EFFECTS OF PROTEIN SUPPLEMENTATION USING CORN BY-PRODUCTS IN

SOUTHEASTERN BEEF CATTLE PRODUCTION: A SYSTEMS APPROACH

by

JACOB RUSSELL SEGERS

(Under the Direction of Alexander Stelzleni and Robert Lawton Stewart, Jr.)

ABSTRACT

Three experiments were conducted to compare corn gluten feed (CGF), and distillers dried grains plus solubes (DDGS) as protein supplements for cattle from weaning to slaughter. Experiment 1 studied the effects of DDGS and CGF on stocker performance and compositional development. Feeding DDGS increased ADG, but decreased intramuscular fat and ribeye area. Experiment 2 evaluated these by-products in a feedlot system. Performance data, rumen VFAs, BUN, glucose, insulin, ultrasound, and carcass characteristics were examined. Steers fed DDGS had increased G:F, and both by-products had decreased cost of gain compared to SBM. Experiment 3 examined meat quality characteristics of strip steaks from the above steers. Differences included redder steaks from steers fed SBM after 9 d retail display and increased discoloration in steaks from steers fed DDGS. Increased PUFA concentrations were found in steaks from steers fed DDGS.

INDEX WORDS:      distillers grains, corn gluten feed, meat quality

EFFECTS OF PROTEIN SUPPLEMENTATION USING CORN BY-PRODUCTS IN

SOUTHEASTERN BEEF CATTLE PRODUCTION: A SYSTEMS APPROACH

by

JACOB RUSSELL SEGERS

B. S. A, The University of Georgia, 2008

A Thesis Submitted to the Graduate Faculty of The University of Georgia in Partial

Fulfillment of the Requirements for the Degree

MASTER OF SCIENCE

ATHENS, GEORGIA

2010

EFFECTS OF PROTEIN SUPPLEMENTATION USING CORN BY-PRODUCTS IN

SOUTHEASTERN BEEF CATTLE PRODUCTION: A SYSTEMS APPROACH

by

JACOB RUSSELL SEGERS

Major Professor:      Alexander Stelzleni
     R. Lawton Stewart Jr.

Committee:      T. Dean Pringle
     Mark Froetschel

Electronic Version Approved:

Maureen Grasso
Dean of the Graduate School
The University of Georgia
August 2010

DEDICATION

      To my family and closest friends, this work is dedicated to you for without all of you I could not be the man I have become. To my father and mother, Russell and Martha Segers, you have both sacrificed so much to give me the tools I needed to accomplish this. Please know that I always love you and can never repay you for living a life and having the Faith that has served as a ground work for all that Jason and I may become. To Jason and Courtney, you two have inspired me in so many ways, and taught me that wisdom and compassion are not a signs of age, but character. I know that you have the brightest of futures ahead of you. To my grandparents, Bobby and Pearl Segers, you have never let me look back with regret, and always encouraged me to pursue my education even if you didn't understand it. To my grandmother, Grace Kirk, you have always reminded me that doing what is right is more important than doing what is easy. The wisdom and "common sense" that you have imparted to me have guided me and kept me safe more than you could possibly know. Finally to my grandfather, the late Glenn Kirk, who taught me that above all else you have to love your life and the people in it, regardless of your circumstances, that this life is not rehearsal, and if you don't live now the chance to do it will be gone.

## ACKNOWLEDGEMENTS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

Cattle production in the Southeastern United States largely exists as cow/calf operations. The warm, moist, subtropical climate of the Southeast lends itself to virtually year-round forage production throughout most of the year while the mild winters are conducive for fall, late winter, and spring calving. However, the hot, humid summers in the Southeast often cause decreased intake, and performance due to increased heat stress, and elevated parasite loads for cattle fed in confinement. In addition to climate challenges, transportation costs involved in shipping large quantities of cereal grains to the Southeast are also a limiting factor. In recent years there has been a growing interest in producing an economical, locally grown beef product to meet consumer demand for locally grown food. However, with the recent economic instability and elevated price of corn, soybean meal and other traditional feedstuffs, beef producers in the South are exploring the option of using alternative protein and energy supplements to feed their cattle.

Protein is typically the most expensive dietary component per unit of weight. Therefore, finding a cost effective protein supplement would have the huge impact on the economic viability of a nutrition program for growing and finishing cattle. A large amount of literature is available evaluating the use of corn by-products for protein as well as energy supplementation in ruminants. Corn by-products can come from an array

of industries, and distillers grains plus solubles and corn gluten feed are the most common. During ethanol production for beverage, fuel, and industrial uses, the starch from corn is fermented leaving the protein, fiber, and fat fractions from the corn kernel as components of the by-product (Klopfenstein et al., 2007). The resulting by-product is known as distillers grains. When the thin stillage, in which the kernels were fermented, is condensed and added back to the distillers grains and the mixture is dried, the result is dried distillers grains plus solubles (DDGS) (Berger and Singh, 2010). Similarly, when corn is processed for the production of sweeteners such as high fructose corn syrup, the by-product produced is corn gluten feed (CGF). This product is similar to DDGS but does not contain the fat component. With recent expansion of the ethanol and corn processing industries, there has been increasing amounts of DDGS and CGF available to Southeastern producers.

While research examining the effects of these feeds in different sectors of the beef cattle industry is readily available, there is deficit in the amount of research conducted from a multi-system approach outlining the effects of long-term feeding of these by-products throughout multiple stages of the production cycle. Many Southeastern cattle production systems producing locally grown beef will be comprised of a cow/calf, stockering, and small feeding operation connected and managed as one comprehensive unit. Although, this concept is one that has not yet been researched, this research should be vital to providing useful information to make these operations more economically feasible. It is important for these producers to obtain cost-effective protein supplement that can be fed to cattle at differing stages of production. With production of ethanol

currently at 34.0 billion L/ yr, and an expected growth to 56.8 billion L/yr by 2015, it is only logical for producers to fully utilize these corn by-products. (Renewable Fuels Association, 2009).

As new feeding technologies are developed it is important to ensure new feed sources are also capable of producing a high quality end products for consumers. Not only will Southeastern producers have to manage cattle at different stages of development, but also produce a quality product that is competitive in today's market. Meat quality has been defined by many different characteristics; however, meat color, fatness, tenderness and flavor are the most common ways to evaluate beef quality. A steak that is exceptionally tender is desirable by the consumer, but that product may never be purchased if it is discolored in the retail case. Conversely, a bright cherry red product that is tough or dry may also cause an undesirable eating experience and cause a negative effect on future purchases. Therefore, carcass characteristics, shelf-life stability, tenderness and fatty acid profiles are important when evaluating differing diets for beef cattle.

The objectives for this study were to 1) evaluate the performance and compositional development of beef steers fed corn by-products from weaning through slaughter; 2) evaluate in vitro digestibility and nitrogen disappearance, as well as rumen pH, ammonia ($NH_3$), and VFA production from steers fed DDGS, CGF, and SBM; and 3) evaluate carcass characteristics, shelf-life, tenderness, and fatty acid profiles of strip steaks from beef steers fed corn by-products from weaning to slaughter.

## Literature Cited

Berger, L., and V. Singh. 2010. Changes and evolution of corn coproducts for beef cattle.

J. Anim. Sci. 88:E143-E150.

Klopfenstein T. J., G. E. Erickson, and V. R. Bremer. 2007. BOARD-INVITED

REVIEW: Use of distillers byproducts in the beef cattle feeding industry. J.

Anim. Sci. 86:1223-1231.

Renewable Fuels Association. 2009. Ethanol Industry Statistics.

http://www.ethanolrfa.org Accessed May. 13, 2010

CHAPTER 2

THE REVIEW OF THE LITERATURE

Today's beef producer is facing an increasing number of challenges to his

economic livelihood. Volatile input costs and conflicting views on consumer preferences

are just a couple of the obstacles that face modern beef production. Adding to the

problem, is the impact of current economic instability and an increasing demand for corn

by the ethanol and food processing industry forcing producers to seek alternative

management and nutritional strategies to moderate the costs.

**Overview of Corn By-products**

By-products from ethanol and the corn milling industry may be an option to help

producers alleviate feed costs, and include dried distillers grains with soluble (DDGS)

and corn gluten feed (CGF). These feeds have become increasingly available to

producers in the Southeastern U.S., but research is needed to better understand how to

utilize these products in Southeastern beef productions systems. With production of

ethanol currently at 34.0 billion L/ yr in the U.S., and an expected growth to 56.8 billion

L/yr by 2015, it is only logical for producers to fully utilize these feed resources

(Renewable Fuels Association, 2009).

*Sources and Production*

Grain alcohol has been manufactured for centuries, and DDGS has been utilized

as a feedstuff since the beginning of the 19th Century (Henry, 1900). Distillers dried

grains plus solubles are a byproduct of the dry milling process of corn to produce ethanol.

Outlined by Berger and Singh (2010), ethanol and subsequently DDGS are produced when the corn kernel is ground, typically using a hammer mill, mixed with water and cooked under pressure to gelatinize the starch. The starch is further broken down by the addition of alpha-amylase. This yields dextrins in a substance referred to as mash. After a short tempering phase the mash is fermented by adding yeast and glucoamylase. These enzymes simultaneously break down and ferment the dextrins into ethanol. From the fermentation tank the ethanol is distilled and the whole stillage (all non-fermentable material) is centrifuged to remove the thin stillage. Thin stillage is condensed, and added back to partially dried solids and dried to produce DDGS.

In the food processing industry corn oil and high fructose corn syrup is produced by wet milling. The process begins with steeping corn in water with sulfur dioxide. The corn germ is then removed and processed to produce corn oil. The starch and bran are separated and the starch is used to make sweeteners. The remaining fiber and protein is dried resulting in dry corn gluten feed (Hoffman, 1989). Drying wet distillers grains may account for 40 % of the energy costs incurred by the ethanol manufacturer and that drying may decrease nutritional value (Ham et al., 1994). Corn gluten feed and distillers grains with solubles are available as wet products and are acceptable feedstuffs, if producers have acceptable storage space, ability to transport, and a high enough feed out rate to utilize products before they spoil (Klopfenstein, 1996). Wet CGF has been shown to be more rumen degradable than dry CGF. Firkins et al. (1985) hypothesized that the presence of water caused the cellulose in CGF to swell, and thereby increased it's availability for degradation by rumen microbes.

*Nutritional Value and Variation*

*Rumen Digestibility*

Nutritional values of corn by-products are highly variable. The National Research Council Guidelines for the Nutrient Requirements of Beef Cattle (NRC, 1996) reports nutritive values for DDGS as follows: 90.3% DM, 30.4% CP, 46.0 % NDF, and 10.3 % Fat. For CGF, nutrient values are 90.0% DM, 23.8 % CP, 37.0% NDF, and 3.9% Fat. These values will change between processors and even mills using the same distillation protocol (Berger and Good, 2007). Variation in nutrient content can be due to factors such as grain selection, batch vs. continuous fermentation and drying temperature and duration (Carpenter, 1970; Olentine, 1986; Spiehs et al., 2002). Corn is approximately two-thirds starch, therefore, given an efficient fermentation/distillation process, the CP, fiber, and fat content of DDGS is approximately three times that of corn (Stock et al., 2000). This principle holds true for CGF as well with the exception of fat which is extruded during the wet milling process (Hoffman, 1989). This system agrees with NRC (1996) values; however, nutrient content is not the only factor that makes DDGS and CGF unique.

Firkins et al. (1985) demonstrated a more rapid dry matter disappearance for lambs fed wet and dry corn gluten feed compared to those fed wet or dry distillers grains with solubles. The results were attributed to more rapid passage rate due to the decreased particle size of a high fiber diet (Firkings et al., 1985). Also, rapid and extensive cell wall digestibility has been observed *in vitro* with CGF (Abe and Horii, 1978). This illustrates that CGF is a readily fermentable feedstuff that can supply energy

in the form digestible fiber. Additionally, it was shown that the protein component of CGF was degraded to a greater extent than that of soybean meal (SBM) (Abe and Horii, 1978). These results were confirmed *in situ* when rumen $NH_3$, and propionate, of 5.8 and 13.0 mmol/ ml respectively were recorded for CGF supplemented cows compared to $NH_3$ and propionate levels of 4.1 and 11.6 mg/dl respectively for cows supplemented with SBM , and 0.5 and 11.7 mg/dl respectively in cows consuming only native grass hay (Fleck et al., 1988). As described earlier the germ protein of corn is removed for oil extraction in the manufacture of CGF, so it stands to reason that the protein content would be lower than that of DDGS, however, the steep liquor from the soaking process is condensed and added to CGF before drying (Hoffman, 1989). The steep liquor contains high levels of digestible nitrogen which is likely responsible for the elevated rumen $NH_3$ levels of 18.9 mg/dl compared to 8.4 mg/dl only 1 h postfeeding (Wagner et al., 1983). Firkins et al. (1985) showed greater ($P < 0.05$) DM disappearance in rumenally cannulated steers. In contrast to the findings of Abe and Horii (1978), more NDF remained in the rumen at 18 and 27 h in steers fed CGF diets compared to those fed DDGS (Firkins et al., 1985). After 1 h of *in vitro* incubation, $NH_3$ concentrations were highest for CGF compared to corn bran, corn gluten meal, and SBM. By 6 h, however, CGF produced the lowest $NH_3$ concentration among treatments (Bowman and Patterson, 1988) suggesting a higher rate of CP degradation. These results are in agreement with those of Firkins et al. (1985). Bowman and Patterson (1988) also reported seemingly contradictory results in a lamb feeding trial where DM digestibility in the rumen was lower for lambs fed CGF than those fed corn+urea or corn+SBM while N digestibility

8

was higher.  This apparent decrease was explained by greater microbial efficiency

resulting from the higher fiber in the CGF supplement and subsequent ruminal outflow of

microbial DM (Owens and Issacson, 1977).

In contrast, DDGS has been studied for almost 40 yrs with substantial interest in

the high level of RUP (Klopfenstein et al., 2007).  Zein is the primary protein in corn and

is approximately 40% degradable in the rumen (McDonald, 1954; Little et al., 1968).

Aines et al. (1987) calculated average rumen escape values for DDGS and determined

that 2.6 times the amount of protein from DDGS would escape the rumen undegraded

compared to that of SBM.  Bypass protein is exceptionally important for optimal growth

in young growing ruminants (Nelson, 1997).  Animal sources of bypass protein can be

particularly efficient at supplying metabolizable protein.   Ruminal degradation results in

total N losses from 10 g to 12 g/d between consumption and intestinal absorption in

growing cattle fed silage and supplemented with 500 g or 1000 g of fish meal (high RUP;

Gill and Beever, 1982).  Protein requirements in growing cattle vary based upon age,

BW, and stage of physiological development but are high compared to cattle that have

reached physiological maturity.  Amino acid requirements in growing cattle are

determined largely by the AA compostion of the rumen microbial crude protein (MCP;

Merchen and Titgemeyer, 1992).  The AA supply from MCP is well-balanced and similar

to that of soybean meal (SBM) (Merchen and Titgemeyer, 1992) Individual AA can be

experimentally determined to be first- or second-limiting, and may be colimiting (e.g.

sulfur AA, lysine, histidine, and perhaps threonine, valine, and isoleucine) (Merchen and

Titgemeyer, 1992). Quantity and quality of the postruminal AA supply can be altered by

maximizing net microbial protein synthesis, manipulating supplemental protein source, or feeding ruminally protected AA (Merchen and Titgemeyer, 1992). Microbial crude protein production can be calculated based upon TDN of the diet using the equation (NRC, 1996):

$$MCP\ g/day = 6.25\ (-31.86 + 26.12\ TDN\ (kg\ intake/day))$$

Often microbial protein synthesis will not meet the AA requirements for optimal growth without protein supplementation. Also, Gunn et al. (2009) measured plasma urea nitrogen levels in cattle fed 25 or 50% DDGS compared to isonutrient composites formulated to contain equal CP to DDGS fed at 50% DM. Composites were made from corn gluten meal, dry rolled corn and vegetable oil, and observed to have higher plasma urea nitrogen in high-protein diets. These authors also reported that cattle fed protein at the same level during a period of growth had decreasing plasma urea nitrogen levels every 30 d. Therefore, supplemental RUP is often needed to maximize gain (Nelson, 1997). Waller et al. (1980) showed that DDGS proteins were utilized more efficiently than SBM when fed in combination with urea to sheep and cattle. In that same study, these authors demonstrated that, in Hereford steers, protein utilization in diets formulated with DDGS, SBM and urea was more efficient than in diets including only SBM and urea, but less efficient than in diets including only DDGS and urea as the protein supplement. Because of these unique characteristics, DDGS has been used frequently as a source of RUP (Klopfenstein et al., 1978).

*Rumen Fermentation: Amino Acid Availability and VFA Production*

Corn gluten feed is a highly fermentable protein supplement that can be easily

broken down in the rumen (Abe and Horii, 1978; Fleck et al., 1985; Wagner et al., 1983),

whereas the protein component of DDGS is protected from rumen degradation

(Klopfenstein et al., 1978, 2007; McDonald, 1954; Little et al., 1968; Aines et al., 1987).

There are benfits to both types of AA delivery to the small intestine, but the most

important aspect of a protein supplement is the quality of the protein supplied to the

animal.  The extent to which protein is degraded in the rumen is important in terms of

determining if the amount of protein that reaches the small intestine is greater than, equal

to, or less than the amount of protein consumed (Santos et al., 1984.)

In production systems that do not employ a total mixed ration, such as stocker and

growing systems, it is beneficial to have some form of protein supplementation to meet

the high protein requirement of rapidly growing cattle.  In cattle fed grass silage diets

with 0-500 g of fish meal (high RUP) per d, flow of AAs to the small intestine have been

greatly decreased compared to the same diet supplemented with 1000 g of fish meal per d

(Gill and Beever, 1982).  Also, Charmley and Veira (1990) observed decreased rumen

MCP synthesis in cattle fed silage without supplementation.  This was attributed to

denaturation of plant proteins during the ensiling process. When CGF was fed in

comparison to SBM in lamb diets, total nitrogen (N) flows to the abomasum increased

(Bowman and Patterson, 1988).  These authors attributed higher N passage to heating of

the protein fraction during drying, thereby denaturing the protein (Bowman and

Patterson, 1988). No differences were found between total duodenal N flows in steers fed

dry or wet CGF with urea (Firkins et al., 1985).  It has been shown that lysine,

11

methionine, histidine, and phenylalanine are the most limiting AAs in cattle (Schwabb et al., 1976; Casper and Schingoethe, 1989). Limiting essential AA levels in corn are low compared to most oilseed meals (NRC, 1996), and because corn is the seedstock for production in DDGS and CGF, reduced levels of limiting AAs are inherent in the by-product. However, Bowman and Patterson (1988) found no differences in total AA flow to the abomasum or ileum in lambs fed corn + urea and supplemented with CGF or SBM. Likewise, digesta from calves fed SBM (control), toasted SBM (intermediate RUP), or corn gluten meal (high RUP) was shown to be more similar in terms of AA profile than was the feed prior to ingestion (Koeln and Peterson, 1986). These net gains in post-ruminal AA content suggest increased rumen microbial protein synthesis with CGF diets compared to those with SBM. This was attributed to increased microbial efficiency in higher-fiber diets due to rumen synchronization between protein and carbon source degradation (Bowman and Patterson, 1988).

In order to understand effects of RUP vs RDP as it relates to DDGS, CGF and SBM, it becomes important to consider protein utilization in the ruminant in two phases or, the ruminal phase, and the post-ruminal phase (van't Klooster and Boekholt, 1972). Santos et al. (1984) found duodenal non-$NH_3$-N (NAN) flows at 113%-138% of intake N in dairy cattle supplemented with DDGS and corn gluten meal. This was attributed to high levels of RUP. Despite the apparent high passage rate, NAN from DDGS had the lowest absorption in the duodenum (Santos et al., 1984) which led to concerns regarding the AA availability to the small intestine in high-bypass protein supplements. Santos et al. (1984) went on to find that 14% more total AAs were absorbed in the small intestine

from DDGS when compared to SBM for cattle fed isonitrogenous diets. Finally, although lysine flowing to the small intestine was similar among diets, lysine intake with DDGS diets was only 54-61% that of SBM diets, therefore, it was concluded that the majority of lysine flowing from the rumen was in the form of microbial protein (Santos et al., 1984). Amino acids, specifically lysine, availability can vary drastically based on source and processing of DDGS.  Cromwell et al. (1993)  found higher lysine concentrations in lighter colored grains, and increased protein digestibility was reported for lighter colored grains with higher  yellowness (b*) values when evaluated with a colorimeter by Fastinger et al. (2006).  Cromwell et al. (1993) also showed that physical appearance of DDGS was highly correlated with nutritional properties.   Klopfenstein et al. (2007) stated that a large portion of the protein in distillers solubles (which are added back to DDGS) are yeast cells that have been heated and killed during fermentation and concentrated in the solubles.  Denatured yeast is incorporated into Maillard Reaction products making the protein fraction of distillers solubles more resistant to lysis, ruminal degradation and intestinal absorption (Bruning and Yokoyama, 1988).  These characteristics play a definite role in decreasing the DM and protein digestibility of by-product feeds (Uwituze et al., 2010; Santos et al., 1984; Klopfenstein et al., 2007).

Rumen VFA production from the utilization of by-product feeds is well researched (Firkins et al., 1985; Fleck et al., 1988; Elizalde et al., 1998; Peter et al., 2000; Uwituze et al., 2010).  In lambs fed wet corn gluten feed (WCGF), Firkins et al. (1985) found initial acetate concentrations were high in the rumen post-feeding, probably due to high digestible fiber content.  As time post-feeding increased, acetate concentrations

decreased while propionate concentration increased (Firkins et al. 1985). In WDGS, decreased acetate and increased propionate were found indicating decreased fiber digestion compared to corn bran (Vander Pol et al., 2009). Increased acetate:propionate ratios were reported by Grant (1997) when steers were fed steep liquor, a liquid by product containing distillers solubles. Therefore, it is possible that the level of soluble inclusion in WDGS or DDGS could affect digestion and VFA production (Vander Pol et al., 2009). Similar results were reported by Leupp et al. (2009). Conversely many other studies have found no differences in rumen VFAs with the addition of DDGS or CGF (Fleck et al., 1988; Elizalde et al., 1998; Peter et al., 2000; Al-Suwaiegh et al., 2002). Additionally, Hussein et al. (1995) found no differences in VFA production when comparing protein sources with varying levels of heat damage.

*Fat Content of DDGS*

Typically, the corn oil fraction remains in the DDGS by-product (Stock et al., 2000), but not in the CGF, resulting in a high-fat product. In recent years, increased availability and the high-fat content have driven nutritionist to conduct research on the value of DDGS as an energy supplement. As mentioned above, the fat content of DDGS is approximately 10-13% (NRC, 1996) thereby increasing the energy content available from DDGS to the animal. It should be noted that fat content like metabolizable protein, is variable from source to source (Gunn et al, 2009). Klopfestein et al. (2007) outlined an experiment in which DDGS was fed to feedlot cattle in comparison to corn oil. Cattle fed DDGS increased G:F by 8% where cattle fed corn oil decreased G:F by 10% compared to dry rolled corn. Additionally, 81% of the fat fed to DDGS cattle was digested as opposed

to 70% by cattle fed corn oil. This data suggests DDGS could be a valuable energy source; and quadratic effects on performance, intake, and feed efficiency have been reported with differing rates of inclusion for distillers grains (Klopfenstein et al., 2007; Loza et al., 2010). The added value of using distiller by-products over corn as an energy supplement has been demonstrated (Ham et al., 1994; Lodge et al., 1997a; Vander Pol et al., 2009). Vander Pol et al. (2009) showed increased propionate production in the rumen as well as increased unsaturated fat flow into the intestine in cattle fed wet distillers grains with solubles (WDGS), suggesting that at least a portion of the fat is protected from rumen biohydrogenation. When feeding DDGS as an energy supplement, protein and phosphorus (P) are overfed (Klopfenstein et al., 2007). Klopfestein et al. (2007) stated that both DDGS and WDGS have higher feeding values than corn. This is likely attributed to the fat content, the utilization of protein for energy given the absence of starch, and the high levels of digestible fiber in DDGS and WDGS. Lodge et al. (1997b) illustrated that the fat and bypass protein of these supplements were equally responsible for their advantage in feeding value over corn by developing composite distillers by-products using corn gluten meal and tallow and then removing fat or protein. Klopfenstein et al. (2007) hypothesized that this was the result of greater energetic efficiency of bypass protein as well increased dietary fat passage to small intestine compared to degradable protein or carbohydrates. Fat is extruded after the wet milling process to extract corn oil, so there is only about 3-4 % fat component in CGF (Hoffman, 1989).

**Utilization of CGF and DDGS in Stocker Systems**

The objective of stockering cattle is to achieve low cost gains before cattle are put on a finishing diet, therefore stocker supplementation must be cost effective. Stockering systems are an excellent way to add value to cattle and limit input costs for producers (Allen et al., 2000). Stocker systems are typically forage based with some utilization of supplementation. In the southern Great Plains, wheat pasture is a common method for stockering cattle (Horn et al., 2005). In the Southeast producers utilize a wider array of forages such as fescue, white clover, annual ryegrass, caucasian bluestem, and other grasses (Allen et al., 2000). Annual returns from stocker cattle have been difficult to predict partially due to the volatility of the beef and feed markets, but also because rates of gain are dependent upon weather, forage quality, health and genetics (Coulibaly et al., 1996).

Supplementation strategies for stocker cattle have yielded variable results (Utley and McCormick, 1975, 1976; Gill and Beever, 1982; Rooke et al. 1986; Horn et al., 1995), however, the ability to feed more cattle on less land while improving gains are strong incentives to supplement stocker calves if cost of feed makes this feasible (Horn et al., 1995). There is an inherent risk associated with accurately assesing stocker calf growth rate in cattle that can lead to a less profitable rate of gain. The inability to accurately predict ADG makes formulating a realistic breakeven analysis more difficult (Horn et al., 2005). The use of supplementation in growing cattle may allow for more accurate assessment of gain as well as input costs making breakeven price more

predictable. This allows for the reduction of production risk and the subsequent appreciation in the value of cattle (Coulibaly et al., 1996).

Horn et al. (1995) stated that energy and protein supplements high in soluble fiber are beneficial for growing cattle because they provide a digestible source of energy without the adverse affects of high-starch diets such as increased input costs and decreased gain due to subacute acidosis (Krehbiel et al., 1995). Losses of ingested protein equaling as much as 45% have been reported for stocker cattle fed forage-based diets (Ulyatt and Egan, 1979; Egan and Ulyatt, 1980). This is likely the result of decreased rumen N and C synchronization for protein synthesis. Abe and Horii (1978) showed that corn fiber, the major fraction of corn gluten feed, was rapidly and extensively digested in the rumen. Also, replacing starch with CGF would likely eliminate the negative associative effects and acidosis associated with supplementing forage-based diets with starch (Green et al., 1987; Krehbiel et al., 1995). Rumen degradation has been shown to cause increased protein losses between ingestion and the abomasum in growing cattle (Gill and Beever, 1982). Protein requirements in growing cattle are high compared to mature cattle, and microbial protein synthesis alone will not meet the AA requirements for optimal growth, therefore, supplemental bypass protein should be fed to maximize gain (Nelson, 1997).

In silage based diets, protein supplementation with SBM has been shown to increase G:F (Veira et al., 1995). Gill and Beever (1982) illustrated that post-ruminal AA flow for steers stockered on grass silage was below 200.0 g/kg of silage without

supplementation. This was attributed to protein degradation in the silo due to denaturation from heat and pH (Charmley and Veira, 1990). Examining the effects of SBM supplementation on N digestibility and efficiency in stocker cattle fed barley and corn silage, Rooke et al. (1986) reported that low levels of SBM supplementation increased AA flow to the small intestine. The same authors found that as concentration of SBM increased in the diet, net losses of NAN and AAs increased. However, increases in fecal N levels were not observed; therefore it was determined that N retention had increased. Additionally, increased microbial N, and microbial protein efficiency were found (Rooke et al. 1986). This research helped to explain the findings of Veira et al. (1995) who observed ruminal N disappearances of 97.5% for SBM indicating that post-ruminal flow of AAs should be decreased, however, SBM supplementation produced gains similar to corn gluten meal and bone meal which have higher bypass values. These results can be attributed to greater microbial efficiency and protein synthesis in the rumen (Rooke et al., 1986).

Peter et al. (2000) stockered heifers on corn silage using DDGS, CGF, or a modified corn fiber. Heifers fed DDGS and CGF had increased ADG by approximately 0.25 kg, and feed efficiency by approximately 0.045 kg to those fed the modified corn fiber. The DDGS and CGF treatments were similar to each other in terms of performance and efficiency (Peter et al., 2000). This data does not agree with the findings of Berger and Firkins (1985). They fed similar proportions of DDGS and CGF to steers and saw an increase in performance and efficiency with steers fed DDGS. This was explained by bypass protein and increased energy value added by fat (Berger and Firkins, 1985).

Calves fed alfalfa hay and supplemented with WCGF gained 14% faster and 11% more efficiently than calves stockered on 50% alfalfa hay and 44% dry rolled corn diet ( Ham et al., 1995) leading to the conclusion that WCGF was 13% higher in terms of energy value that dry rolled corn for growing cattle. Distillers dried grains plus solubles used as a supplement in conjunction with urea supplementing Hereford steers fed ground corn cobs, corn meal, and molasses increased ADG up to 60% DM with increasing rate of inclusion in a 12.5% CP DM diet (Waller et al., 1980). Fleck et al. (1988) supplemented native grass hay in beef cows with CGF and noted increased molar proportions of propionate and butyrate as well as increased water intake. This was attributed to the increased forage intake of supplemented animals. It is also possible that the highly soluble fiber and protein in CGF influence rumen fermentation to change molar proportions of propionate and butyrate. MacDonald et al. (2007) supplemented grazing heifers with DDGS compared to corn gluten meal, or corn oil sufficient to equal the CP or ether extract found in DDGS. Dried distillers grains with solubles increased ADG to a greater extent (approximately 60%) than did corn gluten meal or corn oil. Distillers dried grains plus solubles had no effect on DMI while corn gluten meal decreased DMI and corn oil had no effect.

Cattle and feed market fluctuations will continue to be factors in determining the most profitable way to stocker cattle. However, protein supplementation in stocker systems is advantageous in terms of increasing performance, efficiency and intake on forage based diets when protein is limiting (Veira et al., 1995; Rooke et al., 1986; Horn et al., 1995, 2005). Furthermore, digestible fiber such as those found in DDGS and CGF

have increased microbial protein synthesis by providing a readily available C source and

to decrease subacute acidosis caused by high starch (Rooke et al., 1986, Krehbiel et al.,

1995). Most importantly, however, may be the ability of the producer to decrease

financial risk with stockering cattle on forage, by allowing them to more accurately

predict growth and market value of cattle prior to sale (Coulibaly et al., 1996, Horn et al.,

2005).

## Utilization of CGF and DDGS in Feedlot Systems

An increasingly unstable feed market and an increasingly available supply of

DDGS and CGF have led to considerable research on feedlot performance and carcass

quality of cattle fed these by-products in the finishing phase (Gunn et al., 2009). Factors

such as fiber solubility, fat content, level of inclusion, and bypass protein quality are the

common focal points for feedlot research (Vander Pol et al., 2009; Al-Suwaiegh et al.,

2002; Klopfenstein et al., 1978, 2007).

*Performance, Efficiency, and Inclusion Level*

Data on feedlot performance with inclusion of DDGS and CGF is variable

(Kampman and Loerch, 1989; Ham et al., 1994; Leupp et al., 2009). Ham et al. (1994)

found that substitution of WDGS for dry rolled corn at 40% of the diet DM increased

ADG by 0.2 kg and feed efficiency by 0.02 kg in feedlot steers. This implies that WDGS

may contain approximately 40% more energy for gain than corn (Al-Suwaiegh et al.,

2002). This increased performance could be attributed to the higher lipid and fiber

20

providing more energy and the decreased risk of subacute acidosis (Ham et al., 1994;

Krehbeil et al., 1995; Al-Suwaiegh et al., 2002). Examining CGF, Kampman and Loerch

(1989) reported that CGF decreased gain, and feed conversion while increasing feed

intake at levels from 40-80% DM of the diet. Decreased gain was attributed to a 4%

decrease in intake of digestible DM as levels of CGF increased from 0-80%. This

disagrees with the findings of Abe and Horii (1978); however, it concurs with the data

reported by Firkins et al. (1985) who hypothesized that the apparent decrease in DM

digestibility was the result of an increased passage rate from the rumen given the reduced

particle size of dried by-products. This data implies that CGF may better serve as a

protein supplement when fed below the 40% level of inclusion (DeHaan et al., 1983,

Firkins et al., 1985). Wet CGF has been shown to yield similar gain, intake and

efficiency to dry rolled corn at 40% of the diet, but at 70%, efficiency begins to decrease

(Ham et al., 1995).

Ham et al. (1994) demonstrated that wet distillers grains (WDGS) had more

feeding value over DDGS; however, the feeding value of DDGS was still 24% greater

than corn. Leupp et al. (2009) reported a quadratic effect for OM intake when DDGS

was included in the diet with highest intake at 15% DDGS diets and lowest at 60%

DDGS (DM). Decreased OM intake was attributed to increasing fat and sulfur levels in

the diet. These results disagree with Trenkle (2004) who reported increased intake in

calves fed DDGS up to 40% of diet. Steers fed 15% or 30% DDGS replacing a 70:30%

bromegrass hay:alfalfa haylage, mixture performed better at 30% inclusion (Buckner et

al., 2007). This tolerance of higher inclusion levels may be reflective of the amount of

starch in the diet rather than the DDGS (Leupp et al., 2009). Sulfuric acid is used for cleaning and pH control during fermentation, therefore, sulfur levels can become toxic at high levels of inclusion (Klopfenstein et al., 2007). Sulfur levels from 0.12 to 0.41% have been shown to decrease feed intake by 32% (Bolsen et al., 1973). Source variation may prove to be a limiting factor in the ability to control S content.

When DDGS were fed at 0, 15, 30, 45, 60, 75% levels of inclusion with steam-flaked corn in finishing diets the results for intake were quadratic with the maximum effect seen at 15% inclusion with G:F increasing linearly with increasing levels of inclusion up to 75% (Depenbusch et al., 2009). These contradictions in the literature are likely the result of variations in nutritional quality of DDGS. Protein availability can vary among suppliers' fermentation and drying methods (Fastinger et al., 2006). It was therefore, hypothesized that diets formulated to meet metabolizable protein requirements may not meet degradable intake protein requirements when DDGS is fed as the sole protein supplement (Depenbusch et al., 2009). Klopfenstein (1996) conducted a series of feeding trials to evaluate distillers grains (wet and dry) as an energy source and to test the effect of drying on protein availability. It was reported that that cattle fed higher levels of WDGS consumed approximately 2 kg less DM, had increased ADG by 0.1 kg, and were more efficient by approximately 1 kg than cattle fed control diets. Results were attributed to the increased $NE_g$ in WDGS due to elevated fat content and energy value of bypass protein (Klopfenstein, 1996). In another study, DDGS produces similar results with increased DMI, and a higher nutritive value was found in WDGS compared to DDGS (Klopfenstein, 1996). Gunn et al. (2009) fed DDGS at 25 and 50% DM as well as

diets containing fat-free corn protein or vegetable oil or both to equal the CP and fat

content of the 50% DDGS. Gunn et al. (2009) also found that diets with added fat and

protein (50% DDGS, vegetable oil, fat-free corn protein) had reduced ADG by

approximately 0.2 kg and G:F by 0.02 kg than diets containing 25% DDGS. Decreased

performance of steers fed high-protein (50% DDGS and fat-free corn protein) was

attributed to the feeding of excess CP and the inefficient metabolic conversion of this

protein to fat causing more escape and microbial protein to be of lesser value than

carbohydrates or protein degraded in the rumen (Tyrell et al., 1970; Garrett, 1980).

Decreased performance in cattle fed diets with elevated fat (50% DDGS and vegetable

oil) was attributed to inhibition of ruminal fiber fermentation associated with high-fat

diets (Brooks et al., 1954).

Blood urea nitrogen (BUN) in feedlot cattle is typically not expected to vary over

time given that the cattle are fed isonitrogenous diets. Gunn et al. (2009) found an

increase of 2.5 mg/dl of plasma urea nitrogen in cattle fed 50% DDGS compared to those

fed 25% DDGS . Likewise, Vasconcelos et al. (2006) and Cole et al. (2006) reported

similar BUN levels in isonitrogenous diets. Vasconcelos et al. (2006) observed a

tendency toward increased BUN concentration in cattle fed 13% CP compared to cattle

fed 10% CP. Cole et al. (2006) reported significant increases in BUN for cattle fed the

same levels of CP.

One reason for the large amounts of variability in today's beef market is the

inability to monitor compositional development through the production process (Damez

and Clerjon, 2008). The most accessible and common way to do this is through the use of ultrasound. Propagation of acoustic waves is governed by the same physical properties found in biological tissues making ultrasound a viable option for non-invasively evaluating meat texture and fat content of the live animal (Damez and Clerjon, 2008). Fat content has also been correlated with ultrasound propagation speed (Abouelkaram et al., 2000). While ultrasound is not widely used to benchmark compositional development over time, it is often used to determine compositional endpoints for slaughter cattle as demonstrated by Gunn et al. (2009).

## Effects of CGF and DDGS on Meat Quality

*Carcass Characteristics*

With the growing availability of DDGS and CGF on the market it has become necessary to assess the effects of feeding these by-products on meat quality. Several feedlot studies have collected carcass data from cattle fed DDGS (Klopfenstein, 1996; Depenbusch et al., 2009; Eun et al., 2009; Gunn et al., 2009; Uwituze et al., 2010). In a feeding trial utilizing increasing levels of DDGS inclusion (0, 15, 30, 45, 60, and 75 % DM), Depenbusch et al. (2009) found that $12^{th}$ rib fat thickness (FT) decreased as levels of DDGS increased in the diet. However, KPH increased with inclusion up to 60% DM, but decreased at 75%. Ribeye area, marbling score, and USDA yield grades were not different with increasing levels of DDGS inclusion (Depenbusch et al., 2009) However, the number of carcasses grading USDA Select increased with level of inclusion, this corresponds to the decreased FT at the $12^{th}$ rib (Depenbusch et al., 2009). Lodge et al.

24

(1997a) reported no differences in carcass characteristics for cattle fed WDGS at 40% of the diet (DM) in comparison to dry rolled corn. These results could be explained by the increased nutritive value of WDGS compared to DDGS indicated by Klopfenstein (1996) and Al-Suwaiegh et al. (2002). A decrease in HCW and LM area were reported by Depenbusch et al. (2008) when WDGS were fed at 25% of the diet (DM) compared to steam-flaked corn based finishing diets. When feeding DDGS and WDGS both corn and sorghum up to 30 % DM, increased FT and USDA yield grade have been reported (Koger et al., 2004; and Al-Suwaiegh et al., 2002). Eun et al. (2009) reported that DDGS when substituted for barley tended to increase marbling, yield grade and tended to decrease LM area. These data differ from that of Klopfenstein (1996) and Uwituze et al. (2010) who observed no differences in HCW, DP, FT, marbling score, USDA Quality or Yield Grades at the 25 and 40% DM level of inclusion. Alternatively, Gunn et al. (2009) reported decreased HCW, marbling scores and USDA quality grade when cattle were fed elevated levels of protein, fat, or both utilizing DDGS above 25% DM of the diet. However, DP, FT, LM area, KPH, and yield grades were similar among treatments. The decrease in marbling and quality grade can be attributed to decreased levels of starch in the diet (Smith and Crouse, 1984; Choat et al. 2003). Increased dietary starch concentration increases intramuscular fat deposition (Smith and Crouse, 1984; Choat et al. 2003). Also, increased passage rate due to high fiber content and reduced particle size may reduce digestibility of starch present in the diet (Firkins et al., 1985).

*Tenderness*

Tenderness is the most economically important trait that affects beef palatability (Belew et al., 2003), and it can be affected by a number of ante-mortem factors such as animal age, sex, diet, stress, and breed (Muchenje et al., 2009). Muir et al. (2000) stated that the majority of tenderness determining factors have to do with changes in the structure of the myofibrillar protein between slaughter and consumption. Bratcher et al. (2005) illustrated that aging times play a large role in the tenderness of locomotor muscles when stratified by quality grade. Muscles from carcasses that were considered upper 2/3 USDA Choice saw no benefit after 7 d aging as determined by Warner-Bratzler shear force (WBS). Muscles from carcasses classified lower 1/3 USDA Choice and USDA Select required at least 14 d of aging to reach maximum tenderness levels as measured by WBS (Bratcher et al., 2005).

While post-harvest factors undoubtedly play a major role in tenderness we know that dietary effects are important as well. Decreased tenderness has been shown to occur in studies where animals have been fed β-adrenergic agonists (Shook et al., 2009; Strydom et al., 2009). Days on feed up to 180 d, increases tenderness in beef muscle; however after 180 d age tends to have a greater negative effect on tenderness (Zinn et al., 1970). One of the most common ways to measure tenderness is Warner-Bratzler shear force (WBS) analysis. Research attempting to determine consumer acceptability thresholds for tenderness is varied (Savell et al., 1987; Shackelford et al., 1991). Strip steaks with WBS values of 2.3 kg have been deemed unacceptable by consumers, while

26

other steaks have been rated tender with WBS values of 4.6 kg (Savell et al., 1987).

Therefore, the relationship between consumer acceptability and instrumental tenderness

is difficult to predict. However, Shackelford et al., (1991) documented the US consumer

threshold for "slightly tender" in retail food service industries to be from 3.9 to 4.6 kg

WBS.

Meat tenderness from cattle fed elevated levels of protein and fat either in the

form of distillers grains or as isonutrient composites has been well researched (Brandt et

al., 1992; Koger et al., 2004; Roeber et al., 2005; Gill et al., 2008; Gunn et al., 2009).

Inclusion of varying levels of WDGS and DDGS has been shown to have no effect on

longissimus muscle tenderness as measured by WBS (Brandt et al., 1992; Koger et al.,

2004; Roeber et al., 2005; and Gill et al., 2008). Roeber et al. (2005) also reported that

although no tenderness differences were found among strip loin steaks from steers fed

differing levels of DDGS from 12.5-50% of the diet, all steaks were below the consumer

acceptability threshold identified by Shackelford et al. (1991). Similarly, Gunn et al.

(2009) reported no differences for DDGS at 25 or 50% of the diet compared to composite

diets consisting of corn/SBM diets with added vegetable oil, corn protein or both to equal

the protein and lipid content of DDGS. Gunn et al. (2009) did state that only steers on

control diets supplemented with corn protein, or both corn protein and vegetable oil

achieved WBS values within the consumer acceptability threshold noted by Shackelford

et al. (1991).

*Color*

Color is the most influential factor on a consumer's willingness to purchase a beef product (Mancini and Hunt, 2005). Current literature suggests that the diet can affect glycogen storage, chilling rate, and antioxidant accumulation which may affect muscle pH, oxygen usage, and metmyoglobin reduction (Mancini and Hunt, 2005) and play a role in determining muscle color. Factors such as breed, diet and availability of shelter have been shown to affect meat color (Lynch et al., 2002). They fed heifers either under shelter on concentrate or on pasture, and found that redness and color stability increased in confinement-fed cattle. Dietary effects were ascribed to the relationship between lipid and meat color, namely the concentration of PUFA in the diet and subsequently the meat. Also, cattle fed in confinement had higher concentrations of α-tocopherol in the meat product (Lynch et al., 2002). Fat color, although less researched than lean color, has been inversely correlated ($r = -0.52$) to the amount of concentrate in the diet (French et al., 2000). Color differences were attributed to the concentration of β-carotene in the diet (French et al., 2000).

Steers fed diets containing elevated fat (either 50% DDGS or vegetable oil) had darker (lower L*) color in ground top round samples than did steers fed 25% DM DDGS or fat-free corn protein as the protein supplement (Gunn et al., 2009). These results were similar to those of Hutchison et al. (2006) who observed darker instrumental color in muscles associated with high fat diets containing 4% DM tallow or poultry fat. Gunn et al. (2009) also found that steers fed DDGS at 25% DM of the finishing diet had ground

patties that tended to have higher a*(higher numbers indicate redness) (16.55 vs 15.50)

and b* (higher numbers indicate yellowness) (14.55 vs 13.6) values when compared to

steers fed elevated protein or elevated protein and fat levels using 50% DDGS or an

equivalent composite of fat free corn protein and vegetable oil.  Depenbusch et al. (2009)

recorded a quadratic effect for L*(higher numbers indicate brightness) values in a shelf-

life experiment using strip steaks from heifers fed 0, 15, 30, 45, 60, or 75% DDGS.  At d

0 L* decreased linearly with increasing level of DDGS, however, on d 3, 5, and 7

brightness increased quadratically with brightest steaks being at the 45% level of

inclusion (Depenbusch et al., 2009).  Brightness also decreased in steaks from heifers fed

in excess of 45% DM DDGS. However, no differences were found for redness or

yellowness.  Gunn et al. (2009) observed increased a* values in steaks from cattle fed

10% DDGS and 10% WDGS compared to those fed 20% DDGS, 40% DDGS or WDGS.

This was attributed to the presence of xanthophylls, which are yellow to orange pigments

from oxygen derivatives of the carotene in corn (Gunn et al., 2009).  Roeber et al. (2005)

employed a trained consumer panel to evaluate overall acceptance (8 = extremely

desirable, to 1 = extremely undesirable), color (8 = extremely bright cherry red, to 1 =

extremely dark red), and discoloration (8 = 0% to 1 = 76-100%) in beef strip steaks.

Steaks remained on display until 80% were found to be moderately undesirable.  They

reported that steaks from cattle fed 25% WDGS were less likely to receive a score of 3 or

less for acceptance when compared to steaks from steers fed 12.5% DDGS and urea, 25%

DDGS , or 50% DDGS, or WDGS.  However,  in a second experiment where steaks from

steers fed 0, 10, 20,  or 40% DM DDGS or WDGS were compared, steaks from steers fed

the highest levels of DDGS and WDGS were most likely to receive scores of moderately unacceptable or lower when compared to a SBM control.  These data indicate that cattle can be fed  25% DDGS with no deleterious effects on shelf-life, but feeding DDGS at 40% inclusion can cause decreased shelf-life in beef strip steaks (Roeber et al., 2005).

Gill et al. (2008) compared corn and sorghum DDGS and WDGS at 0 and 15% of the diet with and without roughage (alfalfa hay).  Steers were harvested and experiments were conducted in tandem on two different dates, approx 1 month apart.  Results varied based on slaughter group. In slaughter group 1, steers fed corn DDGS or WDGS had redder (higher a*) steaks than those fed sorghum by-products.  The opposite was true for kill group 2.  This variation was attributed to differing weather conditions on harvest days.  Weather on the first harvest day was cool and clear while harvest day 2 was -1° C with freezing rain and snow, making transportation to the abattoir more stressful.   In slaughter group 2, steaks from cattle fed DDGS and WDGS (both corn and sorghum) were lighter (higher L*) with lower a* and b* values than those from cattle fed steam-flaked corn.  Also, b* values were higher in steaks from steers fed wet by-products vs. those from steers fed dry by-products.  Gill et al. (2008) observed no dietary effects on subjective retail display for overall color and surface discoloration by a trained panel.  Steaks were evaluated until 80% of strip steaks on display received a score of moderately undesirable.

*Fatty Acid Profiles and Lipid oxidation*

Fatty acids in meat products are the determining factors behind fat firmness, shelf-life, and flavor (Wood et al., 2002). The amount of influence that fatty acids have on these characteristics is determined by the amount of fat in the tissue (Calkins and Hodgen, 2007). Increased interest in manipulating the fatty acid composition of meats has arisen from health concerns among consumers and the subsequent targeting of the meat as the human dietary component largely responsible for the increased levels of saturated fat in the diet (Wood et al., 2002). More recent research has dealt more with the proportions of PUFA in meat products, more specifically the ratio of n-3 fatty acids to n-6 fatty acids (Williams, 2000). The n-6:n-3 ratio has been linked to the occurrence of blood clots and subsequent heart attacks (Esner, 2001). Therefore, it is recommended that the n-6:n-3 ratio not exceed 4 (Wood et al., 2002). The n-6:n-3 ratio is typically favorable in ruminant tissue given the high levels of 18:3 in the phospholipids of ruminant muscle (Wood et al., 2002; Calkins and Hodgen 2007). Ruminant muscle tissue also has elevated levels of conjugated linoleic acid (CLA) compared with most foods. These CLAs have been associated with anti-carcinogenic and anti-oxidant effects (Wood et al., 2002). These fatty acids have been found in larger amounts in forage-fed cattle when compared to traditionally-finished beef (Calkins and Hodgen, 2007). Conjugated linoleic acid synthesis takes place through several metabolic steps and by way of a key intermediate called vaccenic acid which precedes synthesis of the CLA *cis-9, trans*-11 isomer (Calkins and Hodgen, 2007) Vaccenic acid is elongated by an enzyme known as $\Delta^9$desaturase (Camfield et al., 1997). The activity of this enzyme is slowed in

31

forage-fed cattle leading to the potential build up of vaccenic acid in the tissue (French et al., 2000). Camfield et al. (1997) hypothesized that vaccenic acid was the cause of off-flavors in beef products. Fatty acid profiles of beef can be manipulated by feeding of certain oils, such as fish or linseed oils that are high in long-chain fatty acids (Scollan et al., 2001), and these compounds have been shown to negatively affect meat flavor (Camfield et al., 1997). Calkins and Hodgen (2007) reported that variations in diet, growth rate, and animal management associated with commercial beef production have yielded contradictory results in terms of fatty acid effect on flavor because, the physiology of lipid deposition is affected by nutrition, genetics, stress and other factors that are impossible to regulate. Cattle fed on concentrates were found to produce more desirable flavor profiles than cattle fed on pasture (Melton, 1983). French et al. (2000) stated that cattle with similar growth rates were similar in terms of meat quality and flavor when managed under different nutritional programs (i.e. concentrate, grass silage, or grazing), however, that increasing the amount of grass in the diet increased the benefits to human health by increasing the n-6:n-3 ratio, the PUFA: saturated fatty acid (SFA) ratio, and the molar proportions of CLA in the meat (French et al., 2000)

Perhaps the most influential way that fatty acids can affect meat products is through lipid oxidation (Calkins and Hodgen, 2007). Gatellier et al. (2005) reported increased thiobarbituric acid reactive substances (TBARS) for cattle fed out on concentrate diets with hay and silage compared to forage-fed beef. This was attributed to higher levels of α-tocopherol in the cell membranes and adipose tissue of forage-fed animals as well as increased levels of heme iron, a pro-oxidation factor, in cattle fed

concentrates (Gatellier et al., 2005).  Yang et al. (2002) found that 4-6 µg/g of α-tocopherol in feedlot diets minimized lipid oxidation in concentrate fed cattle, but not in grass-fed animals.

When comparing WDGS and DDGS from corn or sorghum in conjunction with roughages, Gill et al. (2008) reported no differences in total concentrations of saturated fatty acids among strip steaks from steers fed dry or wet distillers grains from corn or sorghum with or without alfalfa hay. However, heptadecanoic (C17:0) and stearic (C18:0) acids were both increased in cattle fed distillers grains from corn and sorghum (Gill et al., 2008). In that same study increased levels of n-6 polyunsaturated fatty acids (PUFA) were found in the form of linoleic acid.  In the first slaughter group, diets containing corn and sorghum distillers grains were found to raise n-6 PUFA whereas in kill group 2 only corn distillers grains were found to increase n-6 PUFA (Gill et al., 2008).  Results were attributed to increased PUFA concentrations in the lipid fraction of distillers grains due to the high percent of corn oil in the feedstuff (Gill et al., 2008). This is in congruence with the findings of Schingoethe et al. (1999) who reported that feeding approximately 31% of corn WDGS in corn silage-based diets increased total fatty acids by approximately 2% due mainly to 18:1 and the 18:2 PUFAs (Schingoethe et al., 1999). Steers fed sorghum DDGS had higher concentrations of α-tocopherol and α-linoleic acid (C18:3 n-3) (Gill et al., 2007).  Trans-vaccenic acid was higher in steaks from steers fed corn distillers grains probably because of increase linoleic acid in corn compared to grain sorghum. Similarly, CLA concentrations were higher in distillers grain diets compared to steam-flaked corn diets (Gill et al., 2007).  Finally, no differences were found for lipid

33

oxidation in kill group one while cattle fed sorghum distillers grains supplemented with roughage had increased TBARS in kill group 2. This likely resulted from increased PUFA concentrations (Gill et al., 2008).

Black et al. (2009) reported decreases in oleic (C18:1) and palmitic (C16:0) acid with the inclusion of DDGS compared to dry rolled and steam-flaked corn.  Also, increases in stearic (C18:0) and linoleic (C18:2) acid including the *trans*-10, *cis*-12 isomer of CLA were recorded (Black et al., 2009).  These are positive effects that encourage the use of DDGS.  Palmitic and myristic acid are primary precursors for plaque formation in arteriosclerosis (Wood et al., 2002).

Total concentrations of saturated fatty acids and monounsaturated fatty acids (MUFA) were unchanged among cooked steaks from heifers fed differing levels of DDGS (Depenbusch et al., 2009).  Pentadecanoic (C15:0) and heptadecanoic (C17:0) acid decreased linearly with increasing levels of DDGS (Depenbusch et al., 2009).  This disagrees with data found by Koger et al. (2004) and Gill et al. (2008) who reported differences in total saturated fatty acids.  This is likely due to differences in management or other environmental factors such as differing roughage:concentrate among feedlot rations in the differing trials (Bowling et al., 1978, Cabezas et al., 1965).  Concentration of CLA also increased with increasing level of DDGS inclusion from 0-75% and was likely due to an increase in the *trans*-10, *cis*-12 isomer as other isomers remained unchanged (Depenbusch et al., 2009). Eicoasapentaenoic acid (C20:5 n-3) concentration decreased as DDGS concentration increased while linoleic acid (C18:2 n-6) increased with DDGS (Depenbusch et al., 2009) . Total PUFA and the n-6:n-3 ratio also increased

with increasing levels of DDGS (Depenbusch et al., 2009).  This increase in PUFA concentration increases health benefits but also increases the likelihood of lipid oxidation decreasing shelf-life and increasing flavor detriments (Wilson et al., 1976; Melton, 1983). No differences were found among increasing levels of DDGS for lipid oxidation compared to steam-flaked corn (Depenbusch et al., 2009).

## Conclusions

Current literature has shown that diet can affect performance, rumen fermentation, blood parameters, and meat quality.  Corn by-products positively affect growth in young cattle, and have been shown to have various effects on carcass characteristics at varying levels of inclusion.  These effects can change based on stage of physiological development. Gill (et al., 2009) found decreased shelf-life in ground beef from steers fed DDGS above 30% at the diet, but no adverse effects were found on shelf-life at 20% inclusion.  Therefore, 25% of the diet DM was chosen as the level of inclusion for this research.  Also, little research has been conducted to determine the effects of feeding these by-products from weaning slaughter while maintaining the same levels of inclusions.  Therefore, the focus of the following experiments was to deteremine the effects DDGS and CGF on performance, compositional development, rumen fermentation, blood parameters and meat quality when fed at 25% DM from weaning to slaughter.

**Literature Cited**

Abe, A. and S. Horii. 1978. Application of the detergent analysis to the feed ingredients and to the various formula feeds. Jpn. J. Zootech. Sci. 49:733-738.

Abouelkaram, S., K. Suchorski, B. Buquet, P. Berge, J. Culioli, and P. Delachartre. 2000. Effects of muscle texture on ultrasonic measurements. Food Chem. 69:447-455.

Aines, G., T. Klopfenstein, and R. Stock. 1987. Distillers Grains. MP51, Nebraska Agric. Res. Div., Lincoln.

Al-Suwaiegh, S., K. C. Fanning, R. J. Grant, C. T. Milton, and T. J. Klopfenstein. 2002 Utilization of distillers grains from the fermentation of sorghum or corn in diets for finishing beef and lactating dairy cattle. J. Anim. Sci. 80: 1105-1111.

Allen, V. G., J. P. Fontenot, and R. A. Brock. 2000. Forage systems for production of stocker steers in the upper south. J. Anim. Sci. 78: 1973-1982.

Belew, J. B., J. C. Brooks, D. R. McKenna, J. W. Savell. 2003. Warner-Bratzler shear evaluations of 40 bovine muscles. Meat Sci. 64:507-512.

Berger, L. L., and J. L. Firkins. 1985. Corn gluten feed for beef cattle. Proc. Corn Gluten Feed for the Livestock Industry. Iowa State University Extension, Ames. pp 1-8.

Berger, L. L., D.L. Good. 2007. Chapter 6. Distillers Dried Grains Plus Solubles Utilization by Livestock and Poultry. Corn-Based Ethanol in Illinois and the U.S.: A Report from the Department of Agricultural and Consumer Economics, University of Illinois. http://www.farmdoc.illinois.edu/policy/research_reports/ethanol_report/Ethanol%20Report%20-%20Ch%206.pdf. Accessed May 17, 2010.

Berger, L., V. Singh. 2010. Changes and evolution of corn coproducts for beef cattle. J. Anim. Sci. 88:E143-E150.

Black, P. L., K. K. Karges, M. L. Gibson, J. S. Droulliard, J. S. Smith, G. L. Parsons, M. K. Shelor, and M. E. Dikeman. 2009. Report of progress. Distillers grains do not change carcass composition but change some fatty acids when added to finishing diets [electronic source] no. 1010: 38-42. http://www.ksre.ksu.edu/library/lvstk2/SRP1010.pdf  Accessed May 25, 2010

Bolson, K. K. , W. Woods, and T. Klopfenstein. 1973. Effect of methionine and ammonium sulfate upon performance of ruminants fed high corn rations. J. Anim. Sci. 36:1186-1190.

Bowling, R. A., J. K. Riggs, G. C. Smith, Z. L. Carpenter, R. L Reddish, and O. D. Butler. 1978. Production, carcass and palatability characteristics of steers produced by different management systems. J. Anim Sci. 46: 333-340.

Bowman, J.G. P., and J. A. Patterson. 1988. Evaluation of corn gluten feed in high energy diets for sheep and cattle. J. Anim. Sci. 66: 2057-2070.

Brandt Jr., R. T., G. L. Kuhl, R. E. Campbell, C. L. Kastner, and S. L. Stroda. 1992. Effects of steam-flaked sorghum grain or corn and supplemental fat of feedlot performance, carcass traits, longissimus composition, and sensory properties of steers. J. Anim. Sci. 70:343-348.

Bratcher, C.L., D. D. Johnson, R. C. Littell, and B. L. Gwartney. 2005. The effects of quality grade, aging, and location within muscle on Warner-Bratzler shear force in beef muscles of locomotion. Meat Sci. 70:279-284.

Brooks, C. C., G. B. Garner, C. W. Gehrke, M. E. Muhrer, and W. H. Pfander. 1954. The

    effect of added fat on the digestion of  cellulose and protein by ovine rumen micro

    organisms. J. Anim. Sci. 13:758-764.

Bruning, C. L., and M. T. Yokoyama. 1988. Characteristics of live and killed brewer's

    yeast slurries and intoxication by intraruminal administration to cattle. J. Anim.

    Sci. 66: 585-591.

Buckner, C. D., T. D. Klopfenstein, G. E. Erickson, K. J. Vander Pol, K. K. Karges, and

    M. L. Gibson. 2007. Comparing a modified dry by-product to dried distillers

    grains with solubles in growing calf diets. Page 15-16. In Nebraska Beef Cattle

    Report. MP90-A. Univ. Nebraska, Lincoln.

Cabezas, M. T., J. F. Hentges, Jr., J. E. Moore, and J. A. Olson. 1965. Effect of diet on

    fatty acid composition of body fat in steers. J. Anim. Sci. 24: 57-61.

Camfield, P. K., A. H. Brown, Jr., P. K. Lewis, L. Y. Rakes, and Z. B. Johnson. 1997.

    Effects of frame size and time-on-feed on carcass characteristics, sensory

    attributes, and fatty acid profiles of steers. J. Anim. Sci. 75: 1837-1844.

Calkins, C. R., and J. M. Hodgen. 2007. A fresh look at meat flavor. Meat Sci. 77: 63-80.

Carpenter, L.E. 1970. Nutrient composition of distillers feeds. In: Proc. Distillers Feed

    Res. Council, Cincinnati, OH. 25: 54-61.

Casper, D. P., and D. J. Schingoethe. 1989. Model to describe and alleviate milk protein

    depression in early lactation dairy cows fed a high fat diet. J. Dairy Sci. 72:3327-

    3335.

Charmley, E., and D. M. Veira. 1990. Inhibition of proteolysis at harvest using heat in

    alfalfa silages:  effects on silage composition and digestion by sheep. J. Anim.

    Sci. 68: 758-766.

Choat, W. T., C. R. Krehbiel, G. C. Duff, R. E. Kirksley, L. M. Lauriault, J. D. Rivera, B.

    M. Capitan, D. A. Walker, G. B. Donart, and C. L. Goad. 2003. Influence of

    grazing dormant native range or winter wheat pasture on subsequent finishing

    cattle performance, carcass characteristics and ruminal metabolism. J. Anim. Sci.

    81: 3191-3201.

Cole, N.A., P. J. Defoor, M. L. Galyean, G. C. Duff, and J. F. Gleghorn. 2006. Effects of

    phase-feeding of crude protein on performance, carcass characteristics, serum

    urea nitrogen concentrations, and manure nitrogen of finishing beef steers. J.

    Anim. Sci. 84:3421-3432.

Coulibaly, N., D. J. Bernardo, and G. W. Horn. 1996. Energy supplementation for wheat

    pasture stocker cattle under uncertain forage availability. J. Agric. App. Econ.

    28:172-179.

Cromwell, G. L., K. L. Herkelman, and T. S. Stahly. 1993. Physical, chemical, and

    nutritional characteristics of distillers grains with solubles for chicks and pigs. J.

    Anim. Sci. 71: 679-686.

Damez, J. –L., and S. Clerjon. 2008. Meat quality assessment using biophysical methods

    related to meat structure. Meat Sci. 80:132-149.

DeHaan, K. A., T. J. Klopfenstein and R. Stock. 1983.  Corn gluten feed as a protein and

    energy source for rumniants p. 28 Nebraska Beef Cattle Report. MP 44:19.

Depenbusch, B.E, C.M. Coleman, J. J. Higgins and J. S. Droulliard. 2009. Effects of
increasing levels of dried corn distillers grains with solubles on growth
performance, carcass characteristics, and meat quality of yearling heifers. J.
Anim. Sci. 87: 2653-2663.

Depenbusch, B. E., J. S. Droulliard. E. R. Loe, M. E. Corrigan, and M. J. Quinn. 2008.
Efficacy of moninsin and tylosin in finishing diets based on steam-flaked corn
with and without corn wet distillers grains with solubles. J. Anim. Sci. 86: 2270-
2276.

Egan, A. R., and M. J. Ulyatt. 1980. Quantitative digestion of fresh herbage by sheep. VI.
Utilization of nitrogen in five herbages. J. Agric. Sci. (Camb.) 94:47–56.

Elizalde, J. C., J.D. Cremin Jr., D.B. Faulkner, and N. R. Merchen. 1998. Performance
and digestion by steers grazing tall fescue and supplemented with energy and
protein. J. Anim. Sci. 76: 1691-1701.

Esner, M. 2001. The role of fats in human nutrition. Oils and fats, Animal carcass fats,
Leatherhead Publishing. Leatherhead, Surrey, UK. 2: 77-122.

Eun, J. –S., D. R. Zobell, R. D. Wiedmeier. 2009. Influence of replacing barley grain
with corn-based dried distillers grains with solubles on production and carcass
characteristics of growing and finishing beef steers. Anim. Feed Sci. Tech. 152:
72-80.

Fastinger, N. D., J. D. Latshaw, and D. C. Mahan. 2006. Amino acid availability and true
metabolizable energy content of corn distillers dried grains with solubles in adult
cecectomized roosters. Poul. Sci. 85: 1212-1216.

Firkins, J.L., L. L. Berger, and G. C. Fahey, Jr. 1985. Evaluation of wet and dry distillers grain and wet and dry corn gluten feeds for ruminants. J. Anim. Sci. 60:847-860.

Fleck A. T., K. S. Lusby, F. N. Owens, and F. T. McCollum. 1988. Effect of corn gluten feed on forage intake, digestibility and runimal parameters of cattle fed native grass hay. J. Anim. Sci. 66:750-757.

French, P., C. Stanton, F. Rawless, E. G. O'Riordan, F. J. Monahan, and P. J. Caffery. 2000. Fatty acid composition, including conjugated linoleic acid of intramuscular fat from steers offered grazed grass, grass silage, or concentrated-based diets. J.Anim. Sci. 55: 2849-2855.

Garrett, W. N. 1980. Factors influencing energetic efficiency of beef production. J. Anim. Sci. 51:1434-1440.

Gatellier, P., Y. Mercier, H. Juin and M. Renerre. 2005. Effect of finishing mode (pasture or mixed diet) on lipid composition, colour stability, and lipid oxidation in meat form Charlois cattle. Meat Sci. 69: 175-186.

Gill, M., and. E. Beever. 1982. The effect of protein supplementation on digestion and glucose metabolism in young cattle fed on silage. Br. J. Nutr. 48: 37-48.

Gill, R. K., D. L. VanOverbeke, B. Depenbusch, J. S. Droulliard, and A. DiCostanzo. 2008. Impact of beef cattle diets containing corn or sorghum distillers grains on beef color, fatty acid profiles, and sensory attributes. J. Anim. Sci. 86: 923-935.

Grant, R. J. 1997. Interactions among forages and nonforage fiber sources. J. Dairy Sci. 80:1438‑1446.

Green, D. A., R. A. Stock, F. K. Goedeken, and T. J. Klopfenstein. 1987. Energy value of
corn wet milling by-product feeds for finishing ruminants. J. Anim. Sci. 65: 1655-
1666.

Gunn, P. J., A. D. Weaver, R. P. Lemenager, D. E. Gerrard, M. C. Claeys, and S. L.
Lake. 2009. Effects of dietary fat and crude protein on feedlot performance,
carcass characteristics, and meat quality in finishing steers fed differing levels of
dried distillers grains with solubles. J. Anim. Sci. 2009. 87: 2882-2890.

Ham, G. A., R. A. Stock, T. J. Klopfenstein, E. M. Larson, D. H. Shain, and R. P.
Huffman. 1994. Wet corn distillers byproducts compared with dried corn distillers
grains with solubles as a source of protein and energy for ruminants. J. Anim. Sci.
72: 3246-3257.

Ham, G. A, R. A. Stock, T.J. Kopfenstein and R. P. Huffman. 1995. Determining the net
energy value of wet and dry corn gluten feed in beef growing and finishing diets.
J. Anim. Sci. 73: 353-359.

Henry, W. A. 1900. Dried distillery grains compared with oats. Feeds and Feeding 2nd
ed. 421. Morrison Publishing Co., Ithaca, NY

Hoffman, P.C. 1989. Corn Gluten Feed. Bulletin No. A3518. University of Wisconsin-
Madison. Accessed 5/17/2010.
http://learningstore.uwex.edu/assets/pdfs/a3518.pdf.

Horn, G. W., M. D. Cravey, F. T. McCollum, C. A. Strasia, E. G. Krenzer, Jr and P.L.
Claypool. 1995. Influence of high-starch vs high-fiber energy supplements on

performance of stocker cattle grazing wheat pasture and subsequent feedlot performance. J. Anim. Sci. 73: 45-54.

Horn, G.W., P. A. Beck, J. G. Andrae, and S. I. Paisley. 2005 Designing supplements for stocker cattle grazing wheat pasture. J. Anim. Sci. 83: E69-78

Hussein, H. S., M. R. Cameron, G. C. Fahey Jr., N. R. Merchen, and J. H. Clark. 1995. Influence of altering ruminal degradation of soybean meal protein on in situ ruminal fiber disappearance of forages and fibrous by-products. J. Anim. Sci. 73: 2428-2437.

Hutchison, S., E. B. Kegley, J. K. Apple. T. J. Wistuba, M. E. Dikeman, and D. C. Rule. 2006. Effects of adding poultry fat in the finishing diet of steers on performance, carcass characteristics, sensory traits, and fatty acid profiles. J. Anim. Sci. 84: 2426-2435.

Kampman, K. A, and S. C. Loerch. 1989. Effects of dry corn gluten feed on feedlot cattle performance and fiber digestibility. J. Anim. Sci. 67:501-512

Klopfenstein, T.1996. Distillers grains as an energy source and effect of drying on protein availability. Animal Feed Science Technology. 60: 201-207.

Klopfenstein T. J., G. E. Erickson, and V. R. Bremer. 2007. BOARD-INVITED REVIEW: Use of distillers byproducts in the beef cattle feeding industry. J. Anim. Sci. 86:1223-1231.

Klopfenstein, T. J., J. Waller, N. Merchen, and L. Peterson. 1978. Distillers grains as naturally protected protein for ruminants. Distillers Feed Conference Proceedings 33: 38-46.

Koeln, L. L. and J. A. Paterson. 1986. Nitrogen balance and amino acid disappearance from the small intestine in calves fed soybean meal-,toasted soybean meal-, or corn gluten meal-supplemented diets. J. Anim. Sci. 63:1258-1266.

Koger, T. J., D. M. Wulf, K. E. Tjardes, K. S. Mateo, T. E. Engle, C. L. Wright, and R. J. Maddock. 2004. The influence of feeding various levels of wet distillers grains on carcass quality, carcass composition, and fatty acid profile of finishing steers. Proc. 57th Recip. Meats Conf. http://www.meatscience.org Accessed May 24, 2010.

Krehbiel, C. R., R. A. Stock, D. W. Herold, D. H. Shain, G. A. Ham, and J. E. Carulla. 1995. Feeding wet corn gluten feed to reduce subacute acidosis in cattle. J. Anim. Sci. 73: 2931-2939.

Leupp, J. L., G. P. Lardy, K. K. Karges, M. L. Gibson, and J. S. Caton. 2009. Effects of increasing level of corn distillers dried grains with solubles on intake, digestion, an ruminal fermentation in steers fed seventy percent concentrate diets. J. Anim. Sci. 87:2906-2912

Little, C. O., G. E. Mitchell, Jr., and G. D. Potter. 1968. Nitrogen in the abomasums of weather fed different protein sources. J. Anim. Sci. 27: 1722-1726.

Lodge, S. L., R. A. Stock, T. J. Klopfenstein, D. H. Shain, and D. W. Herold. 1997a. Evaluation of corn and sorghum distillers byproducts.  J. Anim. Sci. 75: 37-43.

Lodge, S. L., R. A. Stock, T. J. Klopfenstein, D. H. Shain, and D. W. Herold. 1997b. Evaluation of wet distillers composite for finishing ruminants. J. Anim. Sci. 75: 44-50.

Loza, P. L., C. D. Buckner, K. J. Vander Pol, G. E. Erickson, T. J. Klopfenstein, and R. A. Stock. 2010. Effect of feeding combinations of wet distillers grains and wet corn gluten feed to feedlot cattle. J. Anim. Sci. 88: 1061-1072.

Lynch, A., D.J. Buckley, K. Galvin, A.M. Mullen, D.J. Troy and J.P Kerry. 2002. Evaluation of rib steak color from Friesian, Hereford and Charolais heifers pastured or overwintered prior to slaughter, Meat Science 6: 227–232.

MacDonald, J. C., T. J. Klopfenstein, G. E. Erickson, and W. A. Griffin. 2007. Effects of dried distillers grains and equivalent undegradable intake protein or ether extract on performance and forage intake of heifers grazing smooth bromegrass pastures. J. Anim. Sci. 85:2614-2624

Mancini, R. A., and M. C. Hunt. 2005. Current research in meat color. Meat Sci. 71: 100-121.

McDonald, I. W. 1954. The extent of conversion of feed protein to microbial protein in the rumen of sheep. Biochem. J. 56: 120-125.

Melton, S. L. 1983. Effect of forage feeding on beef flavor. Food Tech. 37:239-248.

Merchen, N.R. and E. C. Titgemeyer. 1992. Manipulation of amino acid supply to the growing ruminant. J. Anim. Sci. 70:3238-3247.

Muchenje, V., K. Dzama, M. Chimonyo, P. E. Strydom, A. Hugo, and J. G. Raats. 2009. Some biochemical aspects pertaining to beef eating quality and consumer health: A review. Food Chem. 112:279-289.

Muir, P. D., G. J. Wallace, P. M. Dobbie, and M.D. Brown. 2000. A comparison of animal performance and carcass and meat quality characteristics in Hereford,

Hereford x Friesian, and Friesian steers grazed together at pasture. New Zealand Journal of Agricultural Research. 43:193-205.

Nelson, M. L. 1997. Escape protein supplementation of steers fed grass silage-based diets. J. Anim. Sci. 75:2796-2802.

NRC 1996. Nutrient Requirement of Beef Cattle. 7th ed. National Academy Press, Washington, DC.

Olentine, C. 1986. Ingredient profile: distillers feeds. In: Proc. Distillers Feed Conf., Cincinnati, OH. 41: 13-24.

Owens, F. N. and H. R. Isaacson. 1977. Ruminal microbial yields: factors influencing synthesis and bypass. Fed. Proc. 36:198.

Peter, C. M., D. B. Faulkner, N. R. Merchen, D. F. Parrett, T. G. Nash and J. M. Dahlquist. 2000. The effects of corn milling coproducts on growth performance and diet digestibility by beef cattle. J. Anim. Sci. 78: 1-6.

Renewable Fuels Association. 2009. Ethanol Industry Statistics. http://www.ethanolrfa.org Accessed May. 13, 2010

Roeber, D. L., R. K. Gill, and A. DiCostanzo. 2005. Meat quality responses to feeding distiller's grains to finishing Holstein steers. J. Anim. Sci. 83: 2455-2460.

Rooke, J. A., Alvarez, P., and Armstrong, D. G. 1986. The digestion by cattle of barley and silage diets containing increasing quantities of soya-bean meal. J. Agric. Sci. 107: 263-272.

Santos, K. A., M. D. Stern, and L. D. Satter.1984. Protein degradation in the rumen and amino acid absorption in the small intestine of lactating dairy cattle fed various protein sources. J. Anim. Sci. 58: 244-255

Savell, J. W., R. E. Branson, H. R. Cross. D. M. Stiffler, J. W. Wise, D. B. Griffin, and G. C. Smith. 1987. National consumer retail beef study: Palatability evaluations of beef loin steaks that differed in marbling. J. Food. Sci. 52: 517-519.

Schingoethe, D. J., M. J. Brouk, and C. P. Birkelo. 1999. Milk production and composition from cows fed wet corn distillers grains. J. Dairy Sci. 82: 574-580.

Schwab, C. G., L. D. Satter, and A. B. Clay. 1976. Response of lactating dairy cows to abomasal infusion of amino acids. J. Dairy Sci. 59:1254-1270.

Scollan, N. D., N. –J. Choi, E. Kurt, A. V. Fisher, M. Esner, and J. D. Wood. 2001. Manipulating the fatty acid composition of muscles and adipose tissue in beef cattle. Brit. J. Nutr. 85: 115-124.

Shackelford, S. D. J. B. Morgan, H. R. Cross, and J. W. Savell. 1991. Identification of threshold levels for Warner-Bratzler shear force in beef top loin steaks. J. Muscle Foods. 2: 289-296.

Shook, J. N., D. L. VanOverbeke, L. A. Kinman, C. R. Krehbiel, B. P. Holland, M. N. Streeter, D. A. Yates, and G. G. Hilton. 2009. Effects of zilpaterol hydrochloride and zilpaterol hydrochloride withdrawal time on beef carcass cutability, composition, and tenderness. J. Anim. Sci. 87:3677-3685.

47

Smith, S. B., and J. D. Crouse. 1984. Relative contributions of acetate, lactate, and
glucose to lipogenesis in bovine intramuscular and subcutaneous adipose tissue. J.
Nutr. 114: 792-800.

Spiehs, M. J., M. H. Whitney, and G. C. Shurson. 2002. Nutrient database for distiller's
dried grain with soluble produced from new ethanol plants in Minnesota and
South Dakota. J. Anim. Sci 80: 2639-2645

Stock, R. A., J. M. Lewis, T. J. Klopfenstein, and C. T. Milton. 2000. Review of new
information on the use of wet and dry milling feed by-products in feedlot diets. J.
Anim. Sci. 78(E-Suppl.). http://www.asas.org/symposia/9899proc/0924.pdf
Accessed July 3, 2007.

Strydom, P. E., L. Frylinck, J. L. Montgomery, and M. F. Smith. 2009. The comparison
of three β-agonists for growth performance, carcass characteristics, and meat
quality of feedlot cattle. Meat Sci. 81: 557-564.

Trenkle, A. 2004. Evaluation of wet and dry distiller grains with solubles for finishing
Holstein steers. Pages 1-7 in Iowa Animal Industry Report. A. S. Leaflet R1883.
Iowa State University. Ames.

Tyrell, H. F., P. W. Moe, and W. P. Flatt. 1970. Influence of excess protein intake on
energy metabolism of the dairy cow. Page 65 in Energy Metabolism of Farm
Animals, Proc. 5th Symp. Energy Metabolism. A. Schurch and C. Wenk, ed. Eur.
Assoc. Anim. Prod. Publ. No. 13. Juris Druck and Verlag, Zurich, Switzerland.

Ulyatt, M. J., and A. R. Egan. 1979. Quantitative digestion of fresh herbage by sheep. V. The digestion of four herbages and prediction of sites of digestion. J. Agric. Sci. (Camb.) 92:605–616.

Utley, P. R., and W. C. McCormick. 1975. Dry or high-moisture corn for finishing steers in dry lot or on oat pasture. J. Anim. Sci. 41: 495.

Utley, P. R., and W. C. McCormick. 1976. Corn or grain sorghum for finishing steers in dry lot or on rye pasture. J. Anim. Sci. 43:1141.

Uwituze, S., G.L. Parsons, M.K. Shelor, B. E. Depenbusch, K. K. Karges, M. L. Gibson, C. D. Reinhardt, J. J. Higgens and J. S. Droulliard. 2010. Evaluation of dried distillers grains and roughage source in steam-flaked corn finishing diets. J. Anim. Sci. 88: 258-274.

Vasconcelos, J.T., L. W. Greene, N. A. Cole, M. S. Brown, F. T. McCollum, III, and L. O. Tedeschi. 2006. Effects of phase feeding of protein on performance, blood urea nitrogen concentrations, manure nitrogen: phosphorus ration, and carcass characteristics of feedlot cattle. 84: 3032-3038.

Vander Pol, K. J. M. K. Luebbe, G. I. Crawford, G.E. Erickson, and T. J. Klopfenstein. 2009. Performance and digestibility characteristics of finishing diets containing distillers grains, composites of corn processing coproducts, or supplemental corn oil. J. Anim. Sci. 87: 639-652.

van't Klooster, A. Th. and H. A. Boekholt. 1972. Protein digestion in the stomachs and intestines of the cow. Netherlands J. Agr. Sci. 20: 272-284.

Veira, D.M., H. V. Petit, J. G. Proulx, L. Laflamme, and G. Butler. 1995. A comparison of five protein sources as supplements for growing steers fed grass silage. Can. J. Anim. Sci. 75: 567-574.

Wagner, J. J., K. S. Lusby, and G. W. Horn. 1983. Condensed molasses soluble, corn steep liquor, and fermented ammoniated condensed whey as protein sources for beef cattle grazing dormant native range. J. Anim. Sci. 57: 542-552.

Waller, J., T. Klopfenstein, and M. Poos. 1980. Distillers feeds as protein sources for growing ruminants. J. Anim. Sci. 51: 1154-1167.

Williams, C. M. 2000. Dietary fatty acids in human health. Anim. Research. 49: 165-180.

Wilson, B. R., A. M. Pearson, and F. B. Shorland. 1976. Effect of total lipids and phospholipids on warmed-over flavor in red and white muscle from several species measured by thiobarbituric acid analysis. J. Agric. Food Chem. 24: 7-11.

Wood, J. D., R. I. Richardson, G. R. Nute, A. V. Fisher, M. M. Campo, E. Kasapidou, P. R. Sheard, and M. Esner. 2002. Effects of fatty acids on meat quality. Meat Sci. 66: 21-32.

Yang, A., M. C. Lannari, M. Brewster, and R. K. Tume. 2002. Lipid stability and meat colour of beef form pasture- and grain-fed cattle with or without vitamin E supplement. Meat Sci. 60: 41-60.

Zinn, D. W., C. T. Gaskins, G. L. Gann, and H. B. Hedrick. 1970. Beef muscle tenderness as influenced by days on feed, sex, maturity, and anatomical location. J. Anim. Sci. 31:307-309.

CHAPTER 3

EFFECTS OF CORN BY-PRODUCT SUPPLEMENTATION IN CORN SILAGE

BASED STOCKER SYSTEMS[1]

## Abstract

An 84 d stocker trial was conducted to evaluate two corn by-products and soybean meal as CP supplements in corn silage-based stocker systems. Eighty-one weaned steers (BW=306 kg± 26.06 kg) were stratified by weight and assigned to one of three corn silage based diets: 1) dried distillers grains plus solubles (DDGS), 2) corn gluten feed (CGF) or 3) soybean meal and ground ear corn (SBM) at 25% DM. On d 0, 28, 56, and 84, measurements of BW, hip height, and BCS were recorded. In addition, ribeye area (REA), $12^{th}$ rib fat thickness (FT), intramuscular fat (IMF), and fat thickness over the rump (RF) were assessed via ultrasound. Treatment had no effect on BW ($P > 0.05$). Average daily gain was increased ($P<0.05$) for steers fed DDGS and SBM compared to CGF. Corn gluten feed tended to decrease G:F ($P = 0.06$) compared to DDGS. Cost per kg of gain was not affected by treatment ($P > 0.05$). At d 84 DDGS steers had decreased ($P = 0.02$) BCS compared to steers fed CGF or SBM. Hip heights did not differ ($P > 0.05$) across treatment but did increase over time ($P<0.05$). Ultrasound data indicated that steers fed SBM had greater ($P = 0.04$) ribeye areas than those fed CGF and DDGS, and intramuscular fat was less abundant ($P < 0.05$) in DDGS fed calves than those fed CGF or SBM after 84 d. Also, DDGS steers had less ($P < 0.05$) $12^{th}$ rib fat thickness than those fed CGF and SBM. However, after 84 d of supplementation there was no difference among the treatments for rump fat thickness ($P>0.05$). These performance and predicted carcass advantages, combined with

comparable economic efficiency, indicate that CGF and DDGS can be utilized in silage based stocker systems without compromising economically important traits.

Key words: beef, stocker, distillers grains, corn gluten feed, corn silage, ultrasound

## Introduction

Recent volatility of feed prices and economic instability have forced cattle producers to reevaluate nutritional programs in order to become more cost effective without sacrificing animal performance. The increasing access to local grain processing plants has increased interest in the utilization of corn by-products in cattle production systems nationwide. Data comparing distiller's grains and corn gluten feed to conventional sources of nutrients in Southeastern stocker systems are limited.

The value of dried distillers grains as a protein source is well documented (Firkins et al. 1985; Ham et al. 1994; Klopfenstein et al. 2007). Dried distillers grains protein appears to be partially protected from rumen degradation, making it an appealing alternative for growing cattle. Rumen escape values that are 2.6 times that of soybean meal make dried distillers grains plus solubles an appealing alternative for producers who plan to stocker their cattle before shipping finishing (Aines, 1987).

Corn gluten feed has also been shown to be an effective source of supplemental protein for beef steers fed grass silage-based diets (Nelson, 1997). Readily digestible fiber content makes dried distillers grains plus solubles and corn gluten feed excellent sources of energy, but neither are good sources of eNDF or "roughage" (Benton et al. 2007). This principle indicates that dried distiller's grains plus solubles and corn gluten

53

feed could pair well with corn silage based diets to give added growth and value to steers during the stocker phase.  Therefore, the objective of this study was to evaluate dried distiller's grains and corn gluten feed compared to soybean meal as protein supplements in silage-based beef cattle stocker systems.  Specifically, the aim of this research was to determine the weight gain, feed efficiency, muscularity, and marbling of beef steers during the stocker phase of production when corn by-products are used as protein supplements.

## Materials and Methods

All practices and procedure used in this study were examined and approved by the University of Georgia Animal Care and Use Committee.

*Animal and Diet Management*

The experiment was conducted at the Georgia Mountains Experiment Station located south of Blairsville, GA.  In late October, 110 Angus-based crossbred steers were delivered from the Central Georgia Research and Education Center at Eatonton, GA to the Blairsville station.  Steers were vaccinated at weaning with Triangle 4, Type II BVD, Ultra Vac 7, and Pyramid 5 (Fort Dodge Animal Health, Overland Park, KS) and dewormed using transdermal ivermectin (Pfizer, New York, NY).  Steers were backgrounded for 55 d on stockpiled fescue (*Festuca arundinacea cv* Kentucky 31) and orchard grass (*Dactylis glomerata*) and were supplemented with hammered ear corn (1.36 kg/hd/d).  In early December, 81 test animals (BW=306 kg± 20.06 kg) were stratified by weight and assigned to one of nine pens.  Feed bunks assured 41 cm bunk space for each steer.  Pen (9 hd/pen) was used as the experimental unit.  Each pen was randomly

assigned to one of three corn silage based diets (Table 3.1): 1) corn gluten feed (CGF), 2) dried distillers grains plus soluble (DDGS), or 3) soybean meal and hammered ear corn (SBM). Diets (Table 3.1) were formulated to be isonitrogenous and were fed once each morning to achieve a predicted gain of 1.13 kg/d. On d 0, 28, 56 and 84 BW, hip heights (HH) and BCS (Richards et al., 1986) were measured and ultrasound data for ribeye area (REA), fat thickness (FT), intramuscular fat (IMF), and rump fat (RF) were recorded.

*Laboratory Analyses*

Feed samples from each delivery were collected and mixed for determination of nutritive content. The mixed feed samples were dried, in duplicate, in a forced-air oven at $55^0$C for 72 h and ground to pass a 1 mm plate in a Model 4 Wiley Mill (Thomas Scientific, Swedesboro, NJ). Dry matter was calculated ((dry wt/wet wt) x 100). Ash content was determined after placing 1 g samples, in duplicate, in a $550^0$C muffle furnace (Blue M. Electric Co., Blue Island, IL) for 3 h. Samples were then cooled to room temperature for approximately 30 min and transferred to a 110˚C forced-air oven for 1 h. Samples were placed in a desiccator for 20 min before weights were recorded. Crude protein was determined by weighing 0.1 mg samples were weighed and placed aluminum foil cups (LECO Corp. St. Joseph, MI). Cups were then placed in a LECO auto-sampler, and analyzed for N content with a nitrogen auto-analyzer (LECO FP-528 Nitrogen Analyzer, LECO Corp. St. Joseph, MI) and expressed as a percent of DM.

Neutral detergent fiber and ADF were analyzed with an Ankom 200 Fiber Analyzer (Ankom Technology Corp., Macedon, NY) as described by Van Soest et al.

(1991) with slight modifications. The NDF analysis reagent was prepared by dissolving 180 gm of sodium lauryl sulfate in an Erlenmeyer flask with 2 L of distilled water. In a separate graduated cylinder, 27.42 g of anhydrous $Na_2H PO_4$ was added to 500 ml of distilled water and thoroughly mixed. Then, 111.72 g of EDTA and 40.92 g of sodium borate were added and stirred thoroughly. The solution was brought to volume (700 ml) with distilled water. The mixture was added to the sodium lauryl sulfate solution with constant stirring and the Erlenmeyer flask was filled to 6 L by adding distilled water and 60 ml of ethylene glycol monoethyl ether. When the solution was thoroughly mixed, it was left to sit overnight. The following day, pH was neutralized to 7.0 with $1.0 - 1.5$ ml of 37% HCl. The solution was transferred to and stored in a carboy until used. For NDF analysis, approximately 0.5 g of sample was placed in filter bags previously weighed and labeled with an acetone resistant pen and sealed with a heat sealer machine. The bags were placed in a suspender and agitated under heat in an Ankom 200 Fiber Analyzer (Ankom Corp. Fairport, NY) containing 2 L of the NDF solution, 20 g of sodium sulfite, and 4 ml of heat stable α–amylase for 60 min. After agitation, samples were rinsed twice for 3 min with 2 L of hot water and 4 ml of α–amylase and a final rinse of water. After rinsing, the bags were removed from the agitation vessel, compressed to remove excess water, and soaked in acetone for 3 min to remove residual moisture. The bags were then compressed lightly to remove excess acetone, left to sit for 30 min to allow the remaining acetone to evaporate, and placed in a forced–air oven set at 105˚C for approximately 2 h. After drying, the bags were placed in a desiccator for 15 min and then weights were recorded.

56

Acid detergent fiber was subsequently analyzed. The ADF solution was a mixture of 304 g of sulfuric acid and 6 L of distilled water. Normality of the solution was checked by adding 3 drops of bromocresol green and 10 ml of ADF into a small beaker. The solution was titrated with tromeThamine until the color changed from yellow to blue. The normality was then calculated by dividing the amount of tromeThamine necessary for color change by 10 (ml of ADF). When 1.00 N solution was achieved, 118.2 gm of cetyltrimethylammonium bromide was added to the ADF solution, mixed thoroughly and transferred to carboy. After ADF wash, samples were rinsed in hot tap water and soaked in acetone for 3 min to remove excess water. Samples were then compressed and left to sit at ambient temperature to allow excess acetone to evaporate before being placed in a forced–air oven at 105˚C for 4 h. After drying, samples were placed in a desiccator for 15 min, and weights were recorded.

*Ultrasound Data*

Ultrasound measurements for REA, FT, IMF, and RF were collected by a trained technician from the University of Georgia Meat Science Technology Center. The ultrasound system included an Aloka 500V equipped with a 17 cm-3.5 MHz transducer (Aloka Inc. Tokyo, Japan). The ultrasound location was clipped free of hair and curried clean prior to image collection.

Vegetable oil was used as a sound wave copulant and a wave guide (Designer Genes Technologies Inc., Harrison, AR) was used to ensure proper fit for collection of REA and FT data. Ultrasound images were captured and measured using Beef Image Analysis (BIA) Feedlot software (Designer Genes Technologies Inc, Harrison AR). Ultrasound

images were collected on the steer's right side. Ribeye area and FT were collected

between the $12^{th}$ and $13^{th}$ rib juncture, perpendicular to the spinal column. Intramuscular

fat images were collected parallel to the spine and perpendicular to the $11^{th}$, $12^{th}$, and $13^{th}$

ribs. Rump fat data was collected between the *tuba coxae* of the *ilium* and *tuba*

*ischiadicum* of the *ishium*.

*Statistical Analysis*

Data were analyzed using the proc MIXED procedure of SAS (SAS Institute

Inc. Cary, NC) in a completely randomized design with three protein supplements and

three replicates (3 pens/treatment) and 3 subreplicates (3 animals/trt/pen). Pen was

defined as the experimental unit and animal was used as the observational unit used to

determine differences across the three supplements. Animal in pen was used as the

random error term and was used to test sources of variation. The By statement was

utilized to compare means within a treatment across time and among treatments for a

given point. Least squares means were generated and separated using the P-DIFF option

of LSMEANS. Differences were considered significant at $\alpha = 0.05$ and tendencies were

considered at $\alpha < 0.10$.

## Results and Discussion

*Performance Traits*

Protein supplement did not affect BW ($P = 0.21$; Table 3.2), but ADG for steers

fed DDGS and SBM was greater ($P < 0.05$) compared to CGF steers after d 28 and 56

(Figure 3.1). Steers fed CGF had the lowest ($P = 0.007$) ADG after 28 d on feed.

However, CGF steers increased ($P < 0.05$) an additional 43% in ADG between d 28 and

58

56 compared to a 13% increased achieved by DDGS and a 4% in SBM steers. Total DMI was not affected ($P = 0.27$) by treatment (Table 3.3). Treatment tended ($P = 0.06$) to affect G:F, with CGF steers being slightly less efficient. However, no differences ($P > 0.10$) were detected between DDGS and SBM diets. Cost of gain (COG; Table 3.3) tended ($P = 0.07$) to be lower for steers fed DDGS compared to those fed CGF or SBM.

Palatability of the protein supplement can influence intake and may explain why G:F was lower for CGF steers. At the beginning of feeding, the initial CGF load was observed to be darker in color and exhibited a burnt odor, indicating possible damage could have occurred during the drying process. Excessively heated CGF may be less palatable, thereby increasing acclimation time. Also, protein may have become less available with the formation of advanced Maillard reaction products. Although CGF is high in CP, it is low in lysine and methionine, two of the most limiting amino acids for growing ruminants (NRC, 1996; Santos et al., 1984) compared to SBM. It has been shown in studies using DDGS that higher lysine concentrations and increased protein digestibility exist in grains that are lighter in color, indicating that they have suffered less heat damage compared to those darker in color (Cromwell, 1993; Spiehs et al., 2002). However, it appears that if a longer acclimation period was needed, the steers may have experienced some compensatory gain with increased time on feed using subsequent loads of CGF.

Another explanation for performance differences among the diets may be the difference in rumen degradability of the protein supplement. The value of DDGS as a source of RUP has been shown to be greater than that of SBM or CGF (Klopfenstein et

al., 2007; Santos et al., 1984; Waller et al. 1980).  Zein is the primary form of protein

found in corn (Klopfenstein et al., 2007), and it is resistant to degradation by rumen

microbes (Waller et al., 1980). Also, Klopfenstein et al. (2007) stated that a large portion

of the protein in distillers solubles (which are added back to DDGS) are yeast cells that

have been heated and killed during fermentation and concentrated in the solubles.  This

denatured yeast is incorporated into Maillard Reaction products, making solubles

resistant to lysis and rumen degradation (Bruning and Yokoyama, 1988).  Waller et al.

(1980) suggested that RUP is essential for maximum production efficiency in young

growing ruminants.  Fleck et al. (1989) reported elevated rumen ammonia production, as

well as increases in molar concentrations of propionate and butyrate, 4 h after feeding

CGF when compared to cows fed soybean meal.  These data indicated the protein in CGF

may be more degradable than that provided in SBM or DDGS.  Increased rumen

degradability of corn gluten feed was also reported by DeHann et al. (1983) when an in

vitro experiment showed greater protein degradation for corn gluten feed compared to

soybean meal.

Steers fed SBM had higher ($P < 0.05$) BCS scores than DDGS steers at d 84 with

CGF being intermediate.  It is possible that elevated starch levels from the added corn

increased the energy component of the SBM supplement raising the TDN and resulting in

slightly higher BCS for SBM fed steers.  Examining supplementation of silage-based

diets with differing levels of soybean meal, Rooke et al. (1986) reported increased

microbial efficiency and protein digestibility in cattle fed soybean meal. Veira et al.

(1995) observed rumen N disappearances of 97.5% for SBM, indicating that post-ruminal

flow of amino acids should decrease. However, SBM supplementation produced gains similar to corn gluten meal and bone meal which have higher bypass values, than DDGS. This result was attributed to greater microbial efficiency and protein synthesis in the rumen (Rooke et al., 1986).

Although differences were detected, steers from all 3 treatment groups were in moderate condition ranging from 6-7. Hip heights increased ($P < 0.05$) with time, but did not differ ($P > 0.05$) among treatments indicating that treatment did not affect skeletal growth (Table 3.2).

*Ultrasound Data*

All predicted carcass traits (REA, IMF, FT, and RF) increased over time (Figure 3.2). No differences ($P < 0.05$) were detected among treatments at d 0 or d 56 for REA. The REA of SBM fed steers tended ($P = 0.07$) to be larger than DDGS fed steers by 4.75 cm$^2$ at d 28, with CGF being intermediate. On d 84 steers fed SBM had the largest ($P = 0.04$) REA compared to steers fed CGF and DDGS by 3.91 and 4.75 cm$^2$, respectively. Steers were similar in terms of FT across treatment except at d 28 where steers fed DDGS had the least ($P = 0.04$) FT compared to CGF and SBM. Steers fed DDGS tended to have less IMF ($P = 0.06$) at d 0. Throughout the remainder of the trial, DDGS steers had 0.20-0.40 % less ($P < 0.05$) IMF than CGF or SBM fed steers. Steers were similar in terms of RF at d 0 and 84, however, DDGS steers had less RF ($P = 0.04$) at d 28 than CGF or SBM steers, and SBM had higher ($P = 0.03$) RF at d 56 than CGF or DDGS.

Differences in ultrasound measurements could be attributed to a number of factors including the increased protein digestibility associated with SBM in stocker cattle (Rooke

et al., 2002). Supplementation with SBM has also been shown to increase microbial

protein efficiency (Bowman and Patterson, 1988). Santos et al. (1984) found that DDGS

had the lowest intestinal amino acid absorption rate when compared to other sources of

RUP such as corn gluten meal. However, 14% more total amino acids were absorbed in

the small intestine when compared to SBM (Santos et al., 1984). This may be due to

decreased ruminal degradation of DDGS due to decreased particle size and subsequent

rapid passage rate (Firkins et al., 1985). Therefore, the increased muscle protein

accretion indicated by larger REA is more likely the result of increased concentrations of

lysine and methionine in SBM (NRC, 1996; Santos et al., 1984). Lysine RUP values are

reported as 6.08, 2.06, and 1.57 % of CP fed for soybean meal, distillers dried grains

plus solubles, and corn gluten feed, respectively (NRC, 1996). However, it has been

shown that high levels of amino acids can be synthesized in the rumen of steers fed CGF

due to readily available soluble fiber (Bowman et al., 1988). Therefore, it is possible that

smaller REAs in DDGS fed steers were the result of protein with a lower biological value

for growing cattle.

Minor differences in FT, IMF, and RF could have been due to several factors. In

the case of SBM steers, ground corn was included to make the diets isonitrogenous. It is

possible that the increased, rapidly fermentable carbohydrate could account for the

increased IMF, FT and RF in steers fed SBM. Firkins et al. (1985) illustrated an

increased rate of rumen DM disappearance in steers fed wet corn gluten feed compared to

wet distillers grains plus solubles. Also, lambs fed corn gluten feed showed increased

acetate:propionate ratios in the rumen compared to those fed DDGS indicating a greater partitioning of nutrients toward fat deposition (Firkins et al., 1985).

## Conclusions and Implications

With continuing expansion of the ethanol industry into the Southeastern United States and the subsequent availability of corn processing by-products, it is important that further research be conducted to evaluate the role of various feed sources in southeastern production systems.  This research has shown corn gluten feed and dried distillers grains plus solubles to be comparable to soybean meal/corn supplementation in terms of performance and predicted carcass merit for winter stockering systems using corn silage as a forage source.  The added instability of today's economy has caused a renewed interest in finding lower inputs in terms of nutrient sources for ruminants.  This research demonstrates that utilizing dried distillers grains plus solubles or corn gluten feed in place of a soybean meal/corn mix to supplement protein in growing cattle will result in similar economically important traits such as growth and carcass composition.

## Literature Cited

Abe, A., and S. Horii. 1978. Application of the detergent analysis to the feed ingredients and to the various formula feed. Jpn. J. Zootech. Sci. 49:733-738.

Aines, G., T. Klopfenstein, and R. Stock. 1987. Distillers Grains. MP51, Nebraska Agric. Res. Div., Lincoln.

Benton, J. R., G. E. Erickson, T. J. Klopfenstein, K. J. VanderPol, and M. A. Greenquist. 2007 Effects of roughage source and level in finishing diets containing wet distillers grains on feedlot performance. J. Anim. Sci. 85(Suppl. 2):76.(Abstr.)

Bowman, J.G. P. and J. A. Patterson. 1988. Evaluation of corn gluten feed in high energy diets for sheep and cattle. J. Anim. Sci. 66:2057-2070.

Bruning, C. L., and M. T. Yokoyama. 1988. Characteristics of live and killed brewer's yeast slurries and intoxication by intraruminal administration to cattle. J. Anim. Sci. 66:585-591.

Cromwell, G. L., K.L. Herkelman, and T.S. Stahly. 1993. Physical, chemical, and nutritional characteristics of distillers dried grains with soluble for chicks and pigs. J. Anim. Sci. 71:679-686.

DeHaan, K., T. Klopfenstein, and R. Stock. 1983. Corn gluten feed. Protein and energy source for ruminants. Univ. Nebraska Beef Cattle Rep. MP 44, Pg. 19.

Evans, R. J., and H. A. Butts. 1949. Inactivation of amino acids by autoclaving. Science (Washington DC) 109:569-571

Firkins, J.L., L. L. Berger, and G. C. Fahey, Jr. 1985. Evaluation of wet and dry distillers grain and wet and dry corn gluten feeds for ruminants. J. Anim. Sci. 60:847-860.

Fleck A. T., K. S. Lusby, F. N. Owens, and F. T. McCollum. 1988. Effect of corn gluten feed on forage intake, digestibility and runimal parameters of cattle fed native grass hay. J. Anim. Sci. 66:750-757.

Ham, G. A., R.A. Stock, T. J. Klopfenstein, E.M. Larson, D. H. Shain, and R. P. Huffman. 1994. Wet corn distillers byproducts compared with dried corn distillers grain with soluble as a source of protein and energy for ruminants. J. Anim. Sci. 72:3246-3257

Hancock, J.D., E.R. Peo, Jr., A. J. Lewis, and J. D. Crenshaw. 1990. Effects of ethanol extraction and duration of heat treatment of soybean flakes on the utilization of soybean protein by growing rats and pigs. J. Anim. Sci. 68:3233-3243.

Klopfenstein T. 1996. Distillers grains as an energy source and effect of drying on protein availability. Animal Feed Science and Technology. 60:201-207.

Klopfenstein T. J., G. E. Erickson, and V. R. Bremer. 2007. BOARD-INVITED REVIEW: Use of distillers byproducts in the beef cattle feeding industry. J. Anim. Sci. 86:1223-1231.

Nelson, M. L. 1997. Escape protein supplementation of steers fed grass silage-based diets. J. Anim. Sci. 75:2796-2802.

NRC 1996. Nutrient Requirement of Beef Cattle. 7th ed. National Academy Press, Washington, DC.

Santos, K. A., M. D. Stern, and L. D. Satter. 1984. Protein degradation in the rumen and amino acid absorption in the small intestine of lactating dairy cattle fed various protein sources. J. Anim. Sci. 58:249-255.

Spiehs, M. J., M. H. Whitney, and G. C. Shurson. 2002. Nutrient database for distiller's

　　　dried grain with soluble produced from new ethanol plants in Minnesota and

　　　South Dakota. J. Anim. Sci 80:2639-2645

Van Soest, P. J., J. B. Robertson, and B. A. Lewis. 1991. Methods for dietary fiber,

　　　neutral detergent fiber, and nonstarch polysaccharides in relation to animal

　　　nutrition. J. Dairy Sci. 74:3583-3597.

Waller, J., T. Klopfenstein, and M. Poos. 1980. Distillers feeds as protein sources for

　　　growing ruminants. J. Anim. Sci. 51:1154-1167.

**Table 3.1**. Dry matter and chemical composition of corn silage-based stocker diets supplemented with corn gluten feed (CGF), dried distillers grains plus soluble (DDGS) or soybean meal/corn (SBM)

| | Protein Supplement | | |
|---|---|---|---|
| | CGF | DDGS | SBM |
| *Ingredient[1], % DM* | | | |
| Corn Silage | 75 | 75 | 75 |
| Ground corn[2] | 0 | 0 | 15 |
| Soybean meal[2] | 0 | 0 | 10 |
| Dried distillers grains[2] | 0 | 25 | 0 |
| Corn gluten feed[2] | 25 | 0 | 0 |
| *Chemical Composition,%* | | | |
| DM | 47.67 | 48.31 | 47.02 |
| CP | 16.52 | 18.57 | 16.94 |
| NDF | 51.72 | 52.38 | 53.33 |
| ADF | 18.91 | 19.53 | 17.58 |
| Ash | 3.68 | 3.33 | 3.13 |

[1]All sources were procured from the same distributor and are expressed on a DM basis. Different loads of CGF, DDGS and SBM were averaged.

**Table 3.2.** Growth performance for beef steers on a corn silage based diet receiving corn gluten feed (CGF), dried distillers grains plus solubles (DDGS) or soybean meal/corn (SBM) as a protein supplement

| Item | Protein source | | | SEM |
| | CGF | DDGS | SBM | |
| --- | --- | --- | --- | --- |
| BW, kg | | | | |
| 0 d | $305^z$ | $304^z$ | $303^z$ | 5.07 |
| 28 d | $318^z$ | $330^y$ | $330^y$ | 5.41 |
| 56 d | $353^y$ | $365^x$ | $361^x$ | 6.49 |
| 84 d | $387^x$ | $400^w$ | $401^w$ | 6.11 |
| SEM | 5.55 | 5.63 | 6.20 | |
| BCS[1] | | | | |
| 0 d | 6.1 | 6.2 | 6.3 | 0.08 |
| 28 d | 6.0 | 6.1 | 6.2 | 0.15 |
| 56 d | 6.1 | 6.0 | 6.1 | 0.06 |
| 84 d | $6.1^{ab}$ | $5.9^b$ | $6.3^a$ | 0.08 |
| SEM | 0.07 | 0.08 | 0.11 | |
| Hip Height, cm | | | | |
| 0 d | $121.5^z$ | $121.2^z$ | $120.8^y$ | 0.93 |
| 28 d | $123.2^z$ | $122.5^z$ | $122.5^y$ | 0.66 |
| 56 d | $125.8^y$ | $125.7^y$ | $124.6^{xy}$ | 0.64 |

| | | | | |
|---|---|---|---|---|
| 84 d | 128.0$^x$ | 127.6$^x$ | 126.7$^x$ | 0.70 |
| SEM | 0.89 | 0.74 | 0.89 | |

[abc] Means within a row without a common superscript differ (*P<0.05*).

[xyz] Means within a column and item without a common superscript differ (*P<0.05*).

[1]Richards et al., 1986

**Table 3.3.** Efficiency and DMI of beef steers across 84 d on a corn silage based diet receiving corn gluten feed (CGF), dried distillers grains plus solubles (DDGS) or soybean meal/corn (SBM) as a protein supplement

|  | Protein Source | | | |
| --- | --- | --- | --- | --- |
| Item | CGF | DDGS | SBM | SEM |
| G:F, kg | 0.15 | 0.17 | 0.17 | 0.01 |
| Cost of Gain[1], $/kg | 0.33 | 0.28 | 0.35 | 0.06 |
| DMI, g/kg BW | 18.7 | 18.8 | 20.1 | 0.06 |

[1]cost of gain – silage = $50/ton, CGF = $160/ton, DDGS = $140/ton, soybean meal = $410/ton, corn = $110
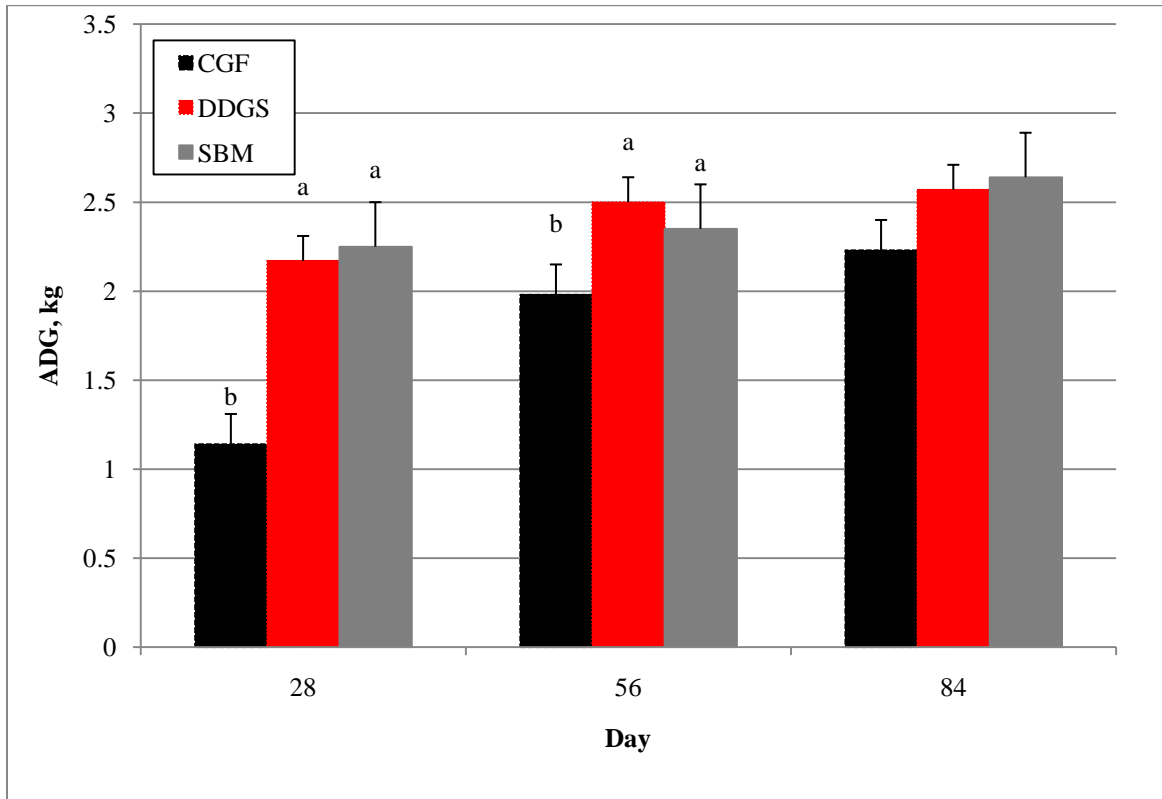
**Figure 3.1.** Cumulative ADG for beef steers fed corn silage-based diet supplemented

with corn gluten feed (CGF), dried distillers grains plus solubles (DDGS), or soybean

meal (SBM) as a protein supplement.. Treatment effect ($P < 0.05$); Day effect ($P < 0.01$)

[ab]Means with differing superscripts indicate treatment differences within d
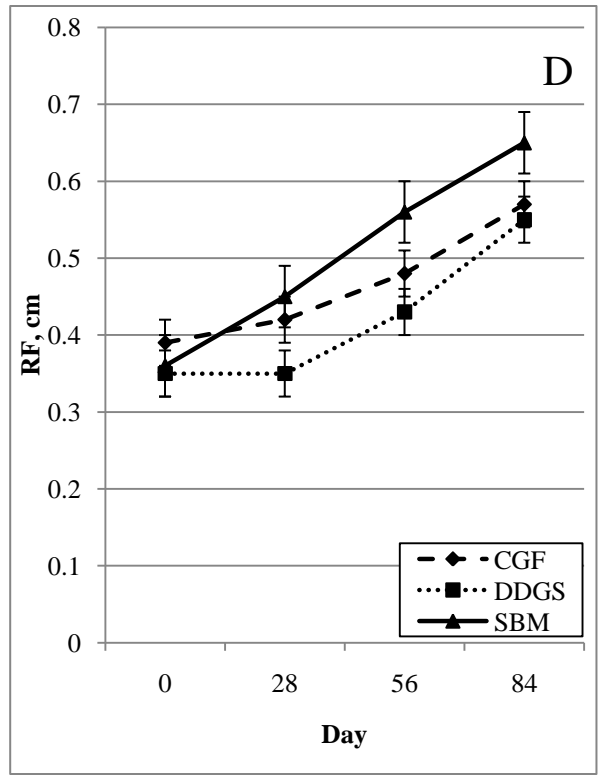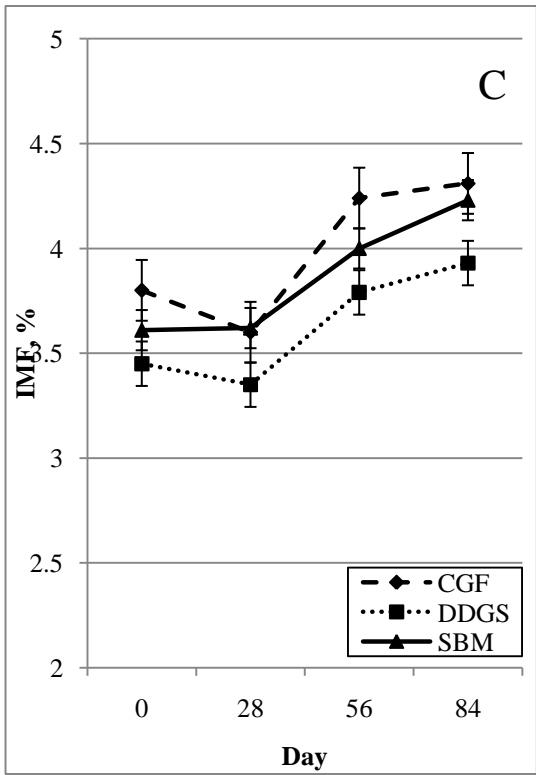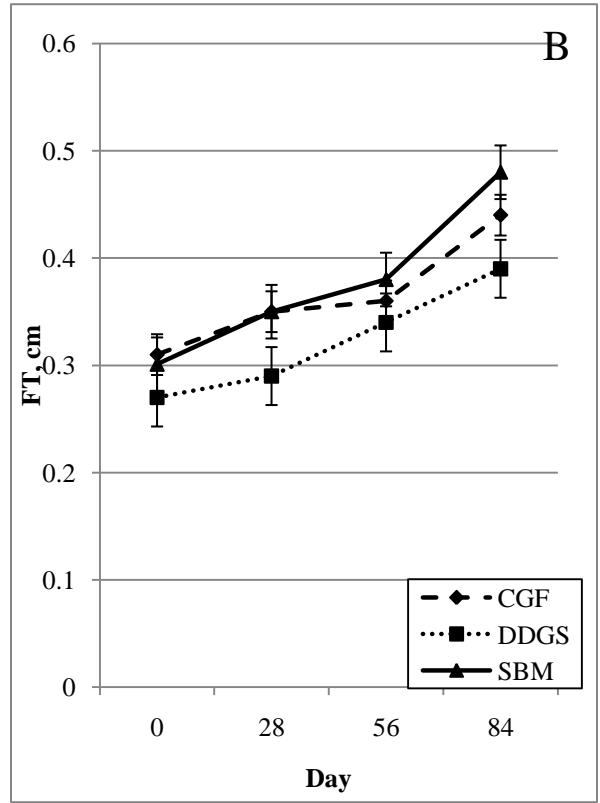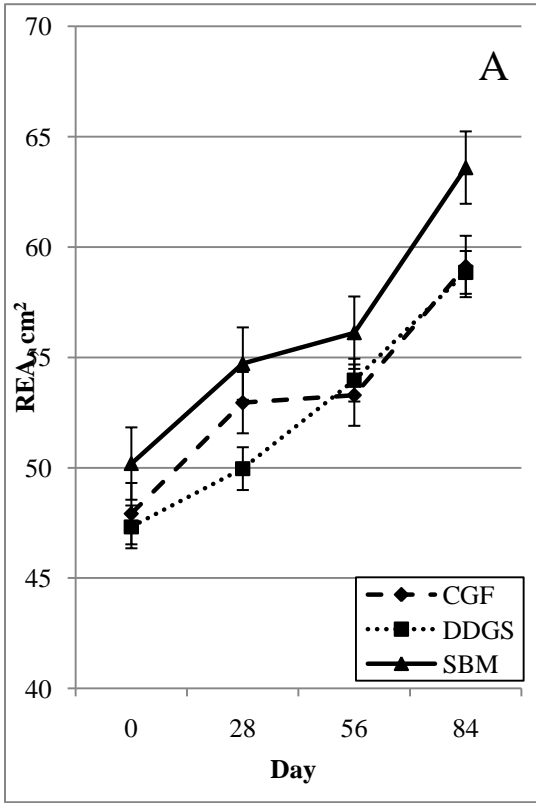
**Figure 3.2.** Ultrasound data for beef steers fed corn silage with corn gluten feed (CGF), dried distillers grains plus solubles (DDGS), or soybean meal/corn (SBM) as a protein supplement. **A.)** Ribeye area (REA). Treatment effect ($P < 0.05$); Day effect ($P < 0.01$); **B.)** 12$^{th}$ rib fat thickness (FT). Treatment effect ($P < 0.05$); Day effect ($P < 0.01$); **C.)** Intramuscular Fat (IMF). Treatment effect ($P < 0.05$); Day effect ($P < 0.01$); **D.)** Rump fat thickness (RF). Treatment effect ($P < 0.05$); Day effect ($P < 0.01$)

CHAPTER 4

EFFECTS OF CORN BY-PRODUCT PROTEIN SUPPLEMENTATION IN

SOUTHEASTERN FEEDLOT SYSTEMS[1]

# Abstract

Thirty six steers (BW 397 ± 23.96 kg) were randomly selected to evaluate three sources of CP 1) corn gluten feed (CGF) ; 2) dried distillers grains (DDGS) or 3) soybean meal and ground corn (SBM) in a 100-d finishing trial. Steers were individually fed a corn-based finishing diet formulated to be isonitrogenous across treatments. Weights were recorded on d 0 and every 25 d thereafter. At d 0, 50, and 100 BCS were recorded and ruminal fluid was collected for determination of pH, VFA, and $NH_3$ concentrations. On the same days ultrasound data were collected to monitor compositional development, and blood was collected for subsequent determination of BUN, glucose (GLU) and insulin (INS) concentrations. At the end of finishing, steers were slaughtered and carcass data were collected. Steers fed DDGS were heavier ($P = 0.01$) at the end of the trial than CGF steers. Treatment had no affect ($P < 0.05$) on ADG, BCS or DMI. Feed efficiency (G:F) was increased ($P = 0.02$) by feeding DDGS compared to CGF and SBM. Cost of gain was increased ($P < 0.001$) in steer fed SBM compared to those fed CGF or DDGS. Intake increased across treatments ($P < 0.001$) through d 50, but decreased ($P < 0.05$) over the remainder of the trial. Compositional ultrasound data showed that diet did not influence ($P > 0.05$) ribeye area , $12^{th}$ rib fat thickness , intramuscular fat , or rump fat. Rumen $NH_3$ and pH were not affected ($P < 0.05$) by treatment. Ruminal pH was higher ($P = 0.03$) at d 0 compared to d 50 and 100. All VFAs except isovaleric had no response ($P > 0.05$) to treatment. Isovalerate concentration was increased ($P = 0.03$) in steers fed SBM. Acetate concentration increased ($P < 0.001$) over time while butyrate, isobutyrate, and isovalerate decreased ($P < 0.05$) with days on feed. Valerate was higher

($P = 0.01$) at d 50 than at d 0 or d 100.  Treatment did not affect ($P > 0.1$) concentration

of BUN, GLU, or INS.  At d 0 GLU and INS were higher ($P < 0.001$) than d 50 or d 100.

Post-harvest data suggested that CGF increased ($P < 0.05$) lean L* and b* values as well

as fat L* values.  Decreased ($P < 0.05$) fat a* values were also observed in CGF

carcasses. Unaffected ($P > 0.05$) carcass characteristics include HCW, DP, KPH, ribeye

area, 12$^{th}$ rib fat over the eye, intramuscular fat, pH, redness, texture, firmness, subjective

color, as well as overall maturity.  These data indicate DDGS and CGF can be used in

place of SBM in finishing operations without compromising efficiency or growth while

decreasing input costs.

**Keywords:**  distillers grains, corn gluten feed, beef

## Introduction

Recently, the demand for locally-grown beef has been on the rise, and with it

there has been increasing interest in finding ways to feed cattle in the Southeastern

United States.  The increasing access to local grain processing plants has fueled increased

utilization of corn by-products in Southeastern beef production.  The use of by-products

such as dried distillers grains plus solubles (DDGS), and corn gluten feed (CGF) in the

beef cattle feeding industry has been extensively researched (Gunn et al., 2009; Vander

Pol et al., 2009; Klopfenstein et al., 2007; Ham et al., 1994; Firkins et al., 1985);

however, due to the lack of feedlots in the Southeast, research evaluating these feedstuffs

in these production systems is limited.

When DDGS is fed to meet energy requirements, protein and P are both overfed (Klopfenstein et al., 2007).  Buckner et al. (2007) concluded that the optimal level of inclusion for   DDGS was approximately 20%.  Depenbusch et al. (2009) showed a quadratic response in DMI and ADG to levels of inclusion ranging from 0-75%.  It was determined that 15-20% was optimal as $12^{th}$ rib fat thickness decreased, and number carcasses grading select increased as level of DDGS increased (Depenbusch et al., 2009). Gunn et al. (2009) reported a significant decrease in shelf-life in ground beef from steers fed diets containing 30% or greater DDGS as compared to those fed 20% DDGS rations.

Firkins et al. (1985) stated that CGF is comparable to DDGS in terms of DM, NDF and N digestibility.  However, CGF is faster in terms of rumen degradability.  In vitro fiber digestibilities of CGF have been reported above 80% (Abe and Horii, 1978). Therefore, the objective of this study was to evaluate the effects of corn gluten feed (CGF) and dried distillers grains plus solubles (DDGS) on feedlot performance, blood metabolites, VFA production, and on ultrasound and carcass characteristics of beef steers. The hypothesis was that CGF and DDGS could be included at 25% DM while maintaining profitability, performance, and carcass quality.

## Materials and Methods

*Animal and Diet Management*

All practices and procedure used in this study were examined and approved by the University of Georgia Animal Care and Use Committee.

In late March 36 Angus-based crossbred steers were delivered from the Georgia Mountains Experiment Station, Blairsville GA (Chapter 3) following an 84 d stockering

trial where steers were fed a corn silage-based diet with CGF, DDGS , or SBM included at 25% of the diet DM to the University of Georiga Wilkins Beef Cattle Research Unit (Rayle, GA). Steers had been vaccinated at weaning with Triangle 4, Type II BVD, Ultra Vac 7, and Pyramid 5 (Fort Dodge Animal Health, Overland Park, KS).  Steers were also dewormed using transdermal ivermectin (Dectomax, Pfizer Animal Health New York, NY).  Steers were backgrounded for approximately 30 days on Tall Fescue (*Festuca arundinacea cv.* Kentucky 31) pasture and Bermuda grass (*Cynodon dactylon cv.* Russell) hay.  Approximately 10 d before the start of the experiment steers were trained to use Calan gate feeders (American Calan Inc., Northwood, NH) and animal was used as the experimental unit.  Steers were assigned to 1 of 3 feedlot rations with differing protein supplements (Table 4.1). Treatments were defined as protein supplement in the ration and care was taken to insure that steers were fed the supplement previously received in the stockering phase (Chapter 3).  Treatments included: CGF, DDGS, or soybean meal with corn (SBM).  Corn was added to the SBM treatment at 15% of the supplement to insure that diets remained isonitrogenous.  Diets were formulated to be isonitrogenous, and mixed daily using a Calan® Data Ranger (American Calan Inc., Northwood, NH) operated by trained personnel.  When present, orts were removed and weighed on a weekly basis and used to calculate daily DMI. On d 0, 25, 50, 75 and 100, BW was taken and used to calculate ADG, G:F , and cost of gain.  On d 0, 50, and 100 BCS, rumen fluid for VFA determination, and ultrasound data were collected; also, blood was collected from all steers for subsequent determination of BUN, glucose and insulin concentrations. At d 100 steers were randomly divided by pen into two groups with each treatment

represented equally in each group. On d 101 and 108 respectively, each group was transported to the University of Georgia Meat Science Technology Center in Athens, GA and harvested according to Humane Slaughter Guidelines under Federal Inspection. Steers in group 2 received a maintenance ration of their respective diet from d 100 till d 108 (NRC, 1996).

*Ultrasound Data*

Ultrasound data was collected for ribeye area (UREA), 12th rib fat thickness (UFT), intramuscular fat percentage (UIMF), and rump fat thickness (URF) by a trained technician from the University of Georgia Meat Science Technology Center. The ultrasound system included an Aloka 500V equipped with a 17 cm-3.5 MHz transducer (Aloka Inc. Tokyo, Japan). Vegetable oil was used as a sound wave copulant and wave guide (Designer Genes Technologies Inc., Harrison, AR) was used to ensure proper fit for collection of UREA and UFT data. Ultrasound images were captured and measured using Beef Image Analysis (BIA) Feedlot software (Designer Genes Technologies Inc, Harrison AK). Ultrasound images were collected on the steer's left side. Ribeye area and UFT were collected between the 12th and 13th rib juncture, perpendicular to the spinal column. Intramuscular fat images were collected parallel to the spine and perpendicular to the 11th, 12th, and 13th ribs. Rump fat data was collected between the *tuba coxae* of the *ilium* and *tuba ischiadicum* of the *ishium*. The ultrasound location was clipped free of hair and curried clean prior to image collection.

*Blood Collection*

At d 0, 50, and 100 plasma and serum collection was performed following the procedure used by Hersom et al. (2004) with the following changes. Blood was collected via caudal venipucture except in cases where the animal was uncooperative in which case jugular venipuncture was employed. Blood was collected into tubes containing potassium oxalate and sodium fluoride used for glycolytic inhibition then placed on ice overnight and centrifuged (2415 × $g$ for 30 min at 4˚C; IEC-6000 centrifuge, International Equipment Company, Needham, MA). Blood was also collected into serum tubes, placed on ice and allowed to clot for 24 h, serum was then harvested by centrifugation (2415 × $g$ for 30 min at 4˚C; IEC-6000 centrifuge, International Equipment Company, Needham, MA). Plasma and serum were stored at -60˚C in cryotubes until laboratory analysis. Steers did not receive morning feed until processing was completed.

*Ruminal Fluid Collection*

Approximately 250 ml of rumen fluid were collected from each animal using plastic tubing (1.8 m in length with 1.27 cm internal diameter) fitted with a stainless steel strainer. Tubing was fitted to a low pressure vacuum pump (Fisher Scientific Pittsburgh, PA) equipped with a pressure release valve. A Frick speculum tube (Nasco Corp. Fort Atkinson, WI) was used to pass the tube into the rumen. Fluid was then removed under vacuum, and stored on ice for less than 4 h, and stored at -20˚C until laboratory analysis.

*Laboratory Analyses of Feedstuffs*

Feed samples collected for nutritive value were dried in a forced-air oven at $55^0$C for 72 h until a constant weight was reached and ground to pass a 1 mm plate in a Model

4 Wiley Mill (Thomas Scientific, Swedesboro, NJ). Dry matter percentage was calculated (dry wt/wet wt x 100). Ash content was determined after placing samples in a $550^0$C muffle furnace (Blue M. Electric Co., Blue Island, IL) for 3 h. Samples were then cooled to room temperature for approximately 30 min and transferred to a 110˚C force-air oven for 1 h. The samples were placed in a desiccator for 20 min before weights were determined and recorded.

Crude protein was determined by weighing 0.1 mg samples were weighed and placed aluminum foil cups (LECO Corp. St. Joseph, MI). Cups were then placed in a LECO auto-sampler, and analyzed for N content with a nitrogen auto-analyzer (LECO FP-528 Nitrogen Analyzer, LECO Corp. St. Joseph, MI) and expressed as a percent of DM.

Neutral detergent fiber and ADF were analyzed with an Ankom 200 Fiber Analyzer (Ankom Technology Corp., Macedon, NY) as described by Van Soest et al. (1991) specifically, using a sequential version of the method. The neutral detergent fiber analysis reagent was prepared by dissolving 180 g of sodium lauryl sulfate in an Erlenmeyer flask with 2 L of distilled water. Separately, 27.42 g of anhydrous $Na_2H PO_4$ was added to 500 ml of distilled water and thoroughly mixed. Then, 111.72 g of EDTA and 40.92 g of sodium borate were added and stirred thoroughly The solution was brought to volume (700 ml) with distilled water. The mixture was then added to the sodium lauryl sulfate solution and with constant stirring. The Erlenmeyer flask was filled to 6 liters by adding distilled water and 60 ml of ethylene glycol monoethyl ether. When the solution was thoroughly mixed, it was left to sit overnight. The following day, the pH

was neutralized to 7.0 with $1.0 - 1.5$ ml of HCl. The solution was transferred to and stored in a carboy until used. For NDF analysis, approximately 0.5 g of sample was placed in filter bags previously weighed and labeled with acetone resistant pen and sealed with heat sealer machine. The bags were placed in a suspender and agitated under heat in an Ankom 200 Fiber Analyzer (Ankom Corp. Fairport, NY) containing 2 L of the NDF solution, 20 g of Sodium Sulfite, and 4 ml of heat stable $\alpha -$ amylase for 60 min. After agitation, samples were rinsed twice for 3 min with 2 L of hot water and 4 ml of $\alpha -$ amylase, and a final rinse of water only. After rinsing, the bags were removed from the agitation vessel, and compressed to remove excess water, and soaked in acetone for 3 min to remove residual moisture. The bags were then compressed lightly to remove excess acetone, and left to sit for 30 min to let the remaining acetone evaporate, and placed in a force – air oven set at 105˚C for at approximately 2 h. After drying, the bags were placed in a desiccator for 15 min and then weighed and recorded.

Acid detergent fiber was subsequently analyzed. The ADF solution was a mixture of 304 g of sulfuric acid and 6 L of distilled water. Normality of the solution was checked by adding 3 drops of bromocresol green into 10 ml of ADF into a small beaker. The solution was titrated with tromeThamine until the solution changed from yellow to blue. The normality was then calculated by dividing the amount of tromeThamine necessary for color change by 10 (ml of ADF). When a 1.00 $N$ was achieved, 118.2 g of cetyltrimethylammonium bromide was added to the ADF solution, mixed thoroughly and transferred to a carboy. After performing ADF, samples were rinsed in hot tap water and soaked in acetone for 3 min to remove water. Samples were then compressed, and left to

sit at ambient temperature to allow excess acetone to evaporate, and placed in a force –

air oven at 105˚C for 4 hours. After drying, samples were placed in a desiccator for 15

min, weighed and recorded.

*Laboratory Analysis of Ruminal Fluid*

Rumen fluid samples were analyzed for VFA using a Varian 3400 Gas

Chromatograph (Varian Inc., Palo Alto, CA). Samples were thawed for 12h at 25˚ C,

mixed and strained through 4 layers of cheesecloth. In a test tube, 1 ml of 25% meta-

phosphoric acid was added to 5 ml aliquots of the strained rumen fluid. The test tubes

were covered with a rubber stopper and were thoroughly mixed. The samples were then

placed in a freezer overnight. After freezing, samples were thawed, mixed and

centrifuged for 20 minutes at $1073 \times g$ (IEC-6000, International Equipment Company,

Needham, MA). The supernatant was decanted into a clean 5 ml test tube, placed into

septum covered vials, and loaded on the gas chromatograph auto-sampler for VFA

determination.  Separations were accomplished using a 1.80-m SP1200 packed column

(Supelco, Bellafonte, PA).  The GC frame ionization detector was programmed with the

initial column oven temperature set at 100˚ C and was held for 1 min and then increasing

20˚ C/ min to 170˚ C and was held for 7 min.  Sample injection volume was 0.50 μl.

Nitrogen was the carrier gas set at a flow rate of 40 ml/ min.  Individual VFAs were

identified by comparisons of retention times with standards (Sigma, St. Louis, MO;

Supleco; Matreya, Pleasant Gap, PA).  The fatty acids were quantified by comparison to

the GC response to an external standard of acetate (50 μmoles/ml), propionate (25

μmoles/ml), isobutyrate (5 μmoles/ml), butyrate (15 μmoles/ml), isovalerate (5

μmoles/ml), and valerate (5 μmoles/ml). Individual fatty acids were identified by comparisons of retention times with standards (Fisher Scientific; Pittsburg PA).

Free $NH_3$-N analysis was also conducted on the rumen fluid samples using a specific ion electrode method (Model 95 -12, Orion Research Inc., Beverly, MA). A standard curve was established from known concentrations of ammonium chloride. This was accomplished by adding 25 ml of standard in a 50 ml beaker with stir bar. Initial pH reading was taken and then a 50% solution NaOH was added by drops until pH was greater than 11.0. The $NH_3$ electrode was then placed in the beaker for ammonia reading and recorded. The ammonia concentration of the samples were fit and predicted based on a standard curve of $NH_4Cl$ standards.

*Laboratory Analysis of Plasma and Serum*

Serum concentrations of BUN were determined spectrophotometrically by hydrolyzing urea in blood serum with urease, and catalyzing the indo-phenol reaction to produce the blue color indicative of BUN concentration (Chaney and Marbach, 1962). Samples were then analyzed using a spectrophotometer (Jasco V-630 Spectrophotmeter, Jasco Inc., Easton, MA) in reference to a standard curve of known urea concentrations made by using stock samples.  Reactions were performed by adding 10 μl of sample to borosilicate glass tubes (12×75 mm) with 250 μl of urease reagent.  Samples were then vortexed, and incubated in 37˚C water bath for 10 min.  Next, 500 μl each of Phenol-Nitroprusside solution and hypochlorite solution were added in sequence, vortexing between additions. Phenol-nitroprusside solution was made by adding 50 g of phenol and 0.25 g sodium nitroprusside to a 1L volumetric flask and bringing the solution to volume

with deionized water.  The solution was then stored in an amber container at 4°C.

Hypochlorite solution was made by adding 25 g NaOH and 40 ml 5.25% sodium

hypochlorite to a 1L volumetric flask. The solution was then brought to volume with

deionized water, and stored in an amber container at 4°C.  Urease solution was

constituted by adding 50 ml deionized water to a 100 ml volumetric flask and mixing

thoroughly with 0.788 g EDTA (27 mM solution at 292.2 g MW-Sigma #E9884-100 g).

Then pH was adjusted to 6.5 using 50% NaOH.  Finally, the solution was completed by

adding 0.1 g of 29,500 U/g Type III Jack Bean Urease (Sigma #U1500-20KU).

Finally, 1 ml of deionized water was added and samples were allowed to incubate

at room temperature for 30 min.  Absorbance at 570 nm was read using a

spectrophotometer (Jasco V-630 Spectrophotmeter, Jasco Inc., Easton, MA).

Concentration was calculated using the following equation:

*BUN mg/d l= ((abs of sample/abs of standard) ×concentration of standard)*

Plasma GLU was determined as described by Trinder (1969). Plasma GLU

levels were determined by precipitating protein from plasma samples and oxidizing

glucose to produce gluconic acid and $H_2O_2$.  Then reacting $H_2O_2$ with peroxidase and an

oxygen acceptor in the form of sodium phosphate ($Na_2HPO_4$) (Sigma # S0875-500g) to

produce an oxidized receptor.

Plasma samples (0.1 ml) were added to tubes with 2.9 ml of protein precipitant

and centrifuged to separate protein component.  The supernatant was separated and 0.1

ml was added to 3 ml of color reagent.  Tubes were incubated at 37°C for 10 min shaking

intermittently to insure aeration.  Absorbance was read at 515 nm on a spectrophotometer

(Jasco V-630 Spectrophotmeter, Jasco Inc., Easton, MA).  Blanks were established by

reading absorbance of 1 ml of protein precipitant, and standard containing 0.21 ml

glucose solution and 2.9 ml protein precipitant.  Protein precipitant was made by adding

10 g sodim tungstate, 10 g $Na_2HPO_4$, and 9 g NaCl to 800 ml of water.  Hydrochloric

acid (1$N$) was used to adjust pH to 3.0 then 1g of phenol was added and volume was

brought to 1L.  The color reagent contained 75 ml 4% $Na_2HPO_4$, 215 ml deionized water,

0.0288 g glucose oxidase, 5 ml of 0.1% peroxidase, 300 mg sodium azide and 100 mg 4-

aminoantipyrine.

 Absorbance was read at 515 nm using a spectrophotometer (Jasco V-630

Spectrophotmeter, Jasco Inc., Easton, MA) and compared to a standard to give glucose

concentrations.  Glucose concentraton was then calculated using the following equation:

*Glucose conc.mg/dl=(abs sample-abs blank)/(abs standard/abs blank)×conc. standard*

Serum INS concentrations were determined using ImmunChem™ Coated Tube

Insulin 125/RIA kits (MP Biomedicals LLC Solon, OH), and quantified using a Cobra

Series Gamma Counter (Packard Instruments Downers Grove, IL)

*Carcass Data Collection*

Immediately post-harvest HCW were collected and carcasses were chilled for 24

h at -2˚C.  At approximately 24 h post mortem the right side of the carcasses were ribbed

at the 12th- to 13th-rib junction and allowed to bloom for approximately 30 min.  After

blooming, carcass data were collected, including ribeye area (REA), 12th-rib fat

thickness over the ribeye (FOE), marbling score (MARB), percent kidney, pelvic, and

heart fat (KPH), lean maturity, skeletal maturity, subjective lean color, subjective fat

color , muscle texture and firmness, muscle pH, and instrumental color.  Instrumental

lean color was taken in triplicate on the exposed surface of the ribeye at the 12th and 13th

rib juncture.  Instrumental fat color was measured in triplicate approximately 2 cm

anterior to the 12th rib cut surface and 5 cm ventral to the spinal process.  Objective CIE

color (L* measures lightness where 0 = black and 100 = white; a* measures the red to

green spectrum where positive numbers indicate more red and negative numbers indicate

more green; and b* measures the yellow to green spectrum where positive numbers

indicate more yellow and negative numbers indicate more green) was measured with a

Minolta Chromo Meter (CR-310; Konica Minolta Sensing, Americas Inc. Ramsey, NJ)

with a luminant D65, 2˚ viewing angle, and a 50-mm diameter measuring area.  The

Minolta was calibrated against a standard white tile each day before data was collected.

Yield grade (YG) was also calculated from the above data.

*Statistical Analysis:*

Data were analyzed using the proc MIXED procedure of SAS (SAS Institute

Inc. Cary, NC) in a completely randomized design with three protein supplements and 12

replicates (12 animals/treatment).  Animal was defined as the experimental unit and

animal was used as the observational unit used to determine differences across the three

supplements.  Animal in treatment was used as the random error term and was used to

test sources of variation.  The By statement was utilized to compare means within a

treatment across time and among treatments for a given point. Carcass data were

analyzed only for main effects of treatment.  Least squares means were generated and

separated using the P-DIFF option of LSMEANS.  Differences were considered

significant at $\alpha = 0.05$ and tendencies were considered at $\alpha < 0.10$.

## Results and Discussion

*Performance and Efficiency*

As anticipated, all steers increased ($P < 0.01$) BW over time (Table 4.2).  At d 50

BW for steers fed DDGS tended ($P = 0.06$) to be greater than steers fed CGF, and by d

100 DDGS steers were heavier (P = 0.006) than those fed CGF and tended ($P = 0.08$) to

be heavier than those fed SBM.  ADG was significant ($P = 0.01$) over time with steers in

all treatments having the highest ($P = 0.01$) ADG at d 25 (Figure 4.1).  Steers from all

treatments had decreased ($P < 0.01$) ADG from d 25 to d 50.  Steers fed CGF and SBM

also had decreased ($P \leq 0.05$) ADG after d 75 compared to other days within treatment.

Steers fed DDGS had lower ($P = 0.007$) ADG after d 50 and d 75.  At d 100 DDGS

steers tended to have increased ($P = 0.08$) ADG compared to steers fed CGF or SBM.

Days on feed had an effect ($P < 0.05$) on dry matter intake (Figure 4.2).  Dry matter

intake (DMI) for all treatments increased ($P < 0.001$) from d 25 to d 50 and decreased ($P

< 0.001$) by approximately 0.45 kg/d every 25 d period throughout the remainder of the

trial.  At d 25, steers fed DDGS consumed approximately 0.30 kg less/d ($P = 0.03$) than

CGF and SBM fed steers.  At d 75 DMI for SBM steers was lower ($P = 0.005$) than CGF

and DDGS steers by 0.17 kg and 0.11 kg respectively.  It is likely that the increased ADG

at d 25 was the result of compensatory gain when steers were removed from Tall Fescue

(*Festuca arundinacea cv* Kentucky 31.) with hay supplementation and placed on a high-

energy concentrate diet.  Average daily high temperature at d 0 was approximately 21˚C whereas at d 50 the temperature averaged approximately 32˚C (NOAA).   Decline of ADG in subsequent periods was likely due to increasing heat and humidity and the effect of heat stress on DMI which decreased linearly after d 50.

Ham et al. (1994) found increased ADG in feedlot diets containing 40% wet distillers grains with solubles (WDGS) compared to those containing dry rolled corn. Also, increased ADG and decreased DMI were observed when substituting DDGS for dry rolled corn by Klopfenstein (1996) who attributed his results to increased $NE_G$ due to the fat content of DDGS and energy value of the bypass protein. This increased performance in similar studies has been attributed to higher fat content (Ham et al. 1994; Al-Suwaiegh et al., 2002).  However, steers fed increasing levels of DDGS, replacing dry rolled corn from 0-50% of the diet DM, were reported to have had the highest ADG and G:F at the 20% level of  inclusion (Buckner et al., 2007).

Body condition score did not differ among treatments but increased ($P < 0.01$) in a linear fashion over time (Table 4. 2).  Steers fed DDGS had the higher ($P = 0.02$) G:F than CGF or SBM steers, and steers fed CGF were less ($P = 0.009$) efficient than DDGS steers by 0.03 kg of gain per kg of feed (Table 4.2).  Steers fed SBM were also less ($P = 0.04$) efficient than DDGS but by only 0.02 kg of gain per kg of feed.  Cost of gain for SBM was highest ($P < 0.01$) compared to CGF or DDGS.  Increased ($P = 0.02$) G:F in DDGS steers is likely due to the tendency for improved ADG over the 100 d feeding period combined with decreasing intake after d 50.  When DDGS were fed at 0, 15, 30, 45, 60, 75% levels of inclusion with steam-flaked corn finishing diet Depenbusch et al.

(2009) reported a quadratic response for intake. Maximum affect was seen when DDGS were added at 15% of the diet DM with G: F increasing linearly with increasing level of inclusion (Depenbusch et al., 2009). MacDonald et al. (2007) supplemented grazing heifers with differing levels of bypass protein and fat in the form of DDGS, corn gluten meal and corn oil. Dry distillers grains plus solubles increased ADG to a greater extent than did other treatments (61% greater that corn gluten meal). Fruthermore, it was not reported that DDGS had no effect on DMI while corn gluten meal decreased DMI and corn oil had no effect illustrating improved G:F with the use of DDGS

*Ultrasound Data*

Steers from all treatment groups increased ($P < 0.01$) UREA approximately 10 $cm^2$ every 50 d over the course of the feeding period. However, treatment did not affect ($P > 0.30$) REA. Fat over the $12^{th}$ rib increased ($P < 0.01$) from 0.20 to 0.30 cm every 50 d throughout the trial for steers in all treatment groups. At d 0 and 50 DDGS fed steers had less ($P \leq 0.03$) UFT than steers fed CGF or SBM. All treatments were similar ($P = 0.80$) at d 100. Neither treatment nor time had an affect ($P > 0.05$) on UIMF. Fat over the rump was lower ($P = 0.01$) at d 0 for steers fed DDGS compared to those fed CGF and SBM. By d 50 all treatment groups were similar ($P > 0.05$) and remained so through d 100. In steers from all three treatments URF increased ($P < 0.001$) with increasing days on feed. Decreased fatness in steers fed DDGS was expected. Prior to the feeding phase, steers were stockered using a corn silage based diets and supplemented with the same protein supplements. Steers fed DDGS had decreased ($P < 0.05$) BCS and UFT at the

end of the stocker phase. Increased feed efficiency in the feedlot allowed steers fed DDGS to finish with similar UFT, UIMF, and URF to steers fed CGF and SBM.

*Rumen VFAs*

Treatment had no effect on ruminal acetate concentrations (Table 4.3), however, acetate concentration did increase ($P < 0.01$) over time in CGF and SBM fed steers and tended ($P < 0.06$) to increase in DDGS fed steers as well (Table 4.4). This was unexpected given the higher fiber content of the diets containing by-product supplements. It is possible that rumen protection by corn oil in conjunction with small particle size tended to decrease fiber digestibility, and subsequently lowered acetate production in the rumen of DDGS supplemented steers (Firkins et al., 1985; Klopfenstein et al., 1996). Propionate, butyrate, isobutyrate, and valerate concentrations were unaffected ($P > 0.05$) by treatment (Table 4.3). Butyrate concentrations were decreased ($P = 0.03$) at d 50 and d 100 compared to d 0 (Table 4.4). No differences ($P < 0.05$) were found in rumen butyrate concentrations between d 50 and d 100 (Table 4.4). Isobutyrate concentrations were lower ($P = 0.005$) at d 50 and d 100 than at d 0 for all treatment groups (Table 4.4). However, valerate was higher ($P = 0.01$) at d 50 compared to d 0 and 100. Isovalerate concentrations increased ($P \leq 0.01$) from d 0 to d 50 for all treatment groups (Table 4.4) with steers fed SBM having the highest ($P = 0.03$) concentrations compared to CGF and DDGS fed steers (Table 4.3). This suggests increased rumen protein degradation in SBM compared to DDGS and CGF. Although differences among individual VFAs were observed, no differences ($P > 0.05$) were found for total VFA concentration over time (Table 4.4) or between treatments (Table 4.3). These results were expected and concur

with other similar studies that have found no differences in rumen VFAs with the addition of DDGS or CGF (Fleck et al., 1988; Elizalde et al., 1998; Peter et al., 2000; Al-Suwaiegh et al., 2002). Day effects may be the result of a change in feeding behavior as heat and humidity increased over the course of the study.

Rumen $NH_3$ was not affected ($P = 0.50$) by treatment but did increase ($P < 0.01$) with days on feed (Table 4.4). Song and Kennelly (1990) observed increased rumen degradation of SBM when increased levels of ruminal $NH_3$ were induced by ruminal infusion of ammonium bicarbonate. This suggested a greater rumen microbial acclimation and more extensive protein degradation as day on feed increased. Rumen pH was not affected ($P > 0.05$) by treatment, but was highest ($P < 0.001$) at d 0. A more acidic rumen environment is likely due to increased intake of the concentrate diet and incomplete rumen acclimation to the high-starch content of diet.

*Blood Metabolites*

Treatment did not affect ($P > 0.05$) BUN, GLU or INS (Table 4.5). Glucose was higher ($P < 0.01$) at d 0 than at d 50 or 100 (Table 4.6). Likewise, INS was higher ($P < 0.01$) at d 0 compared to d 50 and d 100 (Table 4.6). Steers were first acclimated to their diets and initial measurements were taken after steers were on full feed. Prior to the d 0 steers had been backgrounded on native forages and Bermuda Grass hay. It is possible that the initial increase in DMI on a high-starch diet caused GLU at d 0 to be elevated. Similar data was presented by Gunn et al. (2010) by feeding increasing levels of glycerin to lambs; it was observed that lambs receiving elevated glycerin levels had increased blood GLU levels. This was attributed to decreased intake by the lambs consuming

92

glycerin at more than 30% of the diet.  Intake decreased (P < 0.01) by d 50 and it is

possible that higher feed intake is responsible for elevated GLU levels early in the trial.

Insulin was likely elevated at d 0 in response to higher GLU concentrations in the blood.

*Carcass Characteristics*

There were no differences ($P < 0.11$) among treatments for any of the measured

carcass yield characteristics (HCW, DP, REA, FOE, marbling, KPH, and YG) indicating

that DDGS and CGF will produce comparable boneless closely trimmed retail cuts to

SBM given equal conditions (Table 4.7).  Subjective lean and fat color, texture, firmness,

and muscle pH were all unaffected ($P > 0.05$) my treatment as well (Table 4.8).

Carcasses from CGF steers were lighter (L*; $P < 0.05$) and more yellow (b*; $P < 0.05$) in

color than DDGS or SBM carcasses (Table 4.8).  It is possible that this observation is due

to the large numerical yet insignificant ($P > 0.1$) differences in marbling between CGF

and the other protein sources.  Increases in marbling should cause greater reflectance and

therefore higher values for L* and b*.   Overall maturity was also unaffected ($P > 0.05$)

by treatment.  Dried distiller grains plus solubles steers had lower ($P < 0.05$) L* values

for fat color, and SBM had lower ($P < 0.05$) a* values for external fat compared to their

contemporaries.  This difference in brightness and redness is likely the result of the

increase DMI of ground corn in the SBM ration.  This disagrees with Kim and Lee

(2002) who found that cattle with increased marbling had similar lean color

characteristics.  However, Depenbusch et al. (2009) reported darker color in strip steaks

from steers fed DDGS in excess of 45% of the diet DM compared to steam-flaked corn.

The data from this study also disagrees with that of Gill et al. (2008) who noted that strip steaks from cattle fed DDGS were brighter in color than cattle fed no DDGS.

## Conclusions and Implications

Nationwide, large-scale retailers are increasingly devoting more shelf space to "locally grown" products (Schmidt, 2008). Also the ethanol and food processing industries are expanding and subsequently corn processing by-products are becoming more and more available. The added volatility of today's economic climate has opened new doors of opportunity to American beef producers. This research demonstrates that utilizing DDGS or CGF in place of SBM to supplement protein in finishing cattle will not negatively affect economically important traits, and if cost is decreased for these by-products, could potentially increase profitability the operation through increased feed efficiency.

## Literature Cited

Abe, A., and S. Horii. 1978. Application of the detergent analysis to the feed ingredients and to the various formula feed. Jpn. J. Zootech. Sci. 49:733-738.

Al-Suwaiegh, S., K. C. Fanning, R. J. Grant, C. T. Milton, and T. J. Klopfenstein. 2002 Utilization of distillers grains from the fermentation of sorghum or corn in diets for finishing beef and lactating dairy cattle. J. Anim. Sci. 80:1105-1111.

Buckner, C. D., T. L. Mader, G. E. Erickson, S. L. Colgan, K. K. Karges, and M. L. Gibson. 2007. Optimum levels of dry distillers grain with soluble for finishing beef steers. Nebraska Beef Cattle Report. Retrieved from http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1067&context=animal scinbcr.

Chaney, A. L. and E. P. Marbach. 1962. Modified reagents for the determination of urea and ammonia. Clin. Chem. 8:130-132.

Depenbusch, B. E., C. M. Coleman, J. J. Higgins and J. S. Drouillard. 2009. Effects of increasing levels of dried corn distillers grains with solubles on growth performance, carcass characteristics, and meat quality of yearling heifers. J. Anim. Sci. 87:2653-2663.

Firkins, J.L., L. L. Berger, and G. C. Fahey, Jr. 1985. Evaluation of wet and dry distillers grain and wet and dry corn gluten feeds for ruminants. J. Anim. Sci.. 60:847-860.

Fleck A. T., K. S. Lusby, F. N. Owens, and F. T. McCollum. 1988. Effect of corn gluten feed on forage intake, digestibility and runimal paramenters of cattle fed native grass hay. J. Anim. Sci.. 66:750-757.

Gunn, P. J., A. F. Schultz, M. L. Van Emon, M. K. Neary, R. P. Lemenager, PAS, C. P. Rusk, and S. L. Lake. 2010. Feedlot performance, carcass characteristics and serum metabolite and hormone concentrations in finishing ewe and wether lambs. Prof. Anim. Scientist. 26 :298-306

Gunn, P. J., A. D. Weaver, R.P Lemenanger, D. E. Gerrard, M. C. Claeys, and S. L. Lake. 2009. Effects of dietary fat and crude protein on feedlot performance, carcass characteristics, and meat quality in finishing steers fed differing levels of dried distillers grains with soluble. J. Anim. Sci.. 87:2882-2890.

Ham, G. A., R.A. Stock, T. J. Klopfenstein, E.M. Larson, D. H. Shain, and R. P. Huffman. 1994. Wet corn distillers byproducts compared with dried corn distillers grain with soluble as a source of protein and energy for ruminants. J. Anim. Sci. 72:3246-3257

Hersom, M. J., R. P. Wettemann, C. R. Krehbiel, G. W. Horn, and D. H. Keisler. 2004. Effect of live weight gain of steers during winter grazing: III. Blood metabolites and hormones during feedlot finishing. J. Anim. Sci.. 82:2059-2068.

Kim, C. J., E. S. Lee. 2002. Effects of quality grade on chemical, physical, and sensory characteristics of Hanwoo (Korean native cattle) beef. Meat Science. 63: 397-405.

Klopfenstein, T.1996. Distillers grains as an energy source and effect of drying on protein availability. Animal Feed Science Technology. 60:201-207.

Klopfenstein T. J., G. E. Erickson, and V. R. Bremer. 2007. BOARD-INVITED REVIEW: Use of distillers byproducts in the beef cattle feeding industry. J. Anim. Sci. 86:1223-1231.

Krehbiel, C. R., R. A. Stock, D. W. Herold, D. H. Shain, G. A. Ham, and J. E. Carulla. 1995. Feeding wet corn gluten feed to reduce subacute acidosis in cattle. J. Anim. Sci. 73:2931-2939.

McDonald, I. W. 1954. The extent of conversion of feed protein to microbial protein in the rumen of sheep. Biochem. J. 56:120-125.

National Oceanic and Atmospheric Administration. http://www.weather.gov/climate/index.php?wfo=ffc.Accessed July 1, 2010.

Schmidt, J. 'Locally grown' food sounds great, but what does it mean?. USA Today, Retrieved from http://www.usatoday.com/money/economy/2008-10-27-local-grown-farms-produce_N.htm

Song, M. K. and J. J. Kennelly. 1990. Rumnial fermentation patter, bacterial population and ruminal degradation of feed ingredients as influenced by ruminal ammonia concentration. J. Anim. Sci. 68:1110-1120.

Trinder, P. 1969. Determination of glucose in blood using glucose oxidase with an alternative oxygen acceptor. Ann. Clin. Biochem. 6. 24:24-27.

Van Soest, P. J., J. B. Robertson, and B. A. Lewis. 1991. Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. J. Dairy Sci. 74:3583-3597.

Vander Pol, K. J. M. K. Luebbe, G. I. Crawford, G.E. Erickson, and T. J. Klopfenstein. 2009. Performance and digestibility characteristics of finishing diets containing distillers grains, composites of corn processing coproducts, or supplemental corn oil. J. Anim. Sci. 87:639-652.

**Table 4.1**. Dry matter composition of feedlot diets supplemented with corn gluten feed (CGF), dried distillers grains plus soluble (DDGS) or soybean meal/corn (SBM).

| | Protein Supplement | | |
|---|---|---|---|
| | CGF | DDGS | SBM |
| *Ingredient[1], % DM* | | | |
| SBM[2] | 0.0 | 0.0 | 9.6 |
| CGF[2] | 24.5 | 0.0 | 0.0 |
| DDGS[2] | 0.0 | 24.5 | 0.0 |
| Ground Corn | 47.9 | 47.9 | 62.6 |
| Soy Hulls | 8.2 | 8.2 | 8.2 |
| Cottonseed Hulls | 8.2 | 8.2 | 8.3 |
| Citrus Pulp | 8.2 | 8.2 | 8.3 |
| Vitamin Premix | 3.0 | 3.0 | 3.0 |
| *Chemical Composition,%* | | | |
| DM | 90.56 | 90.91 | 90.21 |
| CP | 13.37 | 15.88 | 14.16 |
| NDF | 28.23 | 25.53 | 19.99 |
| ADF | 11.67 | 11.28 | 9.92 |
| Ash | 5.31 | 4.42 | 5.00 |

[1]All sources were procured from the same distributor and are expressed on a DM basis.

[2]Different loads were averaged.

**Table 4.2.** Growth performance and efficiency least squares means of beef feedlot steers fed corn gluten feed (CGF), dried distillers grains plus solubles (DDGS), or soybean meal with corn (SBM) as a protein supplement.

| Item | | Protein Supplement | | SEM |
| --- | --- | --- | --- | --- |
| | CGF | DDGS | SBM | |
| BW, kg | | | | |
| 0 | $385.1^{z}$ | $395.3^{z}$ | $400.3^{z}$ | 6.8 |
| 25 | $457.3^{y}$ | $465.3^{y}$ | $474.7^{y}$ | 6.8 |
| 50 | $471.7^{x}$ | $498.4^{x}$ | $487.8^{x}$ | 7.7 |
| 75 | $514.9^{w}$ | $539.3^{w}$ | $522.3^{w}$ | 8.1 |
| 100 | $531.0^{bv}$ | $567.8^{av}$ | $544.9^{av}$ | 8.9 |
| BCS[1] | | | | |
| 0 | $5.9^{z}$ | $6.0^{z}$ | $5.8^{z}$ | 0.1 |
| 50 | $6.6^{y}$ | $6.4^{y}$ | $6.5^{y}$ | 0.2 |
| 100 | $7.6^{x}$ | $7.8^{x}$ | $7.6^{x}$ | 0.1 |
| COG[2], \$/kg | $1.27^{b}$ | $1.08^{b}$ | $1.71^{a}$ | 0.08 |
| G:F | $0.14^{b}$ | $0.17^{a}$ | $0.15^{b}$ | 0.01 |

[abc] Means within a row without a common superscript differ ($P<0.05$).

[xyz] Means within a column and item without a common superscript differ ($P<0.05$).

[1]Richards et al., 1986

**Table 4.3**. Main effect of treatment on rumen VFAs, NH$_3$, and pH in beef feedlot steers fed corn gluten feed (CGF), dried distiller grains plus solubles (DDGS), or soybean meal with corn (SBM) as protein supplements.

| Item | Protein Supplement | | | SEM |
|---|---|---|---|---|
| | CGF | DDGS | SBM | |
| Acetate, µmol/ml | 41.30 | 38.68 | 43.56 | 1.99 |
| Propionate, µmol/ml | 20.08 | 21.34 | 22.52 | 1.41 |
| Butyrate, µmol/ml | 11.44 | 11.34 | 11.62 | 0.80 |
| Isobutyrate, µmol/ml | 1.06 | 1.05 | 1.02 | 0.13 |
| Valerate, µmol/ml | 1.58 | 1.59 | 1.67 | 0.17 |
| Isovalerate, µmol/ml | 1.99[b] | 1.91[b] | 2.48[a] | 0.16 |
| Total VFA, µmol/ml | 77.44 | 75.91 | 82.87 | 3.81 |
| NH$_3$,mg/dl | 8.48 | 8.50 | 10.38 | 1.40 |
| pH | 6.58 | 6.60 | 6.53 | 0.06 |

[ab] Means within a row without a common superscript differ ($P<0.05$).

**Table 4.4.** Least spuares means of time on rumen VFAs, NH₃, and pH in beef feedlot steers fed corn gluten feed (CGF), dried distiller grains plus solubles (DDGS), or soybean meal with corn (SBM) as protein supplements.

| Item | Days on feed | | | SEM |
|---|---|---|---|---|
| | 0 | 50 | 100 | |
| Acetate, μmol/ml | 33.45[c] | 42.67[b] | 47.42[a] | 1.64 |
| Propionate, μmol/ml | 20.06 | 21.63 | 22.25 | 1.29 |
| Butyrate, μmol/ml | 13.72[a] | 11.13[b] | 9.55[b] | 0.80 |
| Isobutyrate, μmol/ml | 1.88[a] | 0.67[b] | 0.58[b] | 0.12 |
| Valerate, μmol/ml | 1.46[a] | 1.96[b] | 1.41[a] | 0.15 |
| Isovalerate, μmol/ml | 2.93[a] | 1.85[b] | 1.59[b] | 0.15 |
| Total VFA, μmol/ml | 73.50 | 79.91 | 82.80 | 3.20 |
| NH₃, mg/dl | 3.09[c] | 8.03[b] | 16.25[a] | 1.27 |
| pH | 6.78[a] | 6.47[b] | 6.47[b] | 0.05 |

[abc] Means within a row without a common superscript differ ($P<0.05$).

**Table 4.5.** Main effects of treatment on blood concentrations of blood urea nitrogen (BUN), glucose (GLU), and insulin (INS) in beef feedlot steers fed corn gluten feed (CGF), dried distiller grains plus solubles (DDGS), or soybean meal with corn (SBM) as protein supplements

| | Protein Supplement | | | |
| Item | CGF | DDGS | SBM | SEM |
|---|---|---|---|---|
| BUN, mg/dl | 14.97 | 17.30 | 15.07 | 0.89 |
| GLU, mg/dl | 72.93 | 70.14 | 71.37 | 3.06 |
| INS, , µIU/ml | 23.92 | 23.67 | 29.11 | 2.94 |

[abc] Means within a row without a common superscript differ ($P<0.05$).

**Table 4.6.** Least squares means of time on blood concentrations of blood urea nitrogen (BUN), glucose (GLU), and insulin (INS) in beef feedlot steers fed corn gluten feed (CGF), dried distiller grains plus solubles (DDGS), or soybean meal with corn (SBM) as protein supplements.

| | Days on Feed | | | |
| Item | 0 | 50 | 100 | SEM |
| --- | --- | --- | --- | --- |
| BUN, mg/dl | 14.64 | 17.15 | 15.54 | 0.89 |
| GLU, mg/dl | $80.17^a$ | $71.34^b$ | $62.94^b$ | 3.02 |
| INS, µIU/ml | $30.60^a$ | $21.65^b$ | $24.45^b$ | 2.39 |

[ab] Means within a row without a common superscript differ ($P<0.05$).

**Table 4.7.** Least squares means of carcass yield characteristics for beef feedlot steers fed corn gluten feed (CGF), dried distiller grains plus solubles (DDGS), or soybean meal with corn (SBM) as protein supplements

| | Protein Supplement | | | |
|---|---|---|---|---|
| Item [1] | CGF | DDGS | SBM | SEM |
| HCW, kg | 354.00 | 350.00 | 341.00 | 7.33 |
| Dressing percent, % | 63.80 | 62.90 | 63.50 | 0.59 |
| Ribeye area, $cm^2$ | 77.65 | 77.68 | 79.23 | 3.25 |
| 12th rib fat thicness, cm | 1.20 | 1.11 | 1.20 | 0.07 |
| Kidney, pelvic, heart fat, % | 2.30 | 2.20 | 2.20 | 0.11 |
| Yield grade | 3.10 | 3.11 | 3.05 | 0.18 |

**Table 4.8.** Carcass quality characteristics for beef feedlot steers fed corn gluten feed (CGF), dried distiller grains plus solubles (DDGS), or soybean meal with corn (SBM) as protein supplements

| | Treatment | | | |
|---|---|---|---|---|
| Item | CGF | DDGS | SBM | SEM |
| Obj. Lean Color | | | | |
| L*[1] | 43.73[a] | 41.21[b] | 40.67[b] | 0.78 |
| a*[2] | 31.29 | 29.54 | 30.74 | 1.17 |
| b*[3] | 12.68[a] | 10.96[b] | 11.02[b] | 0.38 |
| Obj. Fat Color | | | | |
| L*[1] | 73.08[ab] | 72.14[b] | 74.30[a] | 0.63 |
| a*[2] | 10.32[a] | 9.47[ab] | 7.35[b] | 0.93 |
| b*[3] | 16.50 | 13.37 | 14.46 | 1.38 |
| Sub. Lean Color[4] | 6.42 | 6.25 | 6.17 | 0.25 |
| Sub. Fat Color[5] | 1.83 | 1.61 | 1.75 | 0.17 |
| Marbling[6] | 494.2 | 432.5 | 457.5 | 23.44 |
| Texture[7] | 1.42 | 1.75 | 1.50 | 0.17 |
| Firmness[8] | 1.67 | 1.42 | 1.67 | 0.20 |
| pH | 5.57 | 5.64 | 5.59 | 0.05 |
| Overall Maturity[9] | 136 | 131 | 145 | 6.57 |

**Figure 4.1.** Least squares means for ADG in beef feedlot steers fed corn gluten feed (CGF), dried distillers grains plus solubles (DDGS), or soybean meal with corn (SBM) as a protein supplement. Treatment was not significant ($P = 0.08$) at d 100. Day was significant ($P < 0.01$)
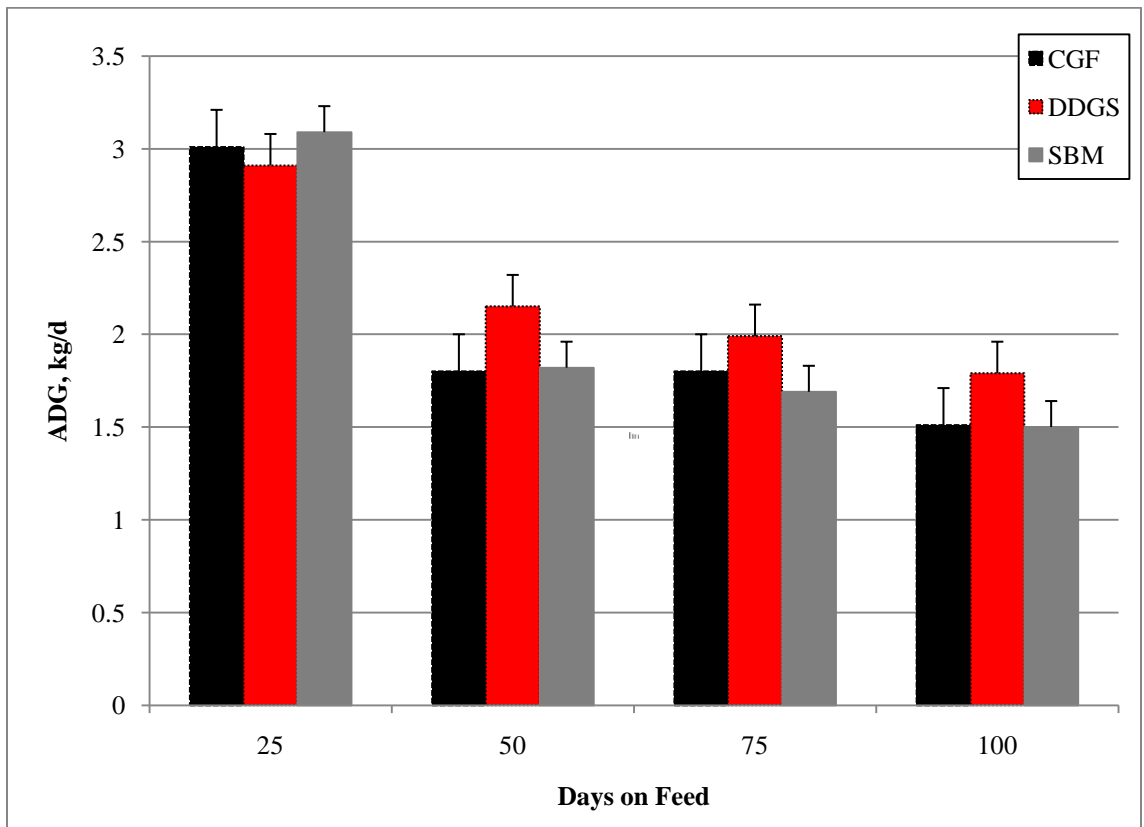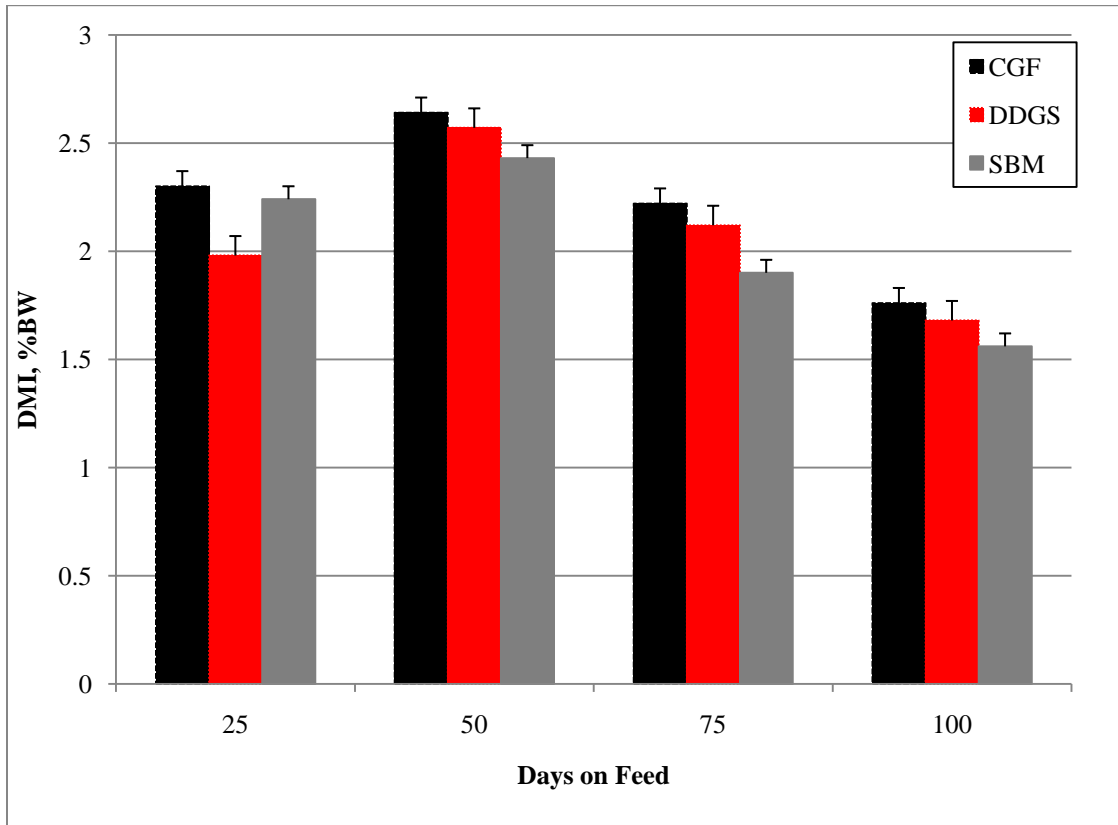
**Figure 4.2.** Least squares means for DMI in beef feedlot steers fed corn gluten feed (CGF), dried distillers grains plus solubles (DDGS), or soybean meal with corn (SBM) as a protein supplement. Treatment was significant ($P < 0.05$) at d 25 and 56. Day was significant ($P < 0.01$)

110
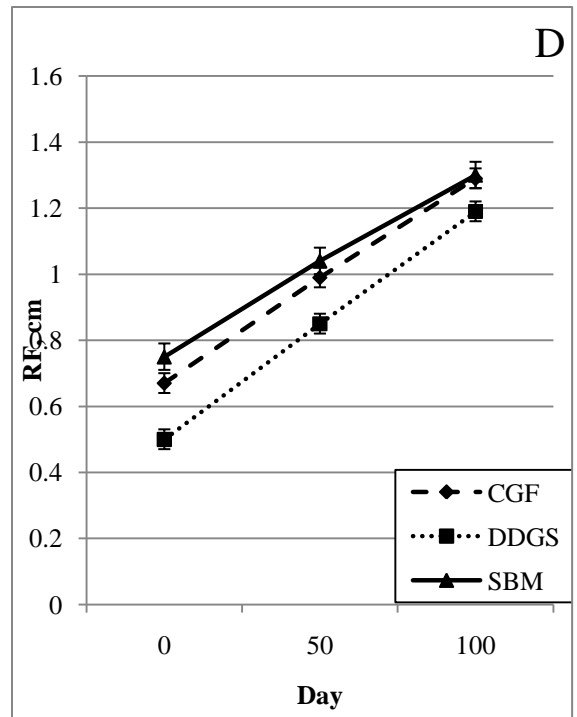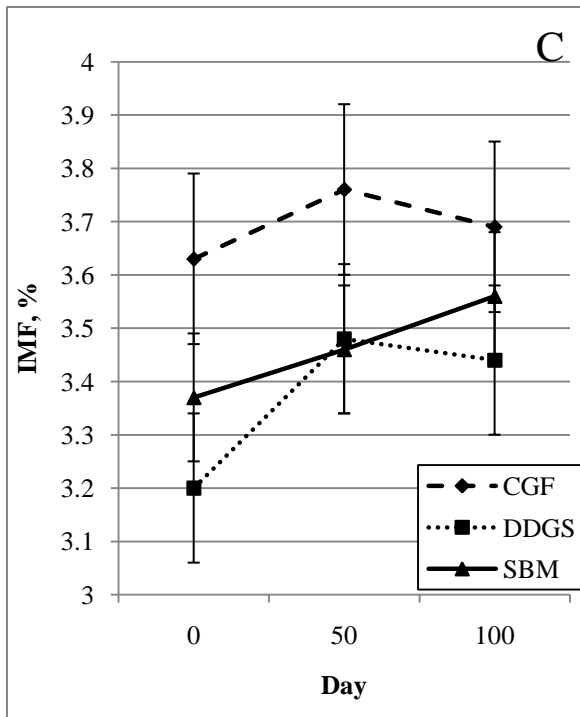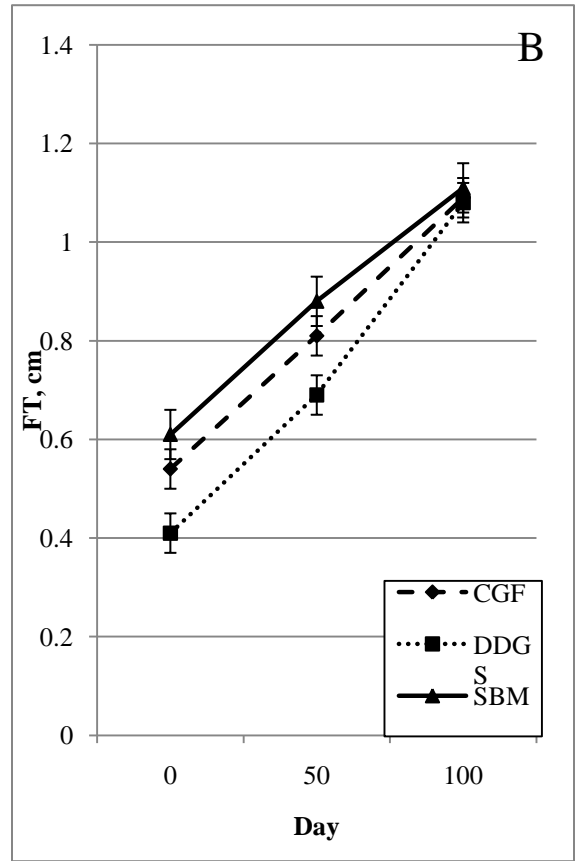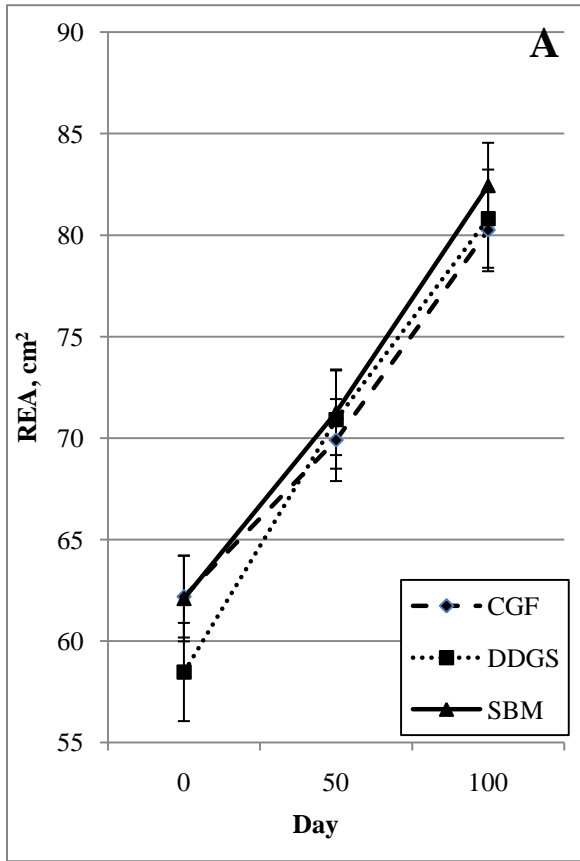
**Figure 4.3.** Ultrasound data for beef feedlot steers corn gluten feed (CGF), dried distillers grains plus solubles (DDGS), or soybean meal/corn (SBM) as a protein supplement. **a.)** ribeye area (REA) over time **b.)** 12th rib fat thickness (FT) over time **c.)** intramuscular fat percentage (IMF) **d.)** rump fat thickness (RF). Treatment was significant ($P < 0.05$). Day was significant ($P < 0.01$)

CHAPTER 5

EVALUATING COMPOSITION, TENDERNESS, SHELF-LIFE STABILITY, AND

FATTY ACID PROFILES OF BEEF STRIP STEAKS FROM STEERS FED CORN

BY-PRODUCTS FROM WEANING TO SLAUGHTER[1]

## Abstract

The objective of this study was to evaluate meat quality and shelf-life of steaks from steers fed distillers dried grains with solubles (DDGS) or corn gluten feed (CGF) compared to soybean meal/corn (SBM) as a protein supplement from weaning to slaughter at 25% DM.  Beef steers (n=81, BW=306 kg ± 26.06 kg) were randomly assigned to pens (n= 9) and stockered using corn silage and DDGS, CGF or SBM.   After a 90 d stockering period, 12 steers (BW=548 kg ± 33.69) were randomly selected from each treatment and were individually fed using the same protein supplement.  Steers were fed for 100 d and slaughtered at 1.27 cm of backfat.   Carcass data were collected 24 h post-mortem and the *longissimus lumborum* was removed and fabricated into steaks at 48 h.   Steaks were assigned to proximate analysis, Warner-Bratzler shear force (aging time = 7, 14, or 21 d), and simulated retail display (display time = 1, 3, 6, or 9 d).

Protein source did not affect proximate composition ($P > 0.05$).  At d 7, SBM steaks were less ($P < 0.01$) tender than DDGS or CGF, however, by d 14 steaks were similar among treatments and remained similar through d 21 ($P = 0.30$).  Protein supplement did not influence overall color acceptance ($P = 0.17$), but acceptance did decline ($P < 0.01$) over time.  Subjective redness was similar ($P < 0.05$) among diets except at d 9 SBM steaks were redder ($P < 0.01$) than DDGS.   On d 3 and 6 CGF steaks exhibited more discoloration ($P < 0.04$) than SBM or DDGS steaks.  However, after 9 d of display DDGS had a greater percent discoloration ($P < 0.01$) than CGF or SBM. Objective L\* was lighter for CGF ($P < 0.04$) over the 9 d of display, and all treatments became darker ($P < 0.01$) as time increased.  Objective redness (a\*) declined ($P < 0.01$)

over time but SBM retained more redness after d 6 and 9 compared to CGF and DDG.

Lipid oxidation increased ($P < 0.01$) over time until d 6, but differences ($P > 0.05$) were

not observed among treatments. These data indicate that using DDGS and CGF as a

protein supplement for beef steers from weaning until slaughter is not detrimental to meat

quality, and yields a comparable product to SBM supplemented steers. Total PUFA

concentrations increased ($P < 0.05$) in DDGS steaks largely due to increased ($P < 0.05$)

CLA concentrations. As expected n6:n3 ratio was also higher ($P < 0.05$) for DDGS

steaks and total MUFAs were increased ($P < 0.05$) in SBM and CGF compared to DDGS

Keywords:  Distillers grains, corn gluten feed, meat quality.

## Introduction

Recent volatility of feed prices and economic instability has forced beef cattle

producers to look for more cost-effective sources of protein and energy. Increased access

to local grain processing plants has renewed interest in using corn by-products in US beef

production.  Inclusion of corn gluten feed (CGF) and dried distillers grains plus solubles

(DDGS) in the beef cattle feeding industry has been extensively researched (Gunn et al.,

2009; Vander Pol et al., 2009; Klopfenstein et al., 2007; Ham et al., 1994; Firkins et al.,

1985). However, research on meat quality and shelf-life of beef from cattle fed these by-

products from weaning to slaughter is lacking.

Color is the most influential determining factor on a consumer's willingness to

purchase a beef product (Mancini and Hunt, 2005).  Diet affects color determinants like

glycogen storage, chilling rate, and antioxidant accumulation which may affect muscle

114

pH, oxygen usage, and metmyoglobin reduction (Mancini and Hunt, 2005). Tenderness

is considered the most important beef palatability attribute (Stephens et al., 2004) and can

be affected by a number of ante-mortem factors such as animal age, sex, diet, stress, and

breed (Muchenje et al., 2009). Inclusion of varying levels of WDGS and DDGS has been

shown to have no effect on tenderness of the longissimus muscle (Brandt et al., 1992;

Koger et al., 2004; Roeber et al., 2005; and Gill et al., 2008). Fatty acids in meat

products are the determining factors behind fat firmness, rate of lipid oxidation which can

influence color and acceptability, and flavor (Wood et al., 2002). Therefore, the

objective for this study was to examine the composition, tenderness, shelf-life stability,

and fatty acid profiles of beef strip steaks from steers fed CGF, DDGS, or soybean meal

with corn (SBM). Our hypothesis was that CGF or DDGS could be substituted for SBM

at 25% DM with no adverse effects on meat quality.

**Materials and Methods**

*Design and Treatments:*

The experiment was conducted at the University of Georgia Meat Science

Technology Center, Athens, GA. Treatments were defined as protein supplement in the

ration and included: corn gluten feed (CGF), distillers dried grains with solubles

(DDGS), or soybean meal with corn (SBM). Treatments were arranged in four replicates

of a completely randomized design with animal as the experimental unit. All live animal

practices and procedures used in this study were examined and approved by the

University of Georgia Animal Care and Use Committee.

In late March 36 Angus-based crossbred steers were delivered from the Georgia Mountains Experiment Station, Blairsville, GA where steers were stockered for 84 d on corn-silage with the same protein supplements (CGF, DDGS, or SBM) utilized in the feedlot included at 25% of the diet DM (See Chapter 4). Steers were vaccinated at weaning with Triangle 4, Type II BVD, Ultra Vac 7, and Pyramid 5 (Fort Dodge Animal Health, Overland Park, KS). Steers were also dewormed using transdermal ivermectin (Dectomax, Pfizer Animal Health New York, NY). After stockering, steers were backgrounded for 30 d on Tall Fescue (*Festuca arundinacea cv.* Kentucky 31) and Bermuda grass hay until feedlot diets could be made available. Approximately 10 d before the start of feeding steers were assigned to pens for individual feeding and acclimated to test diets. Steers were assigned to 1 of 3 feedlot rations with differing protein supplements maintaining consistency with the supplement received during stockering (See Chapter 4). Protein supplement was included at 25% of the diet DM: 1) CGF 2) DDGS 3) SBM (Table 5.1). Diets were formulated to be isonitrogenous, and mixed daily using a Calan Data Ranger (American Calan Inc., Northwood, NH). After 100 d steers were randomly divided by pen into two slaughter groups with each treatment equally represented. On d 101 and 108 respectively, a group was transported to the University of Georgia Meat Science Technology Center in Athens, GA and harvested under federal inspection. Steers that remained in the feedlot until the second slaughter date were fed a maintenance ration of the same feedlot diets utilizing their assigned protein supplements (NRC, 1996).

*Strip Loin Fabrication*

After collection of carcass data (see Chapter 5), the *Logissimus lumborum* (LL) was removed from the right side of each carcass. The anterior end was squared and a 2.54 cm thick steak was removed vacuum-packaged and immediately frozen at -20°C for proximate analysis and fatty acid determination. Seven additional steaks (2.54 cm) were then fabricated from the anterior end of the LL and vacuum-packaged (B-620 series; 30 – 50 ml $O_2/m^2$ per 24 h; 101325 Pa; 23°C; Cryovac, Duncan, SC) using an A300/16 (Multivac, Cryovac, Duncan, SC) vacuum packager, for Warner-Bratzler (WBS) shear force analysis or retail display. Steaks assigned to WBS were randomly assigned to 7, 14, or 21 d of aging. Steaks designated for retail display were randomly assigned to 1, 3, 6, or 9 d of display.

*Proximate analyisis*

Composition of LL was determined as percent moisture, crude protein, and lipid. Steaks were thawed for 24 h at 4°C ± 3°C. All external fat and connective tissue was removed. Steaks were minced, frozen in liquid N and homogenized in a Waring Blender (Waring Laboratory, Torrington, CT).

Moisture determination was made according to the methods of the AOAC (1990). Disposable aluminum pans were dried at 90°C in a forced air oven (Fisher Scienctific, Pittsburgh, PA) overnight then air equilibrated for 10 min in a dessicator. Pan weight was recorded and homogenized samples weighing 1 g ± 0.1 g were dried in duplicate at 90°C on the alluminum pans in a forced air oven for 48 h. Samples were removed and allowed cool for 5-10 min in a desiccator. The dried sample weight was calculated by subtracting the dried pan wt from the weight of the dried pan plus the dried

117

sample.  The following formula was then used to calculate percent moisture:

*% moisture = (dry sample weight/wet sample weight) × 100%*

Crude protein was determined in duplicate by analyzing N content of 0.1 g ± 0.05g with a Nitrogen Auto-analyzer (LECO FP-528 Nitrogen Analyzer, LECO Company, St. Joseph, MI).

*Lipid Extraction*

For lipid extraction, LM tissue samples were frozen in liquid nitrogen and powder homogenized.  Total lipids were extracted in duplicate (1 g per sample) according to the procedure of Folch et al. (1957) with the following modifications.  Eight and one half milliliters of methanol: water (3.5: 1) and 3.25 ml of chloroform were added to 1 g ± 0.1 g of homogenized muscle tissue in a screw-cap glass extraction tube.  Samples were vortexed for 20 s and place on a wrist-action shaker for 1 h.  Next, 3.8 ml of chloroform and 3.8 ml of aqueous KCl (0.37%) were added to each sample and tubes were inverted three time.  Samples were centrifuged for 20 min at $2250 \times g$ (IEC-HN SII centrifuge, International Equipment Company, Needham, MA).  After centrifugation the upper aqueous layer was aspirated off and 5 ml of KCl was added.  Tubes were again inverted 3 times and the centrifugation and aspiration processes were repeated.  Samples were filtered into a second extraction tube through a Buchner funnel with Whatman #1 (4.25cm) filter paper (pre-wet with 2 ml of chloroform) by using a suction flask.  After filtration, the remaining chloroform was evaporated to a volume of 7 ml.  Any remaining aqueous layer was evaporated using a Pasteur pipette.  Entire volume was then

transferred to a 10 ml volumetric flask and brought to volume using chloroform.  Finally, samples were transferred to 25 ml amber vials and labeled.

For percent lipid determination, 12×75 mm culture tubes were dried overnight in a force air oven at 90° C, and allowed to air equilibrate in a desiccator for 10 min followed by weighing.  The total lipid extract was vortexed by hand and 2 ml of lipid extract was transferred to labeled culture tubes.  Chloroform was then evaporated from the culture tube under $N_2$ gas, and tubes were dried for 30 min in a forced air oven at 90 ° C, and allowed to equilibrate in a desiccator for 10 min and weighed.  Percent lipid was determined using the following equation:  *% lipid = [(((tube + lipid wt) / tube wt) × 5)/wet tissue wt] × 100.*

*Warner-Bratzler shear force*

Steaks were vacuum-packaged (B-620 series; 30 – 50ml $O_2/m^2$ per 24 h; 101325 Pa; 23°C; Cryovac, Duncan, SC) using an A300/16 (Multivac, Cryovac, Duncan, SC)after fabrication and aged in boxes at 4°C ± 2°C.  After their respective aging period, steaks were frozen at -20°C for further analysis.  The frozen steaks were weighed and then allowed to thaw for 18 h at 4°C ± 2°C.  After thawing, steaks were blotted dry and reweighed to determine thaw loss; thaw loss was calculated using the equation:  *((frozen wt – thawed wt)/frozen) × 100%.*

After thawing, steaks were then cooked on broilers (model 450N Open-Hearth Broiler, Farberware, Bronx, NY) preheated for 20 min.  The steaks were cooked to an internal temperature of 71°C and turned once when their internal temperature reached 35°C (AMSA, 1995).  Internal temperature was monitored by a Digi-Sense® 12-channel

119

scanning thermocouple thermometer (Model 9200-00, Cole-Palmer, Vernon Hills, IL) with copper-constantan thermocouples (Omega Engineering, Stamford, CT) placed in the geometric center of each steak. When internal temperature was reached, steaks were weighed and cook loss was determined using the following formula: *((thawed wt – cooked wt) / thawed wt)×100%.*

After cooked weight was collected, a 1-cm slice from the distal end from the vertebral column was removed and degree of doneness was evaluated on a 6-point scale (1 = very rare, 6 = well done; AMSA , 1995). Steaks were cooled for 12 h at 4˚C ± 3˚C and 6 cores (1.27-cm diameter) were taken parallel to the longitudinal orientation of the muscle fibers with a hand-held coring device. Cores were sheared once perpendicular to the longitudinal orientation of the muscle fibers using an Instron Universal Testing Machine (Dual Column Model 3365, Instron Corp Worldwide Headquarters, Norwood, MA) equipped with a Warner-Bratzler shear head, and a 51 kgf load cell set at a crosshead speed of 25cm/min. The peak force was reported in kgf for all 6 core measurements.

*Simulated Retail Display*

After fabrication steaks were vacuum-packaged packaged (B-620 series; 30 – 50ml $O_2/m^2$ per 24 h; 101325 Pa; 23˚C; Cryovac, Duncan, SC) using an A300/16 (Multivac, Cryovac, Duncan, SC) vacuum packager and stored at 4˚C ± 3˚C for 7 d in the dark. Steaks were removed from vacuum bags and placed on absorbent pads (Dri-Loc® AC-40, Cryovac Sealed Air Corporation, Duncan, SC) in polystyrene trays (Cryovac® thermoformed polystyrene processor trays, Cryovac) which were then over-wrapped with

an $O_2$ permeable polyvinylcholoride overwrap ($O_2$ transmission = 23,250 ml/m$^2$/24 h, 72 gauge; Pro Pack Group, Oakland, NJ).  Steaks were displayed  at 4˚C ± 2˚C in a cold storage room with 24 h fluorescent luminescence (960 lux) to simulate retail display over 9d.  Objective and subjective color was measured on the steaks over 9 d.  Objective CIE (L* measures lightness where 0 = black and 100 = white; a* measures the red to green spectrum where positive numbers indicate more red and negative numbers indicate more green; and b* measures the yellow to green spectrum where positive numbers indicate more yellow and negative numbers indicate more green) was measured with a Minolta Chromo Meter (CR-310; Konica Minolta Sensing, Americas Inc. Ramsey, NJ) with illuminant D65, 2˚ viewing angle, and a 50-mm diameter measuring area.  The Minolta was calibrated against a standard white tile each day before data was collected.  Objective measurements were taken in triplicate and averaged with in each category (L*a*b*). Subjective color was evaluated by a trained 8 member panal of University of Georgia personnel on d 1, 3, 6, and 9 for redness ( 8 = light cherry red, 7 = moderately bright cherry red, 6 = cherry red, 5 = slightly dark red, 4 = moderately dark red, 3 = dark red/purple/ brown, 2 = very dark red/purple/brown, 1 = extremely dark red/purple/brown), overall acceptance (8 = extremely desirable, 7 = very desirable, 6 = desirable, 5 = slightly desirable, 4 = slightly undesirable, 3 = undesirable, 2 = very undesirable, 1 = extremely undesirable), and  discoloration (8 = no discoloration, 7 = 0-5% discolored, 6 = 5-10% discolored, 5 = 10-25% discolored, 4 = 25-50% discolored, 3 = 50-75% discolored, 2 = 75-90% discolored, 1 = 100% discolored) (Hunt et al., 1991).  On d 1, 3, 6, and 9 designated steaks were removed from display, vacuum-packaged (B-620

121

series; 30 – 50ml $O_2/m^2$ per 24 h; 101325 Pa; 23˚C; Cryovac, Duncan, SC) using an

A300/16 (Multivac, Cryovac, Duncan, SC) and frozen at -29˚ C for subsequent lipid

oxidation analysis.

*Lipid Oxidation*

Frozen steaks designated for lipid oxidation analysis were thawed for 12 h

before analysis. Steaks were trimmed of all external fat and connective tissue. The

steaks were minced and a 150 g sample was collected for further analysis. The remaining

sample was vacuum-packaged (Multi-vac C 200, Multi-vac Inc. Kansas City,MO) and

placed back in frozen storage. Thiobarbituric acid reactive substance (TBAR) analysis

was conducted from the procedure outline by Ahn et al. (1998) with the following

modifications. A 5 g tissue sample was placed in 50 ml conical centrifuge tube and

homogenized (Tissumizer®, Mark II, Tekmar® Company, Cincinnati, OH) with 15 ml of

deionized water for 30 s. A 1 ml aliquot of homogenate was transferred to a labeled

disposable glass test tube ($13 \times 100$ mm). Fifty microliters of butylated hydroxyanisole

(7.2%) and 2 ml thiobarbituric acid/trichloroacetic acid (TBA/TCA) solutions were added

to the homogenate. The solution was votexed and then incubated in a boiling water bath

for 15 min for color formation. After color formation, the sample was cooled for 10 min

in 25˚C tap water. The test tubes were then centrifuged at $3130 \times g$ (CR 312, Jouan Inc.,

Winchester, VA) for 15 min. Absorbance of the supernatant was read at 531 nm (Jasco

V-630 Spectrophotmeter, Jasco Inc., Easton, MA). Samples were analyzed in duplicate

and lipid oxidation was expressed in mg of malonaldehyde (MDA) per kg of tissue.

*Preparation and Analysis of Fatty Acid Methyl Esters (FAME)*

The lipid extract (procedure previously defined) from the muscle tissue containing approximately 2 mg of total lipids, based on the calculated percentage of lipids on a wet tissue basis, were transmethylated (Park and Goins, 1994). Fatty acid methyl esters were analyzed using an Agilent 6850 gas chromatograph (Agilent Technologies, Santa Clara, CA) equipped with an Agilent 6850 automatic sampler Agilent Technologies). Separations were accomplished using a 100-m Sp2560 capillary column (5 mm i.d. and 0.20-µm film thickness; Supelco, Bellafonte, PA) according to the method of Duckett et al. (2002). Column oven temperature increased from 150 to 160°C at 1°C per min, from 160-167°C at 0.2°C per min, from 167 to 225°C at 1.5°C per min, and was then held at 225°C for 16 min. The injector and detector temperature were maintained at 250°C. Sample injection volume was 1µl. Hydrogen was the carrier gas at flow rate of ml/min. Individual fatty acids were identified by comparisons of retention times with standards (Sigma, St. Louis, MO; Supleco; Matreya, Pleasant Gap, PA). The fatty acids were quantified by incorporating an internal standard, methyl heptacosanoic acid (C27:0), into each sample during methylation and were expressed as % of total fatty acids.

*Statistical Analysis*

All data were analyzed using the Mixed procedure of SAS V.9.1 (2002, SAS Institute Inc., Cary, NC). Means were separated using the PDIFF option in LSMEANS for all analysis. Proximate analyses, fatty acid analysis and lipid oxidation were analyzed as a completely randomized design with the steak from each animal serving as experimental and observational unit. Carcass within treatment was considered the

123

random variable. Data for WBS were analyzed similar to proximate, fatty acid and lipid

oxidation analysis with the exception that muscle core was considered the observational

unit and degree of doneness was analyzed as a covariate.  Data for objective and

subjective color over the course of retail display were analyzed using REPEATED

measures with day as the repeated variable.  Steak was considered the experimental and

observational unit. Carcass within treatment was considered the random variable.

Multiple value recordings were not averaged prior to statistical analysis. Differences

among means were considered significant at $\alpha < 0.05$ with tendencies at $\alpha < 0.10$.

## Results and Discussion

*Proximate analysis*

Moisture content tended to be higher ($P = 0.07$) in steaks from steers fed DDGS

than those fed CGF with SBM being intermediate (Table 5.2). Protein and lipid content

were similar ($P > 0.10$) among treatments (Table 5.2).  This data is similar to that of

Jenschke et al. (2008) who found no differences in the moisture, protein, or lipid content

of beef knuckles fed wet distillers grains with alfalfa hay, corn stalks, or corn silage

indicating that concentration of distillers grains in the diet has no affect on moisture,

protein, or lipid content of the muscle.  Aldai et al. (2010) fed corn and wheat dried

distillers grains plus solubles to beef cattle in comparison to a barley-based finishing diet

and found no differences between corn byproducts and either of the alternative treatments

in terms of lean tissue composition.   Furthermore, Mills et al. (1992) examined the

composition of beef rib roasts in Holstein and crossbred beef steers fed differing levels of

bypass protein (soybean meal or fish meal) supplementation on alfalfa haylage or corn

silage-based finishing diets.  No differences were found for percent moisture, protein or lipid in roasts from cattle fed differing protein supplements.

*Warner-Bratzler shear force*

No differences ($P < 0.10$) were found for purge loss or cook loss among treatements (data not shown). However, a treatment by day interaction occurred for WBS where steaks from steers fed SBM were less ($P \leq 0.02$) tender than DDGS or CGF steaks at d 7.   Steaks from all treatments showed improved ($P < 0.01$) tenderness by d 21, and there was no difference ($P > 0.1$) among treatments after d 7.  However, steaks from steers fed CGF were less ($P = 0.01$) tender at d 14 than at d 7. Degree of doneness was similar ($P > 0.05$) for all treatments and times.  These results differ from the majority of research on tenderness in relation to CGF and DDGS.   Koger et al. (2004), Roeber et al. (2005) and Gill et al. (2008) all reported no differences in WBS among increasing inclusion levels of distillers grains or compared to soybean meal controls.  Brandt et al. (1992) observed no difference in WBS of steaks from steers fed yellow grease and corn compared to steam flaked sorghum or steam flaked corn, suggesting that unsaturated fatty acid content of the diet has little effect on tenderness.  Little research has been conducted to determine the effects of CGF supplementation on tenderness.  It is important to note that Shackelford et al. (1991) documented the US consumer threshold for "slightly tender" in retail food service industries to be from 3.9 to 4.6 kg WBS, and that all steaks fell well below this threshold.

*Shelf-life*

A treatment by day interaction ($P = 0.04$) was detected for subjective color evaluation by a trained consumer panel (Figure 6.1). At d 9 steaks from steers fed SBM were considered redder ($P = 0.01$) than DDGS steaks. These findings were corroborated by greater ($P < 0.05$) a* values at d 6 and 9 for DDGS steaks. Because Zerby et al. (1999) reported that visual redness scores were moderately to highly correlated to instrumental a* value, this outcome was expected. These data agree with Roeber et al.( 2005) where a trained panel found strip steaks from soybean meal supplemented steers to be redder than those from steers fed 40% dried distillers grains plus solubles. Also, redness decreased *($P < 0.01$)* over time across treatments. No difference ($P = 0.17$) was found among treatments for overall acceptance, but acceptance did decline ($P < 0.01$) over time. There was a treatment by day interaction ($P < 0.01$) for discoloration where CGF steaks had a higher percentage of discoloration ($P < 0.04$) at d 3 and d 6, but by d 9 DDGS steaks were more discolored ($P = 0.003$) than SBM steaks with CGF steaks being intermediate. Discoloration scores all decreased ($P < 0.01$) over time. This data agrees with Gill et al. (2008) and Nelson et al. (2000) who attributed decreasing shelf-life characteristics to meat deterioration resulting from lipid oxidation during time on retail display, however, Gill et al. (2008) also reported no treatment affects for steaks from steers fed DDGS or sorghum DDGS compared to steam-flaked corn. Roeber et al. (2005) also employed a trained panel to evaluate overall acceptance, color, and discoloration, in a second experiment and reported that when steaks from steers fed 0, 12.5, 25, or 50% DM DDGS or WDGS were compared to a SBM control, steaks from steers fed the highest levels of DDGS and WDGS were most likely to receive scores of

"moderately unacceptable" or lower compared to SBM due to increased discoloration. Decreased redness and acceptance as well as increased discoloration over time on retail display is to be expected given the process of lipid oxidation during time on retail display results in meat color deterioration (Gill et al., 2008)

Objective color changes over time are presented in Figure 6. 2. For objective color measurements over 9 d retail display, L* was affected ($P = 0.04$) by protein supplement with steaks from CGF steers being lightest ($P < 0.04$) compared to those from DDGS or SBM steers (Figure 6.2). This difference may be due to greater reflectance due to the numerically higher ($P > 0.10$) marbling scores between CGF and DDGS or SBM steaks (see Chaper 4). This disagrees somewhat with Romans et al. (1965) who found no differences in pigment content of muscle among steaks with differing marbling scores. However, the conclusions offered by Romans et al. (1965) does not account for differences in reflectance when insturmental analysis is used. Alternatively, Leupp et al. (2009) suggested that 30% inclusion of DDGS in feedlot diets tended ($P = 0.08$) to reduce L* values. This disagrees with Gunn et al. (2009) and Hutchison et al. (2006) who reported lighter L* values in top rounds and strip steaks from steers fed high-fat diets.

A treatment by day interaction ($P = 0.004$) occurred for a* values where all steaks became less ($P < 0.01$) red over time (Figure 6.2). However, steaks from steers fed SBM retained greater ($P < 0.05$) red color at d 6 and 9 than did steaks from DDGS- or CGF-fed steers. This is likely due to reduced rate of color deterioration in SBM steaks as was noted in subjective color evaluations during retail display. Steaks from steers fed DDGS

127

and CGF became less ($P \leq 0.01$) red between each subsequent measurement over time, while SBM steaks were similar ($P = 0.50$) in redness at d 3 and 6. Gill et al. (2008) reported that steers fed no DDGS had redder ($P = 0.013$) steaks than those fed DDGS. Conversely, Roeber et al. (2005) reported increased redness in steaks from steers fed DDGS and attributed it to increased xanthophylls, a concentrated pigmentation from corn. Steaks from steers fed DDGS tended to be less ($P = 0.08$) yellow (lower b*) than steaks from CGF or SBM fed steers.

Lipid oxidation indicated by TBAR concentrations increased ($P < 0.01$) over time as expected, however, no differences ($P = 0.74$) were found among steaks from differing protein supplementation groups (Figure 6.3). Similarly, no differences were found among increasing levels of DDGS for lipid oxidation compared to steam-flaked corn (Depenbusch et al. 2009). Oxidation can be controlled by the amount of antioxidant compounds found in the muscle tissue (Calkins and Hogden, 2007). Grass-fed beef may be less prone to lipid oxidation than grain-fed beef because of the increased levels of vitamins A, C, and E, artonenoids, and flavonoids found in forages (Wood & Enser, 1997). However this disagrees with Gill et al. (2008) attributed increases in pre-display lipid oxidation to the increased PUFA levels from the lipid fraction of DDGS fed at 15% of the diet DM.

*Fatty Acid Composition*

Data for LL fatty acid composition are reported in Table 5.4. Steaks from steers fed DDGS had decreased levels of MUFAs ($P = 0.02$) and increased PUFAs ($P = 0.01$) compared to CGF and SBM steaks. This was expected due to the total n-6 fatty acids ($P$

= 0.01) in steaks from DDGS fed steers. These differences are largely attributed to increased ($P = 0.01$) levels of the C18:2$^{trans-10, \ cis-12}$ isomers by approximately 60 % when compared to CGF and SBM steaks, as well as an approximate 70% increase in ($P = 0.01$) C18:2$^{cis-9, \ cis-12}$ in DDGS steaks. As expected, steaks from DDGS fed steers had higher ($P = 0.01$) PUFA in relation to saturated fatty acids (PUFA: SFA). This was expected due to the increase concentration of corn oil in the DDGS diet (NRC, 1996).

Soybean meal tended ($P = 0.07$) to have a higher ratio of unsaturated to saturated fatty acids than DDGS and CGF. This was unexpected, but is likely due to an increase ($P = 0.02$) of 0.5% in the MUFA:SFA for SBM when compared to DDGS and SBM. Also, CGF steaks tended to have the highest ($P = 0.08$) levels of total SFA. This is likely due to the extrusion of fat during the wet milling process of CGF to produce corn oil (Hoffman, 1989) as this process removes the majority of the unsaturated fatty acids. It is important to note that while increased levels of SFA are expected with high-starch diets. Steaks from steers fed CGF had higher ($P = 0.05$) levels of palmitic acid (C 16:0) and decreased ($P = 0.03$) levels of oleic acid (C18:1$^{cis-9}$) compared to SBM and DDGS steaks. Cabezas et al. (1965) attributed decreased saturation in kidney and 12$^{th}$ rib fat to a decreased ratio of C16:0 to C18:1$^{cis-9}$. They also suggested higher degrees of unstaturation in fatty acids resulted either when rumen fermentation was altered via the acetate:propionate ratio to decrease the activity of hydrogenation enzymes, or when fewer H donor compounds exist in the diet (Cabezas et al., 1965). The SBM diet contained more ground corn than the CGF diets and ground corn contains the corn oil component that has been extruded from CGF. High starch diets have been shown to increase

129

unsaturation of adipose tissue over the 12th rib and in the kidney fat compared to low starch (citrus meal) diets (Cabezas et al., 1965).

The increased ($P = 0.05$) levels of C16:0 in CGF steaks is a point of concern. Hegsted et al. (1965) found that lauric (C12:0), myristic (C14:0) and palmitic (C16:0) acids are the primary fatty acids associated with increasing plasma low-density lipoprotein and total cholesterol concentrations in the human body. Steaks from DDGS steers had higher ($P = 0.003$) levels of n-6 fatty acid and subsequently a higher ($P = 0.01$) n-6:n-3 fatty acid ratio. This was due to increased levels ($P = 0.005$) of linoleic (C18:2$^{cis-9,\ cis-12}$) acid and the C18:2$^{trans-10,\ cis-12}$ ($P = 0.01$ ) CLA isomer given that α-linolenic acid (C18:3$^{cis-9,cis-12,\ cis-15}$), the major n-3 fatty acid in cattle diets (Gill et al., 2008), as well as, total n-3 fatty acids did not differ ($P > 0.05$).

The n-6 and n-3 fatty acids are well known for their positive effects on human health ( Gill et al., 2008). Linoleic acid is utilized by the body to produce proinflammatory eicosanoids (Akoh and Min, 2002) and to moderate blood cholesterol levels (Zock and Katan, 1998). The n-6:n-3ratio has been linked to the occurrence of blood clots and subsequent heart attacks (Esner, 2001). Therefore, it is recommended that the n-6:n-3 ratio not exceed 4 (Wood et al., 2002). While the health benefits of these fatty acids are well known, modern consumers enjoy a diet rich in n-6 fatty acids and yet deficient in n-3 fatty acids, a competitive inhibitor in the inflammatory process (Gill et al., 2008). Realistically improving the n-6:n-3 ratio in the diet from the average 10.6: 1 is unlikely largely due to the high-concentrate diets used in feedlots (Gill et al., 2008).

## Conclusions and Implicatons

Composition and tenderness of LL steaks was unaffected by protein supplement. Although differences in perceived color were observed, consumer acceptability was similar among steaks from differing treatment groups.  No differences were found in concentration of TBARs among treatment groups. However, steaks from steers fed DDGS became more discolored than SBM steaks after 9 d of retail display and contained higher levels of PUFAs suggesting that a numerical increase in lipid oxidation may result in reduced shelf-life for meat products from cattle fed DDGS long-term.  This study suggests that DDGS and CGF can be substituted for SBM in beef cattle diets from weaning to slaughter and maintain meat quality.  With the increasing economic instability of feed inputs these feedstuff may provide producers with access to an opportunity to produce high-quality beef at reduced input costs compared to traditional protein supplements.

## Literature Cited

Ahn, D. U., D. G. Olson, J. I. Lee, C. Jo, C. Wu and X. Chen. 1998. Packaging and irradiation effects of lipid oxidation an volatiles in pork patties. J. Food Sci. 63: 15-19.

Akoh, C. C., and D. B. Min. 2002. Structured lipids. Pages 883-884 in Food Lipids Chemistry, Nutrition, and Biotechnology. 2nd ed. Marcel Dekker Inc., New York, NY.

Aldai, N., J. L. Aalhus, M. E. R. Dugan, W. M. Robertson, T. A. McAllister, L. J. Walter, J. J. McKinnon. 2010. Comparison of wheat- versus corn-based dried distillers' grains with solubles on meat quality of feedlot cattle. Meat Sci. 84:569-577.

Al-Suwaiegh, S., K. C. Fanning, R. J. Grant, C. T. Milton, and T. J. Klopfenstein. 2002 Utilization of distillers grains from the fermentation of sorghum or corn in diets for finishing beef and lactating dairy cattle. J. Anim. Sci. 80: 1105-1111.

AMSA. 1995. Research Guidelines for Cookery: Sensory Evaluation and Instrumental Tenderness Measurements of Fresh Meat. Am. Meat Sci. Assoc. and Natl. Livest. And Meat Board, Chicago IL.

AOAC (Association of Official Chemists), 1990. Official Methods of Analysis of the Association of Official Analytical Chemists, 15th edn. AOAC, Inc. Arlington, VA pp 1298.

Brandt Jr., R. T., G. L. Kuhl, R. E. Campbell, C. L. Kastner, and S. L. Stroda. 1992. Effects of steam-flaked sorghum grain or corn and supplemental fat of feedlot

performance, carcass traits, longissimus composition, and sensory properties of steers. J. Anim. Sci. 70:343-348.

Cabezas, M. T., J. F. Hentges, Jr., J. E. Moore, and J. A. Olson. 1965. Effect of diet on fatty acid composition of body fat in steers. J. Anim. Sci. 24: 57-61.

Calkins, C. R., J. M. Hodgen. 2007. A fresh look at meat flavor. Meat Sci. 77: 63-80.

Depenbusch, B. E., J. S. Droulliard. E. R. Loe, M. E. Corrigan, and M. J. Quinn. 2008b. Efficacy of moninsin and tylosin in finishing diets based on steam-flaked corn with and without corn wet distillers grains with solubles. J. Anim. Sci. 86: 2270-2276.

Duckett, S. K., J. G. Andrae, and F.N. Owens. 2002. Effect of high-oil corn or added corn oil on ruminal biohydrogenation of fatty acids and conjugated linoleic acid formation in beef steers fed finishing diets. J. Anim. Sci. 80:3353-3360.

Esner, M. 2001. The role of fats in human nutrition. Oils and fats, Animal carcass fats, Leatherhead Publishing. Leatherhead, Surrey, UK. 2: 77-122.

Firkins, J.L., L. L. Berger, and G. C. Fahey, Jr. 1985. Evaluation of wet and dry distillers grain and wet and dry corn gluten feeds for ruminants. J. Anim. Sci. 60:847-860.

Folch , J., M. Lees, and G. H. Sloane Stanley. 1957. A simple method for the isolation and purification of total lipids from animal tissues. J. Biol. Chem. 226:497-509.

Gill, R. K., D. L. VanOverbeke, B. Depenbusch, J. S. Droulliard, and A. DiCostanzo. 2008. Impact of beef cattle diets containing corn or sorghum distillers grains on beef color, fatty acid profiles, and sensory attributes. J. Anim. Sci. 86: 923-935.

Gunn, P. J., A. D. Weaver, R. P. Lemenager, D. E. Gerrard, M. C. Claeys, and S. L. Lake. 2009. Effects of dietary fat and crude protein on feedlot performance, carcass characteristics, and meat quality in finishing steers fed differing levels of dried distillers grains with solubles. J. Anim. Sci. 2009. 87: 2882-2890.

Ham, G. A., R. A. Stock, T. J. Klopfenstein, E. M. Larson, D. H. Shain, and R. P. Huffman. 1994. Wet corn distillers byproducts compared with dried corn distillers grains with solubles as a source of protein and energy for ruminants. J. Anim. Sci. 72: 3246-3257.

Hegsted, D. M., R. B. McGrandy, M. L. Myers, and F. J. Stare. 1965. Quantitative effects of dietary fat on serum cholesterol in man. Am. J. Clin. Nutr. 17:281-295.

Hoffman, P.C. 1989. Corn Gluten Feed. Bulletin No. A3518. University of Wisconsin-Madison. Accessed 5/17/2010. http://learningstore.uwex.edu/assets/pdfs/a3518.pdf.

Hunt, M. C., J. C. Acton, R. C. Benedict, C. R. Calkins, D. P. Cornforth, L. E. Jeremiah, D. G. Olson, C. P. Salm, J. W. Savell, and S. D. Shivas. 1991. Pages 1-17 in Guidelines for meat color evaluation. Proceedings of 44th Recip. Meat Conf., Manhattan, KS.

Hutchison, S., E. B. Kegley, J. K. Apple, T. J. Wistuba, M. E. Dikeman, and D. C. Rule. 2006 Effects of adding poultry fat in the finishing diet of steers on performance, carcass characteristics, sensory traits, and fatty acid profiles. J. Anim. Sci. 84: 2426-2435.

Jenschke, B. E., J. R. Benton, C. R. Calkins, T. P. Carr, K. M. Eskridge, T. J. Klopfestein, and G. E. Erickson. 2008. J. Anim. Sci. published online Jan. 11, 2008. http://jas.fass.org

Kinman, L. A., D. L. VanOverbeke, C. R. Richards, R. B. Hicks and J. W. Dillwith. 2008. Influence of feeding various levels of wet and dry distillers grains to yearling steers on carcass characteristics, meat quality, fatty acid profile, and retail case life of longissimus muscle. 2008 Animal Science Research Reports. Oklahoma State University, Stillwater. http://www.ansi.okstate.edu/research/research-reports-1/2008/08kinman_rr.pdf. Accessed online July 2, 2010.

Klopfenstein, T.1996. Distillers grains as an energy source and effect of drying on protein availability. Animal Feed Science Technology. 60: 201-207.

Klopfenstein T. J., G. E. Erickson, and V. R. Bremer. 2007. BOARD-INVITED REVIEW: Use of distillers byproducts in the beef cattle feeding industry. J. Anim. Sci. published online Dec 21, 2007. http://jas.fass.org.

Koger, T. J., D. M. Wulf, K. E. Tjardes, K. S. Mateo, T. E. Engle, C. L. Wright, and R. J. Maddock. 2004. The influence of feeding various levels of wet distillers grains on carcass quality, carcass composition, and fatty acid profile of finishing steers. Proc. 57th Recip. Meats Conf. http://www.meatscience.org Accessed May 24, 2010.

Kris-Etherton, P. M., D. S. Taylor, S. Yu-Poth, P. Huth, K. Moriarty, V. Fishell, R.L. Hargrove, F. Zhao, and T. D. Etherton. 2000. Polyunsaturated fatty acids in the food chain in the United States. Am. J. Clin. Nutr. 71(Suppl.):179S-188S.

Loor, J. J. and J. H. Herbein. 1998. Exogenous conjugated linoleic acid isomers reduce bovine milk fat concentration and yield by inhibiting *de novo* fatty acid synthesis. J. Nutr. 128: 2411-2419.

Mancini, R. A., M. C. Hunt. 2005. Current research in meat color. Meat Sci. 71: 100-121.

McGuire, M. A., and M. K. McGuire. 2000. Conjugated linoleic acid (CLA): A ruminant fatty acid with beneficial effects on human health. Proc. Am. Soc. Anim. Sci. 1999. http://www.asas.org/jas/symposia//proceedings/0938.pdf Accessed Jun 29, 2010.

Mills, E. W., J. W. Comerford, R. Hollender, H. W. Harpster, B. House and W. R. Henning. 1992. Meat composition and palatability of Holstein and beef steers as influenced by forage type and protein source. J. Anim. Sci. 70:2446-2451

Muchenje, V., K. Dzama, M. Chimonyo, P. E. Strydom, A. Hugo, and J. G. Raats. 2009. Some biochemical aspects pertaining to beef eating quality and consumer health: A review. Food Chem. 112:279-289.

Muir, P. D., G. J. Wallace, P. M. Dobbie, and M.D. Brown. 2000. A comparison of animal performance and carcass and meat quality characteristics in Hereford, Hereford x Friesian, and Friesian steers grazed together at pasture. New Zealand Journal of Agricultural Research. 43:193-205.

Nelson, M. L., J. R. Busboom, J. D. Cronrath, L. Falen, and A. Blankenbaker. 2000. Effects of graded levels of potato by-products in barley-and corn-based beef feedlot diets: I Feedlot performance, carcass traits, meant composition, and appearance. J. Anim. Sci. 78: 1829-1836

NRC 1996. Nutrient Requirement of Beef Cattle. 7th ed. National Academy Press, Washington, DC.

Park, P. W. and R. E. Goins. 1994. In situ preparation of FAME for analysis of fatty acid composition in food. J. Food Sci. 59:1262-1266.

Roeber, D. L., R. K. Gill, and A. DiCostanzo. 2005. Meat quality responses to feeding distiller's grains to finishing Holstein steers. J. Anim. Sci. 83: 2455-2460.

Romans, J. R., H. J. Tuma, and W. L. Tucker. 1965. Influence of carcass maturity and marbling on physical and chemical characteristics of bee II. Muscle pigments and color. J. Anim. Sci. 24: 686-690.

Shackelford, S. D. J. B. Morgan, H. R. Cross, and J. W. Savell. 1991. Identification of threshold levels for Warner-Bratzler shear force in beef top loin steaks. J. Muscle Foods. 2: 289-296.

Stephens, J. W., J. A. Unruh, M. E. Dikeman, M. C. Hunt, T. E. Lawrence, and T. M. Loughin. 2004. Mechanical probes can predict tenderness of cooked beef longissimus using uncooked measurements. 82: 2077-2086.

Uwituze, S., G.L. Parsons, M.K. Shelor, B. E. Depenbusch, K. K. Karges, M. L. Gibson, C. D. Reinhardt, J. J. Higgens and J. S. Droulliard. 2010. Evaluation of dried

distillers grains and roughage source in steam-flaked corn finishing diets. J. Anim. Sci. 88: 258-274.

Vander Pol, K. J. M. K. Luebbe, G. I. Crawford, G.E. Erickson, and T. J. Klopfenstein. 2009. Performance and digestibility characteristics of finishing diets containing distillers grains, composites of corn processing coproducts, or supplemental corn oil. J. Anim. Sci. 87: 639-652.

Williams, C. M. 2000. Dietary fatty acids in human health. Anim. Research. 49: 165-180.

Wood, J. D. and M. Enser. 1997. Factors influencing fatty acids in meat and the role of antioxidants in improving meat quality. Brit. J.  Nutr.78 (Suppl. 1), S49–S60.

Wood, J. D., R. I. Richardson, G. R. Nute, A. V. Fisher, M. M. Campo, E. Kasapidou, P. R. Sheard, and M. Esner. 2002. Effects of fatty acids on meat quality. Meat Sci. 66: 21-32.

Zerby, H. N., K. E. Belk, J. N. Sofos, L. R. McDowell, and G. C. Smith. 1999. Case life of seven retail products from beef cattle supplemented with α-tocopheryl acetate. J. Anim. Sci. 77:2458-2463

Zock, L., and M. B. Katan. 1998. Linoleic acid intake and cancer risk:  A review and meta-analysis. Am. J. Clin. Nutr. 68:142-153.

**Table 5.1**. Dry matter composition of feedlot diets supplemented with corn gluten feed (CGF), dried distillers grains plus soluble (DDGS) or soybean meal/corn (SBM).

| Ingredient[1], % DM | Diet | | |
|---|---|---|---|
| | CGF | DDGS | SBM |
| SBM | 0.0 | 0.0 | 9.6 |
| CGF | 24.5 | 0.0 | 0.0 |
| DDGS | 0.0 | 24.5 | 0.0 |
| Ground Corn | 47.9 | 47.9 | 62.6 |
| Soy Hulls | 8.2 | 8.2 | 8.2 |
| Cottonseed Hulls | 8.2 | 8.2 | 8.3 |
| Citrus Pulp | 8.2 | 8.2 | 8.3 |
| Vitamin Premix | 3.0 | 3.0 | 3.0 |
| *Chemical Composition,%* | | | |
| DM | 90.56 | 90.91 | 90.21 |
| CP | 13.37 | 15.88 | 14.16 |
| NDF | 28.23 | 25.53 | 19.99 |
| ADF | 11.67 | 11.28 | 9.92 |
| Ash | 5.31 | 4.42 | 5.00 |

[1]All sources were procured from the same distributor and are expressed on a DM basis.

Different loads of CGF, DDGS and SBM were averaged.

**Table 5.2.** Least squares means for proximate analysis of beef strip steaks from steers fed corn gluten feed (CGF), dried distillers grains plus solubles (DDGS), or soybean meal with corn (SBM) as a protein source from weaning to slaughter

| | Protein Supplement | | | |
|---|---|---|---|---|
| *Item* | CGF | DDGS | SBM | SEM |
| Moisture[1], % | 71.38 | 73.11 | 72.29 | 0.52 |
| Protein, % | 22.83 | 23.08 | 23.51 | 0.39 |
| Lipid[2], % | 5.31 | 3.83 | 4.22 | 0.54 |

[1]AOAC, 1990

[2] Folch et al., 1957

**Table 5.3.** Least squares means for Warner-Bratzler shearforce (kg) in beef strip steaks from steers fed corn gluten feed (CGF), dried distillers grains plus solubles (DDGS), or soybean meal with corn (SBM) as a protein source[1]

|  | Protein Supplement | | |
|---|---|---|---|
| Day | CGF | DDGS | SBM |
| 7 | $3.16^{b,y}$ | $3.34^{b,x}$ | $3.86^{a,x}$ |
| 14 | $3.46^{x}$ | $3.32^{x}$ | $3.70^{x}$ |
| 21 | $2.80^{z}$ | $2.68^{y}$ | $2.95^{y}$ |

[1]SEM = 0.30

[ab]means with differing superscripts differ within row ($P < 0.05$)

[xyz]means with differing superscripts differ within column ($P < 0.05$)

**Table 5.4.** Fatty acid composition beef strip steaks from steers fed corn gluten feed (CGF), dried distillers grains plus solubles (DDGS), or soybean meal with corn (SBM) as a protein source from weaning to slaughter

| Fatty Acid[1], % of total fatty acids | Protein Supplement | | | SEM | Effect |
|---|---|---|---|---|---|
| | CGF | DDGS | SBM | | |
| *Saturated Fatty Acids* | | | | | |
| C 10:0 | 0.02 | 0.00 | 0.01 | 0.01 | $P = 0.32$ |
| C 12:0 | 0.10 | 0.06 | 0.04 | 0.02 | $P = 0.06$ |
| C 14:0 | 3.38 | 3.06 | 3.03 | 0.15 | $P = 0.20$ |
| C 15:0 | 0.55[a] | 0.47[b] | 0.44[b] | 0.20 | $P < 0.01$ |
| C 16:0 | 28.30[a] | 26.42[b] | 26.72[b] | 0.56 | $P = 0.05$ |
| C 17:0 | 1.40[a] | 1.25[b] | 1.24[b] | 0.04 | $P = 0.01$ |
| C 18:0 | 13.32 | 13.90 | 12.72 | 0.50 | $P = 0.24$ |
| C 20:0 | 0.03 | 0.03 | 0.09 | 0.05 | $P = 0.61$ |
| C 21:0 | 0.46 | 0.39 | 0.48 | 0.07 | $P = 0.60$ |
| C 22:0 | 0.38 | 0.54 | 0.49 | 0.09 | $P = 0.46$ |
| *Monounsaturated Fatty Acids* | | | | | |
| *(MUFA)* | | | | | |
| C 14:1 | 0.86 | 0.70 | 0.80 | 0.70 | $P = 0.26$ |
| C 16:1 | 4.14[a] | 3.57[b] | 4.16[a] | 0.20 | $P = 0.03$ |
| C 18:1 *trans-9* | 0.04 | 0.09 | 0.09 | 0.03 | $P = 0.44$ |

| | | | | | |
|---|---|---|---|---|---|
| C 18:1$^{trans-10}$ | 0.22 | 0.26 | 0.22 | 0.30 | $P = 0.50$ |
| C 18:1$^{trans-11}$ | 1.54 | 2.09 | 1.79 | 0.24 | $P = 0.24$ |
| C 18:1$^{cis-9}$ | 39.11$^a$ | 36.28$^b$ | 39.40$^a$ | 0.91 | $P = 0.03$ |
| C 18:1$^{cis-11}$ | 1.37 | 1.25 | 1.33 | 0.07 | $P = 0.45$ |
| *Polyunsaturated Fatty Acids (PUFA)* | | | | | |
| C 18:2$^{cis-9,cis-12}$ | 3.37$^b$ | 4.98$^a$ | 3.55$^b$ | 0.29 | $P = 0.01$ |
| C 18:3$^{cis-9,cis-12, cis-15}$ | 0.24 | 0.21 | 0.26 | 0.02 | $P = 0.20$ |
| C 18:2$^{cis-9, trans-11}$ | 0.34 | 0.32 | 0.38 | 0.03 | $P = 0.51$ |
| C 18:2$^{cis-11,trans-13}$ | 0.049 | 0.044 | 0.038 | 0.003 | $P = 0.25$ |
| C 18:2$^{trans-10,cis-12}$ | 0.016$^b$ | 0.028$^a$ | 0.018$^b$ | 0.002 | $P < 0.01$ |
| C 18:2$^{cis-11, cis-13}$ | 0.00 | 0.002 | 0.00 | 0.001 | $P = 0.41$ |
| C 18:2$^{trans-9, trans-11}$ | 0.01 | 0.01 | 0.03 | 0.02 | $P = 0.51$ |
| C 20:4 $^{cis-5, 8, 11, 14}$ | 0.60 | 0.76 | 0.75 | 0.08 | $P = 0.29$ |
| C 20:5 $^{cis-5, 8, 11, 14, 17}$ | 0.08 | 0.08 | 0.11 | 0.02 | $P = 0.29$ |
| C22:5$^{cis-7, 10, 13, 16, 19}$ | 0.17 | 0.22 | 0.21 | 0.03 | $P = 0.53$ |
| C 22:6 $^{cis-4, 7, 10, 13, 16, 19}$ | 0.01 | 0.03 | 0.02 | 0.01 | $P = 0.35$ |
| *Sums of fatty acid types* | | | | | |
| SFA[2] | 47.97 | 46.11 | 45.26 | 0.84 | $P = 0.08$ |
| MUFA[3] | 47.29$^a$ | 44.24$^b$ | 47.80$^a$ | 0.96 | $P = 0.02$ |
| PUFA[4] | 4.93$^b$ | 6.73$^a$ | 5.42$^b$ | 0.39 | $P = 0.01$ |
| CLA[5] | 3.83$^b$ | 5.43$^a$ | 4.07$^b$ | 0.29 | $P < 0.01$ |
| n-3[6] | 0.50 | 0.54 | 0.60 | 0.05 | $P = 0.44$ |

| | | | | | |
|---|---|---|---|---|---|
| n-6[7] | 4.43[b] | 6.19[a] | 4.82[b] | 0.35 | $P < 0.01$ |
| *Comparison of fatty acid ratios* | | | | | |
| MUFA:SFA | 0.99[b] | 0.96[b] | 1.06[a] | 0.02 | $P = 0.02$ |
| PUFA: SFA | 0.10 | 0.15 | 0.12 | 0.01 | $P < 0.01$ |
| UFA:SFA | 1.09 | 1.11 | 1.18 | 0.03 | $P = 0.07$ |
| n-6:n-3[11] | 9.15[b] | 13.14[a] | 9.13[b] | 1.03 | $P = 0.01$ |

[1]Fatty acids are represented as number of carbon atoms: number of carbon-carbon double bonds

[2]Summation of saturated fatty acids including C10:0, C12:0, C14:0, C15:0, C16:0, C17:0, C18:0,C20:0, C21:0, and C22:0

[3]Summation of MUFAs including C14:1, C16:1, C18:1 $^{trans-9}$, C18:1$^{trans-10}$, C18:1$^{trans-11}$, C18:1$^{cis-9}$, and C18:1$^{cis-11}$

[4]Summation of PUFAs including C18:2$^{cis-9,12}$, C18:3$^{cis-9, 12, 15}$, C18:2$^{cis-11,trans-13}$, C18:2$^{trans-10,cis-12}$, C18:2$^{cis-11, 13}$, C18:2$^{trans-9, 11}$, C20:4 $^{cis-5, 8, 11, 14}$, C20:5 $^{cis-5, 8, 11, 14, 17}$, C22:5$^{cis-7, 10, 13, 16, 19}$, and C22:6 $^{cis-4, 7, 10, 13, 16, 19}$

[5]Summation of CLA isomers including C18:2$^{cis-11,trans-13}$, C18:2$^{trans-10,cis-12}$, C18:2$^{cis-11, 13}$, and C18:2$^{trans-9,11}$

[6]Summation of n-3 fatty acids including C18:3$^{cis-9,cis-12, cis-15}$,C20:5$^{cis-5,cis-8,cis-11,cis-14,cis-17}$, C22:5$^{cis-7, 10, 13,16, 19}$ and C22:6$^{cis-4, 7, 10, 13, 16,19}$

[7]Summation of n-6 fatty acids including C18:2$^{cis-9, 12}$, C18:2$^{cis-11,trans-13}$, C18:2$^{trans-10,cis-12}$, C18:2$^{cis-11, 13}$,C18:2$^{trans-9, 11}$,  and C20:4$^{cis-5,811,14}$

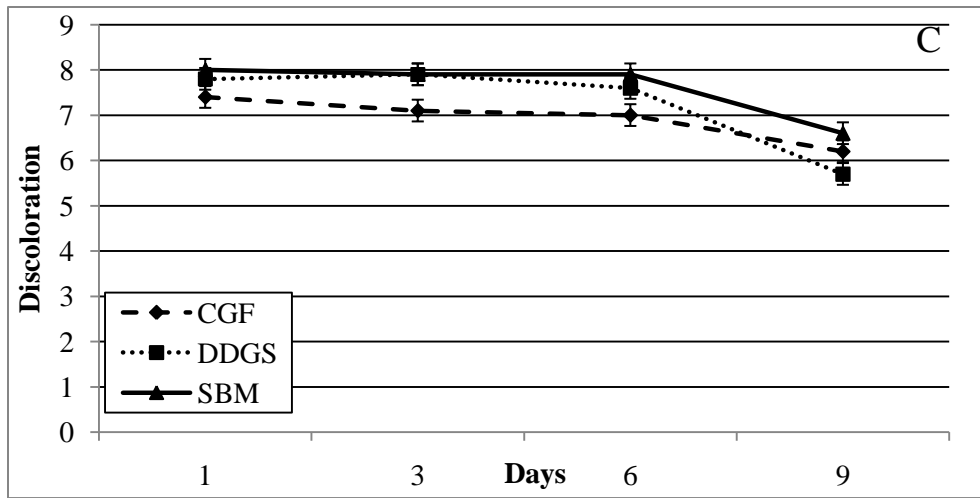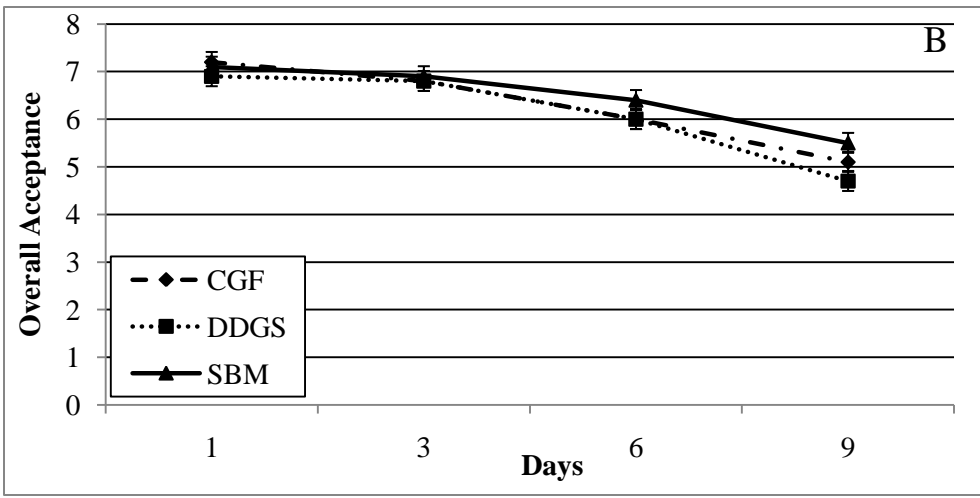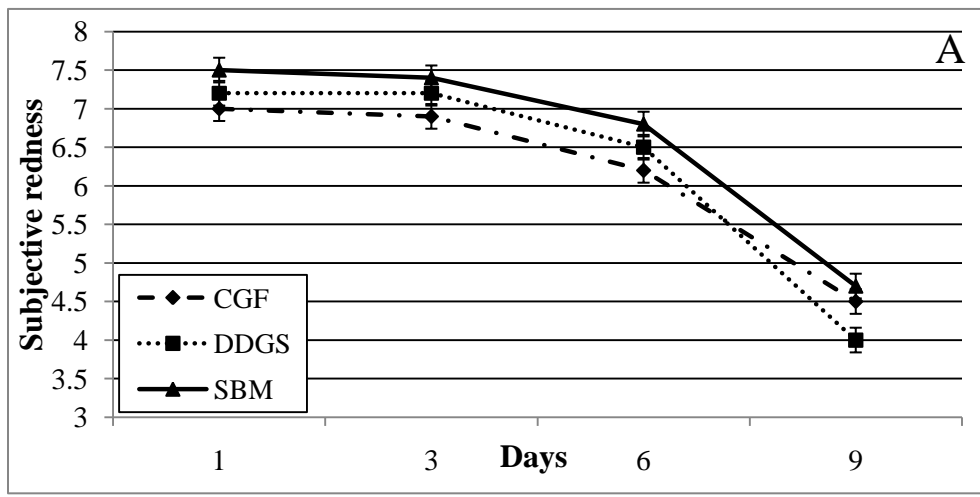[ab]Means with differing superscripts differ within a row ($P < 0.05$)

144

145

**Figure 5.1.** Subjective evaluation over 9 d shelf-life for beef strip steaks from steers fed corn gluten feed (CGF), dried distillers grains plus solubles (DDGS), or soybean meal with corn (SBM) as a protein source from weaning to slaughter.  **A.)** Subjective redness (1 = extremely dark red, 8 = extremely bright cherry red) showed a treatment by day interaction ($P = 0.04$) at d 9 steaks from steers fed DDGS became less red ($P = 0.0004$) than SBM steaks. **B.)** Overall acceptance (1 = extremely unacceptable, 8 = extremely acceptable) had no treatment effect ($P = 0.17$) but decreased ($P < 0.05$) over time **C.)**  Discoloration ($1 = 95 - 100\%$ discolored, $8 = 0 - 5\%$ discolored)  showed a treatment by day interaction ($P < 0.001$) where CGF steaks were more ($P \leq 0.04$) discolored at d 3 and d 6, but by d 9 DDGS steaks were more ($P = 0.003$) discolored than SBM steaks
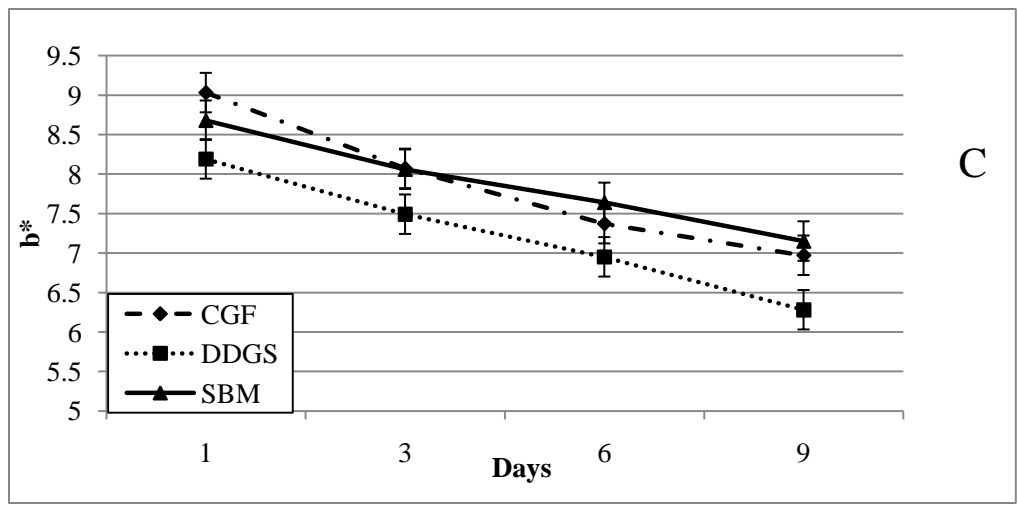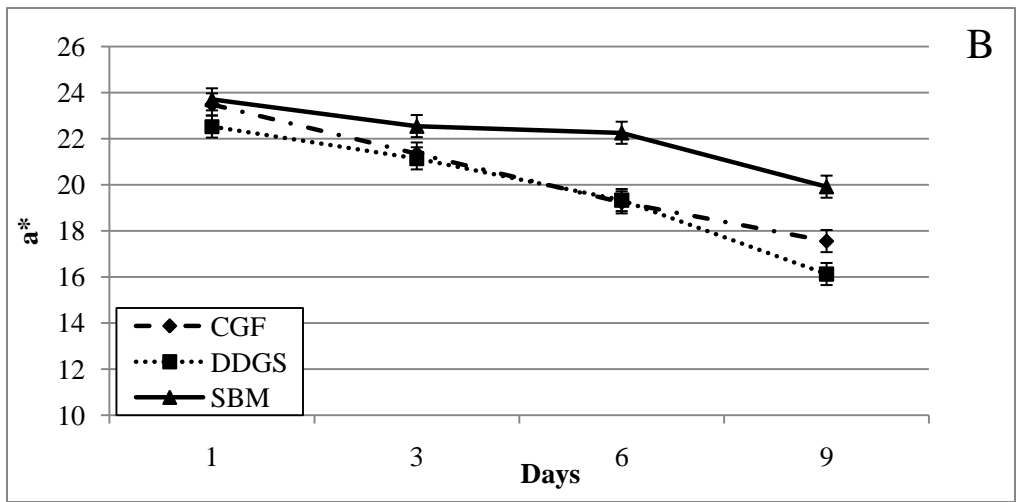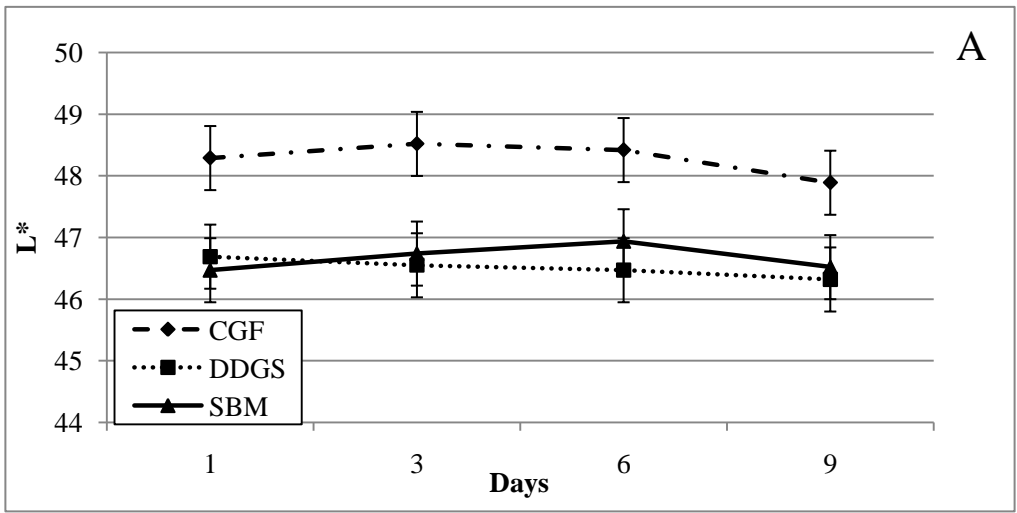
**Figure 5.2.** Objective color over 9 d retail display for beef strip loin steaks from steers fed corn gluten feed (CGF), dried distillers grains plus solubles (DDGS), or soybean meal with corn (SBM) as a protein source from weaning to slaughter.  **A.)** L* (0=black, 100=white) was highest ($P = 0.04$) in steaks from CGF steers.  **B.)**  a* (Higher values indicate redness) showed an interaction ($P = 0.004$) where all steaks became less ($P < 0.01$) red over time.  However, steaks from steers fed SBM retained more ($P < 0.05$) red color at d 6 and d 9.  **C.)**  **b*** (Higher values indicate yellowness) Steaks from steers fed DDGS tended to be less ($P = 0.08$) yellow (lower b*) than steaks from CGF or SBM fed steers.
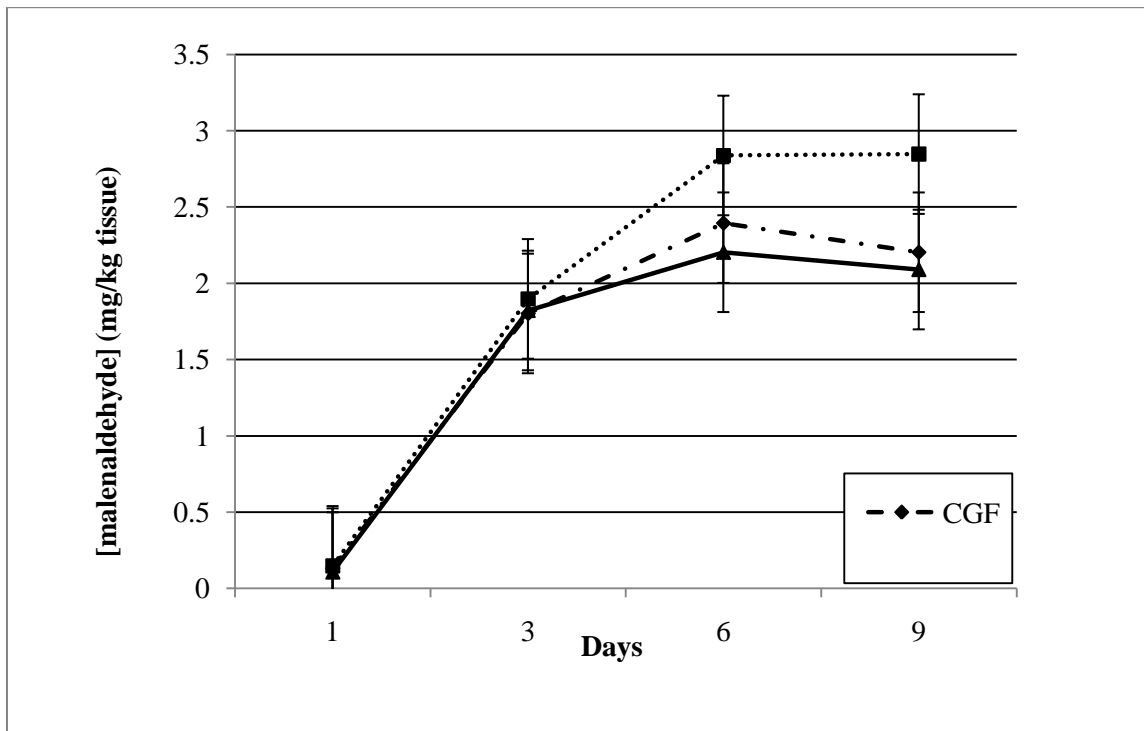
**Figure 5.3.** Lipid oxidation over 9 d shelf-life for beef strip steaks from steers fed corn gluten feed (CGF), dried distillers grains plus solubles (DDGS), or soybean meal with corn (SBM) as the protein source. Thiobarbituric reactive substance concentrations were not different ($P = 0.74$) among protein supplements, but did increase ($P < 0.01$) over time.

CHAPTER 6


CONCLUSION AND IMPLICATIONS


 This research has shown corn gluten feed and dried distillers grains plus solubles to be comparable to soybean meal/corn supplementation in terms of performance and predicted carcass merit for winter stockering systems using corn silage as a forage source.  The added instability of today's economy has caused a renewed interest in finding lower inputs in terms of nutrient sources for ruminants.  Utilizing dried distillers grains plus solubles or corn gluten feed in place of a soybean meal/corn mix to supplement protein in stocker cattle will result in similar economically important traits such as growth and carcass composition.

Nationwide, large-scale retailers are increasingly devoting more shelf space to "locally grown" products.   The added volatility of today's economic climate has opened new doors of opportunity to American beef producers.  This research demonstrates that utilizing DDGS or CGF in place of SBM to supplement protein in finishing cattle will not damage economically important traits, and if cost is decreased for these by-products, it could potentially increase profitability the operation.

Composition and tenderness of steaks was unaffected by protein supplement.  Although differences in perceived color were observed, consumer acceptability was

similar among steaks from differing treatment groups.  No differences were found in

concentration of TBARs among treatment groups. However, steaks from steers fed

DDGS became more discolored than SBM steaks after 9 d of retail display and contained

higher levels of PUFAs suggesting that a numerical increase in lipid oxidation may result

in reduced shelf-life for meat products from cattle fed DDGS long-term.  This study

suggests that DDGS and CGF can be substituted for SBM in beef cattle diets from

weaning to slaughter and maintain meat quality.  With continuing expansion of the

ethanol industry in the United States and the subsequent availability of corn processing

by-products, it is important that further research be conducted to evaluate feed sources in

various roles in southeastern production systems.  These feedstuffs may provide

producers with access to an opportunity to produce high-quality beef at reduced input

costs compared to traditional protein supplements.