EFFECTS OF GRAIN TYPE AND OIL CONCENTRAITON OF CORN DRIED DISTILLERS GRAINS PLUS SOLUBLES ON SITE OF DIGESTION, FINISHING PERFORMANCE, AND CARCASS QUALITY

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Title

Effects Of Grain Type And Oil Concentration Of Corn Dried Distillers Grains Plus Solubles On Site Of Digestion, Finishing Performance, And Carcass Quality

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ABSTRACT

Changes in ethanol processing have resulted in a reduction of oil in the final coproduct, DDGS, available as a feedstuff. Lowering the oil concentration can decrease the total energy in the diet and, therefore, could affect the animal's performance. Therefore, we designed two studies where the objectives were to evaluate the influence of grain type and oil concentration of DDGS on finishing cattle performance, feeding behavior, carcass quality, and site of digestion. Our results indicated that steers fed the barley based diet were more efficient as they had a higher gain to feed ratio. Additionally, there were no effects of oil concentration of DDGS on finishing cattle performance or carcass quality. Finally, there were some differences in site of digestion between barley and corn diets however of DM, OM, CP, and starch however, no differences were found when comparing low versus moderate oil concentration DDGS.

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LIST OF ABBREVIATIONS

ADF.....Acid Detergent Fiber

ADG.....Average Daily Gain ADF

BW.....Body Weight

C.....Celsius

Ca.....Calcium

CDS.....Condensed Distillers Solubles

CO_2.....Carbon Dioxide

CoA.....Coenzyme A

CP.....Crude Protein

Cr_2O_3.....Chromic Oxide

d.....Day

DDGS.....Dried Distillers Grains plus Solubles

DIP.....Degradable Intake Protein

dL.....DeciLiter

DM.....Dry Matter

DMI.....Dry Matter Intake

g.....Grams

G:F.....Gain to Feed Ratio

H+.....Hydrogen Ion

HCL.....Hydrochloric Acid

HCW.....Hot Carcass Weight

kg.....Kilogram

kg/d .....Kilogram per Day

KPH.....Kidney Pelvic Heart

LM.....Loin Eye Muscle

MCT1.....Monocarboxylate transporter 1

MDGS.....Modified Distillers Grains plus Solubles

mg .....Milligram

min .....Minute

mL.....Milliliter

m*M* .....Millimolar

mm .....Millimeter

MP.....Metabolizable Protein

N.....Nitrogen

NaCl .....Sodium Chloride

NAD.....Nicotinamide Adenine Dinucleotide

NADH.....Nicotinamide Adenine Dinucleotide + Hydrogen

NDF.....Neutral Detergent Fiber

NDSU.....North Dakota State University

NRC .....National Research Council

OM .....Organic Matter

P .....Phosphorus

PepT1 .....Peptide Transporter

SGLT1.....Sodium-Glucose Transporter

VFA.....Volatile Fatty Acid

WDGS.....Wet Distillers Grains plus Solubles

CHAPTER 1. LITERATURE REVIEW `

Introduction

Maximizing finishing cattle efficiency is of the utmost importance for producers as feed costs account for approximately 70% of total expenses for producers (Metzger, 2005). Typical receiving diets are higher in forage with the mean forage inclusion being 40% or higher of diet dry matter (Samuelson et al., 2016). The majority of finishing diet contain over 60% grain (Samuelson et al., 2016). Different regions of the United States utilize different grains as their main concentrate. In the Midwest and northern Great Plains of the United States the main grain used is corn, in the southern Great Plains corn is the main grain used, however, milo is often utilized, and barley is the most common grain used in diets in the northwestern United States (Field, 2007). A survey sent to nutritionists in the USA indicated that a majority of finishing operations (87.5%) use corn as the main grain source in backgrounding diets and 100% of finishing operations reported using corn as the main grain source in finishing diets (Samuelson et al., 2016). The use of grain has decreased in finishing diets, however, as coproducts such as grain milling coproducts have partially replaced grains as a source of energy and protein (Samuelson et al., 2016). This review will summarize literature which discusses feeding distillers grains coproducts to cattle as well as how ruminants digest and utilize nutrients such as starch, protein, and lipids.

Feeding DDGS to livestock

Expansion of the grain milling industry for ethanol production has made grain milling coproducts a viable option for use in finishing cattle diets as a source of both energy and protein (Klopfenstein et al., 2008). The use of grain milling coproducts has increased yearly since 2007 (Samuelson et al., 2016). The main coproduct utilized in finishing diets is wet distillers grains

(70.8%) while dried distillers grains is the second most utilized coproduct (16.7%; Samuelson et al., 2016). The NRC (2000) indicates that corn dried distillers grains plus solubles (DDGS) typically has a nutrient composition of 10 to 15% fat, 40 to 45% NDF, 28 to 30% CP, and 5% ash which is approximately three times higher than corn and could potentially have a higher feeding value than corn (Klopfenstein et al., 2008). Therefore, producers can utilize DDGS not only as a protein supplement but also as an energy replacement for grain; typically corn (Klopfenstein et al., 2008). Anderson et al. (2010) showed an increase in gain to feed ratio (G:F) with increasing levels of DDGS in finishing cattle diets. Increasing inclusion of wet distillers grains plus solubles (WDGS) from 0 to 35% resulted in a linear decrease in feed to gain ratio which indicates improved cattle efficiency (Jolly et al., 2014). Bremer et al. (2015) evaluated the effects of increasing concentration of modified distillers grains plus solubles (MDGS) in the diet on cattle performance and reported a linear decrease in feed to gain ratio. Ham et al. (1994) indicated an improvement in cattle efficiency when comparing WDGS to a control diet with no grain milling coproducts as well as an improvement of cattle efficiency when comparing the control diet to a diet containing 40% DDGS. While this is the typical pattern found with increasing levels of distillers grains plus solubles in the diet, a study done by Gibb et al. (2008) indicated that increasing levels of wheat dried distillers grains plus solubles in the diet, did not influence G:F in backgrounding diets but did result in a linear decrease of G:F in finishing diets which indicates poorer cattle efficiency. This indicates that there likely are differences in the quality of distillers grains produced from different grain sources.

Feeding DDGS to finishing cattle could shift the site of nutrient digestion. Leupp et al. (2009) indicated a decrease in ruminal organic matter (OM) digestibility with increasing (0% to 45%) corn DDGS in high grain diets but no difference in total tract OM digestibility was

observed which indicates a shift in the location of digestion to the intestine. This could reduce the incidence of acidosis and liver abscesses in finishing cattle which could increase productivity (Xu et al., 2013). Xu et al. (2013) found increasing levels of DDGS (20% to 40%) increased the percent of total starch digested in the intestine. There was, however, no difference found in mean ruminal pH. The minimum pH was increased in higher DDGS diets vs control and lower DDGS diets and the higher DDGS also decreased the amount of time that ruminal pH was lower than 5.5 per day (Xu et al., 2013). This could be important for barley-based diets as barley is more rapidly fermentable in the rumen than corn (Yang et al., 1997) and therefore could potentially result in a higher risk for an animal to experience acidosis.

Effects of changing oil concentration

The ethanol industry has evolved and changed. DDGS, MDGS, and WDGS currently has a much lower oil concentration than in the past. This is a result of a centrifugation process of the syrup which improves ethanol yields and fermentation efficiency. This however reduces the amount of DGS produced by the dry-grinding process due to the removal of the germ, pericarp fiber, and endosperm fiber (Berger and Singh., 2010). This results in approximately 30% less fat in the final DDGS product (Lüking and Funsch, 2009).

Bremer et al. (2015) evaluated the effects of feeding a modified distillers grains plus solubles (MDGS) with a lower oil concentration (7.2% vs. 12.0%) in increasing concentrations of the diet to finishing cattle and they report a linear increase in G:F with increasing MDGS inclusion irrespective of oil concentration. Bremer et al. (2015) also studied the differences between feeding MDGS containing 7.2% vs 11.5% oil at 15% and 30% of a finishing diet. Their results indicated a numerical slight decrease in efficiency (calculated from reported F:G) with the 7.2% MDGS at a 30% inclusion rate. This pattern was not observed in the 15% inclusion rate.

Utilizing increasing levels of WDGS from 0 to 35% resulted in a linear decrease in feed to gain ratio which indicates improved cattle efficiency (Jolly et al., 2015).

Digestibility

There have been a limited number of studies done to examine the effects on digestibility with feeding reduced-oil distillers coproducts. Jolly-Breithaupt et al. (2015) utilized condensed distillers solubles (reduced CDS at 8.7% fat and normal CDS at 15.4% fat) and modified distillers grains plus solubles (reduced MDGS at 9.2% fat and normal MDGS 12.3% fat) to determine the effect on ruminal digestibility. This study indicated that there was no difference in intake or digestibility of dry matter, organic matter, or neutral detergent fiber among any of the dietary treatments. There was, however, a difference in fat intake (kg/day) for both 8.7% fat CDS and 9.2% MDGS having less fat intake than the 15.4% fat CDS and 12.3% fat MDGS. There was no difference in total tract fat digestibility between the 9.2% fat and 12.3% MDGS diets. There was a difference in total tract fat digestibility between 8.7% fat CDS diet and the 15.4% fat CDS diet with the 8.7% fat CDS diet being less digestible than the 15.4% CDS diet but having similar total digestibility to the control diet which contained no distillers coproducts. However, there was an interaction effect of coproduct type and oil concentration with total tract fat digestibility where the MDGS and CDS diets had a greater total fat digestibility regardless of oil concentration compared to the control diet. An additional study conducted by Ceconi et al. (2013) evaluated the effects of replacing 35% dry-rolled corn with a reduced-oil corn DDGS (4.5% fat) or a higher-oil corn DDGS product (6.7% fat). They observed no differences in total OM digestibility but an increase in DM and OM intake by steers fed either of the dried corn distillers grain plus solubles products. They did, however, find a difference in ruminal total volatile fatty acid (VFA) concentration (m*M*) and ruminal ammonia concentration where cattle

fed the control and reduced oil dried distillers grains plus solubles had increased total VFA and reduced ammonia concentration than the higher oil DDGS. This could indicate an increase in utilization of ammonia and an increase of microbial growth when reduced-oil DDGS was fed (Ceconi et al., 2013).

Ruminal starch digestion

A major part of grains produced in the United States is marketed through livestock. Grains are an ideal feed product due to the high energy feed value in comparison to forages (Huntington, 1997). Digestion of starches in the rumen is by ruminal bacteria and protozoa. They accomplish this through fermentation pathways which include glycolysis and the synthesis of three main (VFA); acetic acid, propionic acid, and butyric acid. The ruminal microbes synthesize VFA to produce ATP for metabolic functions of the microbes. The production of VFA produces approximately 50 percent of the needed ATP utilized by ruminal microorganisms. These VFA can be utilized by the animal and supply up to 90 percent of the animal's energy (Nelson and Cox, 2012). Propionate and acetate are absorbed and not extensively metabolized in the ruminal epithelium while butyrate is absorbed and largely metabolized to ketone bodies, beta-hydroxybutyric acid and acetoacetate in the ruminal epithelium. Much of the dietary starch is utilized by rumen fermentation and, therefore, little typically passes to the small intestine unless high starch diets are fed.

Starch Fermentation

Fermentation in a ruminant provides approximately 50 percent of the energy required by the rumen (Baldwin and Allison, 1983). Glycolysis breaks down a molecule of glucose into 2 molecules of pyruvate and 2 molecules of ATP. This process includes 10 steps in 2 phases, the preparatory phase and the payoff phase. Glucose is first phosphorylated to glucose 6-phosphate

with the addition of phosphorus coming from an ATP molecule. This is then isomerized by phosphohexose isomerase to form fructose 6-phosphate. Fructose 6-phosphate is then phosphorylated to fructose 1,6 bisphosphate with another molecule of ATP being utilized. Aldolase then cleaves the 6-carbon sugar phosphate into two 3-carbon sugar phosphates Glyceraldehyde 3-phosphate and dihydroxyacetone phosphate. Triose phosphate isomerase isomerized diydroxyacetone phosphate to glyceraldehyde 3-phosphate which starts the payoff phase of glycolysis. The next step, which oxidizes and phosphorylates glyceraldehyde 3-phosphate to 1,3-bisphosphoglycerate, produces 2 molecules of NADH and 2 H^+ ions. 1,3 bisphosphoclygerate is then converted to 3-phosphoglycerate with the enzyme phosphoglycerate kinase and this step produces 2 ATP molecules. 3-phosphoglycerate is converted to 2-phosphoglycerate with the enzyme phosphoglycerate mutase. It is then converted to phosphenolpyruvate by the enzyme enolase. In the final stage, phosphenolpyruvate is converted to pyruvate through the action of the enzyme pyruvate kinase. This step not only produces 2 pyruvate molecules but also 2 ATP molecules (Nelson and Cox, 2012).

Volatile fatty acid production

Acetate Production

The first step in the synthesis of acetate is pyruvate being broken down to acetyl-CoA and CO_2 by pyruvate synthase. Carbon dioxide goes on to be a substrate for methane production while acetyl-CoA gets converted to acetyl phosphate by phosphotransacetylase. Finally, with the production of ATP, acetate is produced by acetate kinase (Nelson and Cox, 2012).

Butyrate Production

Butyrate is produced from the same acetyl-CoA as acetate. The acetyl-CoA is converted to acetoacetyl-CoA and then to beta-hydroxybutyryl-CoA. This is then converted to crotonyl-CoA and then the enzyme butyryl CoA dehydrogenase dehydrolyzes to crotonyl CoA to butyryl-CoA which produces NAD^+. Then Butyryl-CoA is converted to butyryl phosphate which is then converted to butyrate which produces an ATP molecule (Nelson and Cox, 2012).

Propionate Production

The first step of propionate production is the conversion of pyruvate to oxaloacetate. NADH is then added to produce NAD and malate. Malate then gets converted to fumarate by removing H_2O. NADH is then added again and succinate and NAD are produced. Succinate is converted in the next step to succinyl-CoA and then this is converted to R-methylmalonyl-CoA then S-methylmalonyl-CoA. CO_2 is removed to produce propionyl-CoA which finally produces propionate and ATP (Nelson and Cox, 2012).

Volatile fatty acid absorption in the rumen

Volatile fatty acids are primarily absorbed passively through the rumen epithelial which means the higher the concentration in the rumen, the faster the rate of absorption (Dijkstra et al. 1993). However, absorption of acetate increases to a greater extent with increases in concentration than propionate and butyrate (Dijkstra et al. 1993). Chain-length also plays a part in how quickly the VFA is absorbed. Therefore, butyrate has the highest absorption rate, followed by propionate, and then acetate. There are also active transporters which play a role in VFA absorption from the rumen. Monocarboxylate transporter 1 (MCT1) has been shown to transport short chain fatty acids from the rumen into circulation. Kirat et al. (2006) showed that when a MCT1 inhibitor was introduced into the rumen of goats, a significant reduction of venous

acetate and propionate concentration was found which indicates the importance of MCT1 in VFA absorption from the rumen. Müller et al. (2002) also showed that MCT1 helps facilitate the removal of ketone bodies and lactate from sheep rumen epithelium.

Butyrate, which is found in the lowest concentration, is absorbed from the rumen and then quickly converted to ketone bodies such as beta-hydroxybutyric acid and acetoacetate. This is an important function because butyrate is toxic due to inhibiting hepatic propionate utilization (Aiello, 1989) and beta-hydroxybutyric acid is utilized as an energy source for tissues throughout the body. Propionate is absorbed from the rumen and transported to the liver through the portal vein. Once in the liver, the enzyme succinate thiokinase will catalyse the reaction with Coenzye A to produce propionyl CoA. Propionyl-CoA carboxylase catalyses the reaction of carboxylation of the second carbon of the propionyl-CoA to produce methylmalonyl-CoA and then gets rearranged to succinyl-CoA by the catalyst methylmalonyl-CoA mutase. Finally, succinyl-CoA is converted to oxaloacetate which in turn is converted to glucose via gluconeogenesis (Nelson and Cox, 2012). Acetate is oxidized through the animal to create ATP. Acetate is also a source of acetyl-CoA which is used for the production of lipids. In ruminants the enzyme succinate thiokinase allows the ruminant to directly form acetyl-CoA which allows for bypassing the need of citrate to transport acetyl-CoA across the mitochondrial membrane (Hanson and Ballard, 1967). This enzyme has more activity in ruminants versus non-ruminants (Hanson and Ballard, 1967) which implies that acetate is more important for lipid synthesis in ruminants while glucose is more important for lipid synthesis in non-ruminants.

Starch assimilation in the small intestine

In cattle fed high concentrate diets, 5 to 20% of starch is digested postruminally (Zinn, 1991). Once starch enters the small intestine, pancreatic amylase is released by the pancreas and

hydrolyzes amylopectin and amylose into limit dextrins and linear oligosaccharides (Harmon, 1993). Then maltase and isomaltase, located on the brush border in the small intestine, further break down the oligosaccharides to glucose molecules for absorption (Harmon, 1992). The amount of starch digested in the small intestine varies greatly. In a review summarizing data on small intestinal starch digestibility in cattle, Harmon (1992) reported a range of digestibility from 17.3 to 84.9%. This may be due to inadequate pancreatic amylase secretion. Pancreatic amylase increases as energy of the diet increases; however, it has been suggested that a lack of pancreatic amylase may be the reason why starch digestion is not 100% in the small intestine (Huntington 1997).

Starch absorption in the small intestine

It also has been suggested, however, that transporting glucose from the intestinal lumen may be a limiting factor in starch assimilation in the small intestine (Owens et al., 1986). There are two main means of glucose absorption in the small intestine, active transport and passive or paracellular diffusion with water (Huntington, 1997). The main transporter for glucose is the sodium-glucose transporter (SGLT1) which transports one glucose molecule and two sodium molecules per cycle and has a range of 50-200 cycles per second (Hediger and Rhoads, 1994). Adapting ruminants to digesting starch or glucose had been thought to increase starch assimilation in the small intestine by increasing the efficiency of transporting glucose. Shirazi-Beechey et al. (1991) showed a 50-80 fold increase in SGLT1 in ewes with a 3 day adaptation to glucose infusion in the duodenum. Bauer et al. (1995) found that unadapted ruminants could still transport glucose out of the intestinal lumen. Adapting the animal to digesting starch, however, did increase the amount of glucose delivered to the liver which indicates a greater capacity for starch assimilation in cattle but did not show increased delivery of glucose to the liver in sheep

(Bauer et al., 1995). These transporters are found in the intestinal mucosa or enterocytes of the small intestine in the wood rat (Ferraris, 1989). However, SGLT1 is very similar from species to species (Ferraris, 1989) so it can be assumed that it would be similar in ruminants.

Nitrogen digestion

In ruminants, nitrogen is necessary for the survival of rumen microbes. Rumen microbes contain 20 to 60% of their dry matter weight in CP (Owens, 1988). Their source of nitrogen comes from either dietary protein or non-protein nitrogen, like urea. Ruminal microbes get flushed from the rumen into the omasum and abomasum then to the small intestine where they get digested and absorbed (Owens, 1988). Microbial nitrogen accounts for approximately 40% of the total non-ammonia nitrogen that enters into the small intestine. This is, however, dependent on the dietary level of CP and ruminal degradability of the dietary CP as lower levels of CP in the diet lead to more non-ammonia nitrogen from microbial CP entering into the small intestine (Owens, 1988).

Nitrogen metabolism in the rumen

Microorganisms produce proteases and peptidases which cleave peptide bonds and release free amino acids and peptides (Owens, 1988). Some of the amino acids are then deaminated by microbes and ammonia and a carbon skeleton are released. Microorganisms can then use the ammonia, carbon skeleton, and ATP to synthesize bacterial amino acids and proteins. Microorganisms can also utilize ruminal amino acids and peptides to produce bacterial CP (NRC, 2000). Since ammonia is readily produced in the rumen, very little free amino acids are left to escape the rumen. Most of the protein that leaves the rumen is microbial CP and rumen undegradeable protein (Owens, 1988).

Nitrogen recycling

Depending on the animal's diet, ruminants absorb most nitrogen as ammonia nitrogen (Reynolds, 1992). The liver then removes this ammonia from the blood and coverts it to urea as ammonia is toxic. Some urea gets excreted through urine and approximately 40 to 60% can enter back into the digestive tract via two methods: saliva and direct transfer from blood (Reynolds, 1992). This can create a negative balance of nitrogen in the rumen as there is more nitrogen being absorbed than there is entering from the diet. Diet plays a large role in the magnitude of this effect so that when there is a large excess of ammonia in the blood, absorption through the gut epithelium increases. Also when saliva production increases, more urea gets recycled back to the rumen through saliva (Owens, 1988).

Protein digestion post-ruminal

The protein that has escaped to the small intestine has a digestibility rate of approximately 65 to 75% (Owens, 1988). Post-ruminal digestion starts in the abomasum where pepsinogen and hydrochloric acid (HCL) are secreted from the chief and parietal cells. (Nelson and Cox, 2012). HCL is important to cleave pepsinogen into pepsin which can actively digest proteins. Proteins are broken down into peptides which then enter into the small intestine. Proteases secreted from the pancreas which aid in digestion are procarboxypeptidase, chymotrypsin, and trypsinogen. The enzyme enteropeptidase is bound to the membrane of the small intestine but is important to the digestions of proteins as it converts trypsinogen to its active form trypsin. Trypsin catalyzes the conversion of procarboxypeptidase and chymotrypsinogen to their active forms, carboxypeptidase and chymotrypsin. These two enzymes then hydrolyze peptides into smaller peptides and free amino acids (Nelson and Cox, 2012).

Protein absorption in the small intestine

Free amino acids are easily absorbed in the small intestine with the help of sodium channels. The sodium dependent transport amino acid channels will only bind to free amino acids after binding to sodium. Once the channel is bound to both, the channel undergoes a conformational change and releases the sodium and amino acid into the cytoplasm. Small peptides get transported with the help of the cotransport of hydrogen through the transporter PepT1. Once absorbed into the enterocyte, most small peptides are digested into free amino acids through cytoplasmic peptidases and then are released into the blood stream (Krehbiel and Matthews, 2003).

Lipid metabolism

While lipids are not present in as large of quantities as protein or starch in typical cattle diets, they can have beneficial effects in cattle diets such as reducing dust of feeds, reduce the incidence of bloat, and to increase the energy density of the diet (Tennis, 2000). Most lipids that enter the rumen are readily modified by rumen microbes and, therefore, little escapes the rumen in the same form it originally entered (Byers, 1988).

Rumen microbes hydrolyze lipids into free fatty acids, glycerol, and sugars (Byers, 1988). The glycerol and sugars will then be fermented into VFAs. Due to the anaerobic nature of the rumen, there is a large hydrogen sink present. Unsaturated fatty acids provide a good way to get rid of hydrogen ions through biohydrogenation (Drackley, 2005). The first step in lipid metabolism is lipolysis which results in the release of free fatty acids from esters (Buccioni et al., 2012). Once free fatty acids are cleaved from the glycerol backbone, the free fatty acids undergo biohydrogenation which is the reduction of the number of double bonds on the carbon chain of the fatty acid (Buccioni et al., 2012) and the unsaturated fatty acids quickly become saturated.

Large amounts of lipids, mainly unsaturated fatty acids, in the diet can be toxic to rumen microbes and decrease rumen fermentation (Dehority, 2003). This is due to lipid hydrolysis occurring more rapidly than biohydrogenation and the unsaturated fatty acids overwhelm the biohydrogenation process (Drackley, 2005). The extent to which a lipid is hydrolyzed depends on the type of lipid it is. Plant oils have a more complete biohyrogenation (90%) than animal lipids (50%; Byers, 1988).

Lipid digestion in the small intestine

Since the rumen microbes readily hydrolyze most dietary lipids, lipids that pass to the small intestine have little resemblance to dietary lipids and contain unesterified fatty acids which are highly saturated (Byers, 1988). Most lipids that enter the small intestine are free fatty acids (85 to 90%) and phospholipids (10 to 15%; Drackley, 2005). With the low pH in the beginning of the small intestine, the lipids are protonated and fatty acid soaps, which are insoluble in the rumen, are solubilized which helps increase the absorption in the small intestine (Byers, 1988). For digestion of the lipids that bypass rumen metabolism to occur, bile must first emulsify the lipid. Pancreatic lipase can then attach and digest the lipid into fatty acids.

Lipid absorption in the small intestine

Absorption of lipids occurs in many steps in the small intestine. First the lipid enters the enterocyte by simple diffusion across the plasma membrane. Next, re-esterification happens in the smooth-endoplasmic reticulum membranes. Apoprotein biosynthesis occurs in the rough endoplasmic reticulum and finally chylomicron synthesis happens in the Golgi apparatus and is released into the intercellular space by exocytosis. Then they enter the lamina propria and proceed to lymphatic lacteals (Byers, 1988). Short fatty acids (14C or less) can enter the blood directly where they are oxidized in the liver (Byers, 1988).

Effect of lipid on starch and nitrogen utilization

There are many factors that can affect how efficient starch digestion is or where the site of digestion occurs. Shifting starch digestion from the rumen to the small intestine could be advantageous in reducing the incidence of acidosis in finishing cattle (Xu et al., 2013). Also starch digestion in the small intestine is much more energetically favorable as heat from fermentation and the production of methane result in a significant loss of energy (Merchen et al., 1997). Owens et al. (1986) used multiple regression analysis to determine the effects of the extent of starch digestion in the small intestine versus the rumen. They found that there is 42% more energy provided to the animal when starches were digested in the small intestine instead of the rumen.

Most bacteria that are involved with biohydrogenation are cellulolytic (Buccioni et al., 2012). With high concentrate diets, there is a reduction in the number of celluloytic bacteria in the rumen (Latham et al., 1972). This type of diet could favor fats that can bypass the rumen without being reduced such as oleic acid and linoleic acid (Chiliard et al., 2007). Maturity of forage and forages that have been ground too fine can also diminish lipolysis and biohydrogenation in the rumen (Gerson et al., 1986). With grinding forages, bacteria struggle to attach to feed particles and passage rates increase thus reducing the time that feedstuffs are exposed to microbial activity (Buccioni et al., 2012).

Including high levels of fat in high concentrate diets can affect the microbial population by other mechanisms as well. High fat diets create a shift in the pathways which play a role in biohydrogenation (Buccioni et al., 2012). Increased fat has also been shown to decrease microbial growth in the rumen which would decrease the amount of microbial nitrogen that flows to the small intestine in the form of microbial protein (Doreau and Ferlay, 1995).

Unsaturated long-chain fatty acids have a larger impact on rumen bacteria than saturated fatty acids or short chain fatty acids do (Demeyer and Henderickx, 1967). It is thought that the effect that fatty acids have on bacterial growth could be due to the adsorption on the cell wall of the substrate which would lead to a slower capitation of amino acids and production of ATP by bacteria (Galbraithe and Miller, 1973). The negative effect of increasing lipids in the diet has on the rumen bacteria is not equal between bacteria types. The effects are greater in cellulolytic than amylolytic bacteria as well as it is greater in gram positive bacteria than gram negative bacteria (Galbraithe et al., 1971). It is commonly reported that increasing dietary lipids have a negative effect on protozoa concentration (Doreau and Ferlay, 1995) but fungi do not seem to be affected by increasing levels of dietary fat as the protozoa and bacteria are (Doreau and Ferlay, 1995).

Another way to measure how increasing dietary lipids affect nitrogen metabolism is through rumen ammonia concentration and duodenal flow of nitrogen (Doreau and Ferlay, 1995). Rumen ammonia concentration is considered to be the steadiness between the inputs of ammonia: degradation of dietary nitrogen and nitrogen recycling to the rumen and the outputs of ammonia: nitrogen utilized by rumen microorganisms, nitrogen absorbed, and nitrogen flow out of the rumen (Doreau and Ferlay, 1995). Most experimental data indicates a decrease in ammonia concentration or no shift in concentration when increased levels of lipids are fed in the diet; however, the extent to which lipids have an effect cannot be determined from these experiments as results are widely variable (Doreau and Ferlay, 1995). Increased dietary lipids, however, do not seem to affect nitrogen recycling either through direct absorption or through saliva, or ammonia absorption since absorption is dependent on rumen pH and lipids do not seem to have an effect on pH (Doreau and Ferlay, 1995). Overall, while increasing dietary lipids alter

the microbial population of the rumen, there are limited effects shown on ruminal nitrogen metabolism.

Overall, lipids seem to have the greatest effect on starch and nitrogen metabolism in ruminant animals. Through manipulation of the rumen microbial environment, increasing levels of lipids can limit starch digestion in the rumen, increase starch digestion in the small intestine, and decrease total microbial populations which decreases nitrogen passage to the small intestine.

Conclusions

Feeding practices vary from region to region in the United States (Samuelson et al., 2016). Producers must utilize feedstuffs to maximize finishing cattle efficiency as feed costs account for approximately 70% of total expenses for producers (Metzger, 2005). With the ethanol production evolving and changing, research has shown that lowering the oil concentration of the final feed product may have little to no effect on average daily gain, feeding efficiency, or diet digestibility of finishing cattle. Through understanding the metabolic pathways of starch, protein, and lipid digestion, the interactions nutrients have with each other can be further investigated. Increasing lipids in finishing diets could have negative effects on the rumen microbiome and, therefore, could impact how starch and protein gets metabolized and utilized by the ruminant animal. This could help explain why decreasing the oil concentration in distillers coproducts may not have a negative effect on growth and animal performance but could potentially benefit the rumen microbiome and help increase efficiency of starch and protein digestibility. Therefore the objectives of this research are to determine the effect of grain type (corn vs barley) and oil concentration of DDGS (4.5% vs 7.9%) on intake and site of digestion (Chapter 2) as well as determine the influence of grain type and oil concentration of DDGS on finishing cattle performance, feeding behavior, carcass quality (Chapter 3).

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CHAPTER 2. EFFECT OF GRAIN TYPE AND DRIED DISTILLERS GRAIN WITH SOLUBLES OIL CONCENTRATION ON SITE OF DIGESTION

Abstract

The objective of this experiment was to determine the effects of grain type (corn vs. barley) and oil concentration of dried distillers grains plus solubles (DDGS; moderate = 7.9% vs low = 4.5% ether extract) on site of digestion. Eight Holstein steers (716 ± 62 kg) that were ruminally and intestinally cannulated were assigned randomly to four dietary treatments in a 2 x 2 factorial arrangement consisting of 1) corn with moderate-fat DDGS, 2) corn with low-fat DDGS, 3) barley with moderate-fat DDGS, and 4) barley with low-fat DDGS. Diets were formulated to meet or exceed NRC recommendations and were offered for ad libitum intake with at least 6% feed refusal. The experiment was designed as a 4 x 4 Latin square with 24-d periods which allowed for 10 d of transitioning diets, 7-d diet adaptation, and 7 d collection period. Measurements collected included: daily DMI, fecal excretion, and total tract digestibility. Dry matter, organic matter and CP intake did not differ ($P \geq 0.46$) among dietary treatments. Total duodenal flow of DM, OM and CP decreased ($P < 0.05$) in steers fed barley diets. Ruminal digestibility (% of intake) of DM and OM decreased ($P < 0.02$) in steers fed corn diets while intestinal digestibility (% of intake) was decreased ($P < 0.004$) in steers fed barley diets. This led to no differences ($P > 0.78$) in total tract digestibility of DM and OM. CP true ruminal digestibility (% of intake) decreased ($P = 0.01$) in steers fed corn diets. There was a tendency ($P = 0.09$) for intestinal digestibility of CP to decrease in barley-fed diets. There was no difference ($P = 0.35$) in total tract digestibility of CP. Starch intake was less ($P = 0.01$) in steers fed barley diets which led to less fecal output ($P = 0.001$) and disappearance ($P = 0.03$). Starch total tract digestibility was less ($P = 0.01$) in steers fed corn diets. However, there were no differences ($P \geq$

0.36) in ruminal or intestinal digestibility of starch. There were no differences ($P \geq 0.11$) between low fat and moderate fat DDGS on intake or the site of digestion of dry matter, organic matter, CP and starch. Our data indicate that including a lower fat DDGS as compared to a moderate fat DDGS in a finishing diet may not have an influence on intake or site of digestion in finishing cattle.

Introduction

Feed costs represent the largest expense in beef production (Metzger, 2005). Utilizing different grain types can influence feed efficiency which is important for optimizing cattle performance. Corn dried distiller grains plus solubles (DDGS) is a valuable feed product utilized in finishing diets (Klopfenstein, 2008). Including corn DDGS has been shown to linearly increase intake and average daily gain (ADG) with increasing levels in the diet (Anderson et al., 2011). Grain type, specifically barley and corn, have differences in digestibility and therefore could affect performance (Gozho and Mutsvangwa, 2008).

Corn dried distillers grains plus solubles is commonly used in finishing diets due to its availability and nutrient profile. The beef cattle NRC (2000) reports DDGS having 11% ether extract on a DM basis. This concentration has changed, however, as the ethanol industry has evolved and extracts more oil from the corn resulting in DDGS with a lower ether extract content of approximately 4 to 5%. This raises the question, what happens to digestibility of this low-oil DDGS product? Therefore, we hypothesized that grain type and DDGS oil concentration would have an effect on site of digestion. Our objectives were to determine the effect and interaction of grain type and DDGS oil concentration on ruminal, intestinal and total tract digestibility.

Materials and methods

All animal care and handling procedures were approved by the North Dakota State University Animal Care and Use Committee.

Animals, Experimental Design, and Dietary Treatments

Eight Holstein steers (716 ± 62 kg) were used in a 4 x 4 Latin Square design consisting of 4 periods and 4 dietary treatments with 2 steers assigned randomly per treatment per period to determine the impact of grain type (corn vs barley) and DDGS oil concentration (DDGS; moderate = 7.9% vs low = 4.5%; Table 2.1) on intake and total tract digestibility. Steers were housed in individual tie stalls (1.0 x 2.2 m) in a temperature controlled environment at the North Dakota State University Animal Nutrition and Physiology Center. Dietary treatments (Table 2.2) were offered to ensure ad libitum intake and 6% feed refusal daily. Treatments included 1) corn with moderate fat DDGS, 2) corn with low fat DDGS, 3) barley with moderate fat DDGS, and 4) barley with low fat DDGS. Diets were formulated to meet or exceed requirements for degradable intake protein (DIP), metabolizable protein (MP), minerals, and vitamins (NRC, 2000). Steers were adapted from a high-forage diet to a high-concentrate diet over a 21-d period. Then steers were adapted to their respective treatments over a 7-d period followed by a 7-d sample collection period. Finally, a 10-d transition period occurred where steers were transitioned to their next treatment diet.

Table 2.1. Analyzed nutrient concentration of DDGS (DM basis)

Dietary Component, % of DM	Low-fat DDGS	Moderate-fat DDGS
Crude protein	31.6	32.6
Neutral detergent fiber	34.8	46.1
Acid detergent fiber	10.9	14.2
Ether extract	4.5	7.9
Calcium	0.04	0.04
Phosphorus	1.04	0.93
Starch	8.87	3.57

Table. 2.2. Dietary composition

	Rolled Corn		Rolled Barley	
Dietary Component, % of DM	Low-fat DDGS	Moderate-fat DDGS	Low-fat DDGS	Moderate-fat DDGS
Rolled Corn	50	50	-	-
Rolled Barley	-	-	50	50
DDGS	25	25	25	25
Corn Silage	20	20	20	20
Limestone	2	2	2	2
Urea	0.15	0.15	-	-
Salt	0.05	0.05	0.05	0.05
Vitamin Premix[1]	0.01	0.01	0.01	0.01
Mineral Premix[2]	0.05	0.05	0.05	0.05
Rumensin[3]	0.02	0.02	0.02	0.02
Tylan[4]	0.01	0.01	0.01	0.01
Fine-ground Corn	2.46	2.46	2.61	2.61
Chromium Oxide	0.25	0.25	0.25	0.25

[1]Contained 48,510 kIU/kg vitamin A and 4,630.5 kIU vitamin D.
[2]Contained 3.62% Ca, 2.56% Cu, 16% Zn, 6.5% Fe, 4.0% Mn, 1.050 mg/kg I and 250 mg/kg Co.
[3]Contained 176.4 g monensin/kg premix.
[4]Contained 88.2 g tylosin/kg premix.

Collection of Feed and Orts

Complete samples were mixed prior to each period. Chromic oxide (Cr_2O_3) was used as an external marker to determine nutrient flows and was included in the ration at 0.25% of diet DM. A sample of feed was collected after mixing for analysis of DM, OM, CP, starch, NDF and ADF (Table 2.3).

Table 2.3. Analyzed nutrient composition of diets (DM basis)

	Rolled Corn		Rolled Barley	
Dietary Component, % of DM	Low-fat DDGS	Moderate-fat DDGS	Low-fat DDGS	Moderate-fat DDGS
Crude protein	13.7	14.0	14.8	14.8
Neutral detergent fiber	29.8	31.8	32.6	34.7
Acid deterdent fiber	11.9	12.5	13.3	14.1
Ether extract	3.49	4.18	2.40	3.11
Calcium	1.09	1.16	1.15	1.07
Phosphorus	0.46	0.46	0.50	0.48
Starch	43.6	42.1	37.1	37.5

Orts were collected at 0800 daily and sampled (2% of weight). Each steer's consumption was calculated and steers were offered fresh feed by 0800 daily. Feed samples were collected immediately after mixing rations while orts were composited over each collection period. Samples was stored at -20°C until analyses.

Collection of Feces

Steers were fitted with fecal collection bags for the duration of the 7-d collection period. Feces were collected twice daily (0600 and 1800) and mixed by hand to ensure a representative sample. A sample (2% of weight on a wet basis) was collected to represent the entire collection period. Fecal samples were stored at -20°C until analyses.

Collection of Digesta

Ruminal fluid and post ruminal chyme samples (approximately 200 mL) were collected into bags (Nasco; 532-mL) from d 3 to 5 in a manner that allowed a sample to be collected every other h in a 24-h cycle. Samples were taken at 0200, 0800, 1400, and 2000 h on d 3; 0400, 1000, 1600, and 2200 h on day 4 and 0600, 1200, 1800, and 0000 h on d 5. Samples were stored at -20°C until the end of the collection period and then thawed, composited, and dried in a freeze drier (VirTis Co., Gardiner, NY).

On the final day of the collection period, a 4-kg sample of ruminal contents was taken from each animal for the isolation of bacterial cells. Random grab samples were gathered from several locations inside the rumen to ensure representation of the liquid and fiber phases. Samples were placed in containers and mixed with approximately 2 L of solution containing 3.7% formaldehyde and 0.9% NaCl. They were then blended at medium speed for at least 5 min using a commercial, heavy-duty blender (model 37BL19CB6, Waring Products division, New Hartford CT), strained through 4 layers of cheese cloth, and frozen at -20°C until chemical analyses.

Laboratory Analysis

Feed, orts, and fecal samples were dried for 48 h at 60°C in a forced air oven (Grieve SB-350, The Grieve Corporation, Round Lake, IL) and ground to pass a 2-mm screen (Wiley mill, Model #3; Arthur H. Thomas, Philadelphia, PA). Feed and orts samples were analyzed for DM, ash, and CP (Kjeldahl method) (Procedure numbers 934.01, 2001.11, and 942.05 respectively; AOAC, 2010), as well as NDF and ADF (Goering and Van Soest 1970). The methods of Herrera-Sal-dana and Huber (1989) were used to analyze starch on a microplate spectrophotometer (Synergy H1 Microplate reader, BioTek Instruments, Winooski, VT). Ruminal fluid samples were centrifuged at 2000 x g for 20 min. The liquid portion was filtered through a 0.45-µm filter and analyzed for ammonia (Broderick and Kang, 1980). Total lipid concentration was analyzed using a method adapted by Folch et al. (1957). Bacterial isolation was accomplished by centrifuging samples in 250-mL bottles at 500 x g for 20 min to remove protozoa and feed particles. The supernatant was removed and then centrifuged at 30,000 x g for an additional 20 min to pellet bacteria. Isolated bacteria were frozen, lyophilized, and analyzed for DM, ash, N (AOAC 1990), and purines (Zinn and Owens, 1986).

Calculations

Total nutrient flows to the small intestine were calculated based on the ratio of nutrients to Cr in the duodenal digesta as compared to intake (Merchen, 1988). Microbial organic matter and N leaving the abomasum were calculated using purines as microbial markers (Zinn and Owens, 1986). Ruminal organic matter (OM) fermented was calculated as OM intake minus the difference between the amount of total OM reaching the duodenum and microbial OM reaching the duodenum. Feed N escape to the small intestine was calculated by subtracting microbial N from total N and thus includes any endogenous and NH3-N contributions. Total tract digestibility were calculated using analyses from intake and total fecal collection.

Statistical Analysis

Data were analyzed as a replicated 4 x 4 Latin square with a 2 x 2 factorial arrangement of treatments using generalized least square means Mixed procedure, (SAS Inst. Inc., Cary, NC). The model included the effects of steer, period, grain type (corn vs barley), DDGS oil concentration (moderate vs low), and the interaction between grain type and DDGS oil concentration. A *P*-value of less than or equal to 0.05 was considered a significant difference while a P-value of greater than 0.05 but less than 0.1 was considered a tendency.

Results

There were no differences in DM intake (kg/d), fecal DM output (kg/d), and disappearance (kg/d) between grain types (Table 2.4). Feed DM duodenal flow (kg/d) and total duodenal flow (kg/d) was less ($P = 0.007$) in barley diets. There was no difference in microbial DM duodenal flow (kg/d). Apparent and true ruminal DM digestibility decreased in corn diets ($P = 0.02$ and $P = 0.004$). Intestinal DM digestibility decreased ($P < 0.03$) in barley diets as a percent of intake and as a percent entering the duodenum. There was no difference in total-tract

DM digestibility between grain types. No effects on DM intake, flow, or digestion were observed between low and moderate oil concentrations of DDGS or the interaction of grain type and oil concentration of DDGS.

Table 2.4. Dry matter intake and digestibility

	Treatment							
	Rolled Corn		Rolled Barley					
Items	Low-fat DDGS	Moderate-fat DDGS	Low-fat DDGS	Moderate-fat DDGS	*P-value* SEM	Grain	DDGS	Grain*DDGS
Intake, kg/d	15.1	14.3	14.7	14.8	0.61	0.99	0.46	0.37
Intake, % of BW	2.15	0.05	2.06	2.05	0.090	0.57	0.43	0.46
Duodenal flow								
Feed, kg/d	5.63	6.10	4.38	3.98	0.578	0.007	0.95	0.41
Microbial, kg/d	2.42	2.52	3.06	2.83	0.447	0.29	0.88	0.69
Total, kg/d	8.23	8.30	7.14	6.77	0.644	0.007	0.67	0.51
Disappearance, kg/d	7.15	5.94	7.52	8.01	0.568	0.04	0.55	0.18
Fecal output, kg/d	3.11	3.06	3.12	3.02	0.171	0.95	0.63	0.87
Digestibility								
Apparent ruminal, % of intake	46.2	43.1	51.7	53.7	3.22	0.02	0.85	0.37
True ruminal, % of intake	64.2	58.3	69.8	73.3	3.34	0.004	0.71	0.17
Intestinal, % of intake	33.2	35.6	26.7	25.8	3.16	0.01	0.78	0.53
Intestinal, % of entering duodenum	61.1	61.3	54.3	54.9	2.91	0.03	0.88	0.94
Total tract, % of intake	79.5	78.7	78.6	79.1	0.94	0.78	0.86	0.45

There were no differences in OM intake (kg/d), fecal OM output (kg/d), and disappearance (kg/d) between grain types (Table 2.5). Feed OM duodenal flow (kg/d) and total duodenal flow (kg/d) decreased ($P < 0.01$). in barley diets. There was no difference in microbial OM duodenal flow (kg/d). Apparent and true ruminal OM digestibility (% of intake) decreased ($P < 0.007$) in corn diets. Intestinal OM digestibility decreased ($P < 0.01$) in barley diets as a percent of intake and as a percent entering the duodenum. There was no difference in total tract digestibility of OM between grain types. No effects were found on digestibility of OM between low and moderate oil concentrations of DDGS or the interaction of grain type and oil concentration of DDGS.

Table 2.5. Organic matter intake and digestibility

	Treatment							
	Rolled Corn		Rolled Barley					
Items	Low-fat DDGS	Moderate-fat DDGS	Low-fat DDGS	Moderate-fat DDGS	SEM	*P-value* Grain	DDGS	Grain*DDGS
Intake, kg/d	14.3	13.7	13.7	13.7	0.57	0.62	0.55	0.49
Duodenal flow								
Feed, kg/d	4.53	4.34	3.66	3.12	0.392	0.01	0.28	0.57
Microbial, kg/d	1.92	2.11	2.20	2.19	0.326	0.53	0.72	0.68
Total, kg/d	6.54	6.52	5.65	5.20	0.500	0.005	0.43	0.43
Disappearance, kg/d	7.85	6.86	8.15	8.68	0.509	0.04	0.66	0.17
Fecal output, kg/d	2.61	2.59	2.60	2.55	0.148	0.86	0.76	0.90
Digestibility								
Apparent ruminal, % of intake	54.4	52.6	59.4	62.0	2.64	0.007	0.84	0.29
True ruminal, % of intake	68.9	68.5	73.1	77.5	1.86	0.002	0.26	0.17
Intestinal, % of intake	26.9	27.9	21.5	19.1	2.49	0.004	0.71	0.34
Intestinal, % of entering duodenum	58.8	58.2	51.9	49.6	3.06	0.01	0.56	0.73
Total tract, % of intake	81.6	80.8	81.1	81.3	0.87	0.97	0.72	0.53

There were no differences in CP intake (kg/d), fecal CP output (kg/d), or disappearance (kg/d) between grain types (Table 2.6). Feed CP duodenal flow (kg/d) and total CP duodenal flow (kg/d) decreased ($P < 0.05$) in barley diets. There was no difference in microbial CP efficiency or microbial CP duodenal flow between grain types. There was a tendency for apparent ruminal CP digestibility (% of intake) to decrease ($P = 0.06$) in corn based diets while true ruminal CP digestibility (% of intake) decreased ($P = 0.01$) in corn based diets. There was a tendency ($P = 0.09$) for intestinal CP digestibility as a percent of intake to decrease in barley based diets. However, no difference was found in intestinal CP digestibility as a percent entering the duodenum between grain types. There were no differences in total tract CP digestibility between grain types. No effects were found on CP intake or digestibility between low and moderate oil concentrations of DDGS or the interaction of grain type and oil concentration of DDGS.

Table 2.6. Crude protein intake and digestibility

	Treatment							
	Rolled Corn		Rolled Barley					
	Low-fat	Moderate-fat	Low-fat	Moderate-fat		*P-value*		
Items	DDGS	DDGS	DDGS	DDGS	SEM	Grain	DDGS	Grain*DDGS
Intake kg/d	2.24	2.19	2.21	2.20	0.099	0.89	0.64	0.76
Duodenal flow								
Feed kg/d	1.53	1.65	1.37	1.27	0.140	0.02	0.88	0.21
Microbial, kg/d	1.09	1.03	1.03	1.12	0.163	0.89	0.85	0.38
Total, kg/d	2.66	2.65	2.28	2.35	0.283	0.05	0.80	0.75
Disappearance, kg/d	-0.402	-0.448	-0.068	-0.155	0.3120	0.07	0.63	0.88
Fecal output, kg/d	0.469	0.483	0.472	0.448	0.0290	0.59	0.87	0.51
Digestibility								
Apparent ruminal, % intake	-18.6	-19.4	-1.15	-7.20	9.32	0.06	0.60	0.67
True ruminal, % intake	31.8	25.7	39.5	42.5	4.89	0.01	0.67	0.23
Intestinal, % intake	96.6	96.8	80.0	87.4	9.32	0.09	0.55	0.55
Intestinal, % entering duodenum	81.1	80.0	77.9	81.2	1.68	0.54	0.47	0.14
Total tract, % intake	78.7	77.6	78.8	79.8	1.08	0.30	0.94	0.33
Microbial efficiency	11.4	11.4	9.2	10.5	2.07	0.35	0.65	0.63

Starch intake (kg/d), fecal starch output (kg/d) and disappearance (kg/g) decreased ($P < 0.03$) in barley based diets (Table 2.7). There was no difference in starch duodenal flow (kg/d) between grain types. Apparent ruminal starch digestibility and intestinal digestibility as a percent of intake did not differ between grain types. There was an interaction ($P = 0.05$) of grain type and DDGS oil concentration where corn with moderate oil concentration DDGS had the lowest starch intestinal digestibility as a percent entering the duodenum while barley with moderate oil concentration DDGS had the highest intestinal starch digestibility as a percent entering the duodenum. Total tract starch digestibility decreased ($P = 0.01$) in corn based diets. There were no effects on intake or digestibility of starch between low and moderate oil concentrations of DDGS and no other differences on the interaction of grain typeand oil concentration of DDGS.

Table 2.7. Starch intake and digestibility

	Treatment							
	Rolled Corn		Rolled Barley					
	Low-fat	Moderate-fat	Low-fat	Moderate-fat		*P-value*		
Items	DDGS	DDGS	DDGS	DDGS	SEM	Grain	DDGS	Grain*DDGS
Intake, kg/d	8.14	7.30	6.75	6.82	0.348	0.01	0.28	0.21
Duodenal flow								
Total, kg/d	0.918	0.495	0.642	0.566	0.1460	0.49	0.09	0.23
Fecal output, kg/d	0.249	0.215	0.116	0.082	0.0453	0.001	0.30	1.00
Disappearance, kg	7.03	6.93	6.11	6.32	0.337	0.03	0.88	0.67
Digestibility								
Apparent ruminal, % of intake	88.3	93.3	90.9	91.8	1.80	0.78	0.11	0.26
Intestinal, % of intake	7.99	3.21	7.58	7.01	1.803	0.36	0.14	0.24
Intestinal, % of entering duodenum	69.6	32.8	72.8	84.6	11.89	0.03	0.28	0.05
Total tract, % of intake	96.6	96.9	98.3	98.8	0.70	0.01	0.49	0.93

Intake (kg/d) of total lipids increased ($P < 0.001$) in steers fed corn diets as well as in steers fed diets with moderate oil of DDGS (Table 2.8). There was an increase ($P = 0.01$) in duodenal total lipids flow (kg/d) in steers fed corn diets. No differences were found in total duodenal lipid flow (kg/d) between oil concentrations of DDGS. No differences were found in fecal lipid output (kg/d) or lipid disappearance (kg/d) between grain type or oil concentration. Apparent ruminal lipid digestibility was increased ($P = 0.02$) in steers fed moderate oil DDGS while intestinal lipid digestibility as a percent of intake was increased ($P = 0.04$) in steers fed low oil DDGS. No differences were found in lipid apparent ruminal digestibility or lipid intestinal digestibility between grain types. Total-tract lipid digestibility was increased ($P = 0.0001$) in steers fed moderate oil DDGS and tended ($P = 0.07$) to increase in steers fed corn diets.

Table 2.8. Total lipid intake and digestibility

	Treatment							
	Rolled Corn		Rolled Barley					
Items	Low-fat DDGS	Moderate-fat DDGS	Low-fat DDGS	Moderate-fat DDGS	SEM	*P-value* Grain	DDGS	Grain*DDGS
Intake, kg/d	0.611	0.766	0.434	0.669	0.0225	<.0001	<.0001	0.03
Duodenal Flow								
Total, kg/d	0.99	1.15	0.78	0.80	0.115	0.01	0.32	0.42
Fecal Output, kg/d	0.115	0.113	0.097	0.105	0.0087	0.13	0.68	0.51
Disappearance, kg	-0.37	-0.37	-0.34	-0.14	0.106	0.19	0.29	0.26
Digestibility, % Intake								
Apparent ruminal, % intake	-58.81	-45.29	-75.12	-22.51	14.240	0.82	0.02	0.13
Intestinal, % intake	139.63	130.31	151.50	107.05	13.690	0.68	0.04	0.15
Intestinal, % entering duodenum	87.85	88.52	86.31	87.85	1.040	0.19	0.43	0.90
Total Tract, % intake	81.09	85.49	77.46	84.43	1.320	0.07	0.0001	0.25

There were no differences in NDF intake (kg/d) between grain type, oil concentration of DDGS, or the interaction of grain type and oil concentration of DDGS (Table 2.9). Neutral detergent fiber duodenal flow (kg/d) decreased ($P < 0.05$) in corn diets and moderate oil concentration DDGS. Fecal NDF output (kg/d) decreased ($P = 0.005$) in corn fed steers. Apparent ruminal NDF digestibility (% of intake) decreased ($P = 0.005$) in barley fed steers and in low oil concentration. There was a tendency ($P = 0.09$) for steers fed low oil concentration DDGS to have decreased NDF intestinal digestibility as a percent of intake. Total tract NDF digestibility (% of intake) decreased ($P = 0.01$) in barley fed steers. There was no difference in NDF total tract digestibility (% of intake) between oil concentrations of DDGS.

Table 2.9. NDF intake and digestibility

	Treatment							
	Rolled Corn		Rolled Barley					
Items	Low-fat DDGS	Moderate-fat DDGS	Low-fat DDGS	Moderate-fat DDGS	SEM	*P-value* Grain	DDGS	Grain*DDGS
Intake, kg/d	3.98	4.25	4.14	4.32	0.193	0.56	0.24	0.80
Duodenal flow								
Total, kg/d	1.09	1.01	1.53	1.07	0.121	0.05	0.03	0.13
Fecal output, kg/d	1.43	1.41	1.73	1.69	0.096	0.005	0.75	0.90
Disappearance, kg	2.82	3.29	2.58	3.29	0.198	0.56	0.01	0.58
Digestibility								
Apparent ruminal, % of intake	72.4	76.8	62.3	75.6	2.65	0.04	0.005	0.14
Intestinal, % of intake	-8.43	-9.70	-4.83	-14.14	3.156	0.89	0.09	0.18
Intestinal, % of entering duodenum	-35.2	-47.7	-18.6	-74.7	15.79	0.75	0.05	0.21
Total Tract, % of intake	64.5	67.1	58.1	60.1	2.03	0.003	0.29	0.89

Intake (kg/d) of ADF decreased ($P = 0.004$) in corn fed steers (Table 2.10). No difference was found in ADF intake (kg/d) between oil concentrations of DDGS. Acid detergent fiber duodenal flow (kg/d) decreased ($P < 0.02$) in corn fed steers and moderate oil concentration of DDGS. Fecal ADF output (kg/d) decreased ($P < 0.001$) in corn fed steers. Apparent ruminal ADF digestibility (% of intake) decreased ($P < 0.04$) in barley fed steers and in low oil concentration DDGS. There was a tendency ($P = 0.08$) for ADF intestinal digestibility as a percent of intake to decrease in moderate oil concentration DDGS. Intestinal ADF digestibility as a percent entering the duodenum was decreased ($P = 0.03$) in moderate oil concentration DDGS. Total tract ADF digestibility decreased ($P = 0.01$) in barley fed steers. There were no differences on the interaction of grain type and oil concentration of DDGS on ADF intake or site of digestion.

Table 2.10. ADF intake and digestibility

	Treatment							
	Rolled Corn		Rolled Barley					
Items	Low-fat DDGS	Moderate-fat DDGS	Low-fat DDGS	Moderate-fat DDGS	SEM	*P-value* Grain	DDGS	Grain*DDGS
Intake, kg/d	1.44	1.46	1.60	1.69	0.065	0.004	0.34	0.51
Duodenal flow								
Total, kg/d	0.450	0.404	0.660	0.471	0.0462	0.007	0.02	0.14
Fecal output kg/d	0.555	0.554	0.754	0.741	0.0410	< 0.001	0.85	0.89
Disappearance, kg	0.983	1.06	0.934	1.21	0.0616	0.41	0.003	0.06
Digestibility								
Apparent ruminal, % of intake	69.1	72.4	58.8	71.6	2.58	0.04	0.005	0.07
Intestinal, % of intake	-6.91	-10.6	-5.65	-16.6	3.82	0.55	0.07	0.36
Intestinal, % of entering duodenum	-25.1	-44.9	-14.5	-77.1	15.96	0.49	0.03	0.25
Total Tract, % of intake	61.2	61.5	52.95	55.9	2.53	0.01	0.50	0.58

Discussion

Corn dried distillers grains plus solubles is commonly used in finishing diets due to its availability and nutrient profile. The 2000 beef cattle NRC reports DDGS having 11% ether extract on a dry matter basis. The ethanol industry has evolved and changed so that the final DDGS currently has a much lower oil concentration than in the past. This is a result of a centrifugation of the syrup which improves ethanol yields and fermentation efficiency while removing valuable edible oil (Berger and Singh, 2010). This results in approximately 30% less fat in the final DDGS product (Lüking and Funsch, 2009). This raises the question, does the removal of oil alter the digestibility of DDGS. Therefore, we hypothesized that grain type and DDGS oil concentration would have an effect on site of digestion. Our objectives were to determine the effect and interaction of grain type and DDGS oil concentration on ruminal, intestinal and total tract digestibility.

Starch in barley grains is more digested in the rumen than starch in corn grain (Ferraretto et al., 2013). However, they also showed similar total tract digestibility of starch between corn and barley. This would lead to the conclusion that site of digestion of starch for corn shifts more to the small or large intestine than for barley. Research has also shown that rumen digestibility, intestinal digestibility and total tract digestibility of barley was greater than that of corn (Tothi et al 2003). Our data shows similar results in that ruminal and total tract starch digestibility was less for the corn diets than barley diets.

Little is known about how the oil concentration of DDGS affects site of digestion in finishing cattle. Jolly-Breithaupt et al. (2015) reported no differences in total-tract DM, OM, NDF, or fat digestibility when comparing low-oil modified distillers grains plus solubles (MDGS; 8.7% fat) with normal-oil MDGS (15.4% fat). They also found no differences in total-

tract DM, OM, or NDF total tract digestibility in low-oil condensed distillers solubles (CDS; 9.2% fat) versus normal-oil CDS (12.3% fat). However; they did report a decrease in total tract digestibility of fat in de-oiled CDS versus normal CDS. Ceconi et al. (2013) also studied the effect of lowering oil concentration of DDGS on site of digestion. Their treatments were 35% traditional DDGS (6.7% total dietary fat) or low-fat DDGS (4.5% total dietary fat) as well as a control which included no DDGS in the diet (3.7% total dietary fat). They found differences in DM and OM intake where the low-fat DDGS and traditional DDGS treatments had greater intake than the control diet but there were no differences between DDGS treatments. Digestibility of organic matter did not differ between DDGS treatments or DDGS treatments compared to the control treatment. Our results are in conjunction with the previous two studies suggesting that there is no difference in total tract digestibility of DM, OM, CP, starch, NDF or ADF when comparing low-oil DDGS with moderate-oil DDGS. Our results also are similar to Jolley Breithaupt et al. (2015) in that the lower oil concentration products of DDGS and CDS had lower total tract lipid digestibility which could suggest that these lower oil concentration products, DDGS and CDS, have lipids that are not as digestible as the lipids in the higher oil concentration products. Additionally, in our study, we found that there was an increase in lipid intake in the moderate vs. the low oil DDGS but no differences found in fecal lipid output which indicates that the animal is utilizing more of the lipid from the moderate oil DDGS than the low oil DDGS which supports the theory that the lipids in the lower oil concentration products may not be as digestible. This theory needs to be studied further to know the full effects and implications that can be associated with feeding an ethanol coproduct with lower oil concentrations.

In conclusion, utilizing barley, as compared to corn, in finishing diets increases total tract starch digestion which may increase the amount of volatile fatty acids and glucose available to

the animal and potentially provide more energy to the animal resulting in improved growth performance. Also, decreasing the oil concentration of DDGS had no effect on site of digestion or total tract digestibility of DM, OM, CP, starch, NDF or ADF of the diets. Therefore, utilizing low oil DDGS in finishing diets may not affect digestibility of finishing cattle diets.

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CHAPTER 3. THE INFLUENCE OF GRAIN SOURCE AND DRIED CORN DISTILLERS GRAINS PLUS SOLUBLES OIL CONCENTRATION ON FINISHING CATTLE PERFORMANCE AND FEEDING BEHAVIOR

Abstract

Eighty-one steers (428 ± 3.5 kg of BW) were used to determine the effect of grain type (corn vs barley) and oil concentration of dried corn distillers grains plus solubles (DDGS; moderate = 7.9% vs low = 4.5%) on finishing performance, feeding behavior, and carcass characteristics. Steers were allotted by BW to 3 pens. Within each pen, steers were assigned randomly to 1 of 4 dietary treatments (n= 6 or 7 steers per treatment): 1) corn and moderate-fat DDGS, 2) corn and low-fat DDGS, 3) barley and moderate-fat DDGS, and 4) barley and low -fat DDGS. Intake and feeding behavior traits were calculated from data generated via the Insentec feeding system. Steers were weighed the first 2 d, then every 28 d thereafter. Steers were slaughtered with an average BW of 668 ± 4.4 kg and were marketed in 2 groups at 119 (n = 40) and 155 (n = 41) d. Final BW and ADG were not affected ($P \geq 0.68$) by grain type or DDGS oil concentration. The ADG of the first 28 d was lesser ($P = 0.002$) for the steers fed barley-based diets (1.23 ± 0.101 kg/d) than steers fed corn-based diets (1.65 ± 0.102 kg/d). Overall DMI (kg/d) decreased ($P = 0.002$) and G:F increased ($P = 0.01$) with steers fed barley-based diets. Daily visits to the feeder decreased ($P = 0.05$) but time eating per visit increased ($P = 0.03$) by steers fed barley-based diets compared to those fed corn-based diets. Blood urea N concentration was greater in steers fed barley-based diets ($P < 0.001$) compared to those fed corn-based diets as well as steers fed low-fat DDGS diets ($P = 0.05$) compared to those fed moderate-fat DDGS. Blood glucose concentration was not affected ($P \geq 0.20$) by treatment. There was no effect ($P \geq 0.26$) of treatment on carcass traits; HCW, marbling, LM area, 12th rib fat, and KPH fat. These

data indicate steers fed barley-based diets had improved gain efficiency, having a greater G:F, than steers fed corn-based diets. Oil concentration of DDGS had no effect on finishing performance. Steers fed barley-based diets spent more time eating per visit but visited the bunk less per day than those steers fed corn-based diets which could account for the lower DMI with steers fed barley diets. Carcass traits were not affected by either grain type or oil concentration of DDGS. Our data indicate that including a lower fat DDGS as compared to a moderate fat DDGS in a finishing diet may not influence finishing performance, feeding behavior, or carcass measurements.

Introduction

Feed costs represent the largest direct cost in beef production (Metzger, 2005). Utilizing different grain types can influence feed efficiency which is important for optimizing cattle performance (Owens, 1997). Corn dried distiller grains plus solubles (DDGS) is a valuable feed product utilized in finishing diets (Klopfenstein 2008). Including corn DDGS has been shown to result in a linear increase on DMI and ADG with increasing levels in the diet (Anderson et al., 2011) and optimal inclusion may differ depending on grain source (Klopfenstein, 2008).

The ethanol industry is evolving and changing their production practices. This has resulted in changes in the nutrient composition of the final coproduct available as a feedstuff. Decreasing fat in the diet has been shown to decrease ADG in finishing steers (Zinn, 1988). However, increasing oil concentration in the diet can also have a negative effect on digestibility of non-lipid energy sources (Jenkins, 1993) so DDGS with a lower oil concentration could actually provide beneficial affects to ruminants. Therefore, research is needed to determine what affect DDGS oil concentration has on finishing cattle performance, feeding behavior, and carcass quality when commonly fed feed grains are fed. We hypothesize that grain type and DDGS oil

concentration will influence finishing performance and feeding behavior. Our objectives were to determine the effects of grain source (corn vs. barley), DDGS oil concentration (4.5 Vs 7.9% DM), and the interaction of grain type and DDGS oil concentration on finishing performance, feeding behavior, and carcass quality.

Materials and methods

All procedures with animals were approved by the North Dakota State University (NDSU) Animal Care and Use Committee.

Animals, Experimental Design, and Dietary Treatments

Eighty-one steers (428 ± 3.5 kg of BW) predominately of Angus, Simmental, and Shorthorn breeding were used in a 2 x 2 factorial arrangement of treatments (grain type [rolled corn vs barley] and DDGS oil concentration [low fat vs moderate fat]; Table 3.1). The DDGS were obtained from two different ethanol plants because each plant only produced DDGS with one oil concentration and would be options for producers to use in the northern Great Planes. The steers were sorted by BW into 3 pens (light, medium, and heavy pens; n = 27 per pen) and housed at the NDSU Beef Cattle Research Complex. Within each pen, steers were assigned randomly to 1 of 4 experimental treatment diets (n = 6 or 7 steers per treatment within pen; n=20 or 21 per treatment): 1) corn with moderate fat DDGS, 2) corn with low fat DDGS, 3) barley with moderate fat DDGS, and 4) barley with low fat DDGS (Table 3.2). Diets were formulated to meet or exceed recoendations for dietary intake protein (DIP), metabolizable protein (MP), vitamins and minerals (NRC, 2000). Diets were offered for ad libitum intake. Steers were adapted to experimental diets by transitioning to the final diet over a 21-d period.

Table 3.1. Analyzed nutrient concentration of DDGS (DM basis)

Dietary Component, % of DM	Low-fat DDGS	Moderate-fat DDGS
Crude protein	31.6	32.6
Neutral detergent fiber	34.8	46.1
Acid detergent fiber	10.9	14.2
Ether extract	4.5	7.9
Calcium	0.04	0.04
Phosphorus	1.04	0.93
Starch	8.87	3.57

Table. 3.2. Dietary composition

	Rolled Corn		Rolled Barley	
Dietary Component, % of DM	Low-fat DDGS	Moderate-fat DDGS	Low-fat DDGS	Moderate-fat DDGS
Rolled Corn	50	50	-	-
Rolled Barley	-	-	50	50
DDGS	25	25	25	25
Corn Silage	20	20	20	20
Limestone	2	2	2	2
Urea	0.15	0.15	-	-
Salt	0.05	0.05	0.05	0.05
Vitamin Premix[1]	0.01	0.01	0.01	0.01
Mineral Premix[2]	0.05	0.05	0.05	0.05
Rumensin[3]	0.02	0.02	0.02	0.02
Tylan[4]	0.01	0.01	0.01	0.01
Fine-ground Corn	2.71	2.71	2.86	2.86

[1]Contained 48,510 kIU/kg vitamin A and 4,630.5 kIU vitamin D.
[2]Contained 3.62% Ca, 2.56% Cu, 16% Zn, 6.5% Fe, 4.0% Mn, 1.050 mg/kg I and 250 mg/kg Co.
[3]Contained 176.4 g monensin/kg premix.
[4]Contained 88.2 g tylosin/kg premix

Body Weight and Feed Intake Measurements

Steers were weighed before feed delivery for 2 consecutive days at the beginning and ending of the feeding period and every 28 d throughout the feeding period. Average daily gain was calculated by regressing BW on day of the experiment.

Radio frequency ID tags were placed in the right ear before the experiment. Each pen contained 8 electronic feeding stations (Inesentec, B. V., Marknesse, The Netherlands) as

described by Mader et al. (2009) and Islas et al (2013) allowing for offering specific dietary treatments and monitoring individual feed intake and feeding behavior characteristics. Each experimental diet was provided in 2 feeders per pen. Total DMI and feeding behavior traits were summarized (Montanholi et al., 2010) as follows; events (number of bunk visits and meals daily), eating time (minutes; per visit, per meal, and per day) and feed intake (grams; per visit, per meal, and per minute) and these data were summarized as the average of each individual steer starting on d 1 if the experiment. A visit was defined as each time the Insentec system detected a steer at a bunk. A meal was defined as eating periods that might include short breaks separated by intervals no longer than 7 minutes (Forbes, 1995; Montanholi et al., 2010).

Feed Analysis

Diet samples were collected weekly. Weekly samples were analyzed for DM by drying in a 55°C oven and ground to pass a 1-mm screen. Weekly samples were analyzed for DM, ash, N (Kjehldahl method), ether extract, Ca, and P by standard procedures (AOAC, 1990) and for NDF (assayed with heat stable amylase and sodium sulfite and expressed inclusive of residual ash) and ADF (expressed inclusive of residual ash) concentration by the method of Robertson and Van Soest (1981) using a fiber analyzer (Ankom Technology Corp., Fairport, NY). Percent CP was calculated by multiplying N concentration x 6.25. Samples also were analyzed for starch (Herrera-Saldana and Huber, 1989; Table 3.3).

Table 3.3. Analyzed nutrient composition of diets (DM basis)

	Rolled Corn		Rolled Barley	
Dietary Component, % of DM	Low-fat DDGS	Moderate-fat DDGS	Low-fat DDGS	Moderate-fat DDGS
Crude protein	13.7	14.0	14.8	14.8
Neutral detergent fiber	29.8	31.8	32.6	34.7
Acid deterdent fiber	11.9	12.5	13.3	14.1
Ether extract	3.49	4.18	2.40	3.11
Calcium	1.09	1.16	1.15	1.07
Phosphorus	0.46	0.46	0.50	0.48
Starch	43.6	42.1	37.1	37.5

Carcass Characteristics

Steers were fed until they were visually estimated to have approximately 12 mm subcutaneous fat thickness at the 12th rib and marketed in 2 groups. Group one (heaviest steers) was fed for 119 d (n = 40; n = 10 per treatment) and group two was fed for 155 d (n = 41; n = 10 per treatment except n = 11 for corn with low fat DDGS) before transport to the abattoir. Hot carcass weight was measured on the day of slaughter and carcass measurements were measured following a 24-h chill. Measurements collected were marbling, subcutaneous fat thickness at the 12th rib, LM area, and KPH fat.

Blood Collection, Plasma Urea-N Analysis, and Plasma Glucose Analysis

Blood samples were collected by jugular venipuncture into vacuum tubes containing sodium heparin (Becton Dickinson, Rutherford, NJ) on d 28, 56, 84 and 112 before feeding on the same days as BW measurements. Plasma was isolated by centrifugation (Sorvall ST16R; Thermo Fisher Scientific, Waltham, MA) at 3,000 x g for 20 min at 4°C and stored at -20°C until analysis. Plasma Urea-N was determined using the urease/Berthelot procedure (Chaney and Marbach, 1962; Fawcett and Scott, 1960). Plasma glucose was analyzed using the hexokinase/gluxose-6-phosphate dehydrogenase method (Farrance, 1987) using a kit from

Thermo Scientific (Pittsburgh, PA) Analyses were conducted using a 96-well microplate reader (Synergy, HI Microplate Reader; BioTek Instruments, Winooski, VT).

Statistical Analysis

Data were analyzed as a completely randomized block (days to slaughter) design using generalized linear means mixed procedure (SAS Inst. Inc., Cary, NC) with a 2 x 2 factorial arrangement of treatments. The model included the effects of block (days on feed), grain type (corn vs. barley), DDGS oil concentration (low vs. moderate), and grain type x DDGS oil concentration interaction. Plasma urea-N and glucose were analyzed using repeated measures and included block (days on feed), day, grain type, DDGS oil concentration, grain type x DDGS oil concentration, grain type x day, and DDGS oil concentration x day in the model statement. Appropriate (minimize information criterion) covariance structures were used (Wang and Goonewardene, 2004). The diagonal covariance structure was used because it had the smallest Akaike information criterion, finite sample corrected Akaike information criterion, and Schwarz's Bayesian information criterion. Data was considered significant when $P \leq 0.05$ and a tendency was considered when $0.05 < P \leq 0.10$.

Results

Finishing Performance

Initial BW (kg) did not differ between grain types or DDGS oil concentration; (Table 3.4). Average daily gain (kg/d) for the first 28 d decreased (P = 0.002) steers fed barley as compared to corn; however, there were no differences found in day 28 ADG between DDGS oil concentration. Final weights (kg) did not differ between grain types or DDGS oil concentration. Gain (kg) did not differ between grain types or DDGS oil concentration. There was no difference in overall ADG between grain types or DDGS oil concentration. Overall, DMI (kg) decreased (*P*

= 0.002) in steers fed barley as compared to corn, however there were no differences in DMI between DDGS oil concentration. Barley fed steers had improved gain efficiency over corn fed steers as the gain to feed ratio was increased (P = 0.01) in barley fed steers and there were no differences in efficiency between DDGS oil concentrations.

Table 3.4. Effects of grain type and fat concentration of dried distillers grains plus solubles on performance and carcass traits in finishing cattle

	Treatment							
	Rolled Corn		Rolled Barley					
	Low-fat	Moderate-fat	Low-fat	Moderate-fat				*P-value*
Items	DDGS	DDGS	DDGS	DDGS	SEM[1]	Grain	DDGS	Grain*DDGS
Initial Weight, kg	425	426	432	425	7.1	0.74	0.66	0.57
Final Weight, kg	664	672	671	663	8.8	0.89	0.94	0.34
Gain, kg	239	246	240	238	5.9	0.55	0.69	0.45
Day 28 ADG, kg/d	1.66	1.63	1.37	1.33	0.093	0.002	0.69	0.97
ADG, kg/d	1.79	1.84	1.82	1.8	0.04	0.79	0.68	0.41
DMI, kg	12.1	11.9	11.3	11.3	0.22	0.002	0.85	0.75
G:F	0.149	0.154	0.161	0.159	0.0034	0.011	0.62	0.24
HCW, kg	410	412	407	407	6.3	0.52	0.82	0.85
Marbling score[2]	508	477	475	483	26.8	0.62	0.67	0.46
LM area, cm^2	88.4	91.6	89.0	87.7	0.33	0.55	0.59	0.26
12th Rib Fat, cm	1.37	1.27	1.28	1.34	0.0416	0.96	0.86	0.45
KPH fat[3], %	1.84	1.82	1.83	1.79	0.042	0.56	0.53	0.84

[1]Standard error of the mean (n = 20)

[2]Marbling Score – 400-499 = small & 500-599 = modest

[3] KPH fat – Kidney, pelvic, and heart fat

Carcass Characteristics

No differences were observed in hot carcass weight, marbling score, LM area, 12th rib fat, or kidney, pelvic, and heart fat between steers fed different grain types or oil concentration of DDGS (Table 3.4).

Plasma Glucose and Urea N

There was an effect of time ($P < 0.001$) with blood glucose concentrations (mg/dL) as blood glucose was least on d 28 (Figure 3.1). Grain type, oil concentration of DDGS, the interaction of grain type and oil concentration of DDGS, and the interaction of time with grain type and oil concentration of DDGS did not affect plasma glucose concentrations.

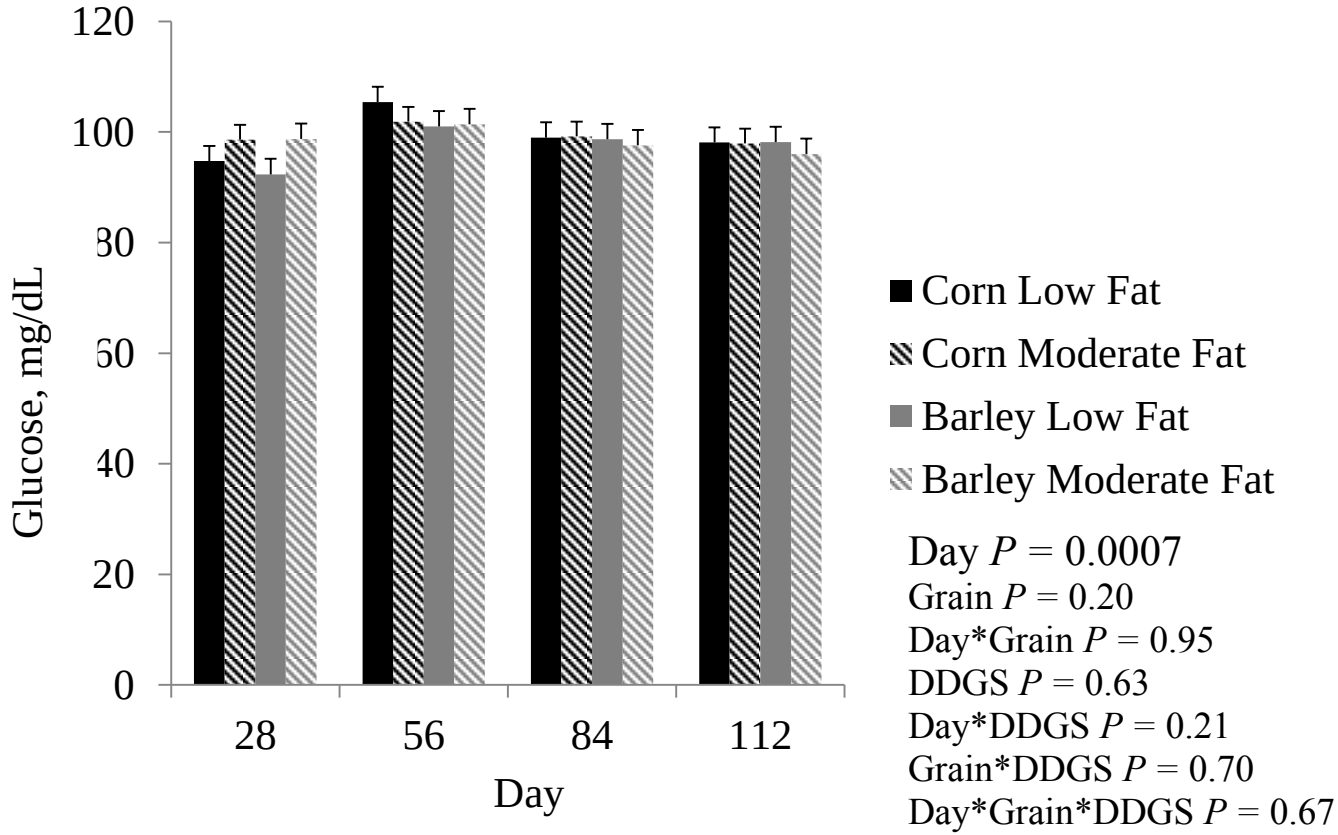

Figure 3.1. Effects of grain type and oil concentration of dried distillers grains plus solubles on blood glucose concentrations

There was an effect of time ($P < 0.001$) with plasma urea N concentrations (mg/dL) as plasma urea N was least on d 28 (Figure 3.2). There was a difference ($P < 0.001$) between grain type as barley increased plasma urea N concentration over corn. Oil concentration of DDGS also had an effect ($P = 0.05$) as that the low oil concentration DDGS had higher plasma urea N concentration than the moderate oil concentration DDGS. There was no effect of the interaction of grain type and oil concentration of DDGS, or the interaction of time with grain type and oil concentration of DDGS on plasma urea N concentrations.

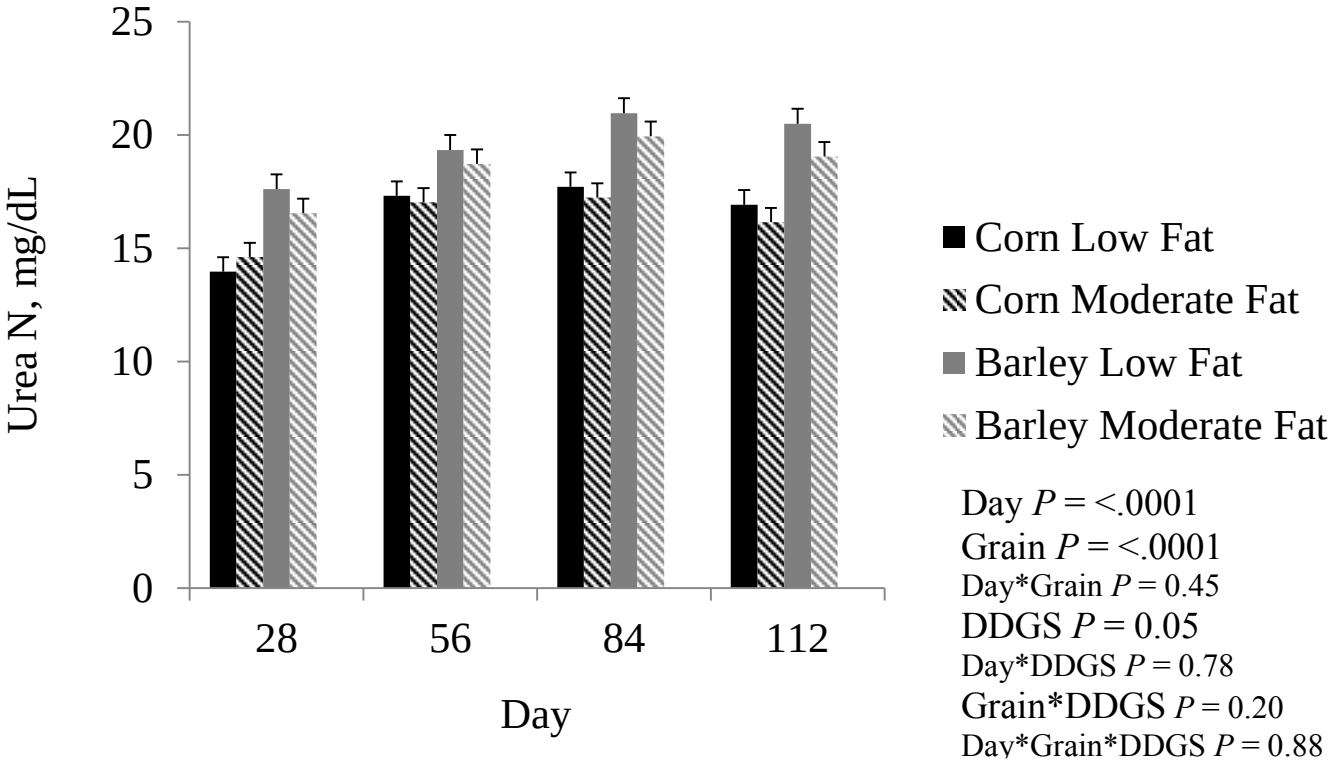

Figure 3.2. Effects of grain type and oil concentration of dried distillers grains plus solubles on blood urea concentrations

Feeding Behavior

There was a decrease ($P = 0.05$) in visits to the bunk per day in steers fed barley compared to those fed corn but no differences were found between DDGS oil concentration (Table 3.5). There were no differences found in meals per day between grain types and DDGS oil concentration. Time eating per visit increased ($P = 0.03$) in barley fed steers. There was a tendency ($P = 0.06$) for time eating per visit with DDGS oil concentrations to increase in low oil concentration DDGS. Time eating per meal did not differ between grain type and oil concentration of DDGS. No differences were found in eating rate per visit between grain type. There was a tendency ($P = 0.09$) for a decrease in eating rate per visit for steers fed moderate oil concentration DDGS. There was also a tendency ($P = 0.06$) for a decrease in eating rate per meal to decrease in barley fed steers. No differences were found in eating rate per meal between oil concentrations of DDGS. There were no differences found with eating rate per minute between grain types and oil concentration of DDGS. No differences were found with the interaction of grain type and oil concentration of DDGS.

Table 3.5. Effects of grain type and fat level of dried distillers grains plus soluble on feeding behavior in finishing cattle

	Treatment							
	Rolled Corn		Rolled Barley					
Items	Low-fat DDGS	Moderate-fat DDGS	Low-fat DDGS	Moderate-fat DDGS	*P-value* SEM[1]	Grain	DDGS	Grain*DDGS
Events, per d								
Visits	27.1	28.6	23.1	26.2	1.6	0.05	0.16	0.6
Meals	7.35	7.62	7.61	7.55	0.257	0.71	0.68	0.53
Time eating, min								
Per visit	3.46	3.18	4.21	3.55	0.248	0.03	0.06	0.44
Per meal	12.67	11.3	11.68	11.88	0.561	0.71	0.29	0.17
Eating Rate, kg								
Per visit	0.465	0.451	0.547	0.454	0.0312	0.17	0.09	0.2
Per meal	1.69	1.6	1.53	1.52	0.066	0.06	0.42	0.53
Per min	0.136	0.142	0.135	0.13	0.0047	0.17	0.95	0.25

[1]Standard Error Mean (n = 20)

Discussion

Feed costs represent the largest direct cost of feeding cattle. Utilizing different grain types, specifically barley and corn, can have an impact on efficiency and, therefore, should be taken into consideration when formulating diets to optimize feed costs and growth performance in cattle. Changes in the nutrient composition of DDGS could potentially impact efficiency and, therefore, it is important to determine the effects on performance in finishing cattle.

There is conflicting research in regards to the effects on gain efficiency when different grain types are fed in finishing diets. Research suggests that when feeding barley versus corn, feed to gain ratio is decreased in cattle; therefore, suggesting that barley is the superior grain to use in finishing diets (Beauchemin et al., 1997; Boss and Bowman, 1996; Milner et al., 1995, 1996; Mathison and Engstrom, 1995; Kincheloe et al., 2003). However, other research suggests that when feeding corn versus barley, corn-fed cattle had equal or improved efficiency (Nelson et al., 2000; Owens, 1995; Hill and Utely, 1989). These differences could be due to a number of variables such as: diet composition, grain source (field by field, state, and region variety), grain variety, etc. It appears that DMI is the driving influence behind the improved efficiency in this study. Dry matter intake could also be why these studies show discrepancies. Intake can be affected by roughage source in the diet (Galyean and Defoor, 2002) and grain processing (Owens et al., 1997) and, therefore, differences in each experiment's diets could affect intake. This could affect the animal's efficiency when comparing grain types. Our results were in agreement with the data suggesting that feeding barley improves gain efficiency as compared to feeding corn.

Anderson et al. (2011) examined the influence of increasing DDGS inclusion in growing and finishing diets from 0% DDGS to 36% DDGS. In the growing diet, gain efficiency (gain:feed) was improved in steers fed diets including DDGS than steers fed diets without

DDGS. This was mainly due to an increase in ADG with steers fed diets including DDGS. In the finishing diet there was a linear increase in ADG for increasing DDGS inclusion in the diet. These results indicate that including DDGS in the diet appeared to increase growth rate in finishing cattle. Another study by Depenbusch et al. (2009) showed similar results where increasing DDGS in finishing diets (0% DDGS to 75% DDGS) resulted in increases in final BW and ADG. Bremer et al. (2015) studied the effect of increasing distillers products with a reduced oil concentration on cattle performance to determine if the oil concentration affect ADG. Their results indicated there was an increase in ADG with increasing reduced-oil MDGS (7.2% fat) similar to normal-oil MDGS. Similar results were found when analyzing a reduced oil concentration (7.9% fat) wet distillers grains plus solubles (WDGS) compared with a normal WDGS (11.3% fat). Our research showed similar results when comparing 4.5% vs 7.9% fat DDGS, there were no differences in finishing performance or carcass quality.

There is also little known about how decreasing the oil concentration of DDGS affects feeding behavior. Montanholi et al. (2010) suggested that more efficient calves had slower eating rates, spent less time at the feeder per day, and ate smaller meals. There was a tendency for differences found in feeding behavior when comparing low-oil DDGS to moderate-oil DDGS. Steers fed moderate oil concentration DDGS showed a tendency to spend less time at the bunk per visit. However, oil concentration of DDGS did not seem to have an effect on animal performance.

In conclusion, utilizing barley, in comparison to corn, in finishing cattle diets decreased DMI, increased G:F, and altered feeding behavior in cattle consuming a 90% concentrate diet without affecting carcass mass or quality. Utilizing a lower oil concentration DDGS did not significantly impact performance, feeding behavior, or carcass quality, and there were no

interactions with either barley or corn, in the finishing diets. There was a tendency for oil concentration of DDGS to alter feeding behavior however; this did not seem to alter performance. Therefore, producers may be confident that utilizing DDGS with a lower oil concentration in finishing diets will not affect performance or carcass quality of finishing cattle.

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CHAPTER 4. IMPLICATIONS AND CONCLUSIONS

Optimizing finishing cattle efficiency is of the utmost importance for producers as feed costs account for approximately 70% of total expenses for producers (Metzger, 2005). A survey of finishing nutritionist indicated that the majority of finishings feed finishing diets that are over 60% grain (Samuelson et al., 2016). The type of grain used depends on many factors which include: regional availability, price of grain, storage capabilities, processing capabilities, among others. In the United States specifically, most barley that is grown is of the malting variety instead of feed varieties. These varieties have slightly different nutritional attributes that have been developed for the specific purpose for brewing. When barley does not meet malting standards it often gets utilized as feed barley. In order to purchase barley as a feed, in North Dakota, producers are typically charged the price for malt barley. For this reason, producers would typically pay more per bushel to feed barley than they would corn. The commodity markets also support this as currently corn is trading for approximately $1.50 less than barley is (Barchart, 2016).

Our studies indicate that barley was more digestible than corn and that steers fed barley based finishing diets had improved growth efficiency as they had a higher gain to feed ratio (G:F). This effect was mainly driven by a reduction in dry matter intake (DMI) for the steers fed barley based diets. This could indicate that feeding barley is beneficial for producers versus corn. Feeding barley, however, could reduce a producer's profit as it costs more than corn does. The increase in G:F was not significant enough to make feeding barley as profitable.

Another aspect to consider is accessibility. If producers were to grow feed varieties of barley it could be beneficial to feed over corn. Producers must consider their geographical location as to which grain would be the best to grow. Considering the opportunity of an early

frost in North Dakota, it may be a safer option to grow feed barley versus corn which has a longer growing season.

Expansion of the grain milling industry for ethanol production has made grain milling coproducts a viable option for use in finishing cattle diets as a source of both energy and protein (Klopfenstein et al., 2008). The use of grain milling coproducts has increased yearly since 2007 (Samuelson et al., 2016). Extracting oil from the condensed distillers solubles results in approximately 30% less fat in the final DDGS product (Lüking and Funsch, 2009). Our studies indicated that there was little difference in digestibility, animal performance, or carcass quality with cattle fed finishing diets with DDGS with a lower oil concentration (4.5% fat). This indicates that producers may be able to utilize a DDGS with a lower oil concentration in their finishing diets without negative effects on performance or carcass quality. Producers may be able to utilize this DDGS with a lower oil concentration (4.5% fat) in finishing diets with either corn or barley and see similar results as feeding a DDGS with a traditional oil concentration (7.9% fat). This could indicate that a producer may not see a reduction in profitability when feeding low fat DDGS as compared to high fat DDGS if priced similarly.

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