA and palmitoyl-CoA are the major substrates for delta-9 desaturase activity, *trans-11* $C_{18:1}$ and several other saturated and unsaturated acyl CoA can also serve as substrates (Griinari and Bauman, 1999). Delta- 9 desaturase is active with several acyl-coenzyme A (acyl-CoA) substrates and is often identified as a stearoyl-CoA desaturase (Palmquist et al., 2005).

Ntambi (1995) found stearoyl-CoA desaturase in the liver of rats. In ruminants, the primary site of stearoyl-CoA was adipose tissue for growing ruminants and the mammary gland for lactating ruminants (Griinari et al., 2000). Enzyme activity is regulated by many factors including diet, physiological state and hormonal balance. Studies showed that Δ-^{9} desaturase mRNA expression and activity was constant in adipose tissue of growing cattle (Martin et al., 1999), increased at the onset of lactation in sheep in the mammary gland and decreased in the adipose tissue (Ward et al., 1998).

Delta-9 desaturase is the key regulatory enzyme in the endogenous synthesis of CLA in ruminants (Ntambi, 1995). Endogenous synthesis can occur in adipose tissue of growing

animals or in the mammary gland of lactating animals and is the primary source of CLA in meat and milk products (Palmquist et al., 2005).

Strategies to increase CLA content in beef

There are many hypotheses regarding influences of CLA content in ruminant milk and meat products. While there have been many studies investigating CLA content in milk, there is limited literature exploring CLA content in meat. However, factors include dietary, breeding and management. Of these factors, dietary factors seem to have the greatest effect.

Grazing ruminants on pasture, increasing the forage: concentrate ratio or feeding fresh forages in the ration can increase the CLA content in meat, which is similar to milk from dairy cows. French et al., (2000) conducted a trial feeding steers diets with varying levels of grass silage, grazed grass and concentrate in the ration. Increasing intake of grass increased CLA concentration of intramuscular fat compared to steers fed silage and/or concentrates. The study also demonstrated that high grass intake resulted in a higher polyunsaturated fatty acid: saturated fatty acid (PUFA: SFA) ratio as well as a lower omega-6: omega-3 ratio. Similar results were observed in a study conducted by Poulson et al., (2004). Concentration of CLA of the beef samples were increased by as much as 466% by only feeding forage and grazing pastures compared with cattle that were fed typical high-grain diets.

Feeding plant oils that are rich in $C_{18:2}$ and $C_{18:3}$ is another method to increase CLA content in muscle and adipose tissue, but have had varying results. These oils include: soybean, sunflower, safflower and linseed. Inclusion rates of 4-6% (on a dry matter basis) of soybean oil to high-grain diets marginally increased or did not increase CLA content of muscle and adipose tissue (Beaulieu, et al., 2002 and Dhiman, et al., 1999). When supplementing linseed oil, CLA content of beef muscle was increased compared to the

control (0.80% vs. 0.32%) at a 6% inclusion rate of the diet DM (Mir et al., 2002). Consequently, linseed and sunflower oil have been viewed as the most promising of seed oils when feeding oils to increase CLA content.

Feeding processed oilseeds have had similar results as feeding the seed oils; marginally increasing or having no effect on increasing CLA content of muscle and adipose tissue. One study did show that feeding whole sunflower seeds at 5% of diet DM increased the CLA content of beef carcass tissue (0.73% vs. 0.31%), when compared to the control group not fed sunflower seeds (Garcia et al., 2003).

The same feeding strategies have been used in dairy cattle and have had much greater effects on milk fat composition. This could be due to the higher forage: concentrate ratio of dairy rations. Also, very little is known about factors that regulate CLA synthesis; ruminally or endogenously and further research needs to be done to demonstrate the synthesis that occurs in adipose tissue.

Limited research has been done investigating breed effects on CLA content in beef. Mir et al., (2000) compared European x British crossbred steers to steers with 75% Wagyu genetics. The study found no difference in CLA content on a lipid basis. However, on a beef DM basis, the Wagyu-influenced cattle had significantly greater CLA content (0.75% vs. 0.51%) compared to the European x British cattle. Since a larger portion of the lipid in Wagyu meat is intramuscular fat and is less likely of being trimmed away, consumers could benefit from the increased CLA content in Wagyu beef. In another study, Limousin cattle and Limousin x Wagyu bred cattle showed no significant difference as the Limousin cattle only had marginally increased CLA content (Mir et al., 2002). Again, research is limited and

further investigation needs to be conducted to examine the effects of breed on CLA content in muscle and adipose tissue.

One final strategy to increase CLA content of beef is management. Laborde et al., (2002) fed steers a high-grain diet immediately after weaning to slaughter and compared it to backgrounding steers for 112 days on a diet of alfalfa silage (98% diet DM). After the backgrounding phase, steers were fed the same high-grain diet as the control group. Conjugated linoleic acid content was modestly increased in the backgrounded cattle (0.35% vs. 0.32% of total fat) compared to the cattle that were immediately put on the high-grain diet postweaning. It was assumed that the CLA deposited during the backgrounding phase stayed in the muscle until harvest.

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CHAPTER 3. PERFORMANCE, CARCASS TRAITS AND FATTY ACID PROFILES OF YEARLING BEEF CATTLE SUPPLEMENTED WITH SELF-FED BYPRODUCTS ON PASTURE[1]

A paper to be submitted to the Journal of Animal Science

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ABSTRACT

Due to rising costs of conventional feedstuffs, more research has been focused on feeding non-conventional feedstuffs, such as byproducts of ethanol production or further processing of grains (i.e. soyhulls). Because of the health benefits of conjugated linoleic acid (CLA) shown in studies on laboratory animals, consumer interest in foods enriched with CLA has increased. The objective of this study was to investigate the effects of finishing yearling market steers on pasture supplemented with combinations of self-fed byproducts on live animal performance, carcass traits and fatty acid profiles; specifically CLA. British and Continental crossbred beef steers (n = 162, BW = 404 ± 29 kg) were stocked on cool season grass pastures (5.6 hd/ha) while being supplemented with ad libitum byproduct supplement. Cattle were supplemented with soyhulls and dried distillers grain with solubles (DDGS) or corn and DDGS offered through self-feeders. Supplements were mixed at a 1:1 ratio with a mineral balancer that included Rumensin®. Supplement effects were observed only for fatty acid profiles. Values for CLA were greater for cattle fed soyhulls-DDGS (0.63 vs. 0.44 mg/g muscle, $P < 0.0001$) compared to cattle supplemented corn-DDGS. Live cattle performance

and carcass traits were not affected by supplement. This pasture-based system of production is an opportunity for producers to increase income from non-tillable, erodible acres.

Key Words: beef cattle, dried distillers grains, soyhulls, conjugated linoleic acid

INTRODUCTION

Availability of corn milling byproducts has increased dramatically due to the increase of ethanol production (RFA, 2010). Distillers grains (DG), in the wet or dry form, offer options when developing feeding rations for finishing cattle. Distillers grains with solubles (DGS) contain the bran, which is high in fiber, and the germ, which is high in fat and the available protein is not removed in the processing (Depenbusch et al., 2007). Due to the heating process during drying, dried distillers grains with solubles (DDGS), do have a lower feeding value when compared to the wet form. However, DDGS are recognized for being high in digestible fiber, protein and phosphorus (Loy et al., 2008).

As a substitute for traditional protein and energy feedstuffs, DDGS have been found to be suitable in many studies. In regards to feedlot performance, previous studies show that feed intake, feed efficiency or average daily gains were at least similar when compared to traditional protein sources in control diets (Firkins et al., 1985; Depenbusch et al., 2007). Previous studies have also shown favorable results when supplementing high forage diets with DDGS (Martinez-Perez et al., 2010; Corrigan et al., 2009). Total DMI, ADG, and feed efficiency increased with increasing levels of supplemented DDGS to finishing cattle (Martinez- Perez et al., 2010; Corrigan et al., 2009).

When included in a forage-based diet, soybean hulls (SH) have a feeding value similar to corn (Anderson et al., 1988). However, when SH replaced corn or other cereal grains in concentrate diets, ADG and gain efficiency of finishing cattle have decreased

(Ludden et al., 1995). Ruminant milk and meat products are a primary source of CLA in the human diet. The predominant isomer of CLA is *cis*- 9, *trans*- 11, which been identified as *rumenic acid* (Bauman et al., 2000; Kramer et al., 1998; Parodi, 1977). The potential health benefits of this form of CLA include reduction in tumor growth, protection of arterial walls from plaque formation, enhancing the immune system and altered fat partitioning (McGuire and McGuire, 2000; Belury, 2002; Stankus, 2008). Because of these potential benefits, food products from ruminant animals are now viewed as a "functional food" (NRC, 1994) and are receiving premiums at the retailer level (McGuire and McGuire, 2000).

Many strategies have been investigated to increase CLA content in beef including dietary, genetics and production system management; of which dietary has been shown to have the greatest effect. Increasing the forage: concentrate ratio (French et al., 2000; Poulson et al., 2004; Dhiman et al., 2005) or supplementing plant oils rich in $C_{18:2}$ and $C_{18:3}$ (Beaulieu et al., 2002; Dhiman et al., 1999) have all been shown to increase CLA content in muscle and adipose tissue of cattle.

Finishing cattle in a forage-based system can take longer periods of time than conventional, high-concentrate diet systems (Martinez-Perez, et al., 2010). Supplementation of cattle in a forage-based system with high energy feeds may decrease days on feed (Depenbusch et al., 2007), potentially making the system more profitable and more realistic in areas of the country that have shorter grazing seasons. Byproducts from ethanol production and further processing of grains could provide supplemental energy and protein when incorporated into these forage-based systems. The effect of supplementing cattle in this type of system with these alternative feedstuffs and its impact on fatty acid profiles of beef from those cattle has not been thoroughly investigated.

The objective of this study was to investigate the effects of supplementing self-fed byproducts on live animal performance, carcass traits and fatty acid profiles of yearling market beef cattle finished on pasture.

MATERIALS AND METHODS

Animals and Experimental Treatments

All procedures for animal use in this study were reviewed and approved by the Institutional Animal Care and Usage Committee at Iowa State University. A two-year study was conducted during the 2007 and 2008 grazing seasons at the Iowa State University Neely-Kinyon Research Farm near Greenfield, Iowa. Over the two grazing seasons, British and Continental crossbred steers (n=162; BW= 404 ± 84 kg) were initially commingled, weighed, and sorted on body weight off-site prior to the feeding trial. The experimental design was a 2 x 2 x 2 factorial (Table 1) with two supplement regimens (Supplement 1-soyhulls/DDGS or Supplement 2-corn/DDGS) and two implant statuses (Yes- implanted with Synovex®-S (200mg progesterone/20mg estradiol) or No) and year (Year 1-2007 or Year 2-2008). Supplements were composed of a mixture of ground corn or soyhulls with DDGS at a 1:1 ratio with 4% (DM) balanced mineral supplement that included Rumensin® offered through self-feeders.

Upon arrival, cattle were placed onto cool-season grass pasture that was predominantly tall fescue. Cattle were continuously stocked throughout the entire finishing period (Table 1) in a 7.28 hectare pasture (5.6 hd/ha) within their supplement treatment.

Cattle were weighed approximately every six weeks throughout the finishing period. Body condition (BCS) were recorded at the initial sort, the second weighing and the final

weighing. Final live performance measurements (average daily gain, feed: gain) were recorded on the day that cattle were shipped.

Meat Sample Collection

Cattle were harvested at a commercial facility when all had reached a minimum BCS of 6.5 (on a 9 point scale). At 24 hr post-harvest, carcass measurements (HCW, REA, 12th rib fat thickness, KPH, and marbling score) were recorded. One 1.27 cm slice was collected from the ribbed area of each carcass containing the longissimus and gracillis muscle. Each sample was identified individually for further analyses. After transport to the Iowa State University Meats Laboratory, visible adipose tissue was removed from each sample and the sample was frozen at -20˚C until further analysis.

Fatty Acid Analysis

Lipid Extraction. Lipid extraction was conducted by weighing 2 g of finely chopped tissue into a 50-mL capped tube to which 17.0 mL of 3.5:1 methanol: water (v: v) was added and vortexed for 15 sec. To this mixture, 6.5 mL of chloroform was added, vortexed for 20 sec and shaken on a wrist-action shaker (Model 75 wrist action shaker, Burrell Scientific, Pittsburgh, PA, USA) for 1 hr. After shaking, 7.5 mL chloroform and 7.5 mL aqueous 0.37% (wt/vol) potassium chloride were added and the tubes were agitated 3 times prior to centrifugation at 500 x *g* for 20 min. The upper aqueous layer was removed and the remainder was filtered into a weighed chloroform-rinsed scintillation vial by using a Buchner funnel and suction flask. Samples were filtered (Cat. No. 1822 042, 42.5 mm dia; Whatmann International Ltd., Maidstone, England) into scintillation vials. Scintillation vials were placed in a concentrator (Sample Concentrator SC/48R, Brinkmann, USA) and dried under flowing

nitrogen at 50˚C. Vials were weighed after cooling to calculate lipid percentage. All extractions were completed in triplicate.

Esterification. After lipid extraction, 10 mg of lipid were weighed into a 10-mL centrifuge tube and 2 mL of methanol and 200 μL of sodium methoxide were added. Tubes were purged with nitrogen, capped and vortexed for 5 sec. The samples were heated in a dry bath for 20 min. After cooling to room temperature, 200 μL of 1 M HCl were added to stop the reaction. Two milliliters of 4% (wt/vol) K_2CO_3 and 2 mL of hexanes were added and the tubes were purged with nitrogen and vortexed for 20 sec. Tubes were centrifuged for 15 min at 500 x *g*. The lower aqueous layer was removed after centrifugation, and the top layer rinsed with 3 mL of distilled water. The tubes again were purged with nitrogen, vortexed for 10 sec, and centrifuged at 500 x *g* for 20 min. One milliliter of the upper layer was aspirated into vial for subsequent analysis by gas chromatography. Vials were stored at -20˚C until analysis.

Gas Chromatography. Fatty acid methyl esters were analyzed using a Varian 3350 gas chromatography (Varian Instruments) equipped with a SP^{TM}-2380 fused silica capillary column (30 m x 0.25 mm x 0.2 um film thickness; Supelco, Bellefonte, PA) and a Varian autosampler. The detector temperature was kept at 220˚C. Initial column temperature was 70˚C, increased at 13˚C/min to 175˚C and held for 37 min and then increased at 4˚C/min to 215˚C and held for 28 min. The total run time was 77 min, and the carrier gas was helium. Individual fatty acids were identified by comparison to standards (Nu-Chek Prep, Inc., Elysian, MN). Fatty acids were reported as mg/g muscle.

Statistical Analyses. Statistical analysis was conducted by using the GLM procedure of SAS (SAS Inst., Cary, NC). Live animal performance and carcass data were analyzed as a

split plot design with a 2 (supplement 1 vs. supplement 2) x 2 (non-implanted vs. implanted) x 2 (year 1 vs. year 2) factorial treatment assignment. The model included supplement, implant status, year and the interactions thereof. Least square means were computed for all main and interaction effects. *P*-values of less than 0.05 were considered significant.

Fatty acid data were analyzed for year 1 as a 2 (supplement 1 vs. supplement 2) x 2 (non-implanted vs. implanted) factorial treatment. The model included supplement and implant status and the interactions thereof. Least square means were computed for all main and interaction effects. *P*-values of less than 0.05 were considered significant.

RESULTS AND DISCUSSION

Year. There were several significant differences in live performance and carcass traits. Cattle were procured from different sources each year and the differences in breed composition (British crossbred steers in year 1; Continental crossbred steers in year 2) could be part of the reason for these differences. Cattle were significantly heavier at the initiation of the finishing period in year 2 (432.0 kg vs. 375.6 kg, $P < 0.0001$) which shortened the time on feed in year 2 (Table 1). Cattle in year 2 measured with significantly larger ribeyes (87.63 vs. 78.49 cm^2, $P < 0.0001$), less 12^{th} rib fat (1.20 vs. 1.53 cm, $P < 0.0001$) and subsequently lower calculated numerical yield grades (2.86 vs. 3.65, $P < 0.0001$). The differences in carcass measurements could be attributed to the difference in genetics between years or the heavier initial weights and shortened finishing period. Cattle had higher marbling scores in year 1 (1023 vs. 985, $P < 0.0001$). Main effect interactions that included year were attributed to the year differences (Table 3).

There is limited research regarding breed effects on CLA content in beef. Mir et al., (2000) compared European x British crossbred steers to steers with 75% Wagyu genetics. On

a beef DM basis, cattle that were 75% Wagyu had significantly greater CLA content (0.74 vs. 0.51 mg/100mg fatty acid). This increased CLA content was due to a larger portion of the adipose tissue being intramuscular fat and not being trimmed away.

Supplement. There were no significant differences observed between supplements regarding performance and carcass traits (Table 3). This result is in agreement with results found by Martinez-Perez et al., (2010) and Corrigan et al., (2009) that showed live performance traits were similar or greater when DDGS were supplemented or substituted to steers being fed diets with higher forage: concentrate rations.

Trans-11 $C_{18:1}$, or trans-vaccenic acid (TVA) and CLA, among other isomers, are intermediates in the ruminal biohydrogenation (BH) pathway. When TVA escapes during BH to the mammary gland or adipose tissue and is endogenously synthesized to CLA. The major endproduct of BH is stearic acid ($C_{18:0}$). Cattle fed supplement 1 had greater stearic acid values (17.44 vs. 15.49 mg/g muscle, P <0.0070) and greater CLA values (0.6338 vs. 0.4555 mg/g muscle, P <0.0001) than cattle fed supplement 2 (Table 5). It can be concluded that because of the greater stearic acid values, more ruminal BH was occurring, thus more TVA was being produced and escaping the rumen to promote endogenous synthesis of CLA. This theory could also explain the greater CLA values for cattle on supplement 1. The greater fiber content of supplement 1 may have contributed to the more favorable rumen environment for BH to occur and the subsequent greater TVA and CLA values.

In a study by Morrical et al. (2008), cattle were finished on pasture and supplemented with DDGS, soybean hulls and wheat middlings (50.0, 25.0, and 20.9% on a DM basis, respectively). The cattle were split into two groups that grazed cool season forage by continuous or rotational stocking. Conjugated linoleic acid values were similar to values

found in the current study (0.69 vs. 0.66 mg/100 mg FA, continuously stocked vs. rotationally stocked, respectively). Average daily feed intake of the supplement was estimated at 10.2-10.4 kg/hd/d. Using Iowa State University Beef Ration Nutritional Decision Software (BRaNDS) average daily feed intake of the supplement for the current study was estimated to be 10.5-11.1 kg/hd/d and average daily feed intake of forage was estimated to be 1.97 kg/hd/d. At these intake levels, cattle would have been consuming more than 80% of their daily intake from the supplement. In a previous study by Knock et al. (2008), cattle finished in a conventional feedlot were compared to pasture-finished cattle supplemented with DDGS, soybean hulls and wheat middlings (50.0, 25.0 and, 20.9% on a DM basis, respectively). The pasture-finished cattle received 10 lbs/d during the early grazing season. When pastures deteriorated, cattle were supplemented 15 lbs/d. Conjugated linoleic acid values of the feedlot cattle were significantly less than the pasture-finished cattle (0.19 vs. 0.94 mg/100mg fatty acid, respectively, $P < 0.05$). Limiting supplementation and increasing the forage: concentrate ratio in this study could have possibly increased the CLA content of cattle.

Implant Status. It is well established that implanted cattle have greater gains, are more efficient in converting feed to gain and typically yield heavier muscled carcasses (Duckett et al., 1996). In this study, implanted cattle did have significantly greater average daily gains (1.59 vs. 1.44 kg/d, $P <0.0075$) (Table 3). The increased ADG led to implanted cattle being heavier at harvest (600.2 vs. 579.5 kg, $P =0.0002$) and having heavier hot carcass weights (374.8 vs. 363.0 kg, $P <0.05$). Implanted cattle, as well, had larger REA measurements (84.19 vs. 81.94 cm^2, $P =0.0450$) than non-implanted cattle. These differences are similar to a study by Duckett et al., (1999). The use of implants can be one strategy to

increase average daily gain and produce heavier weight cattle at harvest that are heavier muscled.

The use of implants has been believed to be the cause for declining number of carcasses grading USDA Choice (Belk, 1992). Duckett et al., (1996) found that implanted cattle on average had reduced marbling scores of 24% of a degree. In that same study, there was a 14.5% reduction in carcasses grading USDA Choice. In the current study, marbling scores were similar (1010 vs. 999, non-implanted vs. implanted cattle, respectively, *P* =0.2698). However, the authors note that because the marbling scores were close to the break line for grading USDA Select or USDA Choice, it could be implied that a lower percentage of implanted cattle graded USDA Choice.

Conjugated linoleic acid values were significantly different between non-implanted and implanted cattle (Table 5). Fritsche et al., (2001) did not find significant differences in CLA content between non-implanted cattle and cattle implanted with Synovex®-S. Other studies investigating the effects of CLA content on cattle implanted with an implant similar to the one used in the current study also found no significant difference (Fritsche et al., (2001). In the current study, no significant differences were found among total lipid values and fatty acid group profiles (Table 4). While there were differences in CLA content and fatty acid composition due to implant status (Table 5); the differences are minor when compared to other factors such as breed, weight and feeding regimen.

IMPLICATIONS

Steers grazing grass and supplemented with soybean hulls and dried distillers grains with solubles performed similarly to cattle supplemented with ground corn and dried distillers grains with solubles. Conjugated linoleic acid values were greater in cattle on the

soyhulls supplementation due to a higher degree of biohydrogenation occurring in the rumen and consequently greater endogenous synthesis occurring in adipose tissue. Supplementing finishing cattle with byproducts from ethanol production and/or further milling of cereal grains can be a potential method for producers looking to increase income from highly erodible, non-tillable acreage. Greater utilization of alternative feedstuffs is also a viable option for smaller scale producers, as the source of these feedstuffs has become more readily available. There were also no digestive disturbances or other health issues observed in any of the cattle. The authors conclude that this production system is a viable option as it is low in labor and can provide use for non-tillable, highly erodible, non-productive acreage.

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Table 1. Allotment of cattle by treatment.

	Year 1	Year 2
Supplement 1		
Non-implanted, n	20	20
Implanted, n	21	20
Supplement 2		
Non-implanted, n	20	20
Implanted, n	21	20
Feeding period, d	135	111

Table 2. Supplement of pasture finished yearling steers supplemented with self-fed by products.

	% of diet, DM	
Ingredient	Supplement 1	Supplement 2
DDGS	46	46
Ground corn	--	46
Soyhulls	46	--
Mineral supplement	4	4
Total	100	100
Nutrient composition		
DM, %	90.0	89.0
CP, %	19.0	10.5
TDN, %	89.0	83.0
NE_g, Mcal/kg	1.50	1.30

Table 3. Least square mean of performance and carcass traits of pasture finished yearling steers supplemented with self-fed byproducts.

	Supplement			*Implant Status*			*Year*			*P-values*						
Item	1	2	SEM	No	Yes	SEM	1	2	SEM	Supp.	Implant	Year	Supp. x Imp.	Supp. x Yr.	Yr. x Imp.	Supp. x Yr. x Imp.
On test wt., kg	403.9	403.6	6.337	403.4	404.2	6.333	375.6	432.0	6.375	NS	NS	<0.0001	NS	NS	NS	NS
Off test wt., kg	587.3	592.4	8.401	579.5	600.2	8.396	585.9	593.8	8.451	NS	0.0002	NS	NS	NS	NS	NS
ADG, kg/d	1.49	1.54	0.050	1.44	1.59	0.050	1.56	1.47	0.049	NS	0.0075	NS	NS	NS	NS	NS
Initial BCS[1]	5.6	5.5	0.0407	5.3	5.8	0.041	5.5	5.6	0.0041	NS	NS	<0.0001	NS	NS	NS	NS
Final BCS[1]	7.3	7.3	0.0458	7.3	7.3	0.0458	7.2	7.3	0.046	NS	NS	NS	NS	NS	NS	NS
HCW, kg	366.7	371.1	5.617	363.0	374.8	5.613	367.3	370.5	5.650	NS	0.0012	NS	NS	NS	NS	NS
Dressing %	62.44	62.65	0.0018	62.63	62.46	0.0018	62.69	62.65	0.0018	NS	NS	NS	NS	NS	NS	NS
12th rib FT, cm	1.39	1.35	0.015	1.39	1.34	0.015	1.53	1.20	0.015	NS	NS	<0.0001	NS	NS	NS	NS
REA, cm^2	83.10	83.03	0.1225	81.94	84.19	0.1224	78.49	87.63	0.1232	NS	0.0450	<0.0001	NS	NS	NS	NS
YG[2]	3.25	3.26	0.062	3.28	3.23	0.062	3.65	2.86	0.063	NS	NS	<0.0001	NS	NS	NS	NS
Marbling Score[3]	1002	1007	6.780	1010	999	6.775	1023	985	6.820	NS	NS	<0.0001	NS	0.0379	NS	NS

[1]BCS= body condition score: 5= moderate condition, 6= high moderate condition, 7= fleshy condition

[2]Calculated YG= 2.5+2.5*FT+0.0038*HCW+0.2*KPH-0.32*REA

[3]Marbling score: 900=slight, 1000=small

Table 4. Year 1 least square means of fatty acid group profiles (mg/g muscle) of longissimus and gracillis muscles of pasture finished yearling steers supplemented with self-fed byproducts.

	Supplement			*Implant Status*			*P-values*		
Item	1	2	SEM	No	Yes	SEM	Supplement	Implant	Supp. x Imp.
SCFA[1]	3.254	3.267	0.0953	3.536	3.168	0.0953	NS	NS	0.0061
LCFA[2]	96.75	96.73	0.0953	96.65	96.83	0.0953	NS	NS	0.0061
SFA[3]	45.95	44.07	0.3221	44.90	45.12	0.3221	<0.001	NS	NS
MUFA[4]	45.83	46.21	0.3989	46.15	45.43	0.2033	NS	NS	NS
PUFA[5]	8.671	9.720	0.3138	8.948	9.443	0.3138	0.0198	NS	NS
n-3 FA[6]	1.428	0.970	0.0965	1.205	1.193	0.096	0.0012	NS	NS
n-6 FA[7]	7.080	8.553	0.2606	7.573	8.061	0.2606	0.0001	NS	NS
MUFA:SFA	0.9917	1.052	0.0148	1.033	1.011	0.015	0.0052	NS	NS
PUFA:SFA	0.1881	0.2213	0.0076	0.1998	0.2096	0.0076	0.0025	NS	NS
USFA:SFA	1.181	1.274	0.0160	1.233	1.221	0.0160	<0.0001	NS	NS
n-3 FA:n-6 FA	0.1998	0.1167	0.0105	0.1610	0.1555	0.0105	<0.0001	NS	NS
AI[8]	0.6527	0.6094	0.0111	0.6427	0.6194	0.0111	0.007	NS	0.0303

[1]SCFA= short chain fatty acids

[2]LCFA= long chain fatty acids

[3]SFA= saturated fatty acids

[4]MUFA= monounsaturated fatty acids

[5]PUFA= polyunsaturated fatty acids

[6]omega-3 fatty acids

[7]omega-6 fatty acids

[8]index of atherogenicity

Table 5. Year 1 least square means of individual fatty acids (mg/g muscle) of longissimus and gracillis muscles of pasture finished yearling steers supplemented with self-fed byproducts.

	Supplement			*Implant Status*			*P-values*		
Item	1	2	SEM	No	Yes	SEM	Supplement	Implant	Supp. x Imp.
Total lipid	3.814	4.631	0.3019	4.205	4.240	0.3087	NS	NS	NS
Saturated fatty acids									
C10:0	0.0240	0.0155	0.0060	0.0202	0.0193	0.0062	NS	NS	NS
C12:0	0.0502	0.1205	0.0251	0.0771	0.0936	0.0257	NS	NS	NS
C13:0	0.0011	0.0765	0.5288	0.0021	0.0755	0.541	NS	NS	NS
C14:0	2.301	2.476	0.0936	2.523	2.254	0.0957	NS	0.0494	0.0494
C15:0	0.2972	0.2950	0.0288	0.2842	0.3080	0.0295	NS	NS	NS
C16:0	25.38	24.37	0.3606	25.36	24.39	0.3687	NS	NS	NS
C17:0	0.8384	1.045	0.0191	0.9104	0.9730	0.0196	<0.0001	0.0261	NS
C18:0	17.44	15.49	0.3754	16.08	16.85	0.3838	0.007	NS	0.0226
C20:0	0.0479	0.0180	0.0098	0.0291	0.0368	0.0100	0.0363	NS	NS
C22:0	0.0014	0.0010	0.0013	0.0000	0.0024	0.0013	NS	NS	NS
C24:0	0.0010	0.0005	0.0006	0.0006	0.0010	0.0006	NS	NS	NS
Monounsaturated fatty acids									
C14:1	0.3830	0.3880	0.0322	0.4337	0.3374	0.3330	NS	0.0412	NS
C16:1	2.532	2.772	0.1204	2.772	2.532	0.1231	NS	NS	NS
C17:1	0.3636	0.5670	0.0154	0.4767	0.4539	0.0157	<0.0001	NS	NS
C18:1	36.99	38.59	0.6475	38.25	37.34	0.6620	NS	NS	NS
C18:1c11	0.2070	0.2310	0.0396	0.1743	0.2636	0.0405	NS	NS	NS
C18:1t11	3.877	4.417	0.4139	3.782	4.511	0.4232	NS	NS	NS
C20:1	0.3432	0.0590	0.0202	0.1828	0.2195	0.207	<0.0001	NS	NS
Polyunsaturated fatty acids									
CLA[1]	0.6338	0.4555	0.0257	0.5306	0.5587	0.0263	<0.0001	NS	NS
C18:2n6	6.222	6.458	0.2791	6.091	6.588	0.2853	NS	NS	NS
C18:3n3	0.0880	0.2685	0.2467	0.1759	0.1806	0.0252	<0.0001	NS	NS
C18:3n6	0.0062	0.0020	0.0026	0.0017	0.0065	0.0027	NS	NS	NS
C20:2n6	0.0488	0.0290	0.0070	0.0356	0.0422	0.0071	NS	NS	NS
C20:3n3	1.141	0.2300	0.0953	0.6532	0.7176	0.0974	<0.0001	NS	NS
C20:3n6	0.3468	0.3100	0.0209	0.3067	0.3500	0.0214	<0.0001	<0.0001	<0.0001
C20:5n3	0.0552	0.0290	0.0076	0.0443	0.0398	0.0078	0.0202	NS	NS
C22:2	0.0000	0.0085	0.0034	0.0030	0.0055	0.0035	NS	NS	NS
C22:4	0.1675	0.1580	0.0136	0.1489	0.1767	0.0139	NS	NS	NS
C22:4n6	0.0018	0.9240	0.1098	0.4670	0.4589	0.1122	<0.0001	NS	NS
C22:5n3	0.1998	0.1925	0.0178	0.1854	0.2069	0.0182	NS	NS	NS

[1]CLA= conjugated linoleic acid (C18:2c9t11)

CHAPTER 4. GENERAL CONCLUSIONS

GENERAL DISCUSSION

As biofuel demand increases, so will competition for feed grains; livestock production will not be the primary consumer of those feed grains. This added competition will force feed grain prices to increase. As prices increase, livestock producers will need to look for alternative feedstuffs that can be purchased for cheaper prices. Understanding what feedstuffs are available and how they can be utilized to lower production costs will be critical for producers' sustainability. As biofuel production increases, the byproducts and coproducts will be more readily available to both small and large scale producers.

Distillers grains, both in the wet and dried form, have been found to be suitable substitutes for the higher priced feed grains; especially corn and soybean meal, when substituting for energy and protein in the ration. When using distillers grains, meeting protein requirements for the animal is the first use and, if cheap enough, they can be used for an energy source also. Wet distillers grains have a higher feeding value then DDGS on a dry matter basis. The lower feeding value of DDGS is due to the heat damage that occurs during the drying process. Despite the lower feeding value, cattle fed dried distillers grains can still be expected to perform similarly to cattle fed more traditional finishing diets and DDGS can be used in rations for all stages of cattle production. Variability in processing methods can alter the nutritional value of distillers grains on a per load or per source basis; therefore regular nutritional analysis is recommended.

Soybean hulls are another alternative feedstuff that can be used as a substitute in cattle diets for protein and energy. Soybean hulls are more effective and have a similar feeding value of corn when used in grazing systems or in high forage rations. Soybean hulls

are high in fiber and digestibility can be reduced, thus reducing their feed value by as much as 80% when substituted for corn.

Cis-9, *trans*-11 conjugated linoleic acid (CLA) enriched foods have been shown to have health benefits in laboratory animals and because of this are receiving premium prices at the retail level. Conjugated linoleic acid is synthesized in the body via ruminal biohydrogenation and endogenous synthesis in the mammary gland and adipose tissue. Ruminant milk and meat products are a primary source of CLA and can be elevated through many strategies involving diet, genetics and production system management. Because of the niche that CLA enriched foods have created, producers can capitalize on the premiums being received by employing those strategies to increase CLA content.

Increasing forage intake is one of the most effective methods to increase CLA content in ruminant products. Creating an ideal environment in the rumen (i.e. optimal pH, increased microbe population) can increase production of CLA and TVA, which can escape the rumen and be converted to CLA via endogenous synthesis. Not only increasing forage quantity, but feeding higher quality forage can also increase CLA. Supplementation of plant oils high in $C_{18:2}$ and $C_{18:3}$ can also accomplish this, but has not proved to be as effective as increasing forage content.

When looking at the production system of supplementing byproducts to cattle being finished on grass, this system shows promise. Live animal and carcass performance are similar to that of cattle being fed in a conventional feedlot system while having cheaper costs of gain from using cheaper alternative feedstuffs. This system is a method for producers to utilize land resources not suited for row crop production either because it is not tillable or highly erodible.

NEED FOR FUTURE RESEARCH

The health benefits of CLA in laboratory animals are well established. Further research is needed on the human side to see if the health benefits transfer over. As well, a deeper understanding of endogenous synthesis and the role that Δ^9 desaturase plays in that process is warranted. Strategies to increase CLA content in ruminant meat products need to be further investigated. The role that genetics could possibly play in CLA synthesis and if there are certain breeds of cattle that have a greater ability to produce CLA is an exciting concept and could give greater value to breeds of cattle that are not highly utilized.

Management strategies such as backgrounding feeder cattle prior to feedlot placement has shown some promise of increasing CLA values; further investigation of similar management practices are merited. Length of feeding higher forage diets should be investigated to recommend feeding and management protocols for producers who could implement this protocol.

As more alternative biofuels are investigated, this could cause traditional feedstuffs to be used as energy sources and create more competition for livestock producers. Investigating the byproducts and coproducts of biofuel production could as potential feeds needs to continue to give producers alternatives to high-cost feedstuffs while not compromising performance and ensuring a safe and wholesome food product.

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