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EVALUATION OF ALPHA AMYLASE CONTAINING CORN ON FINISHING CATTLE PERFORMANCE AND DIGESTIBILTY

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EVALUATION OF ALPHA AMYLASE CONTAINING CORN ON FINISHING CATTLE PERFORMANCE AND DIGESTIBILTY

by

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One digestion and four finishing trials were conducted to evaluate the effect of a new corn hybrid containing an α-amylase trait, Syngenta Enogen Feed Corn (SYT-EFC) on site and extent of digestion, ruminal fermentation parameters, and feedlot performance. Experiments utilized corn containing the enzymatic gene compared to controls, the near isoline parental corn (NEG) or commercially available corn grain (CON), processed as dry-rolled corn (DRC) or high moisture corn (HMC) in diets with dry [distillers grains plus solubles (DGS)] or wet (Sweet Bran) milling byproducts. The corn grain of the experimental diets were fed as the sole grain source, comprising 100% of the concentrate in the diet. Cattle fed SYT-EFC, processed as DRC with Sweet Bran had increased G:F resulting in feeding values ranging from 103 to 116% of CON or NEG. Steers fed SYT-EFC, processed as DRC with DGS had increased G:F resulting in feeding values ranging from 101 to 107% of CON or 105% of NEG. However, when processed as HMC, feeding SYT-EFC resulted in 96 and 102% that of NEG when fed with Sweet Bran or DGS, respectively. Marbling and 12th rib fat thickness data were mixed among trials with being increased in cattle fed SYT-EFC or observing no detectable difference among treatments. Cattle fed SYT-EFC had greater postruminal starch digestibility compared to NEG resulting in a 2.2 and 6.3% increase in total tract starch digestibility in DGS and Sweet Bran diets, respectively. Overall, feeding corn

containing an α-amylase trait as DRC would suggest a slight improvement in feed efficiency.

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Chapter I

Introduction

As of July 1, 2017, the current total cattle inventory in the United States was reported to be 103 million head, up 4% from the 98.2 million head in 2015 suggesting that the beef industry is on the rise from the industry's lowest reported point in 2012 (USDA, 2017a). An increase in total cattle inventory, results in an increase in the total number of cattle on feed. In 2016, it was reported that 30.6 million head of cattle were slaughtered in the United States producing 11.48 billion kg of marketable beef product (USDA, 2017b). Along with the increase in cattle numbers, the human population is expected to increase as well. It was estimated in 2017 that world population was 7.55 billion people and expected to increase to 8.55 billion by 2030, 9.77 billion by 2050, and 11.18 billion people by the year 2100 (United Nations, 2017). With the substantial increase in the world population, advancing technologies for increased animal performance are needed to help meet the increasing demand for beef.

To order to reach optimal performance, maximum starch digestion must be reached. The traditional method for increasing feed efficiency and starch digestibility is corn processing (rolling, ensiling, or steam flaking). However, increased corn processing results in more rapidly fermentable grains entering the rumen, thereby increasing the risk for ruminal acidosis. The key to achieving maximum starch digestion is being able to balance the amount of fermentable grains and ruminal acidosis.

An alternative method for increasing feed efficiency in finishing diets could be with the use of dietary exogenous enzymes. Although most of the research with feeding

exogenous enzymes has been with fibrolytic enzymes to increase fiber utilization, the addition of α-amylase can result in improved animal performance. A new corn hybrid, Syngenta Enogen Feed Corn (SYT-EFC), has been created to contain a thermotolerant and pH tolerant α-amylase enzyme which has mainly been utilized by the dry milling ethanol industry. The internal enzymes become activated at increased temperatures, thereby reducing the need for α-amylase addition to convert starch to glucose prior to the fermentation process. It is unclear if the internal enzyme in SYT-EFC will be active in the rumen or small intestine of feedlot cattle fed corn-based concentrate diets. Therefore, the objectives of the research reported in this dissertation were to: 1) evaluate feeding SYT-EFC on feedlot cattle performance and carcass characteristics, 2) evaluate the impact of processing SYT-EFC as dry-rolled or high-moisture corn on animal performance, and 3) determine the effects of SYT-EFC on the site and extent of digestion and ruminal metabolism parameters in finishing cattle diets.

Chapter II

Review of Literature

Corn Kernel Characteristics.

Five Classes of Corn. In general, there are five different classes of corn that are produced – flint corn, popcorn, flour corn, sweet corn, and dent corn (Watson, 1987). The differences between the different types are based on kernel characteristics. Flint corn has a distinguishable rounded crown and the hardest kernels due to the large abundance of horny endosperm within the kernel. Popcorn is a small type of flint corn and is a traditional snack food in the United States. Flour corn has either a rounded or flattened crown but is comprised of essentially all floury or soft endosperm. Sweet corn is different from field corn due to a mutation on chromosome 4 at the sugary locus with sweet corn containing the su gene. Dent corn, a flint-flour hybrid, is the largest seed that contains a concaved crown produced during the kernel maturation process. During the dehydration process of the corn kernel, the horny endosperm that surrounds the floury endosperm inhibits uniform shrinking of the floury endosperm resulting in a depressed crown (Watson, 1987). This review will discuss dent corn unless otherwise specified.

Components. The four principle parts of a corn kernel are the tip cap, pericarp or hull, endosperm, and germ. The tip cap is the attachment point of the kernel and the cob. The pericarp, the outside waxy coating, encases the endosperm and germ making up approximately 5-6% of the kernel (Kotarski, et al., 1992; Delcour and Hoseney, 2010). The pericarp is composed of 71.5% nonstarch polysaccharides, 6% protein, 2% ash, 20% cellulose, and 0.5% fat (Delcour and Hoseney, 2010). Disruption of the pericarp, either

through mastication or kernel processing, must occur in order for rumen microorganisms to access the endosperm for efficient starch degradation (McAllister, et al., 1990; Beauchemin et al., 1994).

The endosperm makes up 82-84% of the corn kernel dry weight and on a weight basis contains 86-89% starch (Watson, 1987). The remaining fractions are comprised of mainly protein and small quantities of fat, minerals, and sugar. The endosperm consists of two components: outer aleurone layer and starchy endosperm. The aleurone layer is a thin layer that surrounds the starchy endosperm and germ. During the wet milling process, the aleurone and pericarp are removed to produce corn bran. The starchy endosperm is comprised of two different types of endosperm, a vitreous or horny endosperm and an opaque, floury, soft endosperm. In general, the vitreous endosperm is located near the aleurone containing tightly compacted cells comprised of starch granules that are embedded in zein protein bodies. The strength of the interacting bond between the starch granules and zein protein bodies gives the endosperm its characteristic hardness. The floury endosperm, surrounding the central fissure of the corn kernel, contains starch granules that are encased in air pockets resulting in opacity of the endosperm. The starch granules are concealed by a protein matrix that does not contain protein bodies (Delcour and Hoseney, 2010). Because of these physical features, starch located within the floury endosperm is more susceptible to external forces such as grain processing and digestion (Huntington, 1997). The endosperm of different corn types will vary in the proportion of horny/floury ratio which can have an impact on animal performance.

The germ makes up 10-12% of corn kernel on a dry weight basis and is composed of the embryo and scutellum, which functions as a nutritive organ for the embryo (Watson, 1987). On a percent DM basis, the germ is relatively high in fat (averaging 33.2%), protein (18.4%), sugar (10.8%; mainly sucrose), and ash (10.5%; Watson, 1987).

Starch. The primary nutrient in finishing cattle diets is starch. Starch is a storage polysaccharide in plants and a major energy source for animals. Most cereal grains contain approximately 70% starch with the corn kernel containing 72-73% starch (Rooney and Plugfelder, 1986; Watson, 1987). Starch is a heterogeneous polysaccharide composed of two highly organized molecules, amylose and amylopectin, held together by hydrogen bonding. Amylose, making up 25-30% of the starch, is a linear polymer comprised of α-1,4 linked D-glucose units (Watson, 1987). Amylopectin, composing 70-75% of the starch, is a larger, more complexed, branched polymer containing linear chains of α-1,4 linked D-glucose joined at branch points by α-1,6 bonds at approximately every 20-25 glucose units (Delcour and Hoseney, 2010; Rooney and Plugfelder, 1986). Proportions of amylose and amylopectin vary among species and hybrids. Corn varieties that are at the end of spectrums have been identified containing either 70% amylose, referred to as amylotypes, or 100% amylopectin, referred to as waxy maize (Delcour and Hoseney, 2010).

Starch granules are pseudo-crystals that contain crystalline (organized) and amorphous (non-organized) regions. The crystalline area, primarily amylopectin, is resistant to enzymatic attack and water entry, whereas the amorphous area, primarily amylose, is less dense allowing for amylase attack and water movement (Rooney and Plugfelder, 1986).

When sufficient energy is applied to disrupt intermolecular hydrogen bonds, the starch granules undergo gelatinization. In order for gelatinization to occur, starch granules must be heated in water as starch is insoluble in cold water (Ratnayake and Jackson, 2006). When heated, the granules within the amorphous region will absorb water and swell but penetration of heat and moisture will break intermolecular hydrogen bonds and destabilize the crystalline structure (Rooney and Plugfelder, 1986). This process irreversibly alters the starch granules resulting in an increase in enzyme susceptibility and digestibility.

Kernel Processing

Description of Processes. Of the nutritionists surveyed by Samuelson et al., (2016), corn was stated as the primary grain utilized in all finishing diets. Corn is comprised of 70% starch making it the primary energy component. Attaining optimal starch digestion is critical for improving cattle efficiency and maximizing production. Therefore, the purpose of grain processing is to maximize total tract starch digestibility by increasing ruminal starch fermentation, while avoiding digestive disturbances (National Academies of Science, Engineering, and Medicine, 2016).

Overwhelmingly, corn that is fed in finishing diets is processed prior to feeding with the most common method being steam flaking (70.8%), followed by high-moisture harvesting and storage (16.7%), and dry rolling (12.5%; Samuelson et al., 2016). However, Samuelson et al. (2016) was a nutritionist-based survey targeting the southern plains region which may or may not reflect the diet percentages fed throughout the United States. Complete descriptions of the three most common processing methods have been published (Hale and Theurer, 1972; Ensminger et al., 1990). Dry-rolled corn

(DRC) refers to corn that has passed between a set of grooved rollers to mechanically compress or crack the hull and pericarp. This allows ruminal microorganisms and enzymes access to the endosperm and increased surface area for microbial attachment. Without this rolling process, i.e. feeding whole corn, microorganisms can only obtain access to the internal endosperm from physical mastication by the animal. There is variation in particle size for corn that has been rolled and can be influenced by groove spacing, roller pressure, and moisture content of the corn. High-moisture corn (HMC) refers to corn that is harvested and ensiled at a moisture level of 25-30% (Buchanan-Smith et al., 2003). High-moisture corn can be stored in an oxygen-limiting silo, plastic bag, or concrete bunker. Typically, HMC is rolled or ground before storing which facilitates proper anaerobic fermentation and packing. Steam flaked corn (SFC) refers to corn that has been steeped in 3-6% added water for 15 minutes to 24 hours prior to rolling. Large roller mills will produce thin flakes of corn that will typically weigh 0.31 to 0.41 kg/L (24 to 32 lb/bushel) and contain 19 to 24% moisture when they exit the rollers (National Academies of Science, Engineering, and Medicine, 2016). The process of flaking (added moisture and heat) results in gelatinization of the starch granules causing the starch to become more readily digestible (Zinn et al., 2002).

Impacts of processing on cattle performance. Owens et al., (1997) conducted a review evaluating the impact of corn processing on feedlot cattle performance. The review consisted of 353 experiments; 183 trials fed DRC, 117 trials fed HMC, and 53 trials fed SFC, from various journals, experiment stations, and feeder's day reports ranging from 1974 through 1995. The data suggested that average DMI was 9.45, 8.72, and 8.35 kg/d for DRC, HMC, and SFC fed

cattle, respectively. This proposes that cattle fed HMC and SFC will result in an 8.4 and 13.2% lower DMI compared to cattle fed DRC with a 4.4% reduction for SFC compared with HMC ($P < 0.05$). Average daily gains (1.45, 1.37, and 1.43 kg/d for DRC, HMC and SFC, respectively) were not different between DRC and SFC but ADG was reduced by 5.8 and 4.4% for HMC compared to DRC and SFC, respectively. Feed efficiency was not different between DRC and HMC, but cattle fed SFC were 11.9 and 9.5% more efficient than cattle fed DRC or HMC, respectively.

Huck et al., (1998) fed 74.5% processed corn (DRC, HMC, and SFC) to calf-fed steers. There was no difference in DMI among the three processing treatments (10.4, 10.0, and 10.3 kg/d for DRC, HMC, SFC, respectively; $P = 0.12$). Steers fed SFC had 7.7% and 8.9% greater ADG compared to DRC and HMC, respectively, while DRC and HMC were similar. Feed efficiency (0.175, 0.181, and 0.190 for DRC, HMC, and SFC, respectively) was 8.6 and 5.0% greater for steers fed SFC compared to DRC and HMC, respectively.

Cooper et al., (2002a) fed DRC, HMC, and SFC in 82%-concentrate diets to yearling steers. Dry matter intakes (9.9, 10.5, and 8.1 kg/d for DRC, HMC, SFC, respectively) were not different between DRC and HMC, however cattle fed SFC had a 25.9% reduction in DMI compared to the average intakes for DRC and HMC. Average daily gains were (1.54, 1.68, and 1.36 kg/d for DRC, HMC, SFC, respectively) similar for DRC and HMC, however steers fed HMC had a 9.1% numeric increase in ADG compared to DRC. Cattle fed SFC had a 13.2 and 23.5% decrease in ADG compared to steers fed DRC and HMC, respectively.

Feed efficiencies, calculated from reported ADG and DMI values, (0.156, 0.160, and 0.168 for DRC, HMC, and SFC, respectively) were 7.7 and 5.0% greater for steers fed SFC compared to DRC and HMC, respectively.

Starch Digestion.

The primary goal of processing corn is to increase starch availability. Optimizing starch digestibility is critical in maximizing efficiencies and production. The extent of starch digestion can be influenced by factors such as dietary composition, starch consumption, mechanical modifications (grain processing), and chemical modifications (gelatinization).

Rumen. Once starch has been consumed, it enters the ruminoreticulum where rumen microorganisms can begin the process of starch fermentation. Approximately three-fourths of ruminal starch digestion is performed by ruminal bacteria via attachment of feed particles (Huntington, 1997). Bacterial attachment is divided into 1 of 2 categorizes: 1) loosely attached through an electrical charge or 2) firmly attached to feed particles via receptors. Because bacteria are so small in size they must actively secrete amylase, produce surface-associated amylases, or blend cell membranes with amylases and binding proteins to hydrolyze starch (Kotarski et al., 1992). Kotarski et al., (1992) reported 15 different strains of amylolytic bacteria and 8 different endo- or exo-amylolytic enzymes produced by those bacteria. However, not all bacteria contain all of the essential enzymes for digestion; therefore, integration of bacterial species is necessary for maximum starch digestion.

Although small in numbers, protozoa and fungi can exert an influence on ruminal starch hydrolysis rates (Kotarski et al., 1992). Protozoa are capable of decreasing the rate

of starch digestion by ingesting bacteria and ingesting starch granules and soluble sugars making them inaccessible to the faster growing bacteria. Mendoza et al., (1993) reported that the rate and extent of ruminal starch digestion were increased in defaunated sheep fed HMC diets. Protozoa can comprise up to 38% of its DM as polysaccharide with more typically values ranging from 6 to 10% (Jouany and Thivend, 1972). While protozoa may decrease ruminal starch hydrolysis rates, fungi may aid in extent and rate by physically breaking apart the surface and creating lesions in feed particles resulting in increased surface area for bacterial attachment (McAllister et al., 1994).

The main end-products of microbial fermentation are volatile fatty acids (VFA), with the majority being acetate, propionate, and butyrate, CH_4, CO_2, NH_3, and microbial cells (Wolin et al., 1997). During microbial fermentation, 75-85% of feed energy is converted to VFA (with the majority being acetate, propionate, and butyrate) with the remainder lost as CH_4 and heat (Sutton, 1979). Of the three principle VFA's, propionate is more preferred as more energy is produced, no carbon is lost, and 2 hydrogens are consumed when propionate is derived from glucose. Propionate is the only gluconeogenic VFA with 27 to 54% of glucose within the animal formed from propionate (Lindsay, 1970). Acetate and butyrate do not contribute to the glucose supply. Most acetate is transported through the portal vein to the liver unchanged where it is converted to acetyl-CoA or ketone bodies and transported to peripheral tissues to be utilized. Butyrate is metabolized extensively by the rumen epithelium producing acetoacetate and β-hydroxybutyrate ketone bodies which are oxidized in many tissues for energy (National Academies of Science, Engineering, and Medicine, 2016).

The effect of diet can impact the proportion of the VFA's produced as the result of ruminal fermentation. Cattle fed diets high in forage promote the production of acetate resulting in VFA proportions (acetate:propionate:butyrate) to range from 70:20:10 to 65:25:10 (Owens and Goetsch, 1988). However, high concentrate diets promote the production of propionate at the expense of acetate, altering the VFA proportions (acetate:propionate:butyrate) to approximately 50:40:10 to 50:35:15 (Bevans et al., 2005).

While production of VFA's are one of the main end-products of ruminal fermentation, when the rate of ruminal acid production exceeds the rate of absorption, acidosis will result (Owens et al., 1998). By definition, acidosis is the reduction of alkali compared to the acid (hydrogen ions) in bodily fluids (Stedman, 1982). In finishing cattle, acidosis is the result of biochemical and physiological stressors caused by rapid production and absorption of ruminal organic acids resulting in over consumption of rapidly fermentable carbohydrates. The over-accumulation of organic acids will reduce ruminal pH. The extent of the pH reduction will determine the degree of acidosis; subacute or acute. Subacute acidosis is characterized as ruminal pH below 5.6 and may result in decreased animal performance, rumenitis, or liver abscesses; however, cattle may not show signs of illness. Acute acidosis is characterized as ruminal pH below 5.2 and can cause erratic feed intakes, diarrhea, rumen stasis, and impair physiological functions resulting in death. During an acidosis event, ruminal osmolarity will increase resulting in water to be drawn into the rumen from the blood to help alleviate the elevated concentrations of organic acids. The increased osmolarity can damage the rumen wall allowing for ruminal bacteria to flow freely from the rumen and into the bloodstream

leading to abscess formation within the liver (Owens et al., 1998). Depending on the extent of rumen epithelial damage, rumen absorption rate can be affected.

Small Intestine. Digestion and absorption of starch within the small intestine has previously been reviewed (Owens et al., 1986; Huntington, 1997; Harmon, 1992, 1993). Intestinal starch digestion and absorption occurs in three phases 1) pancreatic α-amylase secretion, 2) secretion of brush border carbohydrases, 3) transportation of glucose out of the intestinal lumen and into portal circulation (National Academies of Science, Engineering, and Medicine, 2016). Absorption of glucose has been reported to be more energetically efficient than fermentation and absorption of organic acids (Owens et al., 1986).

Carbohydrate assimilation in the small intestine begins with chyme entering the duodenum from the abomasum triggering the secretion of pancreatic α-amylase. Alpha-amylase will begin hydrolyzing the α1,4 glycosidic bonds randomly along the polysaccharide producing dextrins, limit dextrins and linear oligosaccharides consisting of two or three glucose units (Gray, 1992; Harmon, 1993). Research has suggested that intake, specifically energy intake, can have a major influence on pancreatic α-amylase secretion. Russell et al., (1981) fed 24 yearling Holstein steers a diet consisting of ground alfalfa hay and alfalfa pellets or 32% corn, 60% corn silage to meet metabolizable energy (ME) maintenance requirements and then slaughtered to measure pancreatic α-amylase concentrations. Although not significant, steers fed the corn:silage diet decreased pancreatic α-amylase concentrations by 31% compared to steers fed alfalfa hay. In the same trial, steers were fed 1, 2, or 3 times the animal's maintenance ME requirement. While not significant, the authors observed a 185% improvement in

pancreatic α-amylase concentration when ME intake increased from 1 to 2 times with no additional improvement when ME intake increased to 3 times maintenance. To evaluate dietary energy and forage effects, Kreikemeier et al., (1990) fed calves 90% alfalfa or 90% wheat:sorghum diets at one or two times their maintenance energy requirements for 140 d. For the main effect of ME intake, α-amylase concentration increased by 55% and total content of α-amylase within the pancreas increased by 140%. However, a 51.8% reduction in α-amylase concentration and 79.1% reduction in total pancreatic α-amylase content was observed in calves fed the 90% concentrate diet compared to the calves fed 90% forage. The authors reported that calves consuming forage had increased concentrations of α-amylase and total α-amylase content in the small intestine. These findings contradict previous research stating that steers consuming an all-concentrate diet had 40% greater pancreatic α-amylase activity compared to steers maintained on pasture for 126 d prior to slaughter (Clary et al., 1969). However, the trial conducted by Clary et al,. (1969) may have been confounded by dietary energy intake.

The second phase of intestinal digestion and absorption of starch transpires at the brush border membrane utilizing brush border carbohydrases; isomaltase and disaccharidases. Isomaltase is the only enzyme capable of hydrolyzing α 1,6 bonds within the amylopectin of starch. The disaccharidases; sucrase, maltase, and lactase, hydrolyze the disaccharide bonds yielding sucrose, maltose, and lactose, respectively. Researchers have eluded to measurable maltase and isomaltase activities within the ruminant small intestine with minimal adaptive response to diet (Janes et al., 1985; Kreikemeier, et al., 1990). Unlike nonruminants, ruminants depend on maltase and isomaltase to produce glucose for absorption as sucrase activity is minimal (Harmon,

1992). Once disaccharidases have yielded monosaccharides, the monosaccharides can be absorbed.

The third phase of intestinal starch digestion and absorption is the transport of glucose out of the intestinal lumen, into the enterocyte, and into portal circulation. There are three main routes of glucose transport from the intestinal lumen and into circulation: paracellular diffusion, active transport, and passive transport. Paracellular diffusion is the mechanism of absorption where sugars exit the intestinal lumen and into portal circulation via intercellular spaces (Harmon and McLeod, 2001). This process only occurs at high luminal glucose concentrations (> 25 mM) and concentrations exceeding approximately 200 mM will result in paracellular absorption exceeding active transport (Pappenheimer and Reiss, 1987). However, Krehbiel et al., (1996) demonstrated that paracellular diffusion was a minor component in glucose absorption as 2-deoxyglucose, a nonmetabolizable glucose analog, only represented 0.7 to 1.7% of the glucose reaching the portal blood. Active transport is the utilization of 1 mole of ATP required to transport 1 monosaccharide. The sodium glucose transporter 1 (SGLT1) is the main glucose transporter in ruminants. The SGLT1 couples glucose through a Na^+ gradient that is maintained by Na^+/K^+-ATPase in the basolateral membrane (Harmon and McLeod, 2001). Zhao et al., (1998) observed expression of SGLT1 in lactating dairy cows and reported activity throughout the intestine (duodenum, jejunum, and ileum) as well as in the rumen and omasum. However, previous research has reported that glucose transporter activity will decline with age, nevertheless, transporter expression can be regulated by the presence of glucose (Shirazi-Beechey et al., 1991). Passive transport utilizes a carrier protein to transport sugars across the brush border membrane without

expending energy. The transporter GLUT2; a low affinity, high volume transporter, is located in the brush border and basolateral membrane of enterocytes and serves as a route of glucose entry and exit from the blood and enterocytes (Thorens, 1993). When glucose concentrations are increased in the intestinal lumen the GLUT2 transporter will translocate to the brush border membrane for increased absorption. The increased insulin response to increased blood glucose will translocate the transporter from the brush border membrane back into the cell.

Starch Digestion among corn processing methods. The primary goal for processing corn grain in finishing cattle diets is to increase starch availability. The extent of starch digestion within the digestive tract can be influenced by factors such as the amount of starch consumed and grain alterations; i.e. mechanical (grain processing) and chemical (gelatinization).

Huntington (1997) summarized data on the impact of corn processing on starch digestibility from fourteen trials published from 1986 to 1995. Starch intakes were reported to be 2.06, 3.89, and 2.20 kg/d on average for DRC, HMC, and SFC, respectively. The major site of corn grain starch digestion is typically the rumen (Theurer, 1986). Ruminal starch digestibilities averaged 76.2, 89.9, and 84.8% of intake for DRC, HMC, and SFC, respectively. These data suggest that ruminal starch digestion was increased by 18.0 and 11.3% when corn was processed as HMC or SFC compared to DRC, respectively. Post-ruminal starch digestibilities averaged 68.9, 67.8, and 92.6% entering, respectively. By steam flaking corn, postruminal digestion of starch entering the duodenum increased by 35% compared to the average of DRC and HMC. Lastly, total tract starch

digestibilities averaged 92.2, 95.3, and 98.6% of intake, respectively, supporting that grains that are extensively degraded in the rumen will have the greatest total tract starch digestibilities (Theurer, 1986).

Galyean et al., (1976) fed 78% corn based diets processed as DRC, HMC, or SFC to yearling steers. There was no difference in starch intake between corn processing treatments; however, steers fed HMC had an 11% numerical increase in starch intake compared to DRC. Ruminal starch digestibility was 77.8, 89.3, and 83.0% for corn processed as DRC, HMC, or SFC, respectively, resulting in a 14.8% increase for HMC compared to DRC ($P < 0.05$). Postruminal starch digestibilities were similar among processing treatments; however, steers fed SFC had 11.3% numerically greater percentage of starch entering the small intestine compared to DRC. Total tract starch digestibilities were 96.3, 99.1, and 99.1% for corn processed as DRC, HMC, or SFC, respectively, resulting in a 2.9% increase for HMC and SFC compared with DRC ($P < 0.05$).

Cooper et al., (2002b) compared the three main corn processing methods (DRC, HMC, and SFC) on site and extent of starch digestion. Diets consisted of 81.75% processed corn with no ethanol byproducts. Starch intakes were similar ($P > 0.10$) among corn processing treatments. However, in agreement with Galyean et al., (1976), steers fed HMC had 12% numerically greater starch intakes compared to DRC. True ruminal starch digestibilities were similar between HMC and SFC (97.3 and 94.7%, respectively) and averaged 18.2% greater ($P < 0.05$) than DRC (81.2%). Postruminal starch digestibilities were similar between DRC and HMC (84.4 and 86.5%, respectively). Conversely,

steers fed SFC (98.3%) had 15% greater postruminal starch digestibility compared to DRC or HMC ($P < 0.05$). Total tract digestibilities were 96.1, 98.7, and 99.8% for DRC, HMC, SFC, respectively, resulting in a 3% increase for SFC compared to DRC.

The three previous trials analyzed all three processing methods within the same trial. On average, ruminal, postruminal, and total tract starch digestibilities were 78.4, 79.4, and 94.9% for DRC; 92.1, 81.7, and 98.8% for HMC; and 87.5, 95.1, and 99.2% for SFC.

Addition of Exogenous Amylase Enzymes to Diets

In all species, enzymes are a necessity for digestive processes to occur. Enzymes are produced by living cells to bring about specific biochemical reactions. Supplemental enzymes, categorized as a feed additive, catalyze the degradative reactions by which feed ingredients (substrates) are digested into their nutritive components (simple sugars, fatty acids, amino acids; McAllister et al., 2001). These nutritive components can then be utilized for cell growth by either the ruminal microbes or by the animal. This has brought about the notion of increasing cattle productivity through the use of feeding supplemental exogenous enzymes.

The first reported use of exogenous enzymes in cattle diets was described by Burroughs et al., (1960) in a series of ten feeding trials utilizing 325 steers and heifers in 43 pens. The enzyme supplement (Agrozyme; combination of amylolytic and proteolytic enzymes) was fed to half of the pens at either 3.40 or 6.80 g per animal per day. The length of the feeding periods across all ten trials

varied but averaged 140 days. The diet varied across trials with cattle in trials 1-6 fed a high concentrate, finishing diet and cattle in trials 7-10 fed a growing silage diet containing corn, oats, or an oat alfalfa-brome mixture. Performance of cattle fed the high enzyme dose (6.80 g per animal per day) was similar to the performance of cattle fed the lower dose (3.40 g per animal per day), therefore, the authors reported the main effect of enzyme. On average, feeding the enzyme supplement increased ADG by 6.5% and improved feed conversion by 6.0% compared to the non-enzyme control diets. This research was the beginning of feeding exogenous supplemental enzyme in cattle diets leading to many experiments exploring the use of fibrolytic enzymes as a means of increasing fiber digestibility. However, there is potential for increased performance and starch digestibility in cattle feed exogenous amylase enzymes.

Beef Cattle. Data from feeding exogenous alpha-amylase enzymes in beef cattle diets are limited as ruminal starch digestion is considered extensive and digestive disorders such as acidosis, can result from rapid digestion of excessive amounts of starch (Owens et al., 1998). However, experiments have been conducted to evaluate the use of feeding a supplemental α-amylase enzyme in finishing diets.

Tricarico et al., (2007) evaluated feeding a supplemental α-amylase enzyme (Amaize, Alltech Inc., Nicholasville, KY) containing *Aspergillus oryzae* extract and *Saccharmoyces cerevisiae* fermentation solubles on feedlot cattle performance and carcass characteristics. Three experiments were conducted to examine 1) supplemental α-amylase and roughage source on cattle performance

(Exp. 1), 2) two concentrations of supplemental α-amylase and corn processing on cattle performance (Exp. 2), and 3) restricting DMI and the effects of supplemental α-amylase on ADG (Exp. 3). Experiment 1 utilized 162 crossbred, calf-fed steers in 24 pens with 6 weight blocks, 4 treatments, 6 pens per treatment, and 5 steers per pen. Treatments were designed in a 2x2 factorial with factors being roughage source (cottonseed hulls or alfalfa) and enzyme inclusion [0 or 950 dextrinizing units (DU)/kg of DM] in a SFC based diet. There were no roughage source × amylase interaction for final BW, DMI, ADG, or G:F ($P \geq 0.11$) or main effect of amylase inclusion differences for final BW, DMI, ADG, or G:F ($P \geq 0.11$) over the feeding period. There were no roughage source × amylase interactions for all carcass characteristics ($P \geq 0.12$). However, cattle fed the α-amylase supplement had greater LM area compared to the cattle fed the control supplement ($P = 0.02$). The authors attributed the increase in LM area to the numerically greater ADG and carcass adjusted BW observed for steers fed amylase with cottonseed hulls. Experiment 2 utilized 96 crossbred yearling heifers in a randomized complete block design with 4 weight blocks, 6 treatments, 4 pens per treatment, and 4 heifers per pen. Dietary treatments were designed as a 2x3 factorial with factors consisting of corn processing (dry cracked or high-moisture corn) and α-amylase concentration (0, 580, or 1,160 DU/kg of dietary DM). All diets contained 15% corn silage as the roughage source. There were no corn processing × amylase interactions for final BW, DMI, ADG, or G:F ($P \geq 0.14$) over the entire feeding period. The authors reported a quadratic increase ($P = 0.04$) in ADG and a tendency ($P = 0.07$) for a quadratic increase in DMI with

cattle fed 580 DU/kg of DM of α-amylase having the greatest DMI and ADG. There were no roughage source × amylase interaction for all carcass characteristics ($P \geq 0.13$). However, cattle fed the 580, DU/kg of DM of α-amylase supplement had the greatest HCW ($P = 0.03$), greatest LM area ($P = 0.04$), and lowest calculated yield grade ($P = 0.02$). Experiment 3 utilized 64 crossbred steers in a 56 d programmed-gain system to target 1.52 kg/d with an assumed 567 kg final BW, and a target end point of USDA Choice grade. Steers were blocked into 4 BW blocks with 4 pens per treatment, and 8 steers per pen. Treatments consisted of α-amylase supplementation at 0 or 930 DU/kg of dietary DM in a SFC based diet. The authors observed no differences in animal performance ($P \geq 0.15$) when fed the α-amylase supplement.

DiLorenzo et al., (2011) evaluated feeding a supplemental α-amylase enzyme (Ronozyme RumiStar, DSM Nutritional Products, Inc., Kaiseraugst, Switzerland) on feedlot cattle performance and nutrient digestibility. The authors utilized 32 crossbred steers in a 42 d digestion trial designed as a randomized complete block design and treatments designed as a 2x2 factorial. Factors included amylase concentration at 0 or 600 kilo novo units/kg of dietary DM and corn processing being DRC or SFC. Fecal samples were collected twice daily (0800 and 1600 h) on d 39 to 42. There were no corn processing × amylase concentration interaction for final BW, daily DMI, ADG, or G:F ($P \geq 0.20$) or main effect of amylase concentration differences for final BW, daily DMI, ADG, or G:F ($P \geq 0.35$) over the 42 d feeding period. No corn processing × amylase concentration interactions were observed for DM, OM, NDF, and ADF

digestibilities ($P \geq 0.09$). A tendency for an interaction was observed for total tract starch digestibility ($P = 0.06$) with steers fed DRC having a greater magnitude of difference compared with SFC. Steers fed DRC-600 had a lower total tract starch digestibility compared to DRC-0. There were also no differences for the main effect of amylase concentration on DM, OM, NDF, ADF, and starch total tract digestibilities ($P \geq 0.21$).

Zerby et al., (2011) conducted two experiments evaluating the effects of *Aspergillus oryzae* extract of *Saccharmyces cervisiae* on growth and carcass characteristics of lambs and steers. Experiment 1 utilized 48 crossbred lambs in a randomized complete block experiment blocked by sex (n = 24, respectively) and initial BW (light, medium, and heavy) with a total of 6 pens per treatment and 4 lambs per pen. Treatments consisted of inclusion of *Aspergillus oryzae* extract [Amaferm (AMF); Biozyme Inc., St. Joseph, MO] at either 0 or 1 gram/animal/day in a pelleted feed. There were no differences in final BW, DMI, or ADG ($P \geq 0.12$) for lambs fed AMF compared to the controls. Lambs fed AFM had an 8.8% numeric increase in ADG resulting in a 4.9% greater G:F compared to controls ($P = 0.07$). There were no significant differences for all carcass characteristics measured ($P \geq 0.14$). Experiment 2 utilized 168 crossbred calf-fed steers in a completely randomized design with 6 treatments, 4 pens per treatment, and 7 steers per pen. Dietary treatments were designed as a 2 × 3 factorial with factors being corn processing [dry whole shelled corn (DWSC) or HMC] and supplement type [no added enzyme (CON), *S. cervisiae boulardii* CNCM 1079-Levucell SB (LEV), and AMF]. Amaferm and LEV enzymes were

fed at 3 and 0.5 g/animal/day, respectively. An interaction between corn processing and supplement was reported for G:F ($P = 0.03$) with cattle supplemented with AMF had a 7.2% increase ($P < 0.05$) in G:F when fed with DWSC but was not different when HMC was fed. There were no significant differences for the main effect of supplement type for final BW, DMI, and ADG ($P \geq 0.30$). There were no interactions ($P \geq 0.13$) or main effect of supplement type ($P \geq 0.33$) on HCW, dressing percent, 12th rib fat thickness, LM area, marbling score, and yield grade.

Although the responses to the addition of amylase enzymes in cattle diets are contradicting, it appears that there is no additional response gained in animal performance in diets with more extensively processed grains such as HMC or SFC. This could be attributed to the enzyme being masked due to a high percent of starch digestion already occurring. Research on the utilization of amylase enzyme in less processed diets is warranted to fully understand the impact of additional alpha-amylase on beef cattle performance.

Dairy Cattle. The objective of utilizing exogenous enzymes in dairy cattle production is to improve milk yield components as well as overall milk production. While multiple trials have investigated the efficacy of fibrolytic enzymes such as cellulases and/or xylanases in dairy rations on ruminal fiber digestion, the evaluation of amylases on ruminal starch digestion has been less. Four trials have evaluated the commercial α-amylase product Amaize (Alltech Inc., Nicholasville, KY) on ruminal fermentation, milk production, and/or digestion.

Defrain et al., (2005) evaluated the impact of feeding Amaize during the transition period on rumen fermentation and lactation performance. Alpha-amylase enzymes have been shown to increase ruminal concentrations of butyrate (Hristov et al., 2000), the authors hypothesized that shifting the rumen fermentation profile would aid in alleviating metabolic issues associated with the transition period and improve energy balance and performance during the transition period. Twenty-four multiparous Holstein cows were utilized, and amylase treatment was administered on d 21 prepartum at 0.1% of the diet DM. Treatments were fed until cows were 21 days in milk (DIM) with a common lactation diet fed until cows were 70 DIM. The authors reported that prepartum DMI, BW, and BCS were not different ($P \geq 0.41$) between the amylase and control treatment. No significant differences were observed in postpartum DMI, milk yield, energy corrected milk, and milk composition ($P \geq 0.13$) with feeding the Amaize product. No significant differences were observed for pre and postpartum VFA concentrations ($P \geq 0.14$). However, cows that were fed the amylase treatment had greater NEFA and BHBA prepartum ($P \leq 0.01$) and a tendency ($P = 0.08$) for an increase in plasma blood glucose postpartum. The increase in BHBA may have impacted the gluconeogenic activity prepartum as BHBA is metabolized to acetyl-CoA, an allosteric activator of pyruvate carboxylase, which converts pyruvate to oxaloacetate during gluconeogenesis (Utter and Keech, 1963). While performance characteristics were minimal, the increase in BHBA and NEFA prepartum and plasma glucose postpartum suggests

an improvement in energy balance and ability to maintain blood glucose concentrations.

Tricarico et al., (2005) evaluated the impact of Amaize on milk composition and production, ruminal starch disappearance and fermentation, and metabolite concentrations in 20 intact and 4 ruminally fistulated lactating Holstein cows. The experiment was designed as 4×4 Latin-square with four 21 d periods, 14 d adaptation and 7 d collection. The amylase supplement was feed at 0, 240, 480, or 720 DU/kg (DM basis). The addition of supplemental amylase increased milk production quadratically ($P = 0.02$) with the greatest milk yield coming from cows consuming the 240 DU/kg treatment diet. Enzyme supplementation quadratically increased fat corrected ($P = 0.01$) and energy corrected ($P = 0.01$) milk resulting from a quadratic increase in milk fat yield ($P = 0.02$) and a tendency for increased milk protein yield ($P = 0.06$). *In situ* ruminal starch disappearance was not different among treatments for 6 or 24 h incubation. Molar proportions of butyrate were increased ($P = 0.05$) and a tendency for an increase in acetate ($P = 0.06$) were observed resulting in a greater acetate to propionate ratio ($P = 0.04$) with the addition of amylase supplementation compared to the control. Similarly to DeFrain et al., (2005), feeding the amylase enzyme increased serum concentrations of BHBA ($P = 0.01$) and NEFA ($P = 0.03$), however, linearly decreased blood glucose concentrations ($P = 0.01$) compared to controls. The authors concluded that feeding Amaize at 240 DU/kg is the optimize inclusion to increase milk production, milk fat and protein.

Klingerman et al., (2009) evaluated the impacts of feeding α-amylase enzymes, Amaize and an experimental enzyme, on dairy cattle performance and digestibility. The experiment utilized 28 Holstein cows individually fed via the Calan gate system and designed as a 4 × 4 Latin Square with 21 d periods, 14 d adaptation and 7 d collection. Cattle were blocked by pretreatment milk production, DMI, BCS, lactation number, and DIM and randomly assigned to 1 of 4 treatments. Treatments consisted of 1) control, with no addition of enzyme supplement (CON); 2) diet containing an experimental enzyme at 0.88 ml/kg DM (7BL); 3) diet containing 4.4 ml/kg DM of the experimental enzyme (7BH); 4) 0.4 g/kg DM of Amaize (AMA). The experimental enzymes were mixed with water and applied to the concentrate feed via a hand-held sprayer. The AMA and CON treatments received the same amount of water applied [approximately 20 L per 1,000 kg of the total mixed ration (TMR) DM] to the concentrate as the experimental enzyme diets. After the addition of the water, the AMA enzyme was mixed in with the concentrate. All concentrate was then mixed in with the daily allotted forage amount to form the mixed TMR. Cows fed the AMA and 7BH had greater DMI compared to CON ($P < 0.05$); however, had similar milk yield. Cows fed the AMA and 7BL produced greater amounts of milk fat and milk protein compared to cows fed CON ($P < 0.05$). The apparent total tract digestibilities for DM, OM, NDF, and starch were not significantly different between AMA and CON, however, AMA was numerically greater in all instances. The authors concluded that the addition of exogenous amylase enzymes have the potential to improve milk production and increase DMI.

A case study was compiled to evaluate feeding a *Aspergillus oryzae* extract (Amaize) in 45 commercial dairy herds representing 8,150 cows across the United States and Canada (Harrison and Tricarico, 2007). Milk production and composition data were collected from dairy herd improvement (DHI) test records and cows were supplemented with 12 g/cow/d after the first monthly testing and continued receiving the supplemental enzyme through the second DHI test. The authors reported that milk production tended to increase ($P = 0.059$), on a herd basis, during the one month of feeding the amylase enzyme. On an individual cow basis, a trend towards increased milk production was observed ($P = 0.097$). Unlike two previous studies, milk fat yield was unaffected by the addition of supplemental amylase.

Overall, milk yield increased quadratically (Tricarico et al., 2005), tended to increase (Harrison and Tricarico, 2007); or was unaffected (DeFrain et al., 2005; Klingerman et al., 2009) by the addition of AMA supplementation. Milk fat was either increased (Tricarico et al., 2005; Klingerman et al., 2009) or was unaffected (DeFrain et al., 2005; Harrison and Tricarico, 2007). Lastly, feeding exogenous α-amylase supplement Amaize increased the molar proportion of butyrate (Tricarico et al., 2005) or had no significant impact (DeFrain et al., 2005), increased BHBA and NEFA (DeFrain et al., 2005; Tricarico et al., 2005), and had no effect on nutrient digestibility (Klingerman et al., 2009).

Hristov et al,. (2008) evaluated a predominately amylase (Enz A) exogenous enzyme on ruminal fermentation and digestion. Four ruminally and duodenally fistulated multiparous late-lactation Holstein cows were utilized in a

4x4 Latin Square experiment with 22 d periods, 15 d adaptation and 7 d collection. Cows were ruminal dosed with 10 g/d of the enzyme during the morning feeding. Ruminal pH, acetate, propionate, and butyrate were not different between cows dosed with Enz A compared to the controls ($P \geq 0.41$). Cows fed Enz A had DM, OM, NDF, and starch intakes similar to the controls ($P \geq 0.62$). Ruminal true digestibilities were also similar to controls for DM, OM, NDF, and starch ($P \geq 0.68$). Although not significant ($P \geq 0.33$), cattle fed Enz A had numerically greater DM, OM, NDF, and starch digestibilities compared to the controls.

The results of feeding exogenous amylase in cattle diets are varied. While an increase in milk production, milk components, and butyrate have shown to increase with amylase supplementation, the exact mechanism to this increase is still unclear.

Wet Milling

Process. The wet milling process is more complex than the dry milling process in that more types of food products are produced for both human and agricultural use. The primary goal of the wet milling industry is to isolate starch from the endosperm; however, with multiple end products produced, the industry has progressed to maximize value from the entire corn kernel. The end products produced during the wet milling process include ethanol, starch, corn oil, corn syrup, and byproduct feeds for the livestock industry. The byproduct feeds include steep liquor, germ meal, corn bran, corn gluten meal, distillers solubles, and corn gluten feed.

In the United States, corn refiners only utilize #1 or #2 yellow dent corn which has been screened to remove debris, broken kernels, and fines (Stock et al., 2000). The cleaned corn is steeped for 40-48 h in dilute sulfurous dioxide solution to begin loosening the interacting bonds between the endosperm and zein proteins. The kernels will absorb the water solution causing them to double in size aiding in the release of starch. After steeping, the corn is coarsely ground to dissociate the kernel components and the steep water is removed to be sold as a sole byproduct or combined with other byproducts. The ground corn slurry undergoes germ separation by spinning the low-density germ out of the slurry. Once the germ, which contains approximately 85% of the oil, is separated, the oil is extracted by a combination of mechanical and solvent processes. The resulting products are finished corn oil and corn germ meal used as animal feed. The corn slurry undergoes a second round of grinding and screening to separate the endosperm, protein, and pericarp. The slurry flows over a set of concave screens which catches the pericarp (fiber portion) but allows the endosperm and protein to pass through (Corn Refiners Association, 2017). The separated pericarp produces corn bran which can be sold as a wet or dry byproduct. The remaining endosperm and protein are separated by centrifuging the low-density protein and produce corn gluten meal and starch. Corn gluten meal is a good source of protein containing 68.2% CP with 69.7% of CP being RUP (National Academies of Science, Engineering, and Medicine, 2016). The starch can be marketed as unmodified corn starch or converted into corn syrups such as high fructose corn syrup and glucose (Corn Refiners Association, 2017). The glucose undergoes fermentation and distillation to produce carbon dioxide, distillers solubles, and ethanol. Corn gluten feed is a major byproduct produced from the wet milling process

that combines many of the products produced such as corn bran, germ meal, steep water, and distillers solubles to produce one byproduct sold as animal feed. From one bushel of corn (25.40 kg As-Is), the wet milling process produces on average 14.29 kg of corn starch, 5.67 kg of corn gluten feed, 1.13 kg of corn gluten meal, and 0.73 kg of corn oil (Davis, 2001).

Nutrient Composition. On average, corn grain contains 72.1% starch, 8.8% CP, 3.8% fat, and 9.7% NDF (National Academies of Science, Engineering, and Medicine, 2016). Once the starch is removed, all other nutrients are increased three-fold compared to the original grain (Stock et al, 2000). The byproduct feeds that are produced during the wet-milling process include steep liquor, germ meal, corn bran, corn gluten meal, distillers solubles, and corn gluten feed.

Steep liquor is 46.4% DM and contains 31.78% CP, 4.51% fat, 3.55% NDF, 2.72% ADF, 11.4% starch, 2.05% P, and 1.19% S (National Academies of Science, Engineering, and Medicine, 2016). When compared to the dry-milling liquid product, condensed distillers solubles, steep liquor contains 2-fold greater CP. Corn germ meal has a DM content of 90.59% and contains 19.67% starch, 11.5% fat, 39.41% NDF, 22.14% CP (47.8% RUP as a percentage of CP), 1.07% P, and 0.06% S (National Academies of Science, Engineering, and Medicine, 2016). Corn bran has a DM content of 91.3% and contains 29.9% starch, 8.1% fat, 36.9% NDF, 13% ADF, 12.6% CP, and 0.4% P, and 0.2% S (Dairy One Forage Lab, 2016). Corn gluten meal has a DM content of 90.4% DM, 15.4% starch, 2.4% fat, 8.07% NDF, 4.8% ADF, 68.2% CP (69.7% RUP as a percentage of CP), 0.55% P, and 0.82% S (National Academies of Science, Engineering, and Medicine, 2016).

The nutrient composition of corn gluten feed is dependent on the concentration of steep to corn bran or germ meal with increased steep producing WCGF higher in CP and energy. Based on the various inclusions of steep, corn gluten feed can vary in CP content (14 to 24% DM basis) resulting in a greater plant to plant variation in product being sold (Stock et al., 2000). Two different WCGF have been evaluated and determined the following nutrient composition: WCGF A contained 40-42% DM, 15 to 18% CP, and 37% NDF, whereas, WCGF B contained 60% DM and 20-25% CP, and 48% NDF (Stock et al., 2000).

Feeding Wet Corn Gluten Feed in Finishing Diets. Wet corn gluten feed has previously been shown to have a feeding value of 94 to 100% that of DRC (Green et al., 1987; Ham et al., 1995), however, with the high-energy, low starch fiber, WCGF can be utilized as a method of reducing ruminal acidosis. Ruminal acidosis occurs with over consumption of rapidly fermentable carbohydrates making WCGF in finishing diets a viable option in processed corn diets for controlling acidosis (Krehbiel et al., 1995).

Scott et al., (2003) evaluated feeding 32% WCGF in diets containing different methods of corn processing; DRC, HMC, and SFC (Trial 1). Dry matter intake (10.6, 9.9, and 10.0 kg/d for DRC, HMC, and SFC, respectively) were increased by 7.1 and 6.0% for steers fed DRC compared to HMC and SFC, respectively. Average daily gains (1.91, 1.87, and 1.92 kg/d for DRC, HMC, and SFC) were similar among processing treatments. Feed efficiencies (0.180, 0.189, and 0.192 for DRC, HMC, and SFC, respectively) were increased by 5.0 and 6.7% for cattle fed HMC and SFC compared to DRC, respectively. Within the

same experiment, the authors examined feeding DRC and SFC diets with and without WCGF to evaluate the impact of WCGF in processed diets. Steers fed WCGF with DRC resulted in 12.8% greater DMI (10.6 and 9.4 kg/d for with and without WCGF, respectively), 9.8% greater ADG (1.91 and 1.74 kg/d for with and without WCGF, respectively), however G:F was reduced by 3.3% (0.180 and 0.186 kg/d for with and without WCGF, respectively) because of greater intakes. Steers fed WCGF with SFC resulted in 7.5% greater DMI (10.0 and 9.3 kg/d for with and without WCGF, respectively), 6.7% greater ADG (1.92 and 1.80 kg/d for with and without WCGF, respectively), and similar G:F (0.192 and 0.194 for with and without WCGF, respectively). Scott et al., (2003) fed a lower inclusion of WCGF, 22% DM basis, with diets with DRC, HMC, and SFC (Trial 2). Similar to trial 1, DMI (11.0, 10.9, and 10.6 kg/d for DRC, HMC, SFC) was greatest for DRC, HMC being intermediate, and cattle fed SFC had the lowest DMI. Average daily gains were similar for DRC and HMC but SFC was increased 6.1 and 5.5% compared to DRC and HMC, respectively. Feed efficiencies were similar for cattle fed DRC and HMC (0.164 and 0.167, respectively), however steers fed SFC had 10.4 and 8.4% greater G:F compared to DRC and HMC, respectively. Similar to Trial 1, the authors fed processed corn diets with and without byproducts to determine the impact of feeding WCGF on performance. Steers fed WCGF with DRC resulted in 10.0% greater DMI (11.0 and 10.0 kg/d for with and without WCGF, respectively), 9.0% greater ADG (1.81 and 1.66 kg/d for with and without WCGF, respectively), and similar G:F (0.164 and 0.166 kg/d for with and without WCGF, respectively). Steers fed

WCGF with SFC resulted in 5.0% greater DMI (10.6 and 10.1 kg/d for with and without WCGF, respectively), 4.9% greater ADG (1.92 and 1.83 kg/d for with and without WCGF, respectively), and similar G:F (0.181 and 0.180 for with and without WCGF, respectively).

Macken et al., (2006) fed 25% WCGF in 60% concentrate diets, processed as DRC, HMC, or SFC, and evaluated cattle performance. In agreeance with Scott et al., (2003), cattle fed WCGF in DRC diets resulted in greater DMI compared to HMC and SFC. There was no difference among treatments for ADG (1.92, 1.91, and 1.97 kg/d for DRC, HMC, and SFC). The increase in DMI and similar ADG resulted in DRC having a 7.1 and 12.1% reduction in G:F compared to HMC and SFC.

Bremer et al., (2008) conducted a meta-analysis utilizing 11 feedlot experiments to evaluate the effects of WCGF inclusion level and WCGF type. Diets consisted of either 0, 10, 20, 30, or 40% inclusion (DM basis) of WCGF. Type A WCGF was composed of wet bran and steep to contain 40 to 42% DM and 15 to 18% CP (DM basis). Type B WCGF was composed of dry bran, steep, and germ meal to contain 60% DM and 22 to 25% CP (DM basis). For steers fed WCGF A, DMI was not different with increasing inclusion. Average daily gain was linearly increased ($P = 0.10$) with increasing WCGF A concentration. However, there was no difference for G:F with increasing levels of WCGF A resulting in the feeding value of WCGF A to be 99% of corn. Steers fed WCGF B had a linear increase in DMI, ADG, and G:F as dietary inclusion increased up to 40% in the diet resulting in a 112% feeding value of corn.

Krehbiel et al., (1995) analyzed feeding WCGF on ruminal pH in cattle fed DRC, 50:50 blend of DRC and WCGF, or WDGS based diets. On d 12, feed was withheld and 7.9 kg (DM), previously determined amount of DRC needed to reduce ruminal pH to 5.6 or lower, of 100% DRC, 50% DRC: 50% WCGF, or 100% WCGF was intraruminally dosed to simulate an acidosis challenge. Rumen pH was measured for 24-h after feed dosing. The authors reported a time × treatment interaction ($P < 0.01$) with steers fed 50% DRC: 50% WCGF or 100% WCGF had decreased ruminal pH at h 3 and 6 compared to steers dosed with 100% DRC, plateaued out, and returned to initial values by 24 h. However, steers dosed with 100% DRC had a reduction in ruminal pH from 3 to 15 h which did not return to initial values by 24 h. The authors suggested that feeding WCGF did not eliminate the incidence of acidosis, however cattle fed WCGF may spend less time exposed to a lower ruminal pH compared to cattle fed DRC.

Dry Milling By-Products in Finishing Diets

Process. The first step in the dry milling process is to remove any debris from the corn grain using a process of screens and then sent through a hammer or roller mill to be ground into a course flour (ICM, 2012). Once the grain is ground, the corn is mixed with processed water to create a slurry mixture. Alpha-amylase enzyme is added to convert starch to dextrose, the pH is adjusted to 5.8 with sulfuric acid, and controlled by the use of ammonia (ICM, 2012; RFA, 2017). The mixture is then heated to 82-88°C to control bacteria and maintained for 30-45 minutes.

Once the slurry has been heated, it is sent through a pressurized jet cooker at 105°C for 5 minutes and then transferred to liquefaction tanks where it is held for 1-2

hours at 82-88°C (ICM, 2012). During this process the alpha-amylase is given time to hydrolyze the starch to produce short chain dextrin's. Once this has occurred, temperature and pH are adjusted and a second enzyme, glucoamylase, is added to convert the short chain dextrin's to simple sugars (ICM, 2012).

The slurry is now referred to as mash and is allowed to ferment for 50-60 hours. Fermentation yeast, primarily *Saccharomyces cerevisiae,* is added to the mash to convert simple sugars to ethanol and carbon dioxide. The carbon dioxide can be captured, purified, and marketed for carbonating soft drinks and manufacturing dry ice or released into the atmosphere (ICM, 2012; RFA, 2017). Once the fermentation process is complete, the mash contains approximately 15% ethanol, yeast, and solids from the grains.

After fermentation, the alcohol needs to be removed, i.e. the distillation step. The mash is transferred into the multi-column distillation system where the ethanol is removed producing whole stillage. The whole stillage contains yeast cells that were used during fermentation and increased amounts of sulfur from sulfuric acid used to manage pH and sterilization of parts of the ethanol plant. The whole stillage is transported to a centrifuge where it is separated into thin stillage (5-10% DM) and wet distillers grains. The thin stillage goes through an evaporation system to produce a syrup-like byproduct known as condensed distillers solubles which contains 20-35% DM (Stock et al, 2000). The wet distillers grains can be sold as wet distillers grains (WDG) or dried to produced dried distillers grains (DDG). Condensed distillers solubles can be added back to the distillers grains to produce wet distillers grains plus solubles (WDGS), dried with distillers grains to approximately 90% DM to produce dried distillers grains plus solubles

(DDGS), partially dried to approximately 42-48% DM to produce modified distillers grains plus solubles (MDGS), or marketed as a separate feed ingredient (Stock et al, 2000; Bremer et al., 2011).

Nutrient Composition. Approximately two-thirds of the corn grain is comprised of starch. Once the starch is removed, all other nutrients (protein, fat, phosphorus, and fiber) can be recovered in the stillage and are increased three-fold compared to the original grain (Stock et al, 2000). The protein content increases from 10 to 30%, fat from 4 to 12%, P from 0.3 to 0.9%, and NDF from 12 to 36% of DM (Klopfenstein et al., 2008).

There are three types of distillers grains that are marketed: WDGS, MDGS, and DDGS. The three types are based on the plants ability of drying the product. Holt et al. (2004) conducted a study to evaluate the nutrient composition of by-products from dry milling ethanol plants. Nutrient composition was determined for WDGS, MDGS, and DDGS. Four regional plants were utilized, and samples were collected four times per day over four consecutive days during March, April, and May 2002. The by-products were sampled from the truck to simulate the product being received by the producer. They determined that WDGS ranged from 29.5-36.5% DM, 34.4-36.6% CP, 11.0-13.1% fat, 36.1-48.1% NDF, 9.8-16.9% ADF, and 2.8-4.2% ash. Dried distillers grains plus solubles ranged from 89.4-90.9% DM, 30.7-36.7% CP, 10.4-14.2% fat, 37.3-48.9% NDF, 10.9-16.0% ADF, 0.66-0.83% P, and 3.9-4.2% ash. Modified distillers grains plus solubles was determined to average 58.9% DM, 29.7% CP, 16.7% fat, 34.9% NDF, 10.9% ADF, and 5.3% ash. A later study conducted by Buckner et al. (2011) found similar results to the nutrient composition of dry milling by-products. By-product was

sampled from 6 ethanol plants with 10 samples taken across a day for 5 consecutive days. This process was repeated over four months throughout the year. The authors reported that distillers grains averaged 31.0% CP and 11.9% fat which are in the ranges given by Holt et al. (2004).

Diets that contain distillers grains at 15-20% of the diet DM or less are utilizing the distillers grains as a protein source (Klopfenstein et al., 2008). Distillers grains are relatively high in crude protein, containing approximately 31.7% (DM basis) making them an excellent protein source for beef cattle (Buckner et al., 2011; Lardy, 2007). Of the 31.7% crude protein in distillers grains, 63% is rumen undegradable protein (RUP; Lopez-Castillo et al., 2013) deducing that 37% is RDP. Rumen undegradable protein is not fermented by the microbes in the rumen allowing the protein to escape the rumen to the small intestine where it can be digested and utilized by the animal. However, Lardy (2007) estimated the RUP% of distillers grains plus solubles to be lower at 47 to 57% of CP. Rumen degradable protein is degraded by rumen microbes and utilized as a nitrogen source to synthesis microbial crude protein. Microbial crude protein and RUP contribute to the metabolizable protein (MP) supply that the animal can utilize. When RDP is deficient, excess MP can be recycled back to the rumen to supply nitrogen to the rumen microbes. Excess MP can also be utilized as a source of energy for the animal. The excess amino acids are deaminated and enter the TCA cycle to be utilized for energy.

Distillers grains also contain a relatively large concentration of fat compared to other feed ingredients. Buckner et al., (2011) reported sampling distillers grains from 6 different dry milling plants and observed that the average fat concentration was approximately 11.9% (DM basis) across all 6 plants. Fat provides more energy to the

animal than any other nutrient component (Zinn et al., 1994). Ruminants have the ability to modify fatty acids via biohydrogenation resulting in differing fatty acid profiles from what was consumed versus flowing into the duodenum. The unsaturated fatty acids that are consumed will undergo biohydrogenation with most of the fatty acids flowing into the duodenum being saturated fatty acids. Vander Pol et al. (2009) conducted a trial to evaluate the impact of feeding WDGS or supplemental corn oil on rumen biohydrogenation. The authors reported that steers fed WDGS had an increase in unsaturated fatty acids flowing to the duodenum compared to steers fed supplemental corn oil. This is indicative of the fat within WDGS being protected from rumen biohydrogenation.

Lodge et al., (1997) suggested that the feeding value of distillers grains could be attributed to both the protein and fat proportions in distillers grains. If fat is contributing to the increased feeding value of WDGS then an increase in fat digestibility needs to occur. Vander Pol et al. (2009) observed an increase in total tract digestibility of fat when 40% inclusion of WDGS were fed. Previously stated, increased concentration of unsaturated fatty acids results in increased digestibility, therefore the improvement in total tract fat digestibility of WDGS diets can be attributed to the increase in unsaturated fatty acids reaching the small intestine. However, research conducted by Jolly-Breithaupt et al. (2018) would suggest that fat may not contribute as much to the increased feeding value as previously thought. The authors fed de-oiled, fat removed via centrifugation of the solubles stream, and full fat MDGS at 40% inclusion (average 6.03 and 7.18% dietary fat, respectively; DM basis) and reported no difference in animal performance, performance calculated NE_g, total tract fat digestibility, and DE between the

concentrations of fat. The same authors conducted another trial feeding 35, 50, and 65% de-oiled or full fat WDGS in finishing diets and reported no difference in ADG, G:F, and performance calculated NE_g between fat concentrations regardless of WDGS inclusion level. Similarly, Bremer et al., (2014) evaluated the effects of feeding de-oiled or full fat MDGS on growing cattle performance. The authors observed no difference in animal performance between de-oiled and full fat MDGS. Olgesbee et al., (2016) evaluated feeding WDGS components; fiber, protein, or fat singly or in combination to attempt to determine the feeding value that each component contributes to the overall feeding value of WDGS in finishing diets. Treatments consisted of a corn based control diet, WDGS at 20 and 40% inclusion (DM basis) as a positive control, corn bran plus solvent extracted meal to mimic fiber portion of WDGS at 20 and 40% inclusion (DM basis), fiber plus condensed distillers solubles to determine the solubles energy portion, fiber plus corn gluten meal to mimic protein, fiber protein solubles, fiber protein plus fat to mimic fat in WDGS, and lastly a diet that combined all components together to mimic feeding WDGS. The authors reported that feeding the fiber component to mimic the 20% inclusion of WDGS resulted in a lower feeding value than WDGS at 119 and 130%, respectively. However, the feeding value of the fiber component was still greater than the corn-based control. The feeding value of the fiber to mimic the 40% inclusion of WDGS decreased to 83% that of the corn-based control. When adding condensed distillers solubles to the fiber, DMI and ADG increased with no improvement in G:F. With the addition of protein to the fiber solubles diet, the feeding value was reported at 121% of the corn-based diet, however, it is still not quite as good as WDGS at 130%. Lastly, when fat was added to the fiber, protein, solubles diet, the feeding value increased

to 127% that of the corn-based control and almost matching the feeding value of WDGS at 130%. This data demonstrates that the increase in performance from feeding WDGS comes from the multiple interactions between fiber, protein, fat, and solubles. Conroy et al., (2016a, b) evaluated the effect of feeding individual components of distillers grains on finishing and growing cattle performance. Treatments for the finishing and growing trials consisted of 40% DGS, components to mimic the protein, fat, and fiber of DGS, and a DRC or grass hay/DRC control. No improvements in finishing cattle performance were detected when components were fed in place of DRC. However, when cattle were fed the grass hay/DRC based growing diets, the protein treatment (20% corn gluten meal) was found to be 134% the feeding value of the corn that it replaced suggesting that the protein within distillers grains can contribute to the increase in feeding value of distillers grains.

Wet Distillers Grains Plus Solubles. Larson et al. (1993) reported two finishing studies evaluating the effects of WDG replacing protein and dry rolled corn (DRC) in calf-fed and yearling steers. Wet distillers grains was fed in the diet at 5.2%, 12.6% and 40.0% DM. As WDG increased in the diet, DMI decreased and ADG increased resulting in a 19.4% and 25.7% improvement in G:F for calf-feds and yearlings, respectively. Similar findings for G:F were reported by Ham et al. (1994), Godsey et al. (2009a), and Corrigan et al. (2009) of 18.8, 16.5, and 13.5% improvement compared to controls, respectively when 40% WDGS were fed and replaced DRC. When replacing cracked corn with 40% WDGS, similar results were observed for G:F with an improvement of 11% (Trenkle, 1996). Ham et al. (1994) conducted two metabolism experiments evaluating the effects of WDG on nutrient digestibility, ruminal pH, and VFA

parameters. Cattle fed WDG had similar OM intakes and digestibilities compared to cattle fed DRC. However, as expected, WDG resulted in greater NDF intakes and digestibilities compared to DRC. Ruminal pH and the acetate to propionate ratio were similar for cattle fed WDG and DRC. Vander Pol et al. (2009) replaced 40% DRC with WDGS in a metabolism experiment. The authors reported that cattle fed WDGS had similar DM, OM, and NDF digestibilities compared to cattle fed DRC. Similarly to Ham et al. (1994) ruminal pH was similar between WDGS and DRC treatments. However, cattle fed WDGS had reduced acetate and increased propionate resulting in an improved acetate:propionate ratio for WDGS compared to DRC.

Corrigan et al. (2009) evaluated the effects of WDGS replacing high moisture corn (HMC). Wet distillers grains plus solubles was included in the diet at 0, 15, 27.5, and 40% on a DM basis. In response to increasing concentration of WDGS in the diet, final BW, DMI, and ADG increased quadratically while G:F increased linearly. Cattle fed 27.5% WDGS with HMC had a 7.8 and 7.7% improvement in ADG and G:F (respectively) compared to cattle fed the control diet. At 40% inclusion of WDGS, improvements in ADG and G:F were 4.8 and 6.0%, respectively. Differences in improvement between DRC and HMC when feeding WDGS can be attributed to the difference in ruminal starch fermentation associated with corn processing. Processing methods that reduce particle size and/or causes gelatinization increases the availability of the starch granules resulting in an increase in the rate of ruminal starch fermentation (Stock and Erickson, 2006). Corn harvested at increased moisture (greater than 24%), ground and stored in a bunker has faster rates of ruminal starch digestion than dry rolled corn which increases the possibility of acidosis (Stock and Erickson, 2006). Acidosis can

affect the efficiency of utilization of the corn fed. An option to overcome this issue is by feeding a combination of processed grains, one with a slower rate of starch fermentation with a second with a rapid rate of starch fermentation (Stock and Erickson, 2006).

Replacing WDGS with a 1:1 blend of HMC and DRC (BLEND) has been reported. Godsey et al. (2009b) replaced BLEND with 20 or 40% WDGS and observed a 5.1 and 5.7% improvement in ADG, respectively. Feed efficiency was improved by 5.5 and 8.1% when 20 or 40% WDGS replaced BLEND. Similar to Godsey et al. (2009b), Vander Pol et al. (2009) observed a 5.8% improvement in G:F when WDGS replaced 40% of BLEND in the diet. Meyer et al. (2013) reported a 6.5 and 6.9% improvement in ADG and G:F when 25% WDGS replaced BLEND. Loza et al. (2010) fed 30% WDGS in a BLEND diet and observed a 15% increase in ADG and 8.7% increase in G:F compared BLEND control diet. Vander Pol et al. (2006) replaced BLEND with 10, 20, 30, 40, and 50% WDGS. As inclusion level of WDGS increased, ADG increased quadratically with cattle fed 30% WDGS having the greatest ADG. Similarly, G:F increased quadratically with optimum efficiency observed when 40% WDGS replaced BLEND.

A review by Owens et al. (1997) reported that steam flaking resulted in corn containing 14.2 and 17.3% more NE_m and NE_g than DRC. This increase in energy from flaking improved G:F by 12% compared to feeding DRC in a corn based diet (Owens et al., 1997). When WDGS replaces SFC in finishing rations, the performance response does not appear to be as great when WDGS replaces DRC, HMC, and BLEND.

Daubert et al. (2005) replaced SFC in increments of 8 percentage units with a maximum concentration of sorghum WDGS of 40%. The authors reported a quadratic

effect for ADG and G:F. Maximum daily gain was achieved when 8% WDGS replaced SFC and G:F was optimized at 16% WDGS, followed by reductions in both as inclusion of WDGS increased. The authors indicated that WDGS should not be included beyond 15% to obtain optimal efficiency. However, Depenbusch et al. (2009) replaced SFC with 12.8% WDGS and did not observe a response for ADG or G:F compared to the SFC control diet. In a previous trial, Depenbusch et al. (2008b) fed 25% WDGS in a SFC diet and observed a 9.1 and 7.1% reduction in ADG and G:F, respectively. Similar to findings by Depenbusch et al. (2008), May et al. (2010) observed an 8.3% decrease in ADG and 3.9% decrease in G:F when SFC was replaced by 30% WDGS. Luebbe et al. (2012) conducted a study analyzing the effects of titrating WDGS in SFC rations. Wet distillers grains plus solubles replaced 15, 30, 45, or 60% of the SFC. The authors reported that ADG, G:F, and the feeding value of WDGS decreased linearly as the concentration of WDGS increased. Overall, cattle performance tends to decrease when WDGS is included in SFC rations at inclusions greater than 25%.

Modified Distillers Grains Plus Solubles. Modified distillers grains plus solubles (MDGS) have been partially dried to approximately 45% to 50% DM. Bremer et al. (2011) conducted a meta-analysis comparing 4 finishing trials with 85 pens that represented 680 steers (Adams et al., 2010; Huls et al., 2008; Luebbe et al., 2011; Nuttelman et al., 2010). All studies were conducted at the same research feedlot under similar conditions with MDGS replacing DRC or BLEND from 0 to 40% in increments of 10 percentage units. The authors observed a quadratic response for DMI, ADG, and G:F as the concentration of MDGS increased. Maximum DMI was reported for 20 to 30% MDGS inclusion, ADG was maximized at 30% MDGS inclusion, and the maximum

G:F was observed for 40% MDGS inclusion. Huls et al. (2008) compared feeding 0 to 50% MDGS, in increments of 10% units, in finishing diets that replaced BLEND. Intakes increased quadratically with 20% MDGS having the greatest intakes. A quadratic response was observed for ADG with 20% and 30% having the greatest gains. A linear response was observed for G:F as the inclusion of MDGS increased. Nuttelman (2013) fed 0, 20, 30, and 40% MDGS that replaced BLEND and observed a quadratic response for DMI. A quadratic effect was observed for ADG with steers fed 20 and 40% MDGS having the greatest gains, 30% was intermediate, and controls had the lowest gains. A linear response was observed for G:F. It was reported that there was a 6-10% improvement in G:F when cattle were fed MDGS compared to corn based controls. Trenkle, (2008) fed 0, 20, 40, and 60% of MDGS in finishing diets. The author observed no difference for DMI when steers were fed 20% or 40% MDGS, however, steers fed 20% MDGS had numerically greater intakes than steers fed 40% MDGS which agrees with previous research (Bremer et al., 2011; Huls et al., 2008). There was no difference for ADG and G:F when cattle were fed 20 or 40% MDGS, but cattle fed 60% MDGS produced the lowest gains and were less efficient.

Dried Distillers Grains Plus Solubles. Dry distillers grains plus solubles (DDGS) are distillers grains that have been dried to approximately 90% DM. This allows producers that are a greater distance away from ethanol plants to incorporate DGS into finishing rations by decreasing shipping and storage costs due to the decreased moisture content of the DGS.

Bremer et al. (2011) conducted a meta-analysis which evaluated replacing corn with increasing concentrations of DDGS. Dried distillers grains plus solubles were fed

from 0 to 40% in increments of 10 percentage units. Four finishing trials were evaluated, containing 66 pens which represented 581 steers. The author observed a quadratic response for DMI with 30 and 40% inclusions having the greatest DMI. There was a linear increase for ADG and G:F resulting in 40% DDGS having the greatest ADG and G:F. Nuttelman (2013) replaced BLEND with 0, 20, 30, and 40% DDGS and observed a linear increase in DMI as the concentration of DDGS increased. There was a linear response for ADG and G:F similar to Bremer et al. (2011). Neville et al. (2012) fed 20, 40 and 60% DDGS to finishing steers and observed a quadratic decrease for DMI and ADG, whereas G:F decreased linearly as the concentration of DDGS increased.

Buckner et al. (2008) evaluated the effects of replacing DRC with increasing concentrations of DDGS from 0 to 50% in increments of 10 percentage units. Due to issues associated with polioencephalomalacia, cattle on the 50% treatment were removed from the study resulting in treatments of 0 to 40% DDGS being reported. There were no differences observed for DMI between treatments. The authors observed a quadratic response for ADG. Using the quadratic prediction equation, ADG was maximized at 23.5% inclusion of DDGS but any concentration of DDGS produced greater gains than the DRC control. Feed efficiency, although not significant, approached a significant quadratic trend for increasing concentrations of DDGS. Using the quadratic prediction equation, G:F was maximized at 24.7% inclusion. Cattle fed the control diet had the poorest G:F while steers fed 30 and 40% were intermediate to 10 and 20%.

Conclusions

Based on this review, it is apparent that achieving optimal starch digestion is critical for improving cattle efficiency and maximizing production. Research has proven

that processing corn increases the rate and extent of starch digestibility. The utilization of exogenous enzymes, specifically amylases, could be an alternative method for increasing starch digestibility and ultimately animal performance in finishing diets. A new corn hybrid, Syngenta Enogen Feed Corn (SYT-EFC), containing a thermotolerant α-amylase enzyme, was created to be utilized by the dry milling ethanol industry. At increased temperatures, the internal enzymes become activated thus reducing the need for α-amylase addition during the fermentation process to convert starch to glucose. The objectives of the research reported in this dissertation were to:

1. Evaluate feeding SYT-EFC on feedlot cattle performance and carcass characteristics,
2. Evaluate the impact of processing SYT-EFC as dry-rolled or high-moisture corn on animal performance,
3. Determine the effects of SYT-EFC on the site and extent of digestion and ruminal metabolism parameters in finishing cattle diets.

Literature Cited

Adams, D.R., T.J. Klopfenstein, G.E. Erickson, M.K. Luebbe, M.A. Greenquist. 2010. The effects of sorting steers by weight into calf-fed, summer yearling and fall yearling feeding systems. Prof. Anim. Sci. 26:587-594.

Beauchemin, K. A, T. A. McAllister, Y. Dong, B. I. Farr, and K. J. Cheng. 1994. Effect of mastication on digestion of whole cereal grains by cattle. J. Anim. Sci. 72:236-246.

Bevans, D. W., K. A. Beauchemin, K. S. Shwartzkopf-Genswein, J. J. McKinnon, and T. A. McAllister. 2005. Effect of rapid or gradual grain adaptation on subacute acidosis and feed intake by feedlot cattle. J. Anim. Sci. 83:1116-1132.

Buchanan-Smith, J., T. K. Smith, and J. R. Morris. 2003. High moisture grain and grain by-products. Chap. 18. In: D. R. Buxton, R. E. Muck, J. H. Harrison (Eds.) Silage Science and Technology, American Society of Agronomy, Crop Science Society of America, Soil Science Society of America, 677. S. Segoe Rd., Madison, WI 53711, USA, Monograph no. 42 in the series Agronomy. pp 825-854.

Buckner, C.D., T.L. Mader, G.E. Erickson, S.L. Colgan, D.R. Mark, V.R. Bremer, K.K. Karges,M.L. Gibson. 2008. Evaluation of dry distillers grains plus solubles inclusion on performance and economics of finishing beef steers. Prof. Anim. Sci. 24:404-410.

Buckner, C.D., M.F. Wilken, J.R. Benton, S.J. Vanness, V.R. Bremer, T.J. Klopfenstein, P.J. Kononoff, G.E. Erickson. 2011. Nutrient variability for distillers grains plus solubles and dry matter determination of ethanol by-products. Prof. Anim. Sci. 27:57-64.

Bremer, V.R., A.K. Watson, A.J. Liska, G.E. Erickson, K.G. Cassman, K.J. Hanford, T.J. Klopfenstein. 2011. Effect of distillers grains moisture and inclusion level on livestock diets on greenhouse gas emissions in the corn-ethanol-livestock life cycle. Prof. Anim. Sci. 27:449-455.

Bremer, M. L., A. K. Watson, D. B. Burken, J. C. MacDonald, and G. E. Erickson. 2014. Energy value of de-oiled modified distillers grains plus solubles in a forage based diet. Nebr. Beef Cattle Rep. MP-99:32-33.

Burroughs, W., W. Woods, S. A. Ewing, J. Greig, and B. Theurer. 1960. Enzyme additions to fattening cattle rations. J. Anim. Sci. 19:458-464.

Clary, J. J., G. E. Mitchell, Jr., C. O. Little, and N. W. Bradley. 1969. Pancreatic amylase activity from ruminants fed different rations. Can. J. Physiol. Pharmacol. 47:161.

Corn Refiners Association. 2017. What is corn refining? https://corn.org/what-is-corn-refining/. Accessed: 3/20/2017.

Conroy, B. B., C. J. Bittner, J. C. MacDonald, M. K. Luebbe, and G. E. Erickson. 2016a. Effects of feeding isolated nutrient components in MDGS on growing cattle performance. Nebr. Beef Cattle Rep. MP-103:29-30.

Conroy, B. B., M. K. Luebbe, G. E. Erickson, J. C. MacDonald, and J. A. Hansen. 2016b. Impact of feeding distillers grains or isolated components in distillers grains on feedlot performance and carcass traits. Nebr. Beef Cattle Rep. MP-103:122-123.

Cooper, R. J., C. T. Milton, T. J. Klopfenstein, and D. J. Jordon. 2002a. Effect of corn processing on degradable intake protein requirement on finishing cattle. J. Anim. Sci. 80:242-247.

Cooper, R., J., C. T. Milton, T. J. Klopfenstein, T. L. Scott, C. B. Wilson, and R. A. Mass, 2002. Effect of corn processing on starch digestion and bacterial crude protein flow in finishing cattle. J. Anim. Sci 80:797-804.

Corrigan, M.E., G.E. Erickson, T.J. Klopfenstein, M.K. Luebbe, K.J. Vander Pol, N.F. Meyer, C.D. Buckner, S.J. Vanness and K.J. Hanford. 2009. Effect of corn processing method and corn wet distillers grains plus solubles inclusion level in finishing steers. J. Anim. Sci. 87:3351-3362.

Dairy One Forage Lab. 2016. Interactive Feed Composition Libraries., Ithaca, NY. http://dairyone.com/analytical-services/feed-and-forage/feed-composition-library/interactive-feed-composition-library/. Accessed January 4, 2018.

Daubert, R.W., J.S. Drouillard, E.R. Loe, J.J. Sindt, B.E. Depenbusch, J.T. Fox, M.A. Greenquist, M. E. Corrigan. 2005. Optimizing use of wet sorghum distiller's grains with solubles in flaked-corn finishing diets. Kansas State University Agric. Exp. Sta. Report in Progress 943:15-21.

Davis, K. S. 2001. Milling, processing and generation of co-products. Page 1-7 in Proc. 62nd Minnesota Nutr. Conf., St. Paul, MN.

DeFrain, J. M., A. R Hippen, K. F. Kalscheur, and J. M. Tricarico. 2005. Effect of dietary α-amylase on metabolism and performance of transition dairy cows. J. Dairy Sci. 88:4405-4413.

Delcour, J. A. and R. C. Hoseney. Principles of Cereal Science and Technology. St. Paul: AACC International, Inc., 2010. Print

Depenbusch, B.E., J.S. Drouillard, E.R. Loe, J.J. Higgins, M.E. Corrigan, M.J. Quinn.

2008. Efficacy of monensin 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.

Depenbusch, B.E., E.R. Loe, J.J. Sindt, N.A. Cole, J.J. Higgins, J.S. Drouillard. 2009. Optimizing use of distillers grains in finishing diets containing steam flaked corn. J. Anim. Sci. 87:2644-2652.

DiLorenzo, N. D. R. Smith, M. J. Quinn, M. L. May, C. H Ponce, W. Steinberg, M. A. Engstrom, and M. L. Galyean. 2011. Effects of grain processing and supplementation with exogenous amylase on nutrient digestibility in feedlot diets. Livest. Sci. 137:178-184.

Ensminger, M. E., J. E. Oldfield, and W. W. Heinemann. 1990. Feeds & Nutrition (2nd Ed.). pp 527-552. Ensminger Publishing Co., Clovis, CA.

Erickson, G.E., C.D. Buckner, T.J. Klopfenstein. 2010. Feeding corn milling co-products to feedlot cattle. 3rd Edition. UNL Extension Publication and Nebraska Corn Board.

Galyean, M. L., D. G. Wagner, and R. R. Johnson. 1976. Site and extent of starch digestion in steers fed processed corn rations. J. Anim. Sci. 43:1088-1094.

Godsey, C.M., W.A. Griffin, M.K. Luebbe, J. R. Benton, G. E. Erickson T.J. Klopfenstein., 2009a. Cattle performance and economic analysis of diets containing wet distillers grains and dry-rolled or steam-flaked corn. Nebr. Beef Cattle Rep. MP-92:66-69.

Godsey, C.M., M.K. Luebbe, J. R. Benton, G. E. Erickson, T.J. Klopfenstein. 2009b. Effect of the grains to solubles ration in diets containing wet distillers grains ± solubles fed to finishing steers. Nebr. Beef Cattle Rep. MP-92:59-61.

Gray, G. M., 1992. Starch digestion and absorption in nonruminants. J. Nutr. 122:157.

Hale, W. H. and C. B. Theurer. 1972. In D. C. Church (Ed.) Digestive physiology and nutrition of ruminants. Vol. 3, Oregon State Univ., Corvallis.

Ham, G.A., R.A. Stock, T.J. Klopfenstein, E.M. Larson, D.H. Shain, R.P. Huffman. 1994. Wetcorn 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.

Harmon, D. L. 1992. Dietary influence on carbohydrases and small intestinal starch hydrolysis capacity in ruminants. J. Nutr. 122:203-210.

Harmon, D. L. 1993. Nutritional regulation of postruminal digestive enzymes in ruminants. J. Dairy Sci. 76:2102-2111.

Harmon, D. L. and K. R. McLeod. 2001. Glucose uptake and regulation by intestinal tissues: Implications and whole-body energetics. J. Anim. Sci. 79(E. Suppl.):E59-E72.

Harrison, G. A. and J. M. Tricarico. 2007. Effects of an Aspergillus oryae extract containing α-amylase activity on lactational performance in commercial dairy herds. Prof. Anim. Sci. 23:291-294.

Holt, S.M. and R.H. Pritchard. 2004. Composition and nutritive value of corn co-products from dry milling ethanol plants. South Dakota State Univ. Beef Research Report 2004:1-7.

Hristov, A. N., T. A. McAllister, and K. Cheng. 2000. Intraruminal supplementation with increasing levels of exogenous polysaccharide-degrading enzymes: Effects on nutrient digestion in cattle fed a barley diet. J. Anim. Sci. 78:477-487.

Hristov, A. N., C. E. Basel, A. Melgar, A. E. Foley, J. K. Ropp, C. W. Hunt, J. M. Tricarico. 2008. Effect of exogenous polysaccharide-degrading enzyme preparations on ruminal fermentation and digestibility of nutrients in dairy cows.

Huck, G. L., K. K. Kreikemeier, G. L. Kuhl, T. P. Eck, and K. K. Bolsen. 1998. Effects of feeding combinations of steam-flaked grain sorghum and steam-flaked, high moisture, or dry-rolled corn on growth performance and carcass characteristics in feedlot cattle. J. Anim. Sci. 76:2984-2990.

Huls, T.J., M.K. Luebbe, G. E. Erickson, T.J. Klopfenstein. 2008. Effect of inclusion level of modified distillers grains plus solubles in finishing steers. Nebr. Beef Cattle Rep. MP-91:66-69.

Huntington, G. B. 1997. Starch utilization by ruminants: from basics to the bunk. J. Anim. Sci. 75:852-867.

ICM, Inc., 2012. Ethanol production process. http://www.icminc.com/innovation/ethanol/ethanol-production-process.html. Accessed March 22, 2017.

Janes, A. N., T. E. C. Weekes, and D. G. Armstrong. 1985. Carbohydrase activity in the pancreatic tissues and small intestine mucosa of sheep fed dried-grass or ground maize-based diets. J. Agric. Sci. (Camb.) 104:435-443.

Jolly-Breithaupt, M. L., B. L. Nuttelman, C. J. Schneider, D. B. Burken, J. L. Gramkow, A. L. Shreck, J. C. MacDonald, T. J. Klopfenstein, and G. E. Erickson. 2018.

Finishing performance and diet digestibility for feedlot steers fed corn distillers grains plus solubles and distillers grains with and without oil extraction.

Jouany, J. P. and P. Thivend. 1972. Postprandial changes in the carbohydrate composition of the microbial population in the rumen in relation to the type of carbohydrate in the diet. 1. Protozoa. Ann. Biol. Anim. Biochem. Biophys. 12:673.

Klingerman, C. M, W. Hu, E. E. McDonell, M. C. DerBedrosian, and L. Kung Jr. 2009. An evaluation of exogenous enzymes with amulolytic activity for dairy cows. J. Dairy Sci. 92:1050-1059. J. Anim. Sci. In Press.

Klopfenstein, T.J., G.E. Erickson, V.R. Bremer. 2008. BOARD-INVITED REVIEW: Use of distillers by-products in the beef cattle feeding industry. J. Anim. Sci. 86:1223-1231.

Kotarski, S. F., R. D. Waniska, and K. K. Thurn. 1992. Starch hydrolysis by the ruminal microflora. J. Nutr. 122:178-190.

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.

Krehbiel, C. R., R. A. Britton, D. L. Harmon, J. P. Peters, R. A. Stock, and H. E. Grotjan. 1996.Effect of varying levels of duodenal or midjejunal glucose and 2-deoxyglucose infusion on small intestinal disappearance and net portal glucose flux in steers. J. Anim. Sci. 74:693-700.

Kreikemeier, K. K., D. L. Harmon, J. P. Peters, K. L. Gross, C. K. Armendariz, and C. R. Krehbiel. 1990. Influence of dietary forage and feed intake on carbohydrase activities and small intestinal morphology of calves. J. Anim. Sci. 68:2916-2929.

Lardy, G.P. 2007. Feeding coproducts of the ethanol industry to beef cattle. North Dakota State Univ. Ext. Service. AS-1242.

Larson, E.M., R.A. Stock, T.J. Klopfenstein, M.H. Sindt, R.P. Huffman. 1993. Feeding value of wet distillers byproducts for finishing ruminants. J. Anim. Sci. 71:2228-2236.

Lindsay, D. B. 1970. Carbohydrate metabolism in ruminants. PP 438+451. *In Physiology of Digestion and Metabolism in the Ruminant: Proceedings of the Third International Symposium*, August 1969, Cambridge, England, A. T. Phillipson, ed. Newcastle upon Tyne, England: Oriel Press.

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

Lopez-Castillo, E., T. J. Klopfenstein, S. C. Fernando, and P. J. Kononoff. 2013. In vivo determination of rumen undergradable protein of dried distillers grains with solubles and evaluation of duodenal microbial crude protein flow. J. Anim. Sci. 91:924-934.

Loza, P.L., C. D. Buckner, K.J. Vander Pol, G.E. Erickson, T.J Klopfenstein, 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.

Luebbe, M.K., G.E. Erickson, T.J. Klopfenstein, M.A. Greenquist, J.R. Benton. 2011. Effect of Dietary cation-anion difference on feedlot performance, N mass balance, and manure pH. J. Anim. Sci. 89:489-500.

Luebbe, M.K., J.M. Patterson, K. H. Jenkins, E.K. Buttery, T.C. Davis, B.E. Clark, F.T. McCollum III, N.A. Cole, J.C. MacDonold. 2012. Wet distillers grains plus solubles concentration in steam-flaked corn based diets: Effects on feedlot cattle performance, carcass characteristics, nutrient digestibility, and ruminal fermentation characteristics. J. Anim. Sci. 90:1589-1602.

Macken, C. N., G. E. Erickson, T. J. Klopfenstein, and R. A. Stock. 2006. Effects of corn processing method and protein concentration in finishing diets containing wet corn gluten feed on cattle performance. 22:14-22.

May, M.L., J.C. DeClerck, M.J. Quinn, N. DiLorenzo, J. Leibovich, D.R. Smith, K.E. Hales, M.L. Galyean. 2010. Corn or sorghum wet distillers grains with solubles in combination with steam-flaked corn: Feedlot cattle performance, carcass characteristics, and apparent total tract digestibility. J. Anim. Sci. 88:2433-2443.

McAllister, T. A., L. M. Rode, D. J. Major, K. J. Cheng, and J. G. Buchanan-Smith. 1990. Effect of ruminal microbial colonization of cereal grain digestion. Can. J. Anim. Sci. 70:571-579.

McAllister, T. A, H. D. Bae, G. A. Jones, and K. J. Chung. 1994. Microbial attachment and feed digestion in the rumen. J. Anim. Sci. 72:3004-3018.

McAllister, T. A., A. N. Hristov, K. A. Beauchemin, L. M. Rode, and K. J. Cheng. 2001. Enzymes in ruminant diets. Enzymes in Farm Animal Nutrition. M. R. Bedford and G. G. Partridge, ed. CABI Publishing. Marlborough, Wiltshire, UK. Pp 273-298.

Mendoza, G. D., R. A. Britton, and R. A. Stock. 1993. Influence of ruminal protozoa on site and extent of starch digestion and ruminal fermentation. J. Anim. Sci. 71:1572.

National Academies of Science, Engineering, and Medicine. 2016. *Nutrient Requirements of Beef Cattle, Eight Revised Edition.* Washington, DC: The National Academies Press. doi: 10.17226/19014.

Nuttelman, B.L., W.A. Griffin, J.R. Benton, G.E. Erickson, T.J. Klopfenstein. 2010. Comparing dry, wet, or modified distillers grains plus solubles on feedlot cattle performance. Nebr. Beef Cattle Rep. MP-94:50-52.

Nuttelman, B. L. 2013. Effects of drying distillers grains plus solubles on feedlot cattle performance and nutrient digestibility. Ph.D. Diss. University of Nebraska.

Neville, B.W., G.P. Lardy, K.K. Karges, S.R. Eckerman, P.T. Berg, C.S. Schauer. 2012. Interaction of corn processing and distillers dried grains with solubles on health and performance of steers. J. Anim. Sci. 90:560-567.

Oglesbee, R. A., C. J. Bittner, F. H. Hilscher, G. E. Erickson, J. C. MacDonald, and M. K. Luebbe. 2016. Evaluation of distillers grains components singly or in combination in a calf fed feedlot study. Nebr. Beef Cattle Rep. MP-103:124-127.

Owens, F. N., R. A. Zinn, and Y. K. Kim. 1986. Limits to starch digestion in the ruminant small intestine. 63:1634-1648.

Owens, F. N. and A. L. Goetsch. 1988. Ruminal fermentation. Pp. 145-171 in *The Ruminant Animal: Digestive Physiology and Nutrition*, D. C. Church, ed. Englewood Cliffs, NJ: Prentice Hall.

Owens, F.N., D.S. Secrist, W.J. Hill, D.R. Gill. 1997. The effect of grain source and grain processing on performance of feedlot cattle: a review. J. Anim. Sci. 75:868-879.

Owens, F. N., D. S. Secrist, W. J. Hill, D. R. Gill. 1998. Acidosis in cattle: A review. J. Anim. Sci. 76: 275-286.

Pappenheimer, J. R., and K. Z. Reiss. 1987. Contribution of solvent drag through intercellular junctions to absorption of nutrients by the small intestine of the rat. J. Membr. Biol. 100:123-136.

Ratnayake, W. S, and D. S. Jackson. 2006. Gelatinization and solubility of corn starch during heating in excess water: New insights. J. Agri. Food Chem. 54:10, pp.3712-3716.

Renewable Fuels Association. 2017. How Ethanol is Made. http://www.ethanolrfa.org/pages/how-ethanol-is-made. Accessed: March 22, 2017.

Rooney, L. W. and R. L Plugfelder. 1986. Factors affecting starch digestibility with special emphasis on sorghum and corn. J. Anim. Sci. 63:1607-1623.

Russell, J. R., A. W. Young, and N. A. Jorgensen. 1981. Effect of dietary corn starch intake on pancreatic amylase and intestinal maltase and pH in cattle. J. Anim. Sci. 52: 1177-1182.

Samuelson, K. L., M. E. Hubbert, M. L. Galyean, and C. A. Loest. 2016. Nutritional recommendations of feedlot consulting nutritionists: The 2015 New Mexico State and Texas Tech University survey. J Anim. Sci. 94:2648-2663.

Scott, T. L., C.T. Milton, G. E. Erickson, T. J. Klopfenstein, and R. A. Stcok. 2003. Corn processing method in finishing diets containing wet corn gluten feed. J. Anim. Sci. 81:3182-3190.

Shirazi,-Beechey, S. P. B. A. Hirayama, Y. Wang, D. Scott, M. W. Smith, and E. M. Wright. 1991. Ontogenic deveolment of lamb intestinal sodium-glucose co-transporter is regulated by diet. J. Physiol. (Lond.) 437:699-708.

Stedman, T. L. 1982. Stedman's Medical Dictionary. Williams and Wilkins, Baltimare, MD.

Stock, R.A., J.M. Lewis, T.J. Klopfenstein, 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. 77:1-12.

Stock, R.A. and G.E. Erickson. 2006. Associative effects and management – Combinations of processed grains. Oklahoma State Univ. Ext. Cattle Grain Processing Symposium. pp. 167-173.

Sutton, J. D. 1979. Carbohydrate fermentation in the rumen-variations on a theme. Proceedings of the Nutrition Society 38:275-281.

Theurer, C. B., 1986. Grain processing effects on starch utilization by ruminants. J. Anim. Sci 63:1649-1662.

Thorens, B., 1993. Facilitated glucose transporters in epithelial cells. Annu. Rev. Physiol. 55-591-608.

Trenkle, A.H. 1996. Evaluation of wet distillers grain for finishing cattle. Iowa State Univ. Beef Cattle Res. Rep. A.S. Leaflet R1342.

Trenkle, A.H. 2008. Performance of finishing steers fed low, moderate and high levels of wet distillers grains. Iowa State Univ. Beef Cattle Res. Rep. A.S. Leaflet R2286.

Tricarico, J. M., J. D. Johnston, K. A. Dawson, K. C. Hanson, K. R. McLeod, and D. L. Harmon.2005. The effects of an *Aspergillus oryzae* extract containing alpha-amylase activity on ruminal fermentation and milk production in lactating Holstein cows. Animal Science. 81:365-374.

Tricarico, J. M., M. D. Abney, M. L. Galyean, J. D. Rivera, K. C. Hanson, K. R. McLeod, and D. L. Harmon. 2007. Effect of dietary *Aspergillus oryzae* extract containing α-amylase activity on performance and carcass characteristics of finishing beef cattle. J. Anim. Sci. 85:802-811.

United Nations, Department of Economic and Social Affairs, Population Division (2017). *World Population Prospects: The 2017 Revision, Key Findings and Advance Tables*. Working Paper No. ESA/P/QP/248.

USDA. National Agricultural Statistics Service. 2017a. Cattle. Released July 21, 2017. ISSN:1948-9099.

USDA. National Agricultural Statistics Service. 2017b. Livestock slaughter 2016 summary (April 2017). ISSN: 0499-0544.

Utter, M. F. and D. B. Keech. 1963. Pyruvate carboxylase. I. Nature of the reaction. J. Biol. Chem. 238:2603-2608.

Vander Pol, K.J, G.E. Erickson, T.J Klopfenstein, M.A. Greenquist, T. Robb. 2006. Effect of dietary inclusion of wet distillers grains on feedlot performance of finishing cattle and energy value relative to corn. Nebr. Beef Cattle Rep. MP 88:51-53.

Vander Pol, K.J., M.K. Luebbe, G.I. Crawford, G.E. Erickson, 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.

Watson, S. A. 1987. Structure and composition. In Corn: Chemistry and Technology. American Association of Cereal Chemists, Inc. St. Paul, MN. Pp 53-82.

Wolin, M., J., T. L. Miller, and C. S. Stewart, 1997. Microbe-microbe interactions. Pp. 467-491 in *The Rumen Microbial Exosystem*, P. N. Hobson and C. S. Stewart, eds. London, UK: Blackie Academic and Progessional.

Zerby, H. N., J. L. Bard, S. C. Loerch, P. S. Kuber, A. E. Radunz, and F. L. Fluharty. 2011. Effects of diet and *Aspergillus oryzae* extract or *Saccharomyces cervisiae* on growth and carcass characteristics of lambs and steers fed to meet requirements of natural markets. J. Anim. Sci. 89:2257-2264.

Zhao, F. Q., E. K. Okine, C. I. Cheeseman, S. P. Shirazi-Beechey, and J. J. Kennelly. 1998. Glucose transporter gene expression in lactating bovine gastrointestinal tract. J. Anim. Sci. 76:2921-2929.

Zinn, R.A. 1994. Effects of excessive supplemental fat on feedlot cattle growth performance and digestive function. Prof. Anim. Sci. 10:66-72.

Zinn, R.A., F.N. Owens, R.A. Ware. 2002. Flaking corn: Processing mechanics, quality standards, and impacts on energy availability and performance of feedlot cattle. J. Anim. Sci. 80:1145-1156.

Chapter III

Effect of Syngenta Enogen Feed Corn containing an alpha amylase trait on finishing cattle performance and carcass characteristics[1]

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ABSTRACT: Two experiments evaluated the effects of feeding a new corn hybrid containing an alpha amylase enzyme trait, Syngenta Enogen Feed Corn (SYT-EFC), on feedlot performance and carcass characteristics at two locations. Experiment 1 utilized 300 calf fed steers (298.5 ± 16.3 kg of BW) at the University of Nebraska-Lincoln Eastern Nebraska Research and Extension Center Mead, NE. Steers were fed treatments consisting of SYT-EFC or Conventional (CON) corn with or without wet corn gluten feed (Sweet Bran), or a BLEND of SYT-EFC and CON without Sweet Bran. In Exp. 2, 240 crossbred, calf-fed steers (287.6 ± 15.4 kg of BW) were utilized at the University of Nebraska-Lincoln Panhandle Research and Extension Center near Scottsbluff, NE. Steers were fed SYT-EFC, CON, BLEND, and CON with a commercial alpha amylase enzyme supplement (CON-E). In Exp. 1, an interaction was observed for ADG (P = 0.05) and G:F (P = 0.02) with steers fed SYT-EFC with SB having greater ADG and G:F than CON; however, in diets without SB, SYT-EFC and CON were not different resulting in a 10.1% change in G:F when steers were fed SYT-EFC in SB diets compared to CON and only 1.6% change between SYT-EFC and CON without SB. Energy values, based on performance data, resulted in a 6.5 and 8.3% increase in NEm and NEg, respectively, for steers fed SYT-EFC compared to CON with SB and 1.6% change for both NEm and NEg for steers fed SYT-EFC compared to CON without SB. Steers fed SYT-EFC had greater marbling scores, fat depth, and calculated yield grade compared to CON ($P \leq 0.03$). In diets without Sweet Bran, there were no differences among SYT-EFC, CON, or BLEND for DMI, final BW, ADG, G:F, NEm, or NEg ($P \geq 0.35$). In Exp. 2, cattle fed SYT-EFC, BLEND, or CON-E had greater final BW, ADG, and G:F than cattle fed CON ($P \leq 0.03$). Energy values were 5.2 and 7.0% greater for NEm and NEg

(respectively) in diets fed amylase treatments compared to CON ($P \leq 0.01$). Hot carcass weights were greater in steers fed alpha amylase treatments compared to CON ($P < 0.01$). Feeding Syngenta Enogen Feed Corn, which contains an alpha amylase enzyme trait, at both locations improved feed efficiency in finishing cattle diets.

Key Words: amylase, beef cattle, corn trait, feedlot

INTRODUCTION

Corn is the most widely utilized source of grain in the finishing cattle diets in the United States (Vasconcelos and Galyean, 2007). With roughly two thirds of corn grain containing starch, it is a major energy component of feedlot diets. In order to achieve optimal cattle performance, starch digestion must be maximized while controlling ruminal acidosis which can occur from rapid ruminal starch digestion (Owens et al., 1998). Two traditional approaches that have been utilized to improve feed efficiency and starch utilization are corn processing methods such as rolling, ensiling, or flaking (Owens et al., 1997; Huck et al., 1998; Hale, 1973) or the use of different corn hybrids and kernel characteristics (Jaeger et al., 2006; Luebbe et al., 2009).

Feeding exogenous enzymes can be an alternative method to increase feed efficiency in finishing diets. Most research available on feeding exogenous enzymes in feedlot diets have analyzed the use of fibrolytic enzymes to increase fiber digestion and ultimately digestible energy intake. However, the addition of exogenous α-amylase in high grain finishing diets have shown to have a 6.5 to 11.9% improvement in ADG (Burroughs et al., 1960; Tricarico et al., 2007) or little impact (DiLornezo et al., 2011). Although not significant ($P = 0.55$) due to limited cattle numbers, DiLorenzo et al., (2011) observed a 9.5% increase in G:F for steers fed supplemental amylase compared to the control.

A new feed corn, Syngenta Enogen Feed corn (SYT-EFC), has been developed to contain a thermotolerant α-amylase enzyme that becomes activated by increased temperatures intended for the dry milling ethanol process. Including the enzyme within the corn grain eliminates the need for exogenous α-amylase to convert starch to sugar

prior to ethanol fermentation. Two experiments have evaluated in vitro and in vivo utilization of the SYT-EFC in finishing diets on digestion characteristics and animal performance. In vitro, starch degradability was observed to be increased from 1.60 to 1.99 which would indicate that starch digestibility and ruminal α-amylase activity may be improved resulting in an increase in animal performance (Hu et al., 2010). However, when corn that was modified to contain α-amylase was fed in finishing diets at 10% or 20% of the diet DM as ground corn, no differences in animal performance or carcass characteristics were observed (Schoonmaker et al., 2014). The objective of the two experiments were to evaluate feeding SYT-EFC, containing an α-amylase enzyme trait, alone, or blended with commercially available corn grain on feedlot cattle performance and carcass characteristics.

MATERIALS AND METHODS

All procedures involving animal care and management were approved by the University of Nebraska Lincoln's Institutional Animal Care and Use Committee protocol #517.

Exp. 1

A 172 day finishing experiment was conducted utilizing 300 crossbred, calf fed steers (initial BW = 298 ± 16 kg) to evaluate the impact of feeding SYT-EFC (Syngenta Seeds, Inc., Minnetonka, MN) containing the α-amylase enzyme trait as the sole grain source or a 50:50 blend with commercially available corn grain in diets with or without Sweet Bran (Cargill Wet Milling, Blair, NE). All corn containing the α-amylase enzyme trait, SYT-EFC, was provided by Syngenta Seeds Inc. The commercial corn (CON) was grown at the University of Nebraska-Lincoln's Eastern Nebraska Research and Extension

Center (ENREC) near Mead, NE during the summer of 2012. Steers were received at the University of Nebraska-Lincoln's ENREC feedlot in October of 2012 and utilized from November 2012 to May 2013.

Initial processing included vaccination for the prevention of *Clostridium chauvoei, septicum, novyi, sordellii, perfringens* Types C&D, and *Haemophilus somnus* (Vision 7 Somnus; *Merck Animal Health, Summit, NJ*) and a modified live virus vaccine for the prevention of IBR, BVD Type 2, BRSV and as an aid in the control of BVD Type 1 and PI-3 (Vista-5; Merck Animal Health). After 60 d, cattle were revaccinated with a modified live virus vaccine for the prevention of IBR, BVD Type 2, BRSV and as an aid in the control of BVD Type 1 and PI-3 (Vista-5; Merck Animal Health) and topically poured with an insecticide to kill flies, fleas, lice, mites, ticks, and deer ticks (Permectrin CD; Boehringer Ingelheim Vetmedica, Inc., Saint Joseph, MO). Steers were implanted with Revalor-XS (20 mg of trenbolone acetate and 4 mg estradiol; Merck Animal Health) on d 1.

Steers were limit fed a common diet consisting of 32% alfalfa hay, 32% corn wet distillers grains plus solubles, 32% dry-rolled corn, and 4 % supplement (DM basis) for 5 d at 2% of BW prior to the initiation of the trial in an effort to reduce variation in gut fill at time of weighing (Watson et al., 2013). Steers were individually weighed using a hydraulic squeeze chute with load cells mounted on the chute (Silencer, Moly Manufacturing Inc., Lorraine, KS: scale readability ± 0.45 kg) for 2 consecutive d (0 and 1) after the limit feeding period for initial BW determination (Watson et al., 2013). Based on initial BW, steers were blocked by BW into light, medium, and heavy blocks (n = 3, 2, and 1 pen replicates, respectively), stratified by BW within each block, and

assigned randomly to one of 30 pens. Pens were assigned randomly to one of five dietary treatments with a total of 10 steers per pen and 6 pens per treatment.

Dietary treatments were designed as a 2 x 2+1 factorial arrangement (Table 3.1). Treatment factors consisted of feeding diets 1) with or without corn containing the alpha-amylase trait, SYT-EFC, 2) with and without Sweet Bran, and a 50:50 blend of SYT-EFC and commercial corn without Sweet Bran (BLEND). Treatment diets with Sweet Bran (25% inclusion, DM basis) utilized the byproduct as a means of subacute acidosis control and a protein source. Decreasing a proportion of excessively fermentable starch with a highly digestible fiber source, such as Sweet Bran, has been shown to reduce the length of time that cattle are exposed to an incidence of acidosis (Krehbiel et al., 1995). Treatment diets that did not contain Sweet Bran, contained corn modified distillers grains plus solubles (MDGS, Green Plains Renewable Energy, Central City, NE) at 15% inclusion (DM basis) as a source of protein. With the inclusion of α-amylase during the dry and wet milling process to convert starch to glucose, byproducts have the potential of containing a trace amount of residual amylase. Steers were adapted to the finishing diets over a 21-d period with 10% corn replacing 10% alfalfa hay, while inclusion of corn silage, corn modified distillers grain plus solubles, and supplement remained the same in all diets at 12, 15, and 5%, respectively. In diets containing Sweet Bran, corn replaced alfalfa hay with inclusion of corn silage, Sweet Bran, and supplement remaining constant at 12, 25, and 5%, respectively. All supplements were formulated to include 33.0 mg/kg of monensin (DM basis, Elanco Animal Health), 9.0 mg/kg of tylosin (Elanco Animal Health), and to meet or exceed MP requirements (NRC, 1996).

Cattle were fed once daily at approximately 0800 and managed for *ad libitum* feed intake. When needed, refused feed was removed from feed bunks, weighed, and dried in a forced-air oven at 60°C (model LBB2-21-1; Despatch Industries, Minneapolis, MN) for 48 h (AOAC, 1999; method 4.1.03) to determine DM for accurate DMI. Ingredient samples were collected weekly, composited by month, and sent to a commercial laboratory (Servi-Tech Laboratories, Hastings, NE) to be analyzed for total starch (Megazyme International, AOAC International, 2000; Method 996.11; AACC Method 76.13), CP (AOAC International, 2000; Method 990.03), NDF (ANKOM, 2006), ether extract (AOAC International, 2006; Method 2003.6), Ca, P, S, K, and Mg (Mills and Jones, 1996).

On d 173, feed was offered at 50% of the previous days DMI and cattle were pen weighed at 1600 h to determine final live BW. A 4% pencil shrink was applied to the final live BW to calculate dressing percentage. After pen weights were collected, cattle were loaded onto a semi-tractor trailer, hauled 91.7 km to Omaha, NE, and harvested the morning of d 174 at a commercial abattoir (Greater Omaha, Omaha, NE). Hot carcass weights (HCW) and liver abscesses were recorded at the time of slaughter. Fat thickness, LM area, and USDA marbling score were recorded after a 48-h chill. Final BW, ADG, and G:F were calculated using HCW adjusted to a common dressing percentage of 63%. Yield grade was calculated using the USDA YG equation: YG = 2.5 + 6.35 (Fat thickness, cm) – 2.06 (LM area, cm^2) + 0.2 (KPH fat, %) + 0.0017 (HCW, kg) (USDA, 1997).

Dietary treatment energy values were calculated by pen utilizing pen performance data in the Galyean (2017) Net Energy Calculator utilizing shrunk initial BW, shrunk

final BW, DMI, ADG, and a target endpoint (assume choice quality grade) to calculate net energy of maintenance and gain. Performance and carcass characteristics were analyzed using the MIXED procedure of SAS (SAS Inst. Inc., Cary, NC). Initial BW block was included as a fixed effect and pen served as the experimental unit. The model included the effects of Sweet Bran, corn trait, the Sweet Bran x corn trait interaction, and block. Data were also analyzed for treatments not containing Sweet Bran (SYT-EFC, BLEND, and CON) as a randomized block design using a protected F-Test. Liver abscess incidence data were analyzed using the GLIMMIX procedure of SAS as binomial variables with steer as the experimental unit. Probabilities less than or equal to alpha ($P \leq 0.05$) were considered significant, with tendencies acknowledged at *P*-values between 0.05 and 0.10.

Exp. 2

Two hundred-forty crossbred steers (initial BW = 288 ± 15.4 kg) were utilized in a feedlot finishing trial at the University of Nebraska-Lincoln's Panhandle Research and Extension Center (PHREC) feedlot near Scottsbluff, NE. The experiment was conducted to evaluate the impact of feeding SYT-EFC corn, which contains the α-amylase enzyme trait, alone, blended with commercially available corn grain, or feeding a commercially available alpha amylase enzyme supplement on feedlot performance and carcass characteristics. Syngenta Enogen Feed Corn was provided by Syngenta Inc. (Minnetonka, MN) and all commercial corn was procured from a commercial grain elevator. Steers were received and utilized at the University of Nebraska-Lincoln's PHREC during the same time frame as Exp. 1.

Two weeks prior to the initiation of the experiment, steers were vaccinated for prevention of *Clostridium chauvoei, septicum, novyi, sordellii, perfringens* Types C&D, and *Haemophilus somnus; (*Vision 7; Merck Animal Health, Summit, NJ), for the prevention of IBR, BVD Type 1 & II, PI-3, BRSV (Bovi-Shield Gold; Zoetis, Florham Park, NJ), and treated for internal and external parasites (Ivomex; Merial, Duluth, GA).

Cattle limit feeding, initial BW protocols, implanting, and grain adaptation procedures were the same as Exp. 1. Based on d 0 BW, steers were blocked into a light, medium, or heavy BW block (n = 3, 2, and 1 pen replicates, respectively), stratified by BW and assigned randomly to 1 of 24 pens. Pens were assigned randomly to one of four dietary treatments with 10 head per pen and 6 replications per treatment. Dietary treatments included 1) SYT-EFC, 2) commercial corn (CON), 3) 50:50 blend of SYT-EFC and commercial corn (BLEND), and 4) commercial corn with an alpha amylase enzyme supplement (Amaize™; Alltech, Inc., Nicholasville, KY) added to the diet at a rate of 5 g/steer daily (CON-E; Table 3.2).

Steers that were blocked into the heavy, middle, and light BW blocks were harvested at a commercial abattoir (Cargill Meat Solutions, Fort Morgan, CO) on days 148, 169, and 181, respectively. On the final day, steers were withheld from feed and weighed at 0800 h before being shipped and slaughtered on the same day. Carcass data collection procedures and calculation of final BW were the same as *Exp. 1*.

Dietary treatment energy values were calculated utilizing pen performance data using the Galyean (2017) Net Energy Calculator similar to Exp. 1. Animal performance and carcass data were analyzed using the MIXED procedure of SAS as a randomized

block design with pen as the experimental unit. The model included block and dietary treatment. Treatments were evaluated using a protected F-Test and mean separation when significant variation was observed due to treatment. Liver abscess incidence data were analyzed using the GLIMMIX procedure of SAS as binomial variables with the number of animals affected by liver abscesses divided by the total number of animals within the pen. Probabilities less than or equal to alpha ($P \leq 0.05$) were considered significant, with tendencies acknowledged at *P*-values between 0.05 and 0.10.

RESULTS AND DISCUSSION

Exp. 1

Effects of Corn Trait by Sweet Bran Interaction on Feedlot Performance and Carcass Characteristics. A tendency for a corn trait x Sweet Bran (SB) interaction ($P = 0.07$) for carcass adjusted final BW was observed (Table 3.3). Cattle fed SYT-EFC with SB had numerically greater final BW than CON but not when cattle were fed diets without SB. Interactions were observed for ADG and G:F (P = 0.05 and 0.02, respectively). Steers that were fed SYT-EFC with SB had greater ADG ($P = 0.02$) and G:F ($P < 0.01$) than CON resulting in a 10.1% dietary improvement in G:F. However, when based on a corn grain inclusion of 58%, there was a 17.4% increase due to grain difference. In diets without SB, SYT-EFC and CON were not different ($P \geq 0.44$) but resulted in a 1.3% numerical improvement in G:F due to treatment and 1.9% improvement based on corn grain inclusion of 68%. A corn trait × SB interaction was observed for NEm ($P = 0.04$) and NEg ($P = 0.05$). Cattle that were fed SYT-EFC with SB had significantly greater dietary NEm and NEg values compared to CON ($P < 0.01$ and $P < 0.01$, respectively), whereas there was no difference for dietary NEm or NEg

between cattle fed SYT-EFC or CON without SB ($P = 0.47$ and $P = 0.41$, respectively). The increased response observed for SYT-EFC when fed with SB resulted in a 6.5 and 9.2% increase in NEm and NEg compared to CON. No interaction was observed for DMI (P = 0.99). Steers consuming SYT-EFC tended ($P = 0.07$) to consume less DM compared to CON.

Hot carcass weights followed the same trend ($P = 0.07$) as final BW (Table 3.3). Interactions were not observed for other carcass characteristics. For the main effect of trait, marbling scores, 12th-rib fat thickness and calculated yield grade were greater ($P < 0.03$) for cattle fed SYT-EFC compared with CON. The increase in marbling score for the steers fed SYT-EFC could be attributed to an increase in glucose being absorbed by the small intestine and utilized by the animal. Smith et al. (2009) reported that glucose contributes a greater proportion of acetyl units to lipid synthesis in intramuscular adipose tissue compared to subcutaneous adipose tissue. In intramuscular adipose tissue, glucose accounted for approximately 62% of the acetyl units to fatty acid biosynthesis, whereas acetate contributed to less than 20% (Smith and Crouse, 1984). The addition of supplemental exogenous α-amylase has been reported to increase or have little effect on 12th-rib fat thickness (Tricarico et al., 2007). However, feeding α-amylase does have the potential to manipulate fat partitioning in cattle by altering ruminal VFA production. It has been reported that α-amylase supplementation in finishing steers has reduced the molar proportion of propionate thus increasing the acetate to propionate ratio (Tricarico et al., 2005). Similarly, Rojo et al., (2005) reported a quadratic decrease in propionate when amylase was supplemented at increasing levels in sorghum based diets to lambs. DeFrain et al. (2005) reported a diet by day interaction for molar proportions of rumen

propionate and acetate to propionate ratio ($P < 0.04$, respectively) for d 21 to 7 in prepartum dairy cows. The authors observed a decrease in propionate and an increase in acetate to propionate ratio in cows fed supplemental α-amylase compared to controls. In subcutaneous adipose tissue, acetate contributed to 70% of the acetyl units to fatty acid biosynthesis whereas glucose accounted for less than 5% (Smith and Crouse, 1984). The increase observed in calculated yield grade can be attributed to the increase in 12th-rib fat thickness.

Effects of SYT-EFC fed without Sweet Bran on Feedlot Performance and Carcass Characteristics. No significant differences ($P \geq 0.35$) between CON, SYT-EFC, and BLEND were observed for final BW, DMI, ADG, G:F, NEm, or NEg when fed with MDGS (Table 3.4). Similarly, Schoonmaker et al., (2014) observed no differences in final BW, DMI, ADG, and G:F when steers were fed 0%, 10%, or 20% of the diet DM of CA3272 corn with 20% wet distillers grains plus solubles. In finishing diets containing supplemental α-amylase, an increase in ADG (Burroughs et al. 1960; Tricarico et al., 2007) or no difference in all performance characteristics (DMI, ADG, or G:F; Tricarico et al., 2007) were observed.

Hot carcass weight, dressing %, marbling score, LM area, and incidence of liver abscesses were not impacted ($P \geq 0.12$) by dietary treatment (Table 3.4). However, cattle fed BLEND had greater marbling scores than CON ($P = 0.05$). Fat depth was greater ($P = 0.03$) for steers fed SYT-EFC and BLEND compared with the CON. This supports the hypothesis that glucose contributes a greater proportion of acetyl units to lipid synthesis in intramuscular adipose tissue and that feeding α-amylase can have the potential to alter fat partitioning in cattle by changing ruminal VFA production (Smith et al., 2009).

Calculated yield grade was also greater ($P = 0.02$) for steers fed SYT-EFC and BLEND compared with CON corn. However, Schoonmaker et al., (2014) reported no differences for all carcass parameters when steers were fed 0%, 10%, or 20% of the diet DM of CA3272 corn with 20% WDGS.

Exp. 2

Dry matter intakes were not different ($P = 0.80$) among all four treatments (Table 3.5). Final BW and ADG were greater ($P < 0.01$) for steers fed SYT-EFC, BLEND, and CON-E compared with CON. Similarly, G:F was improved ($P < 0.01$) for steers fed SYT-EFC, BLEND, and CON-E compared with CON. When comparing feed efficiencies of steers fed SYT-EFC with CON, there was a 5.7% difference due to diet. When accounting for the corn grain inclusion (64%, DM basis) an improvement of 8.9% was observed presumably due to corn differences. Similar improvements in feed efficiency were observed for steers fed BLEND (7.0% due to diet and 21.9% due to 32% grain inclusion) and CON-E (7.0% due to diet and 10.9% due to 64% grain inclusion) compared to CON. Based on cattle performance, steers fed the amylase treatments had greater dietary NEm and NEg values compared to CON ($P < 0.01$ and $P < 0.01$, respectively). The NEm values (2.01, 2.03, and 2.04 Mcal.kg for SYT-EFC, BLEND, and CON-E, respectively) were increased by 4.1, 5.2, and 5.7%, respectively compared to CON. The NEg values (1.36, 1.37, and 1.38 Mcal.kg for SYT-EFC, BLEND, and CON-E, respectively) were increased by 6.3, 7.0, and 7.8%, respectively compared to CON. Previous research with feeding supplemental α-amylase in feedlot finishing diets have not been consistent. The literature has shown a 6.5 to 11.9% increase in ADG (Burroughs et al. 1960; Tricarico et al., 2007) or no difference in all performance characteristics (DMI,

ADG, or G:F; Tricarico et al., 2007; DiLorenzo et al., 2011;) when supplemental α-amylase has been fed in finishing diets. Although not significant ($P = 0.55$) due o limited replication, DiLorenzo et al., (2011) observed a 9.5% increase in G:F for steers fed supplemental amylase compared to the control presumably due to limited power. When corn containing supplemental α-amylase was fed in finishing diets at 0, 10, or 20% inclusion (DM basis), no differences in DMI, ADG, or G:F were observed ($P \geq 0.31$; Schoonmaker et al., 2014). When fed in dairy diets, supplemental α-amylase has been observed to increase milk yield compared to controls diets (Tricarico et al., 2005; Harrison and Tricarico, 2007; Klingerman et al., 2009) or a slight numerical improvement (DeFrain et al., 2005).

Hot carcass weights were greater ($P < 0.01$) for SYT-EFC, BLEND, and CON-E compared to CON (Table 3.5). Similarly, Tricarico et al., (2007) reported a quadratic increase ($P = 0.03$) in HCW in heifers fed supplemental α-amylase. Marbling score tended ($P = 0.08$) to be greatest for BLEND, intermediate for SYT-EFC and CON-E, and least for CON. Longissimus muscle area was greater ($P = 0.03$) for BLEND and CON-E compared with SYT-EFC and CON. Tricarico et al., (2007) observed a quadratic increase ($P = 0.04$) in LM area in heifers fed supplemental α-amylase. Dressing percent, fat depth, calculated yield grade and incidence of liver abscesses were not different ($P \geq 0.22$) among treatments.

Differences that were observed between the two locations and the magnitude of the responses are likely due to factors such as environmental conditions and grain source for the control and/or SYT-EFC. Experiment 1, conducted at ENREC near Mead, NE, is located within the Dissected Till Plains region consisting of a humid continental climate

with an average of 74.80 cm of rainfall per year (U.S. Climate Data, 2016a). Experiment 2, conducted at PHREC near Scottsbluff, NE, is located within the Great Plains region consisting of a semi-arid climate with an average of 39.85 cm of rainfall per year (U.S. Climate Data, 2016b). From November 2012 through May 2013, it was reported that on average the areas of Mead, NE and Scottsbluff, NE received 42.09 and 13.00 cm of rainfall, respectively (U.S. Climate Data, 2016a,b) suggesting that cattle performance observed in Scottsbluff could be contributed to a drier environment. The control and test corn hybrids utilized at each location were procured from different regions in the state.

Our results would suggest that there is an improvement in feed efficiency when feeding SYT-EFC, corn modified to contain α-amylase, is fed compared with conventional, control corn at both locations. There is potential for an increase in marbling score as it is an end product of additional glucose being utilized by the animal resulting in a greater proportion of acetyl units to lipid synthesis in intramuscular adipose tissue. This warrants additional research to further examine the impact of feeding a modified corn containing α-amylase in finishing feedlot diets.

Literature Cited

ANKOM, 2006. Ankom Technology Method 6. Neutral Detergent Fiber in Feeds by Filter Bag Technique. ANKOM Tech., Macedon, NY.

AOAC. 1999. Official method of analysis. 16th ed. Assoc. Off. Anal. Chem., Arlington,VA

AOAC International. 2000. AOAC Official Method 990.3. Protein (Crude) in Animal Feed. Combustion Method. Official Methods of Analysis of AOAC International, 17th ed. Dr. William Horwitz, ed. AOAC Int., Gaithersburg, MD.

AOAC Internaitonal. 2006. AOAC Official Method 2003.6. Crude Fat in Feeds, Cereal Grains, and Forages (Modified for Extraction with Petroleum Ether). Official Methods of Analysis of AOAC International. AOAC Int., Gaithersburg, MD.

Buroughs, W., W. Woods, S. A. Ewing, J. Greig, B. Theurer. 1960. Enzyme additions to fattening cattle rations. J. Anim. Sci. 19:458-464.

DeFrain, J. M., A. R. Hippin, K. F. Kalscheur, and J. M. Tricarico. 2005. Effect of dietary α-amylase on metabolism and performance of transition dairy cows. J. Dairy Sci. 88:4405-4413.

DiLorenzo, N. D. R. Smith, M. J. Quinn, M. L. May, C. H Ponce, W. Steinberg, M. A. Engstrom, and M. L. Galyean. 2011. Effects of grain processing and supplementation with exogenous amylase on nutrient digestibility in feedlot diets. Livest. Sci. 137:178-184.

Galyean, M. 2017. The Home Page of Michael Galyean. NEm and NEg Calculations. http://www.depts.ttu.edu/afs/home/mgalyean/. (Accessed January 9, 2018).

Hale, W. H., 1973. Influence of processing on the utilization of grains (starch) by ruminants. J. Anim. Sci. 37:1075-1080.

Harrison, G. A. and J. M. Tricarico. 2007. Effects of an *Aspergillus oryzae* extract containing α-amylase activity on lactational performance in commercial dairy herds. Prof. Anim. Sci. 23:291-294.

Hu, W., M. E. Persia, and L. Kung, 2010. Short communication: In vitro ruminal fermentability of a modified corn cultivar expressing a thermotolerant α-amylase. J. Dairy. Sci. 93:4846-4849.

Huck, G. L., K. K. Kreikemeier, G. L. Kuhl, T. P. Eck, and K. K. Bolsen. 1998. Effects of feeding combinations of steam-flaked grain sorghum and steam-flaked, high-moisture, or dry-rolled corn on growth performance and carcass characteristics in feedlot cattle. J. Anim. Sci. 76:2984-2990.

Jaeger, S. L., M. K. Luebbe, C. N. Macken, G. E. Erickson, T. J. Klopfenstein, W. A. Fithian, and D. S. Jackson. 2006. Influence of corn hybrid traits on digestibility and the efficiency of gain in feedlot cattle. J. Anim. Sci. 84:1790-1800.

Klingerman, C. M., W. Hu, E. E. McDonell, M. C. DerBedrosian, and L Kung Jr. 2009. An evaluation of exogenous enzymes with amylolytic activity for dairy cows. J. Dairy Sci. 92:1050-1059.

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.

Luebbe, M. K., G. E. Erickson, T. J. Klopfenstein, and W. A. Fithian. 2009. Influence of corn hybrid traits and processing method on nutrient digestibility. Prof. Anim. Sci. 25:496-509.

Megazyme International. 2011. Total Starch Assay Procedure. AOAC Official Method 996.11. AACC Method 76.13. Bray Business Park, Bray, Co. Wicklow, Ireland).

Mills, H. A. and J. B. Jones. 1996. Plant Analysis Handbook II: A practical sampling, Preparation, analysis, and interpretation guide. pp. 122 (Table 5.3). Micromacro Publishing, Inc., Athens, GA.

National Research Council. 1996. Nutrient Requirements of Beef Cattle. Seventh Edition. National Academy Press, Washington, D.C.

Owens, F. N., D. S. Secrist, W. J. Hill, and D. R. Gill. 1997. The effect of grain source and grain processing on performance of feedlot cattle: A Review. J. Anim. Sci. 75:868-879.

Owens, F. N., D. S. Secrist, W. J. Hill, and D. R. Gill. 1998. Acidosis in cattle: A review. J. Anim. Sci. 76:275-286.

Rojo, R., G. D. Mendoza, S. S. González, L. Landois, R. Bárcena, M. M. Crosby. 2005. Effects of exogenous amylases from *Bacillus licheniformis* and *Aspergillus niger* on ruminal starch digestion and lamb performance. J. Anim. Feed Sci. 123-124:655-665.

Schoonmaker, J. P., M. E. Persia, and D. C. Beitz. 2014. Effect of feeding corn modified to contain a unique amylase on performance and carcass characteristics of feedlot steers. Pro. Anim. Sci. 30:561-565.

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.

Smith, S. B., H. Kawachi, C. B. Choi, C. W. Choi, G. Wu, and J. E. Sawyer. 2009. Cellular regulation of bovine intramuscular adipose tissue development and composition. J. Anim. Sci. 87(E. Suppl.):E72-E82.

Tricarico, J. M., J. D. Johnston, K. A. Dawson, K. C. Hanson, K. R. McLeod, and D. L. Harmon. 2005. The effect of an *Aspergillus oryzae* extract containing alpha-amylase activity on ruminal fermentation and milk production in lactating Holstein cows. Anim. Sci. 81, 365-374.

Tricarico, J. M., M. D. Abney, M. L. Galyean, J. D. Rivera, K. C. Hanson, K. R. McLeod, and D. L. Harmon. 2007. Effect of dietary *Aspergillus oryzae* extract containing α-amylase activity on performance and carcass characteristics of finishing beef cattle. J. Anim. Sci. 85:802-811.

U.S. Climate Data. 2016a. Climate Mead-Nebraska. Accessed May 24, 2016. http://www.usclimatedata.com/climate/mead/nebraska/united-states/usne0316

U.S. Climate Data. 2016b. Climate Scottsbluff-Nebraska. Accessed May 24, 2016. http://www.usclimatedata.com/climate/scottsbluff/nebraska/united-states/usne0436

USDA, 1997. Official United States standards for grades of carcass beef. Agric Marketing Serv., USDA, Washington, DC.

Vasconcelos, J. T. and M. L. Galyean. 2007. Nutrition recommendations of feedlot consulting nutritionists: The 2007 Texas Tech University survey. J. Anim. Sci. 85:2772-2781.

Watson, A. K., B. L. Nuttelman, T. J. Klopfenstein, L. W. Lomas, and G. E. Erickson. 2013. Impacts of a limit-feeding procedure on variation and accuracy of cattle weights. J. Anim. Sci. 91:5507-5517.

Table 1.1. Dietary treatments evaluating SYT-EFC and Conventional commercial corn with or without Sweet Bran (Exp 1)

	Modified Distillers Grains plus Solubles			Sweet Bran	
Ingredient, % DM	CON[1]	SYT-EFC[2]	BLEND	CON[1]	SYT-EFC[2]
Conventional Dry Rolled Corn	68.0	-	34.0	58.0	-
SYT-EFC[2] Dry Rolled Corn	-	68.0	34.0	-	58.0
Sweet Bran	-	-	-	25.0	25.0
MDGS[3]	15.0	15.0	15.0	-	-
Corn silage	12.0	12.0	12.0	12.0	12.0
Meal supplement[4]	5.0	5.0	5.0	5.0	5.0
Fine ground corn	2.174	2.174	2.174	2.435	2.435
Limestone	1.6	1.6	1.6	1.6	1.6
Urea	0.6	0.6	0.6	0.4	0.4
Salt	0.3	0.3	0.3	0.3	0.3
Tallow	0.125	0.125	0.125	0.125	0.125
Trace mineral premix	0.05	0.05	0.05	0.05	0.05
Potassium chloride	0.02	0.02	0.02	--	--
Rumensin-90	0.0165	0.0165	0.0165	0.0165	0.0165
Vitamin ADE premix	0.015	0.015	0.015	0.015	0.015
Tylan-40	0.01	0.01	0.01	0.01	0.01
Nutrient Composition, %					
Starch	52.48	52.55	52.52	47.75	47.81
NDF	15.91	15.16	15.54	18.80	18.16
CP	14.15	14.22	14.18	13.45	13.51
Fat	4.07	4.01	4.04	3.19	3.13
Ca	0.63	0.67	0.65	0.61	0.64
K	0.58	0.59	0.59	0.67	0.68
P	0.40	0.39	0.39	0.46	0.44
Mg	0.20	0.20	0.20	0.23	0.23
S	0.16	0.15	0.16	0.19	0.18

[1]CON = Commercially available corn grain without the alpha amylase enzyme trait
[2]Syngenta Enogend Feed Corn provided by Syngenta under identity-preserved procedures. Stored, processed, and fed separately
[3]MDGS = Modified distillers grains plus solubles
[4]Supplement included 372.6 mg/kg Rumensin and 99.2 mg/kg Tylan.

Table 1.2. Dietary treatments evaluating SYT-EFC and Conventional corn with or without added enzyme (Exp 2).

Ingredient	CON[1]	SYT-EFC[2]	BLEND	CON-E[3]
Conventional Dry Rolled Corn	64.0	-	32.0	64.0
SYT-EFC[2] Dry Rolled Corn	-	64.0	32.0	-
WDGS	15.0	15.0	15.0	15.0
Corn silage	15.0	15.0	15.0	15.0
Liquid Supplement[4,5]	6.0	6.0	6.0	6.0
Dietary Nutrient Composition, %				
Starch	51.40	52.23	51.82	51.41
NDF	15.46	15.66	15.56	15.46
CP	12.85	13.30	13.07	12.85
Fat	3.44	3.89	3.67	3.44
Ca	0.60	0.60	0.60	0.60
K	0.55	0.53	0.54	0.55
P	0.34	0.31	0.32	0.34
Mg	0.15	0.15	0.15	0.15
S	0.15	0.15	0.15	0.15

[1]CON = Commercially available corn grain without the alpha amylase enzyme trait
[2]Sygenta Enogend Feed Corn provided by Syngenta under identity-preserved procedures. Stored, processed, and fed separately.
[3]CON-E = Conventional corn with enzyme supplement (Amaize; Alltech, Inc.) added to the diet at a rate of 5g/steer daily
[4]Liquid supplement contained; 0.56% urea, 1.6% Ca, 0.3% salt, 0.02% potassium chloride.
[5]Supplement included 372.6 mg/kg Rumensin and 99.2 mg/kg Tylan.

Table 1.3. Effect of corn hybrid and inclusion of Sweet Bran on finishing steers performance and carcass characteristics (*Exp 1.*)

	Dietary Treatments							
	0% Sweet Bran		25% Sweet Bran			*P*-Value[1]		
	CON[2]	SYT-EFC[2]	CON[2]	SYT-EFC[2]	SEM	Trait	SB	Trait*SB
Animal Performance								
Initial BW, kg	304	305	305	305	0.38	0.09	0.13	0.51
Final BW, kg[3]	587	585	580	597	5.12	0.14	0.68	0.07
Final Live BW, kg	590	587	581	596	5.01	0.17	0.98	0.08
DMI, kg/d	10.4	10.1	10.6	10.3	0.14	0.07	0.36	0.99
ADG, kg[3]	1.64^{ab}	1.62^{ab}	1.58^{b}	1.69^{a}	0.03	0.15	0.74	0.05
G:F	0.158^{bc}	0.160^{ab}	0.149^{c}	0.164^{a}	0.002	<0.01	0.68	0.02
Energy Values[4]								
NEm, Mcal/kg	1.91^{a}	1.94^{a}	1.84^{b}	1.96^{a}	0.02	< 0.01	0.34	0.04
NEg, Mcal/kg	1.27^{a}	1.29^{a}	1.20^{b}	1.31^{a}	0.02	< 0.01	0.32	0.05
Carcass Characteristics								
HCW, kg	370	369	365	376	3.23	0.14	0.72	0.07
Dressing %	62.7	62.8	62.8	63.1	0.20	0.48	0.39	0.79
Marbling Score[5]	456	484	443	488	10.7	< 0.01	0.68	0.43
12th Rib Fat Thickness, cm	1.22	1.42	1.22	1.35	0.05	0.01	0.56	0.41
LM Area, cm^2	83.2	80.6	82.6	83.9	1.24	0.53	0.34	0.20
Calculated Yield Grade[6]	3.18	3.48	3.17	3.33	0.10	0.03	0.46	0.45
Liver Abscesses, %	8.96	5.63	11.12	5.63	--	0.23	0.77	0.77

[1]Trait = *P*-value for the main effect of corn trait, SB = *P*-value for the main effect of Sweet Bran inclusion, Trait*SB= *P*-value for the interaction between corn trait and Sweet Bran inclusion.

[2]CON = Commercially available corn grain without the alpha amylase enzyme trait; SYT-EFC = Syngenta Enogend Feed Corn with the alpha amylase enzyme trait

[3]Calculated from HCW adjusted to a common 63% dressing percentage.

[4]Values calculated by pen using the 1996 NRC equations

[5]Marbling Score: 400= Small^{00}.

[6]Calculated as 2.5 + (6.35 x 12th rib fat, cm) + (0.2[KPH, %]) + (0.0017 x HCW, kg) – (2.06 x LM area, cm^2).

[a,b,c] Means within a row with unlike superscripts differ ($P < 0.05$).

Table 1.4. Effect of corn hybrid on finishing steer performance and carcass characteristics without Sweet Bran (*Exp. 1*)

	Dietary Treatments[1]				
Item	CON	SYT-EFC	BLEND	SEM	F-Test[2]
Animal Performance					
Initial BW, kg	305	305	305	0.46	0.35
Final BW, kg[3]	587	585	591	5.10	0.74
Final Live BW, kg	590	589	592	4.87	0.87
DMI, kg/d	10.4	10.2	10.4	0.14	0.35
ADG, kg[3]	1.64	1.62	1.65	0.03	0.66
G:F	0.158	0.160	0.159	0.002	0.67
Energy Values[4]					
NEm, Mcal/kg	1.92	1.94	1.93	0.02	0.72
NEg, Mcal/kg	1.27	1.29	1.28	0.02	0.67
Carcass Characteristics					
HCW, kg	370	369	373	3.23	0.68
Dressing %	62.7	62.8	62.9	0.20	0.63
Marbling Score[5]	461	489	511	16.6	0.13
12th Rib Fat Thickness, cm	1.22[b]	1.42[a]	1.45[a]	0.06	0.03
LM Area, cm^2	83.0	80.5	79.4	1.15	0.10
Calculated Yield Grade[6]	3.18[b]	3.49[a]	3.60[a]	0.09	0.02
Liver Abscesses, %	8.96	5.63	5.37	-	0.73

[1]CON = Commercially available corn grain without the alpha amylase enzyme trait; SYT-EFC = Syngenta Enogen Feed Corn containing an alpha amylase enzyme; BLEND = 50:50 blend of CON and Enogen on a DM basis

[2]F-Test = F-test statistic for the effect of treatment.

[3]Calculated from HCW adjusted to a common 63% pressing percentage.

[4]Values calculated by pen using the 1996 NRC equations

[5]Marbling Score: 400 = Small[00]; 500 = Modest[00].

[6]Calculated as 2.5 + (6.35 x 12th rib fat, cm) + (0.2[KPH, %]) + (0.0017 x HCW, kg) – (2.06 x LM area, cm^2).

[a,b]Means within a row with unlike superscripts differ ($P < 0.05$).

Table 1.5. Effect of corn hybrid and inclusion of an alpha amylase enzyme supplement on finishing steer performance and carcass characteristics (*Exp 2*)

	Dietary Treatment[1]					
Item	CON	SYT-EFC	BLEND	CON-E	SEM	F-Test[2]
Animal Performance						
Initial BW, kg	293	294	293	293	0.45	0.25
Final BW, kg[3]	570[b]	590[a]	589[a]	589[a]	3.37	< 0.01
Final Live BW, kg	573[b]	589[a]	587[a]	588[a]	2.57	< 0.01
DMI, kg/d	10.7	10.8	10.7	10.6	0.14	0.72
ADG, kg[3]	1.68[b]	1.79[a]	1.78[a]	1.78[a]	0.02	< 0.01
G:F	0.157[b]	0.166[a]	0.167[a]	0.168[a]	0.002	< 0.01
Energy Values[4]						
NEm, Mcal/kg	1.93[b]	2.01[a]	2.03[a]	2.04[a]	0.02	< 0.01
NEg, Mcal/kg	1.28[b]	1.36[a]	1.37[a]	1.38[a]	0.02	< 0.01
Carcass Characteristics						
HCW, kg	359[b]	372[a]	371[a]	371[a]	2.14	< 0.01
Dressing %	62.7	63.2	63.3	63.2	0.30	0.58
Marbling Score[5]	451	468	481	468	7.70	0.08
12th Rib Fat Thickness, cm	1.44	1.52	1.55	1.52	0.04	0.26
LM Area, cm^2	77.9[b]	78.0[b]	80.2[a]	79.7[a]	0.58	0.01
Calculated Yield Grade[6]	3.47	3.64	3.55	3.55	0.07	0.35
Liver Abscesses, %	3.33	5.08	0	5.17	-	0.41

[1]CON = Commercially available corn grain without the alpha amylase enzyme trait; SYT-EFC = Syngenta Enogen Feed Corn containing an alpha amylase enzyme; BLEND = 50:50 blend of SYT-EFC and CON on a DM basis; CON-E = Inclusion of a commercially available alpha amylase enzyme supplement in CON based diets.

[2]F-Test = F-test statistic for the effect of treatment.

[3]Calculated from HCW adjusted to a common 63% pressing percentage.

[4]Values calculated by pen using the 1996 NRC equations

[5]Marbling Score: 300=Slight[00], 400= Small[00].

[6]Calculated as 2.5 + (6.35 x 12th rib fat, cm) + (0.2[KPH, %]) + (0.0017 x HCW, kg) – (2.06 x LM area, cm^2).

[a,b] Means within a row with unlike superscripts differ ($P < 0.05$).

Chapter IV

Effect of feeding Syngenta Enogen Feed Corn containing an alpha amylase trait and corn processing on feedlot cattle performance, carcass characteristics, and site and extent of digestion[1]

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ABSTRACT: Two experiments evaluated the effect of a new corn hybrid containing an alpha amylase enzyme trait, Syngenta Enogen Feed Corn (SYT-EFC), on feedlot performance, carcass characteristics, site and extent of digestion, and ruminal fermentation parameters. Experiment 1 utilized 384 calf fed steers (310 ± 20 kg) in a randomized block design with 8 steers per pen and 6 replications per treatment. Dietary treatments were designed as a 2 x 2 x 2 factorial arrangement. Factors included corn trait [SYT-EFC or negative isoline control (NEG)], corn processing [dry-rolled corn (DRC) or high-moisture corn (HMC)] and fed in diets with Sweet Bran (SB) or modified distillers grains plus solubles (MDGS). In Exp. 2, four ruminally and duodenally cannulated steers (BW = 264 ± 13 kg) were utilized in a 4 steer, 6 period row-column transformation design with a 2 x 2+1 factorial arrangement of treatments. Factors included corn trait (SYT-EFC or NEG), by-product type (SB or MDGS), and a 50:50 blend of SYT-EFC and NEG with MDGS. For Exp. 1, no 3-way interactions were observed *(P* ≥ 0.21) between corn trait, corn processing, and byproduct type, for performance and carcass data. A corn processing x corn trait interaction was observed for final BW and ADG (*P* = 0.02 and *P* = 0.04, respectively). Steers that consumed SYT-EFC as DRC had greater final BW and ADG than NEG while steers fed SYT-EFC as HMC had lower final BW and ADG compared to NEG. No interaction (*P* = 0.15) for G:F was observed; however, cattle fed SYT-EFC as DRC were more efficient (*P* = 0.05) than cattle fed NEG as DRC while steers fed SYT-EFC or NEG as HMC were not different (*P* = 0.88) . In Exp. 2, no interactions were observed for DM, OM, or starch digestibility (*P* ≥ 0.19). Steers fed SYT-EFC had greater total tract OM, post-ruminal starch, and total tract starch digestibility compared to NEG (*P* ≤ 0.08). No interactions (*P* ≥ 0.13) or main effect of

trait ($P \geq 0.22$) were observed for all ruminal pH parameters. Feeding Syngenta Enogen Feed Corn, which contains an alpha amylase enzyme trait, as DRC, resulted in greater starch utilization post-ruminally leading to greater ADG.

Key Words: amylase, beef cattle, corn trait, feedlot, starch digestibility

INTRODUCTION

With the increase in the world population, advancing technologies for increasing beef production on less resources is needed. Starch digestion must be maximized to achieve optimal cattle performance. Research has shown that total tract starch digestibility for cattle fed dry-rolled corn (DRC) or steam flaked corn ranges from 80.1% to 96.0% and 98.2% to 99.8%, respectively (Barajas and Zinn, 1998; Luebbe et al., 2012; Plascencia et al, 2011; Cooper et al., 2002) with the primary limitation for starch digestion of DRC being intestinal. However, if starch availability could be increased in slower fermentable grains such as DRC, the range of starch digestibility for DRC could be increased and more comparable to grains processed to a greater extent.

A new corn hybrid, Syngenta Enogen Feed Corn (SYT-EFC), contains a thermotolerant α-amylase enzyme that during the dry milling ethanol process becomes activated eliminating the need for exogenous α-amylase. Jolly-Breithaupt (2018) fed SYT-EFC as the sole corn grain source and processed as DRC in diets containing byproducts. The authors observed a 2.0% to 17.4% increase in feeding value due to the corn containing α-amylase under different dietary scenarios. It is unclear if the enzyme within SYT-EFC is activated within the rumen or small intestine and how the enzyme responds to more intensive kernel processing. Therefore, the objectives of the two experiments were to evaluate 1) SYT-EFC compared to an isoline parental corn without the α-amylase enzyme trait fed as either DRC or processed as high-moisture corn with ethanol byproducts on cattle performance and carcass characteristics, 2) the effect of SYT-EFC on site and extent of digestion and ruminal metabolism parameters.

MATERIALS AND METHODS

All animal care and management procedures were approved by the University of Nebraska Lincoln Institution of Animal Care and Use Committee protocol numbers 517 and 1282.

Exp. 1

A 173 day finishing trial was conducted utilizing 384 crossbred, calf fed steers (initial BW = 310, SD = 20.9 kg) to evaluate the effect of feeding SYT-EFC (Syngenta Seeds, Inc., Minnetonka, MN) containing the α-amylase enzyme trait or the near negative isoline parental hybrid (NEG) that did not contain the trait, processed as dry rolled corn (DRC) or high moisture corn (HMC) with wet or dry milling byproduct types on finishing cattle performance and carcass characteristics. The experiment was conducted at the University of Nebraska Lincoln's Eastern Nebraska Research and Extension Center feedlot (ENREC) near Mead, NE. All corn containing the α-amylase enzyme trait, SYT-EFC, and the negative isoline control was grown at ENREC during the summer of 2013. Steers were received at the ENREC feedlot in October of 2013 and utilized from November 2013 to May 2014.

Initial processing included vaccination for the prevention of IBR, BVD Type 1 and 2, PI3, BRSV, and *Mannheimia haemolytica* Type A1, (Bovi-Shield Gold One Shot, Zoetis, Florham Park, New Jersey). Cattle were vaccinated to aid in the prevention of *Histophilus somni*, (Somubac, Zoetis), and administered an injectable dewormer for the treatment and control of internal and external parasite (Dectomax, Zoetis). Thirty-three d later, cattle were revaccinated for the prevention of IBR, BVD Type 1 and 2, PI3, BRSV (Bovi-Shield Gold 5, Zoetis), *Clostridium chauvoei*, *septicum*, *novyi*, *sordellii*,

perfringens Types C&D, and *Haemophilus somnus* (Ultrabac-7, Zoetis). On d 1 of the trial, steers were implanted with Revalor-XS (200 mg of trenbolone acetate and 40 mg estradiol; Merck Animal Health, Summit, New Jersey).

Steers were fed a common diet of 50% alfalfa hay and 50% wet corn gluten feed (Sweet Bran®, Cargill, Blair, NE) on a DM basis at 2% of BW for 5 d prior to beginning of the trial. On d 0 and 1 steers were weighed and the average weight was used for initial BW determination (Watson et al., 2013). Based on initial BW, steers were blocked by BW into light and heavy blocks (n= 4 and 2 pen replicates, respectively), stratified by BW within each block, and assigned randomly to one of 48 pens. Pens were assigned randomly to one of eight dietary treatments with a total of 8 steers per pen and 6 pens per treatment.

Dietary treatments (Table 4.1) were designed as a 2 x 2 x 2 factorial arrangement. Treatment factors consisted of feeding diets containing 1) SYT-EFC or NEG, 2) corn processed as DRC or HMC, 3) modified distillers grain plus solubles (MDGS; ADM, Columbus, NE) or Sweet Bran (SB; Cargill Wet Milling, Blair, NE). The byproducts utilized in this trial were provided as either a protein source (18% MDGS) only or a protein source and as a means of acidosis control (35% SB). With the inclusion of α-amylase during the dry and wet milling process to convert starch to glucose, byproducts have the potential of containing a trace amount of residual amylase. Steers were adapted to the finishing diets over a 21-d period with corn replacing alfalfa hay, while inclusion of sorghum silage, Sweet Bran or MDGS, and supplement remained the same in all diets. Diets were formulated to meet or exceed NRC (1996) requirements for MP and minerals. All final diets contained 5% supplement which was formulated to provide 33.0 mg/kg of

monensin (Elanco Animal Health, Greenfield, IN) and 9.0 mg/kg of tylosin (Elanco Animal Health).

Cattle were fed once daily at approximately 0800 and managed for *ad libitum* feed intake. When needed, refused feed was removed from feed bunks, weighed, and dried in a forced-air oven (model LBB2-21-1; Despatch Industries, Minneapolis, MN)for 48 h at 60°C to determine DM (AOAC, 1999; method 4.1.03) for accurate DMI. Ingredient samples were collected weekly, composited by month, and sent to a commercial laboratory (Servi-Tech Laboratories, Hastings, NE) to be analyzed for DM (AOAC, 1999; method 4.1.03), OM (AOAC, 1999; method 4.1.10), CP (AOAC, 1999 Method 990.03), NDF (ANKOM, 2006), ether extract (AOAC International, 2006; Method 2003.6), total starch content (Megazyme International, AOAC International, 2000; Method 996.11; AACC Method 76.13), and Ca, K, P, Mg, and S (Mills and Jones, 1996).

All animals were harvested on d 174 at a commercial abattoir (Greater Omaha , Omaha, Neb.). Feed offered on d 173 was 50% of the previous day DMI. Steers were removed from pens and weighed by pen at 1600 h and a 4% pencil shrink was applied for calculating dressing percent. Steers were shipped to the commercial abattoir and held until the next d for slaughter. Hot carcass weights (HCW) and liver scores were recorded at the time of slaughter. Fat thickness, LM area, and USDA marbling score were recorded after a 48-h chill. Final BW, ADG, and G:F were calculated using HCW and adjusted to a common dressing percentage of 63%. Yield grade was calculated using the USDA YG equation (USDA, 1997): YG = 2.5 + 2.5 (Fat thickness, cm) – 0.32 (LM area, cm^2) + 0.2 (KPH fat, %) + 0.0038 (HCW, kg).

Dietary treatment energy values were calculated by pen utilizing pen performance data in the Galyean (2017) Net Energy Calculator utilizing shrunk initial BW, shrunk final BW, DMI, ADG, and a target endpoint (assume choice quality grade) to calculate net energy of maintenance and gain. Performance and carcass characteristics were analyzed using the MIXED procedure of SAS (SAS Inst. Inc., Cary, NC) as a randomized block design. Initial BW block was included as a fixed effect and pen served as the experimental unit. Data were analyzed as a 2 x 2 x 2 factorial with the main factors including corn processing, corn trait, and byproduct type. The model included the 3-way interaction, all 2-way interaction terms, and the main effects. If the 3-way interaction term was not significant it was removed from the model. Probabilities less than or equal to $\alpha = 0.05$ were considered significant.

Exp. 2

A digestion trial was conducted to evaluate the effects of feeding SYT-EFC as DRC on site, extent of digestion, and rumen parameters in feedlot cattle diets. Both SYT-EFC and NEG were from the same corn crop utilized in Exp. 1. Four ruminally and duodenally cannulated steers were utilized in a 4 steer, 6 period row-column transformation design. Steers were assigned randomly to treatments by utilizing a row by column random number arrangement. Dietary treatments (Table 4.2) were designed in a 2 x 2+1 factorial arrangement with factors consisting of 1) corn trait (SYT-EFC or NEG), 2) byproduct type (MDGS or SB), and the plus one treatment consisted of a 50:50 blend of SYT-EFC and NEG corn with MDGS (BLEND). With the inclusion of α-amylase during the dry and wet milling process to convert starch to glucose, byproducts have the potential of containing a trace amount of residual amylase. All diets contained 360

mg/steer daily of Rumensin (30 g/ton of DM, Elanco Animal Health) and 90 mg/steer daily of tylosin (9 g/ton of DM, Elanco Animal Health).

Steers were fed once daily at 0800 h and had ad libitum access to feed and water. Cattle were housed in individual 3.7 m × 1.8 m, rubber slatted pens in 20°C controlled room. Ingredient samples were taken during the collection period at time of mixing, composited by period, lyophilized (Virtis Freezemobile 25ES, Life Scientific, Inc., St. Louis, MO), and ground through a 1-mm screen using a Wiley Mill (No. 4, Thomas Scientific, Swedesboro, NJ).

Period duration consisted of 21-d with a 16-d adaptation phase and a 5-d collection period. Beginning on d 10 of each period, titanium dioxide was dosed intraruminally at 0800 and 1600 h to provide a total of 10 g/d. Fecal and duodenal samples were collected at four times per d at 0700, 1100, 1500, and 1900 h on d 17-20. Fecal samples were composited wet from hourly to d by a weighted percentage, lyophilized (Virtis Freezemobile 25ES, Life Scientific, Inc., St. Louis, MO), ground through a Wiley Mill using a 1 mm screen, and composited by animal within period. All duodenal sample contents were lyophilized (Virtis Freezemobile 25ES, Life Scientific, Inc., St. Louis, MO), ground through a Wiley Mill using a 1-mm screen and composited by animal within period. Fecal and duodenal samples were analyzed for titanium dioxide to determine nutrient digestibility and flow (Myers, et al., 2004). Feed ingredients, fecal, and duodenal samples were analyzed for DM (AOAC, 1999; method 4.1.03), OM (AOAC, 1999; method 4.1.10), CP (AOAC, 2000 Method 990.03), and total starch content (Megazyme International, 2011; AOAC International, 2000; Method 996.11; AACC Method 76.13).

On d 21, whole rumen contents were collected, mixed with 2 L of formalin/saline (3.7% formaldehyde and 0.9% NaCl) for bacterial cell isolation (Leupp et al., 2009), and were stored frozen at -4°C. At the conclusion of the trial, whole rumen contents were blended (Model 5011, Dynamics Corporation of America, New Hartford, CT) for 1 minute on high speed and strained through three layers of cheesecloth. Fluid was then dispersed into 50-ml conical tubes and centrifuged at 500 x g for 20 min at 4°C to remove feed particles and protozoa. The supernatant was poured into another 50-ml conical tube and re-spun at 500 x g for 20 min at 4°C. Once spun twice, the supernatant was transferred into 16 x 20 mm plastic tube and centrifuged at 15,000 x g for 15 min at 4 °C to separate the bacteria from the free supernatant. Free supernatant was removed via suction leaving the bacteria pellet which was collected and freeze dried. Duodenal contents and bacterial isolates were analyzed for purine concentration to determine microbial flow (Zinn and Owens, 1986). Purine concentration was determined on a spectrophotometer (Spectramax 250, Molecular Devices, Sunnyville, CA) at 260 nm. True ruminal digestibility was calculated as the difference between the amount of nutrient ingested and the amount present at the duodenal cannula after correcting for microbial nutrient contributions.

On d 21, rumen fluid samples were collected five times/d at 0700, 1000, 1300, 1600, and 1900 h. Samples were collected (approximately 50 mL) through the rumen cannula using the suction strainer technique (Raun and Burroughs, 1962). At the time of sampling, the suction probe was moved around the rumen to ensure a representative fluid sample was collected. Rumen fluid samples were immediately frozen at after collection and remained frozen until VFA concentration was analyzed. At the time of analysis,

samples were thawed in a cooler (4°C) to ensure no additional fermentation occurred. Ruminal fluid samples were prepared according to Erwin et al., (1961) and analyzed for VFA (acetate, propionate, and butyrate) concentration using a Trace 1300 (Thermo Fisher Scientific, Inc., Omaha, NE) gas chromatograph fitted with a Zebron capillary column (Phenomenex, Torance, CA, Catalog # 7HM-G009-22).

Ruminal pH was measured continuously from d 17 to 21 with submersible wireless pH probes (Dascor, Inc., Escondido, CA). Probes were attached to weight to ensure that pH sensor remained in the ventral sac of the rumen. All pH probes were calibrated prior to being placed into the rumen by submersing the sensor in pH 4 and 7 standard solutions. Ruminal pH measurements from each period were adjusted using the beginning and ending calibration values. Ruminal pH data were recorded every minute (1,440 measurements/d) and downloaded on d 21 of each period. Measurements for pH include average ruminal pH, minimum and maximum pH, magnitude, ruminal pH variance, and ruminal pH area below 5.6. Ruminal pH variance and time and area below 5.6 were calculated as described by Cooper et al. (1999).

Intake and digestibility data were analyzed using the MIXED procedures of SAS (SAS Inst., Inc., Cary, N.C.) with steer within period as the experimental unit. For all analyzes, treatment and period were included in the model as fixed effects with steer being a random effect. The main effect of corn trait, byproduct type, and interaction between corn trait and byproduct type were included in the model. Ruminal pH and VFA data were analyzed as a repeated measure using the MIXED procedure of SAS. Time within day was the repeated measure. The model for ruminal pH and VFA concentration included period, trait, byproduct type, time(day), and the resultant interaction terms. Six

covariance structures were tested (unstructured, variance components, Cholesky, autoregressive, Toeplitz, and compound symmetry), and the structure that resulted in the lowest Bayesian information criterion was determined the best fit. The autoregressive covariance structure provided that best fit for the pH and VFA data. All data was analyzed to test for the interaction and main effects initially. Three pre-planned contrasts were used to evaluate the effect of corn trait when fed with MDGS. A protected F-Test was utilized to compare the means of all five treatments. Treatment differences were considered significant at $P \leq 0.10$.

RESULTS AND DISCUSSION

Exp. 1

Performance and Carcass Characteristics

There were no 3-way interactions (corn processing × byproduct type × corn trait) observed for cattle performance ($P \geq 0.34$) and carcass characteristic data ($P \geq 0.21$; Table 4.3). However, steers that were fed SYT-EFC as DRC with MDGS were 4.0% more efficient than steers fed NEG as DRC with MDGS. When fed as HMC, feed efficiency between SYT-EFC and NEG with MDGS differed by 1.6%. Cattle fed SYT-EFC as DRC with Sweet Bran had a 1.1% increase in G:F, whereas processed as HMC, feed efficiency was decreased by 2.1% for steers fed SYT-EFC compared to NEG with Sweet Bran.

No corn processing × byproduct type or corn trait × byproduct type interactions were observed for cattle performance ($P \geq 0.13$) and carcass characteristics data ($P \geq 0.12$). A corn processing × corn trait interaction was observed for final BW ($P = 0.02$) and ADG ($P = 0.04$; Table 4.4). Cattle fed SYT-EFC as DRC had greater final BW than

NEG DRC. However, the opposite was true when processed as HMC where cattle fed NEG had greater final BW than cattle fed SYT-EFC. Gains were greater for cattle fed SYT-EFC as DRC with NEG HMC and NEG DRC being intermediate, and SYT-EFC as HMC had the lowest ADG. Conversely, Tricarico et al., (2007) fed an exogenous α-amylase product in cracked corn or HMC finishing diets and reported a quadratic increase in ADG for steers fed the enzyme product compared to controls ($P = 0.04$).

No significant differences for the main effect of corn trait were observed for DMI and G:F ($P \geq 0.21$). Although not significant, steers fed SYT-EFC as DRC had numerically greater G:F compared to NEG as DRC resulting in a 2.2% change. However, this numerical improvement was not observed when processed as HMC. This could be attributed to the already increased ruminal starch digestion of HMC. Data on feeding corn containing an α-amylase enzyme are limited and the results appear to be mixed. Schoonmaker et al., (2014) fed 10 or 20% ground corn containing an α-amylase enzyme and observed no difference in final BW, DMI, ADG, and G:F ($P \geq 0.18$). The lack of response observed by Schoonmaker et al., (2014) could have been attributed to the low inclusion of corn containing the α-amylase enzyme or the fact that it was processed as ground corn increasing the rate of ruminal starch digestion resulting in an increased risk for acidosis. However, Jolly-Breithaupt (2018) fed SYT-EFC as the sole dietary corn grain in two experiments, processed as DRC, and observed a 1.3% to 10.1% increase in feed efficiency. In finishing diets containing an exogenous α-amylase supplement, ADG was increased (Burroughs et al. 1960; Jolly-Breithaupt, 2018; Tricarico et al., 2007), DMI and G:F were increased (Jolly-Breithaupt, 2018) or no

difference in all performance characteristics (DMI, ADG, or G:F; Tricarico et al., 2007; DiLorenzo et al., 2011) were observed.

No significant differences for the main effect of corn trait were observed for carcass characteristic measurements ($P \geq 0.17$). This agrees with Schoonmaker et al., (2014), however, Jolly-Breithaupt (2018) observed an increase in marbling score ($P < 0.01$), 12th rib fat thickness ($P = 0.01$), and calculated yield grade ($P = 0.03$) when SYT-EFC was fed compared to a commercially available corn. In a separate experiment, Jolly-Breithaupt (2018) observed an increase in HCW ($P < 0.01$), LM area ($P = 0.03$), and a tendency for an increase in marbling score ($P = 0.08$) when SYT-EFC was fed. The authors speculated that feeding SYT-EFC increased the concentration of glucose being absorbed and utilized by the animal. With more glucose being absorbed, a greater proportion of acetyl units are utilized for lipid synthesis in intramuscular adipose tissue (Smith et al., 2009). Alpha-amylase supplementation has been shown to quadratically increase HCW, LM area, and yield grade ($P \leq 0.04$; Tricarico et al., 2007). Tricarico et al., (2007) reported an increase in fat thickness ($P = 0.05$) when steers were fed exogenous α-amylase supplement. An increase in fat thickness could be the result of a decreased molar proportion of propionate (Tricarico et al., 2005) resulting in an increase in acetate to propionate ratio and an increase in subcutaneous adipose tissue as acetate contributes to 70% of the acetyls units to fatty acid biosynthesis (DeFrain et al, 2005; Smith and Crouse, 1984).

Processing corn as HMC reduced DMI by 5.9 and 8.0% for NEG and SYT-EFC, respectively ($P < 0.01$) and increased G:F by 7.3 and 4.9% for NEG and SYT-EFC, respectively ($P < 0.01$) compared to steers fed DRC. Owens et al., (1997) reported an

8.4% average reduction in DMI when comparing HMC to DRC finishing diets. The authors attributed the reduction in intake to the increased rate of VFA production in the rumen associated with increased starch availability of the more intensely processed grain. Extensive ruminal fermentation results in subclinical acidosis and could contribute to an increase in day-to-day intake variation (Stock et al., 1995). However, a reduction in DMI when comparing HMC and DRC diets has not been observed in all trials (Stock et al., 1991; Huck et al., 1998). The response to feed efficiency when comparing dry-rolled to high-moisture corn has been reported to increase (Corrigan et al., 2009; Harrelson et al., 2009; Scott et al., 2003) or result in no significant additional improvement (Owens et al., 1997; Mader et al., 1983). There were no significant differences for the main effect of corn processing on HCW, marbling, LM area, fat depth, and calculated YG ($P \geq 0.12$).

Energy Values

Based on animal performance data, there were no 3-way interactions (corn processing × byproduct type × corn trait) observed for NEm ($P = 0.89$) and NEg ($P = 0.90$; Table 4.3). No corn processing × byproduct type or corn processing × corn trait interactions were observed for NEm ($P \geq 0.16$) and NEg ($P \geq 0.14$). A byproduct type × corn trait interaction was observed for NEm ($P = 0.05$; Table 4.5). There was no difference in NEm for cattle fed SYT-EFC compared to NEG with Sweet Bran ($P = 0.41$), however, steers fed SYT-EFC with MDGS had greater a NEm compared to NEG ($P = 0.05$). A tendency for an interaction was observed for NEg ($P = 0.06$) with steers fed SYT-EFC with MDGS had greater NEg compared to cattle fed NEG with MDGS ($P = 0.05$), however, there was no difference among corn traits in cattle fed Sweet Bran ($P = 0.46$).

Exp. 2

Nutrient Intake

A byproduct type × corn trait interaction was observed for DMI, OMI, and starch intake ($P = 0.04$); Table 4.5). Steers that consumed Sweet Bran with either NEG or SYT-EFC had a greater magnitude of difference for DM, OM, and starch intakes, with NEG intakes being greater than SYT-EFC. Steers fed MDGS with NEG or SYT-EFC were not different. When comparing the three treatments containing MDGS, there were no differences in DMI between SYT-EFC and NEG or SYT-EFC and Blend ($P \geq 0.15$). However, steers fed NEG had lower DM, OM, and starch intakes compared to steers fed the Blend treatment ($P \leq 0.06$). Lastly, utilizing the protected F-test to compare all five treatments, cattle fed NEG with SB had the greatest DM and OM intakes with cattle fed NEG with MDGS had the least ($P \leq 0.04$). There was no difference for starch intake among all five treatments ($P = 0.13$).

Ruminal Digestibility

An interaction was observed for apparent ruminal OM digestibility ($P = 0.09$) with cattle fed SYT-EFC and MDGS having 14.6% greater ruminal OM digestibility compared to NEG. No interactions were observed for true ruminal OM, apparent ruminal starch or true ruminal starch digestibility ($P \geq 0.28$). No differences were observed for the main effect of corn trait for ruminal apparent OM, true OM, apparent starch or true starch digestibility ($P \geq 0.34$). Hristov et al., (2008) fed a predominately amylase enzyme supplement and observed no difference in true ruminal OM ($P = 0.68$) and starch ($P = 0.81$) digestibilities compared to a control. Rojo et al., (2005) fed α-amylase from *Bacillus licheniformis* and reported an increase in ruminal starch digestion ($P = 0.02$),

however, in agreement with Hristov et al., (2008) there was no difference in ruminal OM digestibility ($P = 0.57$). True ruminal OM digestibility, apparent ruminal starch digestibility, and true ruminal starch digestibility were not different between byproduct types ($P \geq 0.20$). When comparing the three treatments containing MDGS, cattle fed SYT-EFC had greater apparent ruminal OM digestibility compared to NEG ($P = 0.08$), however no difference were observed for all other ruminal digestibility parameters ($P \geq 0.16$). There were no differences observed when utilizing the protected F-test to compare all five treatments for apparent ruminal OM, true ruminal OM, apparent ruminal starch, and true ruminal starch digestibility ($P \geq 0.20$).

Post-Ruminal Digestibility

No interactions were observed for post-ruminal OM and starch digestibility ($P \geq 0.21$ and $P \geq 0.45$, respectively). The main effect of corn trait was significant ($P = 0.08$) for post-ruminal starch digestibility with cattle fed SYT-EFC having a post-ruminal starch digestibility of 68.1% compared to 51.0% for cattle fed NEG demonstrating an increase in intestinal starch digestion had occurred. The hypothesis that an increase in post-ruminal starch digestion from supplemental α-amylase has been suggested, however, is unlikely due to the enzyme being inactivated by gastric digestion (Tricarico, et al., 2008). If the enzyme within the corn grain is able to withstand rumen degradation and gastric digestion then it could increase intestinal starch digestion which is energetically more favorable for the animal (Owens et al., 1986). The values reported in the present trial for post-ruminal starch digestibility are similar to the values published by Barajas and Zinn, (1998); Corona et al., (2006); and Huntington (1997). Byproduct type had no impact on post-ruminal OM or starch digestion ($P \geq 0.39$). However, post-ruminal starch

digestibility has been reported to increase in steers fed WDGS compared to a corn bran plus corn gluten meal composite (Vander Pol et al., 2009). No differences were observed in post-ruminal OM or starch digestion when contrasting the three treatments containing MDGS ($P \geq 0.44$) or comparing all five treatments ($P \geq 0.32$).

Fecal Output

No interaction was observed for fecal OM output ($P = 0.16$). However, the main effect of corn trait was significant ($P = 0.05$) with cattle fed SYT-EFC having 25.8% less OM excreted compared to NEG suggesting a greater extent of OM digestion occurred. There was no difference for the main effect of byproduct type for OM fecal output ($P = 0.42$). An interaction was observed for fecal starch output ($P = 0.08$) with steers fed NEG with Sweet Bran having the greatest fecal starch excreted, NEG and SYT-EFC with MDGS were intermediate, and SYT-EFC with Sweet Bran had the least. No differences were observed for fecal starch output among MDGS diets ($P \geq 0.45$). However, when utilizing the protected F-Test to compare all five treatments, cattle fed NEG in SB or MDGS diets excreted the greatest amount of starch (0.482 and 0.365 kg/d, respectively), with Blend being intermediate (0.300 kg/d), and cattle fed SYT-EFC with either MDGS or SB excreted the lowest amount of starch (0.308 and 0.217 kg/d, respectively; $P = 0.06$). This equates to a 61.3% reduction in fecal starch excretion in steers fed SYT-EFC suggesting that a greater extent of starch digestion occurred in steers fed SYT-EFC.

Total Tract Digestibility

No interactions were observed for total tract DM, OM, and starch digestibility ($P \geq 0.19$). Cattle that were fed SYT-EFC had greater DM, OM, and total tract starch digestibility as the result of an increase in post-ruminal digestion and a reduction in

nutrient fecal output ($P \leq 0.08$). Starch total tract digestibility was increased from 90.0% for cattle fed NEG to 93.8% for cattle fed SYT-EFC ($P = 0.01$). The increase in starch digestibility helps to explain the increased response in animal performance observed in this current trial as well as previous experiments with DRC (Jolly-Breithaupt, 2018). Rojo et al., (2005) reported a quadratic increase in DM ($P = 0.03$), OM ($P = 0.04$), and starch ($P = 0.05$) total tract digestibility in lambs fed supplemental α-amylase from *Bacillus licheniformis*. Conversely, Hristov et al., (2008) reported no differences in DM, OM, or starch total tract digestibility in lactating dairy cows fed a predominantly amylase enzyme supplement or a control diet. There was no effect of byproduct type on DM, OM, and starch total tract digestibility ($P \geq 0.81$). Vander Pol et al., (2009) reported that cattle fed WDGS had greater DM and OM total tract digestibilities ($P < 0.01$) compared to a corn bran plus corn gluten meal composite diet. Conversely, the authors reported that diet did not impact starch digestion. When comparing the three treatments containing MDGS, were no significant differences reported ($P \geq 0.17$), however, total tract starch digestibilities were numerically increased when cattle were fed amylase treatments (90.9%, 92.9%, and 93.4% for cattle fed NEG, Blend, and SYT-EFC, respectively). The protected F-Test resulted in cattle fed SYT-EFC with either MDGS or SB had greater total tract starch digestibility with the Blend being intermediate, and cattle fed NEG with either MDGS or SB having the lowest total tract starch digestibilities ($P = 0.06$).

Ruminal pH

There were no interactions ($P \geq 0.44$), effect of corn trait ($P \geq 0.80$), or effect of byproduct type ($P \geq 0.20$) observed for average, maximum, minimum, or magnitude of

pH change (Table 4.6). Data from animals fed supplemental α-amylase have shown to either quadratically ($P = 0.05$) increase ruminal pH (Rojo et al., 2005) or have no impact (Hristov et al., 2008; Takiya et al., 2017). There was no interaction ($P = 0.19$) or effect of corn trait ($P = 0.49$) on pH variance, however an effect of byproduct type was observed ($P = 0.06$). Cattle that were fed Sweet Bran resulted in a lower variance of ruminal pH (0.116) compared to cattle fed MDGS (0.152) suggesting that the SB inclusion did help alleviate acidosis to a greater extent. When comparing byproduct types, Vander Pol et al., (2009) reported no difference in average ruminal pH between a corn bran plus corn gluten meal composite and wet distillers grains plus solubles (WDGS). There were no interactions ($P \geq 0.85$), effect of trait ($P \geq 0.80$) or effect of byproduct ($P \geq 0.91$) observed for time and area below 5.6. No differences were observed for all ruminal pH parameters when contrasting the three diets containing MDGS ($P \geq 0.11$). When comparing all five treatments, pH variance tended to be greater for cattle fed Blend, intermediate for NEG and SYT-EFC with MDGS, and lowest for cattle fed NEG and SYT-EFC with SB ($P = 0.08$). When feeding corn containing an α-amylase supplement with DRC, the data would suggest that there is no greater risk of acidosis as ruminal pH were similar across treatments.

VFA Concentration

There were no interactions ($P \geq 0.13$), effect of corn trait ($P \geq 0.59$), or effect of byproduct type ($P \geq 0.63$) observed for the ruminal VFA proportions of acetate, propionate, and butyrate (Table 4.7). An interaction was observed ($P = 0.04$) for the acetate to propionate (A:P) ratio. The A:P ratio for steers fed MDGS were not different ($P = 0.19$), however, cattle that were fed SYT-EFC with SB had a greater A:P ratio ($P =$

0.09) compared to NEG (1.60 and 1.36, respectively). Previous research has shown that supplementation with *Aspergillus oryzae* α-amylase either increased the acetate to propionate ratio in lactating dairy cow and finishing cattle diets (Tricarico et al., 2005) or had no impact in the lactating dairy cow (Takiya et al, 2017). Vander Pol et al., (2009) reported an increase in acetate and a decrease in propionate production resulting in an increased acetate to propionate ratio ($P < 0.10$) when a composite of corn bran and corn gluten meal were fed compared to wet distillers grains plus solubles in finishing diets. Research has shown that replacing concentrates with a high-quality fiber source will increase the acetate to propionate ratio indicating that fiber digestion was being encouraged (Grant, 1997). With the exception of fat, the nutritive properties of MDGS and SB are similar suggesting the fat content of MDGS may have been inhibiting fiber digestion thus improving the acetate to propionate ratio observed in the current trial. An increase in butyrate production has also been reported (Tricarico et al, 2008; DeFrain et al., 2005); however, that response was not observed in our trial. In agreement with previous data, butyrate proportion increased quadratically ($P < 0.01$) in lambs supplemented with *Bacillus licheniformis* α-amylase. While it is not fully understood why the VFA profile may change with the addition of supplemental α-amylase, exogenous polysaccharide-degrading enzymes may be influencing certain groups of ruminal microbes and their impacts on rumen fermentation and end product production (Nsereko et al., 2002; McAllister et al., 2001). There were no significant differences for all VFA parameters when contrasting the three diets containing MDGS ($P \geq 0.14$) or utilizing the protected F-Test to compare all five treatments ($P \geq 0.33$).

Our results would suggest that cattle fed SYT-EFC hybrid with the alpha amylase enzyme trait have increased post-ruminal and total tract starch digestion compared to cattle fed the Negative Isoline corn. When cattle utilize an energy source to a greater extent, it will result in an improvement in feed efficiency. Overall, the increase in starch digestibility helps to explain the increased response in animal performance observed in this current trial as well as previous experiments with DRC (Jolly-Breithaupt, 2018).

Literature Cited

ANKOM, 2006. Ankom Technology Method 6. Neutral Detergent Fiber in Feeds by Filter Bag Technique. ANKOM Tech., Macedon, NY.

AOAC. 1999. Official method of analysis. 16th ed. Assoc. Off. Anal. Chem., Arlington, VAAOAC International. 2000. AOAC Official Method 990.3. Protein (Crude) in Animal Feed. Combustion Method. Official Methods of Analysis of AOAC International, 17th ed. Dr. William Horwitz, ed. AOAC Int., Gaithersburg, MD.

Barajas, R. and R. A. Zinn. 1998. The feeding value of dry-rolled and steam-flaked corn in finishing diets for feedlot cattle: Influence of protein supplementation. J. Anim. Sci. 76:1744-1752.

Buroughs, W., W. Woods, S. A. Ewing, J. Greig, B. Theurer. 1960. Enzyme additions to fattening cattle rations. J. Anim. Sci. 19:458-464.

Cooper, R.J., T.J. Klopfenstein, R.A. Stock, C.T. Milton, D.W. Herold, and J.C. Parrott. 1999.Effects of imposed feed intake variation on acidosis and performance of finishing steers. J. Anim. Sci. 77:1093-1099.

Cooper, R. J., C. T. Milton, T. J. Klopfenstein, T. L. Scott, C. B. Wilson, and R. A. Mass. 2002. Effect of corn processing on starch digestion and bacterial crude protein flow in finishing cattle. J. Anim. Sci. 80: 3:797-804.

Corona, L., F. N. Owens, and R. A. Zinn. 2006. Impact of corn vitreousness and processing on site and extent of digestion by feedlot cattle. J. Anim. Sci. 84:3020-3031.

Corrigan, M.E., G.E. Erickson, T.J. Klopfenstein, M.K. Luebbe, K.J. Vander Pol, N.F. Meyer, C.D. Buckner, S.J. Vanness and K.J. Hanford. 2009. Effect of corn processing method and corn wet distillers grains plus solubles inclusion level in finishing steers. J. Anim. Sci. 87:3351-3362.

DeFrain, J. M., A. R. Hippin, K. F. Kalscheur, and J. M. Tricarico. 2005. Effect of dietary α-amylase on metabolism and performance of transition dairy cows. J. Dairy Sci. 88:4405-4413.

DiLorenzo, N. D. R. Smith, M. J. Quinn, M. L. May, C. H Ponce, W. Steinberg, M. A. Engstrom, and M. L. Galyean. 2011. Effects of grain processing and supplementation with exogenous amylase on nutrient digestibility in feedlot diets. Livest. Sci. 137:178-184.

Erwin, E. S., D. J. Marco, and E. M. Emery. 1961. Volatile faty acid analysis of blood and rumen fluid by gas chromatography. J. Dairy Sci. 44:1768-1770.

Galyean, M. 2017. The Home Page of Michael Galyean. NEm and NEg Calculations.

http://www.depts.ttu.edu/afs/home/mgalyean/. (Accessed March 8, 2018).

Grant, R. J. 1997. Interaction among forages and non-forage fiber sources. J. Dairy. Sci. 80:1438-1446.

Harrelson, F. W., M. K. Luebbe, N. F. Meyer, G. E. Erickson, T. J. Klopfenstein, D. S. Jackson, and W. A. Fithian. 2009. Influence of corn hybrid and processing method of nutrient digestibility, finishing performance, and carcass characteristics. J. Anim. Sci. 87:2323-2332.

Hristov. A. N., C. E. Basel, A. Melgar, A. E. Foley, J. K. Ropp, C. W. Hunt, and J. M. Tricarico. 2008. Effect of exogenous polysaccharide-degrading enzyme preparations on ruminal fermentation and digestibility of nutrients in dairy cows. Anim. Feed. Sci. Technol. 145: 182-193.

Huck, G. L., K. K. Kreikemeier, G. L. Kuhl, T. P. Eck, and K. K. Bolsen. 1998. Effect of feeding combinations of steam-flaked grain sorghum and steam-flaked, high-moisture, or dry-rolled corn on growth performance and carcass characteristics in feedlot cattle. J. Anim. Sci. 76:2984-2990.

Huntington, G. B., 1997. Starch utilization by ruminants: from basics to the bunk. J. Anim. Sci. 75:852-867.

Jolly-Breithaupt, M. L. 2018. Effect of Syngenta Enogen feed corn containing an alpha amylase trait on finishing cattle performance and carcass characteristics. Unpublished.

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

Luebbe, M. K., J. M. Patterson, K. H. Jenkins, E. K. Buttery, T. C. Davis, B. E. Clark, F. T. McCollum, N. A. Cole, and J. C. MacDonald. 2012. Wet distillers grains plus solubles concentration in steam-flaked corn based diets: Effect on feedlot cattle performance, carcass characteristics, nutrient digestibility, and ruminal fermentation characteristics. J. Anim. Sci. 90: 5: 1589-1602.

Mader, T., D. Brink, D. Pankaskie, and J. Merrill. 1983. Corn storage and processing methods for finishing cattle. Nebraska Beef Cattle Rep. MP44:13-15.

McAllister, T. A., A. N. Hristov, K. A. Beauchemin, L. M. Rode, K. J. Cheng. 2001. In. Bedford, M., Partridgem G. (Eds.), Enzymes in Ruminant Diets. In: Enzymes in Farm Animal Nutrition. CABI Publishing, Oxon, UK, pp. 273-298.

Megazyme International. 2011. Total Starch Assay Procedure. AOAC Official Method

996.11.AACC Method 76.13. Bray Business Park, Bray, Co. Wicklow, Ireland).

Mills, H. A. and J. B. Jones. 1996. Plant Analysis Handbook II: A practical sampling, Preparation, analysis, and interpretation guide. pp. 122 (Table 5.3). Micromacro Publishing, Inc., Athens, GA.

Myers, W.D., P.A. Ludden, V. Nayigihugu and B.W. Hess. 2004. Technical Note: A procedure for the preparation and quantitative analysis of samples for titanium dioxide. J. Anim. Sci. 82:179-183.

National Research Council. 1996. Nutrient Requirements of Beef Cattle. Seventh Edition. National Academy Press, Washington, D.C.

Nsereko, V. L., K. A. Beauchemin, D. P. Morgavi, L. M. Rode, A. F. Furtado, T. A. McAllister, A. D. Iwaasa, W. Z. Yang, Y. Wang. 2002. Effect of a fibrolytic enzyme preparation from *Trichoderma longibrachiatum* on the rumen microbial population of dairy cows. Can. J. Microbiol. 48, 14-20.

Owens, F. N., R. A. Zinn, and Y. K. Kim. 1986. Limits to starch digestion in the ruminant small intestine. J. Anim. Sci. 63:1634-1648.

Plascencia, A., R. M. Bermudez, M. Cervantes, L. Corona, H. Davila-Ramos, M. A. Lopez-Soto,D. May, N. G. Torrentera, and R. A. Zinn. 2011. Influence of processing method on comparative digestion of white corn versus conventional steam-flaked yellow dent corn in finishing diets for feedlot cattle. J. Anim. Sci. 89: 1: 136-141.

Raun, N. S. and W. Burroughs. 1962. Suction strainer technique in obtaining rumen fluid samples from intact lambs. J. Anim. Sci. 21:454-457.

Rojo, R., G. D. Mendoza, S. S. Gonzalez, L. Landois, R. Barcena, and M. M. Crosby. 2005. Effect of exogenous amylases from *Bacillus licheniformis* and *Aspergillus niger* on ruminal starch digestion and lamb performance. Anim. Feed Sci. Technol. 123-124, 655-665.

Scott, T. L., C. T. Milton, G. E. Erickson, T. J. Klopfenstein, and R. A. Stock. 2003. Corn processing method in finishing diets containing wet corn gluten feed. J. Anim. Sci. 81:3182-3190.

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.

Smith, S. B., H. Kawachi, C. B. Choi, C. W. Choi, G. Wu, and J. E. Sawyer. 2009. Cellular regulation of bovine intramuscular adipose tissue development and composition. J. Anim. Sci. 87(E. Suppl.):E72-E82.

Stock, R. A., M. H. Sindt, R. M. Cleale IV, and R. A. Britton. 1991. High-moisture corn utilization in finishing cattle. J. Anim. Sci. 69:1645-1656.

Stock, R., T. Klopfenstein, and D. Shain. 1995. Feed intake variation. Okla. Agric. Exp. Sta. Misc. Publ. P-942:956.

Takiya, C. S., G. D. Calomeni, T. H. Silva, T. H. A. Vendramini, G. G. Silva, C. E. C. Consentini, J. C. Bertoni. E. M. C. Zilio, and F.P. Renno. 2017. Increasing dietary doses of an *Aspergillus oryzae* extract with alpha-amylase activity on nutrient digestibility and ruminal fermentation of lactating dairy cows. Anim. Feed Sci. Technol. 228: 159-167.

Tricarico, J., J. Johnston, K. Dawson, K. Hanson, K. McLeod, & D. Harmon. 2005. The effects of an *Aspergillus oryzae* extract containing alpha-amylase activity on ruminal fermentation and milk production in lactating Holstein cows. Animal Science, 81(3), 365-374. doi:10.1079/ASC50410365.

Tricarico, J. M., M. D. Abney, M. L. Galyean, J. D. Rivera, K. C. Hanson, K. R. McLeod, and D. L. Harmon. 2007. Effects of a dietary *Aspergillus oryzae* extract containing α-amylase activity on performance and carcass characteristics of finishing beef cattle. J. Anim. Sci. 85:802-8110.

Tricarico, J. M., J. D. Johnston, K .A Dawson. 2008. Dietary supplementation of ruminant diets with an *Aspergillus oryzae* α-amylase. Anim. Feed. Sci. Tech. 145:136-150.

United Nations, Department of Economic and Social Affairs, Population Division (2017). *World Population Prospects: The 2017 Revision, Key Findings and Advance Tables*. Working Paper No. ESA/P/QP/248.

USDA, 1997. Official United States standards for grades of carcass beef. Agric Marketing Serv., USDA, Washington, DC.

USDA. National Agricultural Statistics Service. 2017. Livestock slaughter 2016 summary (April 2017). ISSN: 0499-0544.

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.

Watson, A.K., B. L. Nuttelman, T. J. Klopfenstein, L.W. Lomas, G. E. Erickson. 2013. Impacts of a limit-feeding procedure on variation and accuracy of cattle weights. J. Anim. Sci. 91:5507-5517.

Zinn and Owens. 1986. A rapid procedure for purine measurement and its use for estimating net ruminal protein synthesis. Can. J. Anim. Sci. 66:157-166.

Table 4.1. Dietary treatments fed to steers to evaluate corn hybrid and corn processing method on cattle performance and carcass characteristics (Exp. 1)

	Negative Isoline[1]				SYT-EFC[2]			
Ingredient, % DM	MDGS		Sweet Bran		MDGS		Sweet Bran	
NEG DRC[1]	69.5	-	52.5	-	-	-	-	-
NEG HMC[1]	-	69.5	-	52.5	-	-	-	-
SYT-EFC DRC[2,3]	-	-	-	-	69.5	-	52.5	-
SYT-EFC HMC[2,3]	-	-	-	-	-	69.5	-	52.5
Sweet Bran	-	-	35.0	35.0	-	-	35.0	35.0
MDGS[4]	18.0	18.0	-	-	18.0	18.0	-	-
Sorghum Silage	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5
Supplement	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Fine Ground Corn	2.223	2.223	2.806	2.806	2.223	2.223	2.806	2.806
Limestone	1.710	1.710	1.677	1.677	1.710	1.710	1.677	1.677
Urea	0.55	0.55	-	-	0.55	0.55	-	-
Salt	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Tallow	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125
Trace mineral premix	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Rumensin-90	0.0165	0.0165	0.0165	0.0165	0.0165	0.0165	0.0165	0.0165
Vitamin ADE premix	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015
Tylan-40	0.0102	0.0102	0.0102	0.0102	0.0102	0.0102	0.0102	0.0102
Nutrient Composition, %								
Starch	47.14	48.74	38.74	39.95	47.56	49.08	39.06	40.21
NDF	16.17	15.40	20.47	19.89	15.54	14.92	20.00	19.52
CP	13.62	13.41	13.85	13.69	13.48	13.41	13.74	13.69
Fat	4.35	5.19	3.19	3.82	4.35	4.98	3.19	3.66
K	0.45	0.45	0.66	0.66	0.47	0.48	0.68	0.68
P	0.34	0.35	0.50	0.51	0.38	0.39	0.53	0.53
Mg	0.22	0.21	0.21	0.21	0.22	0.22	0.21	0.21
S	0.16	0.16	0.23	0.23	0.17	0.17	0.24	0.24

[1]NEG = Negative Isoline control corn grain grown without the alpha amylase enzyme trait

[2]SYT-EFC = Syngenta Enogen Feed Corn provided by Syngenta under identity-preserved procedures. Grain was stored, processed, and fed separately.

[3]DRC = Dry-rolled corn; HMC = High-moisture corn

[4]MDGS = Modified distillers grains plus solubles

[4]Supplement included 30 g/ton monensin and 9 g/ton tylosin.

Table 4.2. Dietary treatments fed to steers to evaluate NEG and SYT-EFC with or without Sweet Bran on digestibility (Exp. 2)

	Modified Distillers Grains plus Solubles			Sweet Bran	
Ingredient, % DM	NEG[1]	SYT-EFC[2]	BLEND[3]	NEG[1]	SYT-EFC[2]
NEG Dry Rolled Corn[1]	65.0	-	32.5	55.0	-
SYT-EFC Dry Rolled Corn[2]	-	65.0	32.5	-	55.0
Sweet Bran	-	-	-	25.0	25.0
MDGS[4]	15.0	15.0	15.0	-	-
Corn silage	15.0	15.0	15.0	15.0	15.0
Meal supplement[5]	5.0	5.0	5.0	5.0	5.0
Fine ground corn	2.12	2.12	2.12	2.76	2.76
Limestone	1.67	1.67	1.67	1.63	1.63
Urea	0.63	0.63	0.63	0.10	0.10
Salt	0.30	0.30	0.30	0.30	0.30
Tallow	0.125	0.125	0.125	0.125	0.125
Trace mineral premix	0.05	0.05	0.05	0.05	0.05
Potassium chloride	0.064	0.064	0.064	--	--
Rumensin-90	0.0165	0.0165	0.0165	0.0165	0.0165
Vitamin ADE premix	0.015	0.015	0.015	0.015	0.015
Tylan-40	0.009	0.009	0.009	0.009	0.009
Nutrient Composition, %					
Starch	52.85	54.54	53.69	49.33	50.75
OM	95.46	95.76	95.61	94.83	95.08
CP	15.39	15.47	15.43	14.66	14.73

[1]NEG = Negative Isoline control corn grain grown without the alpha amylase enzyme trait
[2]SYT-EFC = Syngenta Enogen Feed Corn provided by Syngenta under identity-preserved procedures. Stored, processed, and fed separately
[3]BLEND = 50:50 blend of NEG and SYT-EFC
[4]MDGS = Modified distillers grains plus solubles
[5]Supplement included 30 g/ton monesin and 9 g/ton tylosin.

Table 4.3. Effects of processed corn with MDGS or Sweet Bran on finishing cattle performance (Exp. 1)

	DRC[1]				HMC[1]											
	MDGS[2]		Sweet Bran		MDGS[2]		Sweet Bran									
	SYT-EFC	NEG[4]	SYT-EFC	NEG[4]	SYT-EFC	NEG[4]	SYT-EFC	NEG[4]	SEM	*P*-values[3] Process	Byprod	Trait	P*T	B*T	P*B	P*B*T
Performance																
Initial BW, kg	318	317	318	318	317	317	317	317	0.66	0.31	0.60	0.78	0.39	0.21	0.54	0.71
Final BW, kg[5]	653	644	663	656	649	651	650	662	4.68	0.71	0.01	0.90	0.02	0.38	0.44	0.52
DMI, kg/d	10.6	10.8	11.0	10.8	9.80	10.0	10.2	10.4	0.14	< 0.01	< 0.01	0.23	0.43	0.36	0.56	0.41
ADG, kg[5]	1.94	1.90	2.01	1.95	1.91	1.92	1.92	2.00	0.03	0.64	0.01	0.87	0.04	0.51	0.66	0.34
G:F	0.183	0.176	0.183	0.181	0.195	0.192	0.188	0.192	0.003	< 0.01	0.83	0.21	0.15	0.13	0.28	0.74
Energy Values[6]																
NEm, Mcal/kg	2.32	2.23	2.31	2.31	2.44	2.40	2.37	2.41	0.03	< 0.01	0.89	0.40	0.29	0.05	0.16	0.89
NEg, Mcal/kg	1.62	1.55	1.61	1.61	1.73	1.70	1.67	1.71	0.03	< 0.01	0.97	0.39	0.28	0.06	0.14	0.90
Carcass Characteristics																
HCW, kg	410	406	418	414	409	410	410	417	13.0	0.81	0.01	0.97	0.08	0.44	0.40	0.36
Marbling[7]	490	492	520	493	486	495	500	520	15.2	0.84	0.03	0.89	0.09	0.55	0.85	0.21
LM area, cm^2	92.7	89.9	92.3	91.0	93.2	90.3	89.6	91.4	1.86	0.69	0.66	0.19	0.45	0.12	0.43	0.39
Fat Depth, cm	1.37	1.51	1.41	1.48	1.47	1.50	1.57	1.47	0.06	0.12	0.61	0.36	0.07	0.17	0.65	0.60
Cal. YG[8]	3.18	3.42	3.29	3.40	3.24	3.43	3.53	3.40	0.12	0.31	0.21	0.17	0.30	0.12	0.57	0.52

[1]DRC = Dry rolled corn; HMC = High moisture corn
[2]MDGS = Modified distillers grains plus solubles
[3]P*T = *P* - value for the interaction of corn processing by corn trait; B*T = *P* - value for the interaction of byproduct by corn trait; P*B = *P* - value for the interaction of corn processing by byproduct; P*B*T = *P* - value for the interaction of corn processing by byproduct type by corn trait
[4]NEG = Negative Isoline, parental isoline control corn without the amylase enzyme trait
[5]Calculated from HCW adjusted to a common 63% dressing percentage.
[6]Values calculated by pen using the 1996 NRC equations
[7]Marbling Score: 400 = Small[00]; 500 = Modest[00]
[8]Calculated as 2.5+ (6.35 x 12th rib fat depth, cm) + (0.2 x [KPH, %]) + (0.0017 x HCW, kg) – (2.06 x LM area, cm^2)

Table 4.4. Effects of SYT-EFC corn trait and corn processing on finishing cattle performance (Exp. 1)

	DRC[1]		HMC[1]			*P*-values[2]		
	NEG[3]	SYT-EFC[3]	NEG[3]	SYT-EFC[3]	SEM	Processing	Trait	P*T
Performance								
Initial BW, kg	317	318	317	317	0.46	0.31	0.78	0.39
Final BW, kg[4]	650[b]	658[a]	656[a]	649[b]	3.31	0.71	0.90	0.02
DMI, kg/d	10.8	10.8	10.2	10.0	0.10	< 0.01	0.23	0.43
ADG, kg[4]	1.93[ab]	1.98[a]	1.96[ab]	1.92[b]	0.02	0.64	0.87	0.04
G:F	0.179	0.183	0.192	0.192	0.002	< 0.01	0.21	0.15
Energy Values[5]								
NEm, Mcal/kg	2.27	2.32	2.41	2.40	0.02	< 0.01	0.40	0.29
NEg, Mcal/kg	1.62	1.58	1.70	1.70		< 0.01	0.39	0.28
Carcass Characteristics								
HCW, kg	410	414	413	410	13.05	0.82	0.97	0.08
Marbling[6]	492	505	507	493	13.0	0.84	0.89	0.09
LM area, cm^2	90.5	92.5	90.8	91.4	1.58	0.69	0.19	0.45
Fat Depth, cm	1.50	1.40	1.48	1.52	0.045	0.12	0.35	0.07
Cal. YG[7]	3.41	3.24	3.41	3.39	0.10	0.31	0.17	0.30

[1]DRC = Dry rolled corn; HMC = High moisture corn

[2]NEG = Negative Isoline, parental isoline control corn without the amylase enzyme trait; SYT-EFC = Syngenta Enogen feed corn containing the alpha amylase enzyme trait

[3]P-values: Processing: Main effect of corn processing; Trait: Main effect of trait; P*T: Interaction between corn processing and corn trait

[4]Calculated from HCW adjusted to a common 63% dressing percentage

[5]Values calculated by pen using the 1996 NRC equations

[6]Marbling Score: 400 = $Small^{00}$; 500 = $Modest^{00}$

[7]Calculated as 2.5+ (6.35 x 12^{th} rib fat depth, cm) + (0.2 x [KPH, %]) + (0.0017 x HCW, kg) – (2.06 x LM area, cm^2)

[a,b] Means within a row with unlike superscripts differ ($P < 0.05$)

Table 4.5. Effects of SYT-EFC corn trait and byproduct type on finishing cattle performance (Exp. 1)

	MDGS[1]		Sweet Bran			*P*-values[2]		
	NEG[3]	SYT-EFC[3]	NEG[3]	SYT-EFC[3]	SEM	Byprod	Trait	B*T
Performance								
Initial BW, kg	317	317	317	317	0.48	0.60	0.78	0.21
Final BW, kg[4]	647	651	659	656	3.3	0.01	0.90	0.38
DMI, kg/d	10.4	10.1	10.6	10.6	0.10	< 0.01	0.23	0.36
ADG, kg[4]	1.91	1.92	1.98	1.97	0.02	0.01	0.87	0.51
G:F	0.184	0.190	0.187	0.186	0.002	0.83	0.21	0.13
Energy Values[5]								
NEm, Mcal/kg	2.32[b]	2.38[a]	2.36[ab]	2.34[ab]	0.02	0.89	0.40	0.05
NEg, Mcal/kg	1.62	1.68	1.66	1.64	0.02	0.97	0.39	0.06
Carcass Characteristics								
HCW, kg	408	409	416	414	13.0	0.01	0.97	0.44
Marbling[6]	594	588	606	610	13.0	0.03	0.89	0.55
LM area, cm^2	90.1	93.0	91.2	91.0	1.58	0.66	0.19	0.12
Fat Depth, cm	1.51	1.42	1.47	1.49	0.04	0.61	0.36	0.17
Cal. YG[7]	3.43	3.21	3.40	3.42	0.10	0.21	0.17	0.12

[1]MDGS = Modified distillers grains plus solubles
[2]NEG = Negative Isoline, parental isoline control corn without the amylase enzyme trait; SYT-EFC = Syngenta Enogen feed corn containing the alpha amylase enzyme trait
[3]P-values: Byprod.: Main effect of byproduct typet; Trait: Main effect of trait; B*T: Interaction between byproduct type and corn trait
[4]Calculated from HCW adjusted to a common 63% dressing percentage
[5]Values calculated by pen using the 1996 NRC equations
[6]Marbling Score: 400 = Small[00]; 500 = Modest[00]
[7]Calculated as 2.5+ (6.35 x 12th rib fat depth, cm) + (0.2 x [KPH, %]) + (0.0017 x HCW, kg) – (2.06 x LM area, cm^2)
[a,b] Means within a row with unlike superscripts differ ($P < 0.05$)

Table 4.6. Effects of corn trait and byproduct type in finishing diets on nutrient intake, flow, and digestion (Exp. 2)

	Dietary Treatments						2x2[2]			Contrasts[3]			
	MDGS[1]			Sweet Bran									
Item	NEG[4]	SYT-EFC[4]	Blend	NEG[4]	SYT-EFC[4]	SEM	Int.	Trait	Byprod	SYT-EFC vs. NEG	NEG vs. Blend	SYT-EFC vs. Blend	F-Test[5]
Intake, kg/d													
DM	7.49	7.80	8.31	8.90	7.99	0.58	0.04	0.29	0.01	0.42	0.06	0.23	0.03
OM	7.14	7.47	7.95	8.47	7.59	0.55	0.04	0.31	0.02	0.39	0.06	0.24	0.04
Starch	3.94	4.25	4.46	4.40	4.05	0.30	0.04	0.90	0.39	0.15	0.03	0.35	0.13
Ruminal Digestibility, %													
Apparent OM	47.3	54.2	53.1	56.2	54.0	2.84	0.09	0.36	0.11	0.08	0.16	0.77	0.20
True OM[6]	74.8	75.8	77.1	78.2	80.5	3.41	0.83	0.60	0.20	0.82	0.63	0.78	0.71
Apparent Starch	79.8	82.4	77.6	80.4	77.6	3.36	0.28	0.96	0.40	0.46	0.56	0.21	0.62
True Starch[7]	81.6	83.9	79.0	82.3	84.4	3.21	0.95	0.34	0.80	0.47	0.45	0.17	0.54
Postruminal Digestibility, % Entering													
OM	57.5	58.9	56.6	47.5	60.8	5.18	0.21	0.13	0.39	0.82	0.90	0.74	0.32
Starch	52.6	62.7	60.1	49.3	73.5	10.64	0.45	0.08	0.68	0.44	0.59	0.86	0.39
Fecal Output, kg/d													
OM	1.56	1.45	1.54	1.95	1.34	0.21	0.16	0.05	0.42	0.65	0.96	0.71	0.18
Starch	0.365	0.308	0.300	0.482	0.217	0.088	0.08	0.01	0.82	0.48	0.45	0.93	0.06
Total-Tract Digestibility, %													
DM	77.3	79.4	79.5	76.1	81.2	2.30	0.46	0.08	0.88	0.45	0.47	0.98	0.41
OM	78.2	80.8	80.6	77.2	82.3	2.25	0.52	0.07	0.91	0.37	0.44	0.94	0.38
Starch	90.9	92.9	93.4	89.1	94.7	1.60	0.19	0.01	0.81	0.26	0.17	0.75	0.06

[1]MDGS = Modified distillers grains plus solubles
[2]2x2 = Treatments MDGS NEG, MDGS E, SB NEG, and SB E are treatments within the 2x2 factorial
[3]Contrasts: E vs. NEG = MDGS E vs. MDGS NEG; NEG vs. Blend = MDGS NEG vs. MDGS Blend; E vs. Blend = MDGS E vs. MDGS Blend
[4]NEG = Negative Isoline, the isoline parental control corn without the alpha amylase enzyme trait; SYT-EFC = Corn containing the alpha amylase enzyme trait
[5]F-Test = F-Test statistic for the effect of treatment
[6]True OM = Corrected for microbial OM reaching the duodenum
[7]True Starch = Corrected for microbial starch

Table 4.7. Effects of corn trait and byproduct type in finishing diets on ruminal pH (Exp. 2)

	Dietary Treatments						2x2[2]			Contrasts[3]			
	MDGS[1]			Sweet Bran									
Item	NEG[4]	SYT-EFC[4]	Blend	NEG[4]	SYT-EFC[4]	SEM	Trait	Byprod	Int.	SYT-EFC vs. NEG	NEG vs. Blend	SYT-EFC vs. Blend	F-Test[5]
Average pH	5.59	5.65	5.60	5.62	5.58	0.14	0.94	0.82	0.67	0.69	0.95	0.76	0.99
Maximum pH	6.47	6.47	6.52	6.42	6.38	0.09	0.87	0.24	0.59	0.94	0.59	0.64	0.70
Minimum pH	4.97	4.93	4.89	4.97	4.97	0.10	0.80	0.85	0.79	0.71	0.53	0.78	0.95
pH magnitude	1.51	1.53	1.63	1.45	1.40	0.09	0.98	0.20	0.44	0.86	0.35	0.44	0.45
pH variance[6]	0.150[ab]	0.153[ab]	0.207[b]	0.133[a]	0.099[a]	0.026	0.49	0.06	0.19	0.93	0.11	0.13	0.08
Time < 5.6, min/d[7]	802	790	803	777	750	174	0.93	0.91	0.99	0.96	0.99	0.95	0.99
Area < 5.6, min/d[8]	289	287	290	247	300	104	0.80	0.97	0.85	0.99	0.99	0.98	0.99

[1]MDGS = Modified distillers grains plus solubles
[2]2x2 = Treatments MDGS NEG, MDGS E, SB NEG, and SB E are treatments within the 2x2 factorial
[3]Contrasts: E vs. NEG = MDGS E vs. MDGS NEG; NEG vs. Blend = MDGS NEG vs. MDGS Blend; E vs. Blend = MDGS E vs. MDGS Blend
[4]NEG = Negative Isoline, the isoline parental control corn without the alpha amylase enzyme trait; SYT-EFC = Corn containing the alpha amylase enzyme trait
[5]F-Test = F-Test statistic for the effect of treatment
[6]Variance of daily ruminal pH
[7]Time < 5.6 = Minutes that ruminal pH was below 5.6
[8]Area < 5.6 = Ruminal pH units below 5.6 by minute
[a,b]Means within a row with unlike superscripts differ ($P \leq 0.10$)

Table 4.8. Effects of corn trait and byproduct type in finishing diets on volatile fatty acid profile (Exp. 2)

	Dietary Treatments[1]						2x2[2]			Contrasts[3]			
Item	MDGS NEG	MDGS SYT-EFC	MDGS Blend	SB NEG	SB SYT-EFC	SEM	Trait	Byprod	Int.	SYT-EFC vs. NEG	NEG vs. Blend	SYT-EFC vs. Blend	F-Test[4]
Acetate, mol/100 mol	49.4	48.7	48.4	47.9	50.0	1.4	0.84	0.93	0.27	0.65	0.54	0.88	0.77
Propionate, mol/100 mol	35.6	37.0	36.8	37.5	33.8	1.9	0.60	0.63	0.13	0.58	0.63	0.94	0.59
Butyrate, mol/100 mol	10.2	10.0	10.7	10.0	10.8	0.7	0.59	0.86	0.37	0.85	0.69	0.55	0.91
Acetate:Propionate	1.58[ab]	1.43[ab]	1.43	1.39[b]	1.59[a]	0.11	0.79	0.88	0.04	0.33	0.26	0.87	0.33

[1]MDGS NEG = Modified distillers grains plus solubles with parental Negative Isoline hybrid, MDGS SYT- EFC = Modified distillers grains plus solubles with SYT-EFC hybrid, MDGS Blend = Modified distillers grains plus solubles with 50:50 blend of SYT-EFC and NEG hybrids, SB NEG = Sweet Bran with parental Negative Isoline hybrid, SB SYT-EFC = Sweet Bran with SYT-EFC

[2]2x2 = Treatments MDGS NEG, MDGS E, SB NEG, and SB E are treatments within the 2x2 factorial

[3]Contrasts: EFC vs. NEG = MDGS EFC vs. MDGS NEG; NEG vs. Blend = MDGS NEG vs. MDGS Blend; EFC vs. Blend = MDGS EFC vs. MDGS Blend

[4]F-Test = F-Test statistic for the effect of treatment

[a,b]Means within a row with unlike superscripts differ ($P \leq 0.10$)

Chapter V

Effect of feeding Syngenta Enogen Feed Corn containing an alpha amylase enzyme trait on finishing cattle performance and carcass characteristics[1]

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ABSTRACT: Two feedlot experiments evaluated the effects of feeding a new corn hybrid containing an alpha amylase enzyme trait, Syngenta Enogen Feed Corn (SYT-EFC), on finishing performance and carcass characteristics. Experiments were conducted at the University of Nebraska Lincoln Eastern Nebraska Research and Extension Center (ENREC) and the University of Nebraska Lincoln Panhandle Research and Extension Center (PREC). Each location utilized 300 calf fed steers (319 ± 20 kg at ENREC; 283 ± 15 kg at PREC) with 10 steers per pen and 15 replications per treatment for a total of 600 steers to provide a total of 30 replications per treatment. Dietary treatments at both locations consisted of feeding SYT-EFC or a near negative isoline control (NEG) processed as dry-rolled corn (DRC). Data from both experiments were combined and performance and carcass characteristic data were analyzed using the MIXED procedure of SAS as a generalized randomized block design with pen as the experimental unit. Steers were blocked by BW within location with pen as the experimental unit and the effect of location and treatment included in the model. The treatment × location interaction was analyzed and if it was not significant it was removed from the model. There were no corn trait treatment × feedlot location interactions observed for all performance and carcass characteristics ($P \geq 0.13$). The main effect of corn trait was not significant for all performance measures ($P \geq 0.17$). Cattle fed SYT-EFC resulted in greater 12th rib fat thickness and calculated YG ($P \leq 0.02$) and smaller LM area ($P = 0.02$) compared to NEG; however, HCW and marbling scores were not different ($P \geq 0.33$). Feeding SYT-EFC containing an alpha amylase enzyme trait did not significantly improve G:F.

Key Words: alpha amylase, beef cattle, corn trait, feedlot

INTRODUCTION

The utilization of exogenous supplemental enzymes in ruminant diets have been shown to increase animal performance due to the increase in feed digestion (Beauchemin et al., 2003). Typically, this response has been observed with the use of fibrolytic enzymes as a means of increasing forage utilization (Beauchemin et al., 2003). However, starch is the major energy component of feedlot diets. While starch digestion is thought to generally not be limited in the rumen, research has shown that pancreatic α-amylase secretion decreases with increased small intestinal carbohydrate concentration (Harmon, 1993). This suggests that α-amylase enzymes could have the potential for increasing animal performance by resisting rumen fermentation and increasing the supply of amylase to the small intestine for increased starch utilization.

A new corn hybrid (SYT-EFC) has been developed to contain an α-amylase enzyme that at increased temperatures becomes activated, reducing the need for additional exogenous enzymes during the ethanol fermentation process. Currently, four experiments have evaluated the impacts of feeding SYT-EFC, as the sole grain source, on animal performance, carcass characteristics, and site of digestion (Jolly-Breithaupt, 2018). The authors reported 1.6 to 10.1% increase in G:F and 33.5% increase in post-ruminal starch digestibility resulting in an overall 4.2% increase in total tract starch digestion when steers were fed SYT-EFC. While SYT-EFC has increased G:F, the response has been variable warranting the need for a large, well-replicated trial. Therefore, the objective of this experiment was to determine the feeding value of SYT-EFC when processed as DRC.

MATERIALS AND METHODS

All procedures involving animal care and management were approved by the University of Nebraska Lincoln's Institutional Animal Care and Use Committee.

Eastern Nebraska Research and Extension Center

A 169 day finishing experiment was conducted utilizing 300 crossbred, calf fed steers (initial BW = 319 ± 20 kg) to evaluate the impact of feeding Syngenta Enogen Feed Corn (SYT-EFC; Syngenta Seeds, Inc., Minnetonka, MN) containing an α-amylase enzyme trait compared to a near isoline parental control corn (NEG) at the University of Nebraska Lincoln Eastern Nebraska Research and Extension Center (ENREC) near Mead, NE. All corn (SYT-EFC and NEG) was grown during the summer of 2015 at ENREC, harvested in November 2015, and processed as DRC at time of feeding. Corn was identity preserved and kept separate at all times. Steers were received at the University of Nebraska Lincoln's ENREC feedlot in October 2015 and utilized from November to May 2015.

Initial processing included vaccination to aid in the prevention of disease caused by *Haemophilus somnus* (Somnu Shield; Elanco Animal Health, Greenfield, IN), *Mannheimia haemolytica* (Nuplura PH; Elanco Animal Health), infectious bovine rhinotracheitis, bovine viral diarrhea virus, bovine parainfluenza$_3$ virus, and bovine respiratory syncytial virus (Titanium 5; Elanco Animal Health). Steers were also treated for internal and external parasite with an injectable wormer (Dectomax Injectable Endectocide; Zoetis, Parsippany-Troy Hills, NJ). Thirty d later, steers were vaccinated to aid in the prevention of disease caused by infectious bovine rhinotracheitis, bovine viral diarrhea virus, bovine parainfluenza$_3$ virus, and bovine respiratory syncytial virus

(Titanium 5; Elanco Animal Health) and aid in preventing blackleg caused by *Clostridium chauvoei*, malignant edema caused by *Cl. septicum*, black disease caused by *Cl. novyi*, gas-gangrene caused by *Cl. sordellii*, and enterotoxemia and enteritis caused by *Cl. perfringens* Types B, C and D (Ultrabac-7; Zoetis, Parsippany-Troy Hills, NJ).

Steers were limit fed a common diet consisting of 50% alfalfa and 50% Sweet Bran (Cargill Wet Milling, Blair, NE; DM basis) for 5 d at 2% of BW prior to the initiation of the trial in an effort to reduce variation in gut fill at time of weighing (Watson et al., 2013). Steers were individually weighed using a hydraulic squeeze chute with load cells mounted on the chute (Silencer, Moly Manufacturing Inc., Lorraine, KS: scale readability ± 0.45 kg) for 2 consecutive d (0 and 1) after the limit feeding period for initial BW determination (Watson et al., 2013). Based on initial BW, steers were blocked by BW into 2 weight blocks, light and heavy (n = 10 and 5 pen replicates, respectively), stratified by d 0 BW within each block, and randomly assigned to 1 of 30 pens. Pens were then randomly assigned to 1 of 2 dietary treatments with a total of 10 steers per pen and 15 pens per treatment. Dietary treatments included 1) SYT-EFC and 2) Near negative isoline parental control (NEG; Table 5.1). Diets contained 18% WDGS at both locations and included the potential of containing a trace amount of residual amylase as α-amylase was included during the dry milling fermentation process. Starting on d 1, steers were adapted to treatment diets over a 24 d period utilizing 4 transition diets that replaced 10% alfalfa hay with 10% DRC. During the step-up period, inclusion of modified distillers grains plus solubles (MDGS), corn silage, and supplement remained the same in all diets at 18%, 12%, and 4% (DM basis), respectively. Diets were formulated to meet or exceed the NRC (1996) requirements for protein and provide 33.0

mg/kg of monensin (DM basis, Elanco Animal Health) and 9.0 mg/kg of tylosin (Elanco Animal Health). On d 22, steers were implanted with Component TE-IS (80 mg of trenbolone acetate and 16 mg estradiol; Elanco Animal Health) and on d 92 re-implanted with Component T200 (200 mg of trenbolone acetate and 20 mg estradiol; Elanco Animal Health) and poured with 15 ml of StandGuard (control of lice and horn flies on beef cattle; Elanco Animal Health).

On d 168, feed was offered at 50% of the previous days DMI and cattle were pen weighed at 1600 h to determine final live BW. A 4% pencil shrink was applied to the final live BW to calculate dressing percentage. After pen weights were collected, cattle were loaded onto a semi-tractor trailer, hauled approximately 60 miles to Omaha, NE, and harvested the morning of d 169 at a commercial abattoir (Greater Omaha, Omaha, NE). Hot carcass weights (HCW) and liver abscesses were recorded at the time of slaughter. Fat thickness, LM area, and USDA marbling score were recorded after a 48-h chill. Final BW, ADG, and G:F were calculated using HCW and adjusted to a common dressing percentage of 63%. Yield grade was calculated using the USDA YG equation: YG = 2.5 + 6.35 (Fat thickness, cm) – 2.06 (LM area, cm^2) + 0.2 (KPH fat, %) + 0.0017 (HCW, kg; USDA, 1997).

Panhandle Research and Extension Center

Three hundred crossbred steers (initial BW = 283 ± 15 kg) were utilized in a finishing trial to evaluate the impact of feeding Syngenta Enogen Feed Corn (SYT-EFC; Syngenta Seeds, Inc., Minnetonka, MN) containing an α-amylase enzyme trait compared to a near isoline parental control corn (NEG) at the University of Nebraska-Lincoln's Panhandle Research and Extension Center (PREC) feedlot near Scottsbluff, NE. All corn

utilized in this trial was grown at ENREC and shipped to the PREC to ensure that the same product was fed at both locations. Corn was identity preserved and always kept separate. Steers were received at the PREC feedlot in October 2015 and utilized from November to May 2015.

Prior to the initiation of the trial, cattle were limit fed a diet of 40% alfalfa hay, 30% WDGS, and 30% corn silage. Grain adaptation procedures were similar to the procedure at ENREC with 10% DRC replacing 10% alfalfa hay over 4 steps until the alfalfa hay was completely phased out. Steers were individually weighed using a hydraulic squeeze chute with load cells mounted on the chute (Silencer, Moly Manufacturing Inc., Lorraine, KS: scale readability ± 0.45 kg) for 2 consecutive d (0 and 1) after the limit feeding period for initial BW determination (Watson et al., 2013). Based on initial BW, steers were blocked by BW into 2 weight blocks, light and heavy (n = 7 and 8 pen replicates, respectively), stratified by d 0 BW within each block, and randomly assigned to 1 of 30 pens. Pens were then randomly assigned to 1 of 2 dietary treatments with a total of 10 steers per pen and 15 pens per treatment. Dietary treatments were the same as ENREC with the exception of wet distillers grains plus solubles (WDGS) in place of MDGS and the inclusion of supplement at 6% instead of 4% of the diet DM. Steers were implanted on d 1 with Component TE-IS (80 mg of trenbolone acetate and 16 mg estradiol; Elanco Animal Health, Greenfield, IN) and Component T200 (200 mg of trenbolone acetate and 20 mg estradiol; Elanco Animal Health, Greenfield, IN) on d 91.

Steers were harvested at a commercial abattoir (Cargill Meat Solutions, Fort Morgan, CO) on d 181. On d 181, steers were withheld from feed and weighed at 0800 h

before being shipped and slaughtered on the same day. Carcass data collection procedures and calculation of final BW were the same as ENREC.

At both locations, steers were fed once daily at approximately 0800 and managed at *ad libitum* feed intake. When needed, refused feed was removed from feed bunks, weighed, and dried in a forced-air oven for 48 h at 60°C to determine DM for accurate DMI (Buckner, 2011). Ingredient samples were collected weekly, composited by month, and sent to a commercial laboratory (Servi-Tech Laboratories, Hastings, NE) and analyzed for DM (AOAC, 1999; method 4.1.03), OM (AOAC, 1999; method 4.1.10), CP (AOAC, 2000 Method 990.03), NDF (ANKOM, 2006), total starch content (Megazyme International, 2011; AOAC International, 2000; Method 996.11; AACC Method 76.13), and Ca, K, P, Mg, and S (Mills and Jones, 1996).

Overall, 600 steers were utilized between the two locations to provide a total of 30 replications per treatment. Dietary treatment energy values were calculated utilizing pen performance data in the Galyean (2017) Net Energy Calculator utilizing shrunk initial BW, shrunk final BW, DMI, ADG, and a target endpoint (assume choice quality grade) to calculate net energy of maintenance and gain. Performance and carcass characteristic data were analyzed using the MIXED procedure of SAS as a generalized randomized block design with pen as the experimental unit. Liver abscess incidence data were analyzed using the GLIMMIX procedure of SAS with the number of animals affected by liver abscesses divided by the total number of animals within the pen as binomial variables. The effect of location, treatment, and location × treatment were all included in the model with BW block as a fixed variable. If the location × treatment

interaction was not significant ($P \geq 0.05$), main effects were discussed and the interaction term was removed from the model.

RESULTS AND DISCUSSION

There were no corn trait treatment × feedlot location interactions observed for initial BW, final BW, DMI, ADG, G:F, NEm, and NEg ($P \geq 0.26$; Table 5.2). For the main effect of corn trait, no significant differences in initial BW, final BW, DMI, ADG, G:F, NEm, and NEg were observed for steers fed SYT-EFC compared to NEG ($P \geq 0.17$; Table 5.3). Previous research has shown that cattle fed SYT-EFC, processed as DRC and as the sole grain source within the diet, had increased G:F and starch digestion (post-ruminal and total tract; Jolly-Breithaupt, 2018) compared to commercially available corn or NEG. Feed efficiency was increased by 10.1% when SYT-EFC was fed with Sweet Bran (Cargill Wet Milling, Blair, NE) and 5.7% when fed with WDGS compared to commercially available corn (Jolly-Breithaupt, 2018). Post-ruminal starch digestion was increased from 51.0% to 68.1% ($P = 0.08$) leading to an increase in total tract starch digestibility from 90.0% to 93.8% ($P = 0.01$) when steers were fed SYT-EFC compared to NEG. However, when SYT-EFC was fed as ground corn at either 10% or 20% inclusion (DM basis), no differences in ADG or G:F were reported (Schoonmaker et al., 2014). When feeding an exogenous α-amylase supplement, previous research has shown an increase in ADG (Burroughs et al. 1960; Tricarico et al., 2007), DMI and G:F (Jolly-Breithaupt, 2018) or no difference in performance (Tricarico et al., 2007; DiLorenzo et al., 2011). A location effect ($P \leq 0.01$) was observed for final BW, DMI, ADG, and G:F (Table 5.4). Steers fed at PREC had greater final BW, DMI, ADG, and G:F compared to ENREC.

There were no corn trait treatment × feedlot location interactions observed for HCW, marbling score, 12th rib fat thickness, LM area, and calculated YG ($P \geq 0.34$). No corn trait treatment × feedlot location interaction was observed for liver abscess percentage ($P = 0.13$). The main effect of corn trait was significant for 12th rib fat thickness, LM area, and calculated YG ($P \leq 0.02$). Fat depth and calculated YG were greater ($P < 0.01$ and $P = 0.02$, respectively) for steers fed SYT-EFC compared to NEG; however, LM area was slightly greater ($P = 0.02$) for NEG. Previous research with feeding SYT-EFC has reported an increase in fat depth and calculated YG (Jolly-Breithaupt, 2018) or no difference (Jolly-Breithaupt, 2018; Schoonmaker et al., 2014). Feeding a supplemental alpha-amylase enzyme can increase the acetate to propionate ratio resulting in a greater concentration of acetate available for absorption (Tricarico et al., 2005; Jolly-Breithaupt, 2018). Because acetate contributes to 70% of the acetyl units for fatty acid biosynthesis, the increase in acetate to propionate ratio could be contributing to the increase in the 12th rib fat thickness and ultimately calculated yield grade (Smith and Crouse, 1984). No significant differences by treatment were observed for HCW or marbling score ($P \geq 0.33$). However, steers fed SYT-EFC had a 16 point numerical increase in marbling score compared to cattle fed NEG. Previous research has reported mixed results for marbling score of steers fed SYT-EFC compared to commercial corn or NEG either observing an increase in marbling score or no difference (Jolly-Breithaupt, 2018). Differences in cattle response between previous trials and this current trial could be attributed to growing conditions of the corn resulting in a year effect. A location effect ($P = 0.01$) was observed for HCW with steers fed at PREC having greater HCW compared to ENREC.

In conclusion, previous finishing trials have observed an increase in G:F when SYT-EFC has been fed as the main source of corn grain. However, results from this trial would suggest that there is no significant change in G:F by feeding the Syngenta Enogen Feed Corn hybrid containing an alpha amylase enzyme trait as the response was too small to detect. The change in G:F was only 1% due to diet, which is assumed to be only 1.6% due to corn grain (65% of the diet, average between ENREC and PREC).

Literature Cited

ANKOM, 2006. Ankom Technology Method 6. Neutral Detergent Fiber in Feeds by Filter Bag Technique. ANKOM Tech., Macedon, NY.

AOAC. 1999. Official method of analysis. 16th ed. Assoc. Off. Anal. Chem., Arlington,VA

AOAC International. 2000. AOAC Official Method 990.3. Protein (Crude) in Animal Feed. Combustion Method. Official Methods of Analysis of AOAC International, 17th ed. Dr. William Horwitz, ed. AOAC Int., Gaithersburg, MD.

Beauchemin, K. A., D. Colombatto, D. P. Morgavi, and W. Z. Yang. 2003. Use of exogenous fibrolytic enzymes to improve feed utilization by ruminants. J. Anim. Sci. 81(E Suppl. 2):E347-E47.

Boggs, D. L. and R. A. Merkel. 1993. Beef carcass evaluation, grading, and pricing. In: Boggs, D. L., Merkel, R. A. (ed.) Live animal carcass evaluation and selection manual. Pp. 105-130. Kendel/Hunt Publishing Co. Dubuque, IA.

Buckner, C. D., M. F. Wilken, J. R. Benton, S. J. Vanness, V. R. Bremer, T. J. Klopfenstein, P. J. Kononoff, G.E. Erickson. 2011. Nutrient variability for distillers grains plus solubles and dry matter determination of ethanol by-products. Prof. Anim. Sci. 27:57-64.

Buroughs, W., W. Woods, S. A. Ewing, J. Greig, B. Theurer. 1960. Enzyme additions to fattening cattle rations. J. Anim. Sci. 19:458-464.

DiLorenzo, N. D. R. Smith, M. J. Quinn, M. L. May, C. H Ponce, W. Steinberg, M. A. Engstrom, and M. L. Galyean. 2011. Effects of grain processing and supplementation with exogenous amylase on nutrient digestibility in feedlot diets. Livest. Sci. 137:178-184.

Galyean, M. 2017. The Home Page of Michael Galyean. NEm and NEg Calculations. http://www.depts.ttu.edu/afs/home/mgalyean/. (Accessed January, 17 2018).

Harmon, D. L. 1993. Nutritional regulation of postruminal digestive enzymes in ruminants. J. Dairy Sci. 76:2102-2111.

Hu, W., M. E. Persia, and L. Kung, 2010. Short communication: In vitro ruminal fermentability of a modified corn cultivar expressing a thermotolerant α-amylase. J Dairy. Sci. 93:4846-4849.

Jolly-Breithaupt, M. L. 2018. Effect of Syngenta Enogen feed corn containing an alpha amylase trait on finishing cattle performance and carcass characteristics. Unpublished.

Megazyme International. 2011. Total Starch Assay Procedure. AOAC Official Method 996.11. AACC Method 76.13. Bray Business Park, Bray, Co. Wicklow, Ireland).

Mills, H. A. and J. B. Jones. 1996. Plant Analysis Handbook II: A practical sampling, Preparation, analysis, and interpretation guide. pp. 122 (Table 5.3). Micromacro Publishing, Inc., Athens, GA.

National Research Council. 1996. Nutrient Requirements of Beef Cattle. Seventh Edition. National Academy Press, Washington, D.C.

Schoonmaker, J. P., M. E. Persia, and D. C. Beitz. 2014. Effect of feeding corn modified to contain a unique amylase on performance and carcass characteristics of feedlot steers. Pro. Anim. Sci. 30:561-565.

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.

Tricarico, J. M., J. D. Johnston, K. A. Dawson, K. C. Hanson, K. R. McLeod, and D. L. Harmon. 2005. The effect of an *Aspergillus oryzae* extract containing alpha-amylase activity on ruminal fermentation and milk production in lactating Holstein cows. Anim. Sci. 81, 365-374.

Tricarico, J. M., M. D. Abney, M. L. Galyean, J. D. Rivera, K. C. Hanson, K. R. McLeod, and D. L. Harmon. 2007. Effect of dietary *Aspergillus oryzae* extract containing α-amylase activity on performance and carcass characteristics of finishing beef cattle. J. Anim. Sci. 85:802-811.

USDA, 1997. Official United States standards for grades of carcass beef. Agric Marketing Serv., USDA, Washington, DC.

Watson, A. K., B. L. Nuttelman, T. J. Klopfenstein, L. W. Lomas, and G. E. Erickson. 2013. Impacts of a limit-feeding procedure on variation and accuracy of cattle weights. J. Anim. Sci. 91:5507-5517.

Table 5.1. Dietary treatments evaluating Syngenta Enogen Feed Corn and Near Negative Isoline Parental Control Corn

Ingredient, % DM	NEG[1]	SYT-EFC[2]
NEG Dry Rolled Corn	66.0	-
SYT-EFC[2] Dry Rolled Corn	-	66.0
DGS[3]	18.0	18.0
Corn silage	12.0	12.0
Meal supplement[4]	4.0	4.0
Fine ground corn	1.2362	1.2362
Limestone	1.689	1.689
Urea	0.5	0.5
Salt	0.3	0.3
Tallow	0.10	0.10
Trace mineral premix	0.05	0.05
Potassium chloride	0.083	0.083
Rumensin-90	0.0165	0.0165
Vitamin ADE premix	0.015	0.015
Tylan-40	0.0102	0.0102
Liquid Supplement (PHREC)[5,6]	6.0	6.0
Nutrient Composition, %		
Starch	54.59	52.22
CP	13.15	13.48
NDF	14.71	15.90
Ca	0.75	0.79
K	0.59	0.66
P	0.39	0.43
S	0.18	0.18
Mg	0.16	0.17

[1]NEG: Near negative isoline parental control corn
[2]SYT-EFC: Syngenta Enogen Feed Corn containing α-amylase enzyme
[3]DGS: Distillers grains plus solubles
[4]Meal Supplement fed at the Eastern Nebraska Research and Extension Center
[5]Liquid Supplement fed at the Panhandle Research and Extension Center
[6]Supplement formulated to provide a dietary DM inclusion of 1.34% limestone, 0.5% urea, 0.3% salt, 0.2% potassium chloride, 30 mg/kg Zn, 50 mg/kg Fe, 10 mg/kg Cu, 20 mg/kg Mn, 0.1mg/kg Co, 0.5 mg/kg I, 0.1 mg/kg Se, 1000 IU of vitamin A, 125 IU of vitamin D, 1.5 IU of vitamin E.

Table 5.2. Simple effects of corn trait on finishing performance and carcass characteristics

	ENREC		PREC			*P*-Values		
Item	NEG	SYT-EFC	NEG	SYT-EFC	SEM	Trt	Location	Int.
Animal Performance								
Initial BW, kg	324	324	282	282	0.39	0.25	< 0.01	0.48
Final BW, kg[2]	609	609	617	616	3.20	0.89	0.01	0.86
DMI, kg/d	10.1	9.9	10.6	10.6	0.09	0.20	< 0.01	0.39
ADG, kg[2]	1.69	1.69	1.85	1.85	0.02	0.99	< 0.01	0.97
G:F	0.1677	0.1707	0.1744	0.1748	0.0012	0.17	< 0.01	0.29
Energy Values[3]								
NEm, Mcal/kg	2.118	2.147	2.095	2.094	0.0130	0.28	< 0.01	0.26
NEg, Mcal/kg	1.467	1.473	1.427	1.429	0.0139	0.77	< 0.01	0.88
Carcass Characteristics								
HCW, kg	383	383	389	388	2.02	0.89	0.02	0.89
Marbling Score[4]	466	476	475	497	16.5	0.33	0.37	0.71
Fat Depth, cm	1.32	1.42	1.35	1.42	0.028	< 0.01	0.64	0.73
LM Area, cm[2]	84.6	83.6	85.6	83.6	0.63	0.02	0.44	0.45
Calculated Yield Grade[5]	3.19	3.34	3.25	3.61	0.11	0.02	0.16	0.34
Liver Abscess, %	7.19	8.01	9.88	4.15	9.88	0.23	0.61	0.13

[1]Dietary treatments: NEG = Near negative isoline parental control corn; SYT-EFC = Syngenta Enogen Feed Corn containing alpha amylase enzyme

[2]Calculated from HCW adjusted to a common 63% pressing percentage.

[3]Values calculated by pen using the 1996 NRC equations

[4]Marbling Score: 400 = Small[00], 500 = Modest[00]

[5] Calculated as 2.5+ (6.35 x 12[th] rib fat depth, cm) + (0.2 x [KPH, %]) + (0.0017 x HCW, kg) – (2.06 x LM area, cm[2])

Table 5.3. Main effect of corn hybrid on finishing performance and carcass characteristics

	Dietary Treatments[1]			
Item	NEG	SYT-EFC	SEM	*P*-Value
Animal Performance				
Initial BW, kg	303	303	0.27	0.25
Final BW, kg[2]	613	612	2.2	0.89
DMI, kg/d	10.4	10.3	0.06	0.20
ADG, kg[2]	1.77	1.77	0.012	0.99
G:F	0.1710	0.1727	0.0009	0.17
Energy Values[3]				
NEm, Mcal/kg	2.107	2.121	0.009	0.28
NEg, Mcal/kg	1.447	1.451	0.010	0.77
Carcass Characteristics				
HCW, kg	386	386	1.40	0.89
Marbling Score[4]	470	486	11.6	0.33
Fat Depth, cm	1.34	1.42	0.020	< 0.01
LM Area, cm[2]	85.1	83.6	0.44	0.02
Calculated Yield Grade[5]	3.22	3.47	0.08	0.02
Liver Abscess, %	8.44	5.78	2.31	0.23

[1]Dietary treatments: NEG = Near negative isoline parental control corn; SYT-EFC = Syngenta Enogen Feed Corn containing alpha amylase enzyme

[2]Calculated from HCW adjusted to a common 63% pressing percentage.

[3]Values calculated by pen using the 1996 NRC equations

[4]Marbling Score: 400 = Small[00], 500 = Modest[00]

[5]Calculated as 2.5+ (6.35 x 12th rib fat depth, cm) + (0.2 x [KPH, %]) + (0.0017 x HCW, kg) – (2.06 x LM area, cm^2)

Table 5.4. Main effect of location on finishing performance and carcass characteristics

Item	ENREC	PREC	SEM	*P*-Value
Animal Performance				
Initial BW, kg	324	282	0.28	< 0.01
Final BW, kg[2]	609	617	2.3	0.01
DMI, kg/d	10.0	10.6	0.06	< 0.01
ADG, kg[2]	1.69	1.85	0.012	< 0.01
G:F	0.1692	0.1746	0.0009	< 0.01
Energy Values[3]				
NEm, Mcal/kg	2.133	2.095	0.009	< 0.01
NEg, Mcal/kg	1.470	1.428	0.01	< 0.01
Carcass Characteristics				
HCW, kg	384	389	1.43	0.01
Marbling Score[4]	471	486	12	0.37
Fat Depth, cm	1.37	1.39	0.020	0.64
LM Area, cm^2	84.1	84.6	0.45	0.46
Calculated Yield Grade[5]	3.27	3.43	0.08	0.16
Liver Abscess, %	7.59	6.45	2.17	0.61

[1]Dietary treatments: NEG = Near negative isoline parental control corn; SYT-EFC = Syngenta Enogen Feed Corn containing alpha amylase enzyme

[2]Calculated from HCW adjusted to a common 63% pressing percentage.

[3]Values calculated by pen using the 1996 NRC equations

[4]Marbling Score: 400 = Small^{00}, 500 = Modest^{00}

[5]Calculated as 2.5+ (6.35 x 12th rib fat depth, cm) + (0.2 x [KPH, %]) + (0.0017 x HCW, kg) – (2.06 x LM area, cm^2)