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Evaluation of Alpha Amylase Containing Corn on Beef Cattle Performance and Digestibility and Double-Cropped Annual Forages Following Corn Harvest

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Evaluation of Alpha Amylase Containing Corn on Beef Cattle Performance and Digestibility and Double-Cropped Annual Forages Following Corn Harvest

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One digestion and three feedlot trials evaluated the effect of a new corn hybrid containing an α-amylase enzyme 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 (SYT-EFC) compared to commercially available corn (CON), processed as corn silage (CS) kernel processed or not (KP), dry-rolled corn (DRC), high-moisture corn (HMC), or a blend of DRC and HMC. Growing calves fed high inclusions of CS, displayed increased G:F when CS was KP, resulting in a 6.5% improvement in G:F. Hybrid and kernel processing did not impact digestibility of the corn silages. Finishing cattle fed SYT-EFC as DRC, HMC, or a blend saw no significant improvement in performance or carcass characteristics when compared to CON treatments. Cattle fed DRC based finishing diets with wet distillers grains plus solubles (WDGS) increasing at 0%, 15%, 30%, or 45% had increased G:F when fed SYT-EFC. Inclusion of SYT-EFC and 0% WDGS resulted in a 4.3% increase in G:F compared to the CON treatment. Overall, feeding SYT-EFC corn hybrids would suggest limited improvements in feed efficiency in specific diets.

Double-cropped annual forages (DCAF) following corn harvest provide producers an opportunity to extend their grazing season through the fall. Furthermore, DCAF provide agronomic benefits to crop producers by improving soil characteristics. A two-year experiment was conducted to evaluate the impacts of DCAF planted after CS or HMC on calf gains, forage production, subsequent crop yields, and their economic viability. Oat monocultures planted after CS harvest yielded greater forage biomass compared to those seeded after HMC harvest. Furthermore, average calf gains were greater for calves grazing oats following CS compared to HMC. Subsequent crop yields were not affected by DCAF over the two years. Due to increased forage production and calf gains, cost of gain was lower for calves grazing CS oats, although input costs and achieved gains can greatly impact the economic viability.

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CHAPTER I. Review of the Literature

With the global population expected to exceed 9.7 billion by 2050, growth of the middle class, and those who can afford high quality protein sources, such as beef, is likely to expand as well (United Nations, 2019). Substantial increases in these populations results in the need for advancing technologies for increased animal efficiency, in order to meet the demand in beef. In order to maximize animal performance, starch digestion by the animal must be exploited. Processing of grains has primarily been utilized to increase starch availability and digestion; however, increased processing results in more rapidly fermentable grains entering the rumen, drastically increasing the risk of ruminal acidosis. Maximum starch digestion can be achieved when the amount of fermentable starch and risk for ruminal acidosis is balanced.

Within the beef sector several key improvements have been to implants and ionophores; however, nutritionists and producers are left evaluating novel feed ingredients as a means to maximize energy utilization. Dietary exogenous enzymes could act as an alternative method for increasing starch digestion and subsequently improving animal feed efficiency. Previous research regarding the use of these enzymes has primarily evaluated fibrolytic enzymes, as a means to increase fiber utilization. However, inclusion of α-amylase in beef cattle diets may result in increased starch digestion and beef cattle performance. Syngenta Enogen Feed Corn (SYT-EFC) is a new corn hybrid, that has been developed to be utilized by the dry-milling ethanol industry, and contains an α-amylase enzyme. The enzyme is pH tolerant, and becomes activated at increased temperatures, reducing the need for α-amylase addition to convert starch to glucose prior to the fermentation process. It is not clear if the enzyme within SYT-EFC will remain

active in the rumen or small intestine of beef cattle. The objectives of the following studies were to evaluate SYT-EFC when processed as corn silage, dry-rolled corn, or high-moisture corn, and their effects on animal performance, digestibility parameters, and carcass characteristics.

DIGESTIBILITY OF GRAINS

Cereal grains are a popular feed product for livestock as they offer a substantial increase in energy density relative to roughages, in the form of starch, and are grown in mass quantities all over the United States. Common cereal grains found in ruminant diets include barley, corn, sorghum, oats, and wheat. The amount of starch, metabolizable energy (ME), and subsequent animal performance varies among grain sources (Owens et al., 1997). Owens et al. (1997) reviewed numerous studies and compared the components and effects of different grain sources. Average daily gain (ADG) among these studies was highest for diets including oats, with sorghum and wheat being the least, and corn and barley based diets falling intermediate. Furthermore, ME was greatest for barley, wheat, and corn-based diets, and least for sorghum and oats (Owens et al., 1997). Starch content of grain sources vary with variety, growing conditions, and other agronomic practices (Huntington et al., 2006). On average, wheat has the highest starch content (77%), followed by corn and sorghum (72%) and then barley (57%) and oats (58%; Huntington et al., 1997). Finally, Owens et al. (1997) summarized that corn and sorghum based diets possess the lowest total tract starch digestibility when they are not processed.

Characteristics of Corn

Each grain source also possesses different characteristics based on their variety that can affect their rumen fermentability. Grains contain amylose, which is easily

digested, and amylopectin, which is less fermentable. Corn kernels are made up of four key parts, the tip cap, pericarp, endosperm, and germ. The point of kernel attachment to the cob is termed the tip cap. The pericarp, commonly known as the hull or corn bran, is a waxy coating that covers the endosperm and germ, comprising 5-6% of the kernel (Kotarski et al., 1992; Delcour and Hoseney, 2010). In order for rumen microbiota to access the endosperm, disruption of the pericarp must occur via mastication or kernel processing (McAllister et al., 1990; Beauchemin et al., 1994). Additionally, grains can store their starch granules in floury or vitreous endosperms. Floury endosperm is more easily fermentable, as they store starch granules more loosely in air pockets, resulting in an opaqueness to the kernel. Starch granules in floury endosperms are concealed by a loose protein matrix (Delcour and Hoseney, 2010), making them more susceptible to external forces, and thus digestion (Huntington, 1997). Granules stored in vitreous endosperms are less easily fermentable, as they are bound tightly in a zein protein matrix. This strong bond between the zein matrix and starch granules results in a hard endosperm, which is not easily digested (Huntington, 1997; Delcour and Hoseney, 2010). Finally, the germ makes up 10-12% of the corn kernel on a weight basis, and is high in fat (33.2%), protein (18.4%), sugar (10.8%), and ash (10.5%; Watson, 1987).

Corn Processing

While grains contain characteristics that bind starch granules, making it difficult to digest, there are several processing methods that can render the starch more accessible, rapidly increasing fermentation. Processing methods involve heating, moistening, or mechanical pressure, which disrupts the starch containing endosperm (Huntington et al., 2006). Typical processing methods include leaving grain whole, cracking, steam rolling,

steam-flaking, dry-rolling, grinding, reconstituting, ensiling, and harvesting at high moisture (Owens et al., 1986; Theurer, 1985; Owens et al., 1997; Huntington et al., 2006).

Corn grain is comprised of approximately 70% starch, and as the primary energy component, achieving optimal starch digestion is essential for maximizing beef cattle productivity. The basis for grain processing is to increase fermentation of feedstuffs and maximize total tract starch digestion; however, increased fermentability of grains augments the risk of digestive upsets, such as ruminal acidosis (NASEM, 2016). A nutritionist based survey conducted by Samuelson et al. (2016), evaluated the make-up of beef cattle diets primarily in the southern plains region of the United States. Overwhelmingly, corn was identified as the predominate grain utilized in finishing diets. Furthermore, results from the survey show that the most common processing method is steam flaking (70.8%), followed by harvesting corn as high-moisture, and dry-rolling (16.7% and 12.5%, respectively). Due to the survey by Samuelson et al. (2016) primarily evaluating beef cattle diets in the southern plains, these percentages may not accurately reflect finishing diets fed throughout the United States.

Dry-rolling corn (DRC) is the process of mechanically compressing corn between a set of grooved rollers in order to crack the hull and pericarp. This increases surface area, giving ruminal microbes and enzymes access to the endosperm and increasing microbial attachment. Feeding whole corn, that hasn’t been rolled limits the access that microorganisms have to the internal endosperm, decreasing fermentation of the corn grain. Numerous factors can influence the particle size of DRC, including groove

spacing, roller pressure, and moisture content of the corn during rolling (Hale and Theurer, 1972; Owens et al., 1997; NASEM, 2016).

Harvesting and ensiling corn at a moisture level of 25-30% results in a rapidly fermentable product referred to as high-moisture corn (HMC). During the ensiling process HMC must be stored in an anaerobic or oxygen-limiting environment, such as a packed concrete bunker, or plastic bag. Furthermore, HMC is typically rolled or ground prior to ensiling, in order to ensure proper packing and anaerobic fermentation (Buchanan-Smith et al., 2003). Due to the rapid degradability of HMC in the rumen, replacing a portion of the HMC fed to beef cattle with a more slowly fermentable grain, such as DRC, can be beneficial in improving efficiency (Stock et al., 1991). Thus, it is a common practice today to feed a combination of DRC and HMC in order to achieve maximum fermentation while decreasing the risk of acidosis.

Results from the survey by Samuelson et al. (2016) reported that steam flaked corn (SFC) was the most common processing method utilized in finishing beef cattle diets. Steam flaked corn refers to corn that has been steeped for 15 minutes to 24 hours in 3-6% added water, prior to rolling. Upon rolling the corn through large roller mills, the thin flakes produced typically weigh 0.31 to 0.41 kg / L (24 to 32 lb / bu), and contain 19-24% moisture (NASEM, 2016). Flaking requires added heat and moisture, and results in the gelatinization of the starch granules. This gelatinization results in the starch becoming more readily digestible for the rumen microbial population (Zinn et al., 2002).

One disadvantage to grain processing is the risk of acidosis. As particle size decreases the rate of fermentation increases, causing rapid acid production and a drop in ruminal pH (Owens et al., 1986; Theurer, 1985; Owens et al., 1997; Huntington et al.,

2006). Owens et al. (1997) summarized that extensive processing generally decreased ADG slightly, likely due to reduced DMI, as a result of excessive fermentation and acid production. However, overall efficiency is increased, shown by decreased feed to gain ratios, when cattle are fed extensively processed grains. Processing of grain sources results in improved energetic efficiency regardless of grain source due to enhanced starch access and utilization (Owens et al., 1986; Theurer, 1985; Owens et al., 1997).

Grain that has been extensively processed is rapidly fermented in the rumen, resulting in little ruminally-escaped starch. Larger starch particles are more likely to leave the rumen and enter the small intestine, thus, less processing results in increased intestinal digestion. However, digestion in the small intestine is not as efficient as in the rumen. These digestibility differences cancel out some of the flow differences from grain processing, resulting in little changes in intestinal digestion due to processing (Owens et al., 1986). Grain processing does result in increased total tract starch digestion, decreasing the amount of starch being excreted in feces (Owens et al., 1986; Theurer, 1985).

STARCH DIGESTION

Feeding grains increases the energetic density of beef cattle diets substantially, which can maximize animal efficiency. Starch is the major energy component of corn grain, and the primary goal of processing corn is to increase the availability of starch, and thus, the ability of ruminants to convert starch into animal product. Aside from processing grains to make starch more accessible for ruminal digestion, there is a clear energetic efficiency by shifting the site of digestion from the rumen to the small intestine. However, there are limits to digestion in the small intestine, and there are energy losses if

fermentation occurs in the large intestine. An improvement in efficiency of starch assimilation would result in increased feed efficiency as well as reduced feed costs for the feedlot industry.

Ruminal Fermentation

The process of ruminal fermentation is a complex system, involving numerous species of bacteria, protozoa, and fungi that make up the core of the rumen microbiome. As a feed product, such as starch, is consumed mechanical degradation occurs via mastication and rumination. During mastication, surface area is increased, and saliva is produced. Saliva contains enzymes, buffers, recycled nitrogen, and other lubricating substances that aid in digestion. Once a substrate reaches the rumen, microbial degradation occurs (Huntington et al., 2006). Competition for energy yielding substrates is fierce, thus, starch is rapidly fermented.

Ruminal fermentation is an anaerobic process by which the rumen microbiome degrades feedstuffs, which in turn produces end products that can be used for energy production by the host animal. Protozoa and fungi play a role in ruminal digestion; however, amylolytic bacteria, such as *Selenoma ruminantium, Prevotella species,* and *Streptococcus bovis*, perform a majority of starch fermentation (Huntington, 1997). Although protozoan populations are much smaller than bacterial populations, protozoa play a key role in starch degradation. Protozoa consume large starch particles and store them, thus, delaying their degradation (Nozière et al., 2010; Mendoza et al., 1993). Without protozoa, amylolytic bacteria would rapidly ferment these starch granules, further producing lactate, decreasing pH, and increasing the risk of acute acidosis (Owens et al., 1998). Attachment of feed particles by rumen bacteria is responsible for

approximately three-fourths of ruminal starch digestion. Bacterial attachment occurs in one of two ways: 1) loosely attached to feed particles via electrical charge or 2) tightly attached via receptors. Upon attachment, bacteria begin digestion by producing amylase enzymes, which hydrolyze the α1-4 bonds that bind polysaccharides (Huntington, 1997).

During fermentation of feed, bacteria produce end products which can vary depending on the substrate being fermented, the bacteria species, and the rate and extent of digestion. End products of fermentation include volatile fatty acids (VFAs), ammonia (NH_3), carbon dioxide (CO_2), methane (CH_4), and lactate. Volatile fatty acids primarily produced include acetate, propionate, and butyrate, which can be absorbed across the rumen wall and converted into other sources of energy for the animal. Absorption of acetate results in its transportation to the liver, where it is converted to Acetyl-CoA or ketones to be utilized by tissues. Furthermore, butyrate is absorbed by rumen epithelium, converted to ketone bodies, and is used for energy by the animal's gastrointestinal tract (NASEM, 2016). Each VFA has the capacity to produce different amounts of energy, with propionate being the most energy dense, as no carbon is lost, and two hydrogen ions are consumed when propionate is derived from glucose (Nozière et al., 2010; Lindsay, 1970). Propionate is the only gluconeogenic VFA, and upon transfer to the liver will be used for glucose synthesis, with 27 to 54% of glucose within the animal coming from propionate (Lindsay, 1970; Dengler et al., 2014). Furthermore, acetate and butyrate do not contribute directly to the glucose supply (Dengler et al., 2014).

Different substrates fermented in the rumen produce different proportions of VFAs (acetate:propionate:butyrate). Diets containing high proportions of concentrates promote the production of propionate at the detriment of acetate, resulting in VFA

proportions ranging from 50:40:10 to 50:35:15 (Bevans et al., 2005, Dengler et al., 2014). In contrast, forage based diets promote a greater production of acetate, shifting this ratio to range from approximately 70:20:10 to 65:25:10 (Owens and Goetsch, 1988).

The rumen microbial system has evolved and possesses the ability to digest high concentrations of rapidly fermentable starch. Total tract starch digestibility varies among a variety of factors, from feed source to processing techniques. Nonetheless, total tract digestibility of starch ranges from 90-100% of starch intake (Huntington, 1997; Huntington et al., 2006; and Nozière et al., 2010). However, ruminal digestion of starch is typically only 75-80% of starch intake (Waldo, 1973; Harmon et al., 2004). Varying grain sources, and management practices can shift starch digestibility in the rumen dramatically. This decreased ruminal digestibility leads to ruminal escape starch, which can be digested postruminally in the intestine.

Postruminal Starch Digestion and Absorption

High concentrations of cereal grains in the diet of ruminants can result in digestive upsets due to excessive fermentation in the rumen. These upsets can result in long-term effects, such as decreased VFA absorption, laminitis, or death. A shift in the site of starch digestion from the rumen to the small intestine can prevent these issues, and is more energetically efficient than the absorption of organic acids (Owens et al., 1986). However, shifting digestion to the intestine is not simple, and does not always result in energetic efficiency, as digestion is often decreased. Postruminal starch digestion and absorption occurs in 3 main phases 1) secretion of pancreatic α-amylase, 2) secretion of brush border carbohydrases, and 3) absorption and transportation of glucose from the intestinal lumen through portal circulation (NASEM, 2016).

Intestinal starch assimilation begins in the lumen of the small intestine with the secretion of α-amylase from the pancreas. Protein entering the intestine signals the pancreas to secrete α-amylase into the first segment of the small intestine; the duodenum (Harmon, 2009; Harmon et al., 2004; Huntington, 1997; and Owens, 1986). Alpha amylase will begin randomly hydrolyzing the α1-4 glycosidic bonds that bind polysaccharides, resulting in dextrins, limit dextrins, and linear oligosaccharides, consisting of two or three glucose units (Gray, 1992; and Harmon, 1993). Pancreatic α-amylase secretion has been observed to be affected by dietary energy intake. Previous research by Russell et al. (1981) observed numerical differences in pancreatic α-amylase concentrations when providing steers with varying levels of metabolizable energy (ME). Holstein steers (n = 24) were fed a diet consisting of either 32% corn and 60% corn silage, or ground alfalfa hay and alfalfa pellets to meet ME maintenance requirements. Steers were then slaughtered, and while not significant, the corn and silage diet resulted in decreased pancreatic α-amylase concentrations by 31% compared to steers fed the alfalfa diet. Furthermore, the same trial provided steers with 1, 2, or 3 times their maintenance ME. Similarly, results were not significant; however, a 185% improvement in pancreatic α-amylase concentration was observed when ME intake increased from 1 to 2 times, with no additional improvement with 3 times ME intake (Russell et al., 1981).

The presence of protein in the small intestine signals the pancreas to secrete α-amylase, and elevated protein levels have often increased total tract starch digestibility (Harmon et al., 2004; Owens et al., 1986). Several studies have evaluated the effects of casein infusion on intestinal starch disappearance. Casein infusion has demonstrated increased intestinal starch disappearance and increased pancreatic α-amylase secretions.

However, other studies have shown that increased α-amylase secretion is not maintained when casein is infused with starch. These results indicate that increased α-amylase secretion due to protein infusion may not be maintained in practical diets (Harmon et al., 2004).

Intestinal digestion and absorption of starch continues with the secretion of brush border carbohydrases into the mucosa, such as isomaltase and disaccharidases, which can be absorbed into the blood stream. Amylopectin within starch can only be broken down by isomaltase hydrolyzing the α1-6 bonds within the starch. Furthermore, disaccharidases (sucrase, maltase, and lactase) hydrolyze the disaccharide bonds, resulting in sucrose, maltose, and lactose. The ruminant possesses a similar complement of enzyme activities to the non-ruminant, with the exception of sucrase, which is not expressed (Kreikemeier et al., 1990). Upon formation of these monosaccharides, they can be absorbed into the blood stream, for tissue uptake.

Glucose absorption is the third and final phase of intestinal starch digestion. Sugars in the lumen of the small intestine must be absorbed into the blood stream for transfer to the liver. There are three main routes by which sugars can be taken up from the intestinal lumen; active transport, passive transport, and paracellular diffusion. Paracellular diffusion, termed solvent drag, is the process where sugars exit the lumen via absorption through the intercellular spaces. Solvent drag occurs when luminal glucose is present in very high concentrations (> 25 mM), which may not regularly occur under physiological conditions (Harmon, 2009; Harmon et al., 2004; Huntington, 1997; Pappenheimer and Reiss, 1987). Paracellular diffusion has been demonstrated to be a minor contributor in glucose absorption. Krehbiel et al. (1996) demonstrated that the non-

metabolizable glucose analog, 2-deoxyglucose, only represents approximately 0.7 to 1.7% of the glucose reaching the portal blood supply.

The second, and considered major means of glucose absorption is active transport via the sodium-dependent glucose transporter (SGLT1). The SGLT1 transporter is located in the brush-boarder membrane and possesses a high glucose affinity. Active transport is the utilization of one mole of ATP required to transport one monosaccharide. This transporter couples glucose transport with an inwardly directed sodium (Na^+) gradient, and is maintained by Na^+-K^+-ATP-ase in the basolateral membrane (Harmon, 2009; Harmon et al., 2004; and Huntington, 1997). The SGLT1 transporter has the ability to transport glucose as well as galactose. Previous research in lactating dairy cows by Zhao et al. (1998) reported activity throughout the entire intestine, as well as the rumen and omasum. However, within the small intestine, a higher proportion of SGLT1 transporters are located in the proximal portion, with fewer in the middle, and the fewest located in the distal portion (Harmon, 2009; Harmon et al., 2004; and Huntington, 1997).

The final transporter, GLUT2, contributes to glucose entry and exit from the enterocyte, via passive transport. Passive transport carries sugars across the brush border membrane without the expense of energy by utilizing a carrier protein. The GLUT2 transporter is located in the basolateral membrane and not only transports sugar into the cell, but out of the cell as well. The GLUT2 transporter is low affinity and high volume, possessing the ability to transport high concentrations of glucose, fructose, and galactose. Since GLUT2 is a facilitated (passive) transporter, it may represent what was originally believed to be diffusion. Insulin and glucose concentrations play an important role in regulating GLUT2 transporters. As glucose concentrations in the intestinal lumen

increase, GLUT2 is physically moved from the cytosol to the brush-boarder membrane, allowing absorption. Elevated insulin levels physically remove GLUT2 from the membrane, placing it back into the cytosol (Harmon, 2009). Changes in glucose concentrations allow GLUT2 to readily adapt to increased intestinal carbohydrate, allowing rapid absorption.

Distillers Grains plus Solubles and Starch Digestion

The presence of protein in the small intestine signals the pancreas to secrete α-amylase, and elevated protein levels have often increased total tract starch digestibility (Harmon et al. 2004; Owens et al. 1986). Therefore, it has been hypothesized that as a greater amount of protein reaches the small intestine in the form of RUP, pancreatic α-amylase secretion should increase, and thus, post-ruminal starch digestion. Previous research has evaluated the effect of increasing levels of distillers grains (DGS; 30% CP; 68% RUP) on beef cattle performance, carcass characteristics, and digestion, and DGS may naturally increase post-ruminal starch digestion. Depenbusch et al. (2009) utilized 330 heifers, with six dietary treatments. Treatments were steam flaked corn based and dried DGS increased at 0, 15, 30, 45, 60, and 75% of the diet DM. Dry matter intake, ADG, and final BW responded quadratically as DGS increased in the diet, and were maximized at 15% inclusion ($P \leq 0.03$). Nonetheless, G:F linearly decreased with increasing inclusion ($P = 0.01$). Furthermore, no differences were observed for LM area ($P \geq 0.27$), but back fat thickness linearly decreased with increasing DGS inclusion ($P \geq 0.06$).

One performance and one digestibility experiment were conducted by Corrigan et al. (2009) to evaluate the impact of increasing wet distillers grains plus solubles

(WDGS). Experiment one utilized 480 steers in a 3 × 4 factorial design. Treatments included corn processing (DRC, HMC, or SFC) and increasing levels of DGS (0, 15, 27.5, or 40% DM). Corrigan et al. (2009) observed a corn processing × WDGS inclusion interaction for ADG and G:F ($P < 0.01$). Steers fed DRC displayed a linear increase in ADG and G:F ($P < 0.01$); with a quadratic ($P = 0.04$) and linear ($P = 0.02$) increase in ADG and G:F respectively for those fed HMC; and a quadratic ($P = 0.02$) decrease in ADG and no change ($P = 0.52$) in G:F for steers fed SFC as WDGS increased in the diet. Experiment two utilized seven ruminally cannulated steers in a 3 × 2 factorial design. Treatments included the same three corn processing types, with WDGS included at either 0 or 40% DM. Steers fed 0% WDGS consumed less DM, OM, and NDF than those fed 40% WDGS ($P \leq 0.02$). Furthermore, total tract DM and OM digestibility was greater when diets included 0% WDGS compared to 40% ($P \leq 0.08$; Corrigan et al., 2009).

Due to varying results from feeding different inclusions of DGS in beef cattle diets, Buckner et al. (2007) sought to determine the optimal inclusion level of dried DGS (DDGS) based on feedlot steer performance. Two hundred fifty steer calves were utilized to evaluate increasing DDGS inclusions at 0, 10, 20, 30, and 40% in DRC based diets. Buckner et al. (2007) observed a quadratic increase in final BW with increasing inclusion ($P = 0.04$). As a result, HCW tended to increase quadratically ($P = 0.07$), with maximum live final BW and HCW occurring at 20% DDGS. Additionally, ADG tended to increase quadratically as DGS increased, with maximum gains at 20% DDGS ($P = 0.08$). No differences were observed for marbling score, LM area, backfat thickness, or calculated yield grade as a result of increased DDGS in the diet ($P \geq 0.24$).

Finally, Ovinge (2019) evaluated the impact of feeding high protein dried distillers grains plus solubles on finishing cattle performance. The experiment utilized 360 steers in a 2 × 3 factorial design. Treatments included corn processing (SFC or DRC) and DGS type [no DGS (CON), traditional DDGS (DDGS), or a high protein DDGS (HiPro)] fed at 30% of the diet. A corn processing × DGS type interaction ($P = 0.02$) was observed for G:F, where including DDGS in DRC diets increased G:F; however, no difference was observed when feeding HiPro ($P = 0.20$). Furthermore, DDGS and HiPro tended to reduce G:F in SFC based diets ($P = 0.10$). Inclusion of a high protein containing DGS (HiPro) did not further improve animal performance over the traditional DDGS, thus these results disagree with the authors hypothesis that feeding HiPro in the diet would increase postruminal starch digestion and performance.

Previous research has shown an improvement in feedlot cattle performance when DGS are fed at an increased concentration, up until approximately 35-40% of the diet. However, total tract nutrient digestibility has been decreased at elevated inclusions. This suggests increased supply of RUP to the small intestine may stimulate some increased α-amylase secretion from the pancreas; however, the response is not maintained at higher inclusions. Additionally, evaluation of higher protein byproducts (HiPro) observed no further performance response compared to traditional DGS when included in the diet at 30%. Furthermore, distillers grains plus solubles are a greater source of energy (98% TDN; NASEM, 2016), and thus, performance improvements may be due to the increased energy density of the diet.

EXOGENOUS ALPHA AMYLASE IN BEEF CATTLE DIETS

Enzymes are produced by the cells of living organisms, and act to catalyze biochemical reactions. Exogenous enzymes, often included in diets as a supplemental feed additive, aid in accelerating the digestion of feed ingredients into smaller compounds (McAllister et al., 2001). Smaller compounds, such as, simple sugars, fatty acids, and amino acids can be utilized for growth either directly by the animal or the ruminal microbes. Scientific studies describing the use of exogenous enzymes date back to the mid 1920's; however, the first commercial use of enzymes didn't occur until 1984, within the brewing industry (Campbell and Bedford, 1992). Today, the poultry and swine industries utilize exogenous enzymes as a feed additive extensively. Nonetheless, their application in the ruminant sector has developed at a slower rate, primarily exploring fibrolytic enzymes in order to increase fiber digestion (Campbell and Bedford, 1992; Bedford and Partridge, 2001).

While recent research has evaluated the use of amylolytic and fibrolytic enzymes in dairy and beef cattle, Burroughs et al. (1960), looked at the effectiveness of an enzyme supplement mixture of bacterial origin (Agrozyme; combination of amylolytic and proteolytic enzymes). The authors utilized 325 steers and heifers in a series of ten pen feeding trials. Agrozyme was provided at either 3.40 or 6.80 grams per head per day, and diets varied, with trials 1-6 including a finishing ration, while 7-10 included a silage based growing diet. Furthermore, trial length varied from 84 to 250 days; averaging 140 days on feed. Similar performance was observed between cattle fed 3.40 and 6.80 grams per head per day, thus the authors reported only the main effect of the enzyme. On average, liveweight gains increased 7.0% over the ten trials when Agrozyme was fed;

however, little to no influence on DMI was observed. Thus, Burroughs et al. (1960) observed an increase in ADG of 6.5% and improved feed conversions of 6.0% when supplementing with the exogenous enzyme mixture.

A majority of research regarding feeding supplemental enzymes to ruminants has evaluated the use of fibrolytic enzymes; however, supplementation of amylase enzymes offers the potential to maximize starch digestion and thus, cattle performance. Ruminal starch digestion is considered extensive, and too rapid of digestion can lead to acidosis (Owens et al., 1998). Nonetheless, increasing ruminal and postruminal digestion via exogenous α-amylase supplementation in cattle has warranted further evaluation, and may improve feedlot performance and milk production of dairy cattle.

Amylase in Beef Cattle Rations

Several studies have evaluated feeding Amaize (Alltech, Inc., Nicholasville, KY), an α-amylase enzyme supplement containing *Aspergillus oryzae* and *Saccharmoyces cervisiae* on feedlot cattle performance and carcass characteristics (Tricarico et al., 2007). Tricarico et al (2007), evaluated the effect of α-amylase supplementation on cattle performance with different roughage sources, varying concentrations of α-amylase and corn processing methods, and with restricted DMI in a series of three experiments. Experiment one utilized 162 calf-fed steers, with four treatments arranged in a 2 × 2 factorial. Treatments were SFC based, and included either cottonseed hulls or alfalfa as roughage sources, and Amaize included at 0 or 950 DU/kg (DU = dextrinizing unit, the amount of enzyme needed to solubilize starch at 1 g/h at 30°C and pH 4.8). No interaction for roughage source by enzyme inclusion, and no main effect of enzyme inclusion differences were observed for final BW, DMI, ADG, or G:F ($P \geq 0.11$).

Furthermore, no interactions were observed for any of the carcass characteristics; however, LM area was greater for cattle fed the α-amylase supplement compared to the control ($P = 0.02$). Experiment two utilized 96 yearling heifers, with six treatments arranged in a 2 × 3 factorial. Treatments consisted of either dry-cracked or high-moisture corn (corn processing methods), and the enzyme included at 0, 580, or 1,160 DU/kg. No corn processing × amylase interactions were observed for final BW, DMI, ADG, or G:F ($P \geq 0.14$). However, a quadratic increase in ADG ($P = 0.04$) and a tendency for a quadratic increase in DMI ($P = 0.07$) was observed, with cattle fed 580 DU/kg displaying the greatest ADG and DMI. Furthermore, no corn processing × amylase interactions were observed for any of the carcass characteristics ($P \geq 0.13$). Heifers fed the 580 DU/kg α-amylase enzyme treatment had the greatest HCW, LM area, and lowest calculated yield grade ($P \leq 0.04$). Finally, experiment three utilized 64 steers in a 56 d programmed-gain trial, with a target gain of 1.52 kg/d, an assumed final BW of 567 kg, and a target end grade of USDA choice. Diets were SFC based, and treatments included α-amylase supplementation at 0 or 930 DU/kg. No differences were observed for animal performance when steers were fed the α-amylase enzyme supplement ($P \geq 0.15$). No significant performance differences were observed in the three trials by Tricarico et al. (2007) with the supplementation of the α-amylase containing Amaize.

Two experiments conducted by Zerby et al. (2011) also evaluated the effects of *Aspergillus oryzae* [Amaferm (AMF); Biozyme Inc., St. Joseph, MO] and *Saccharmoyces cervisiae bouldarii* [CNCM 1079-Levucell SB (LEV)] on performance and carcass characteristics of lambs and steers. Experiment one utilized 48 lambs, and treatments included two AMF inclusions at either 0 (control) or 1 gram per head per day

via a pelleted feed. Final BW, DMI, and ADG were not different for lambs fed AMF compared to the control ($P \geq 0.12$). However, an 8.8% numerical increase in ADG was observed when AMF was fed, resulting in a 4.9% difference in G:F compared to the control ($P = 0.07$). Furthermore, no significant differences were observed for any of the lamb carcass characteristics ($P \geq 0.14$). Experiment two utilized 168 calf-fed steers, with six treatments arranged in a 3 × 2 factorial. Treatments included three supplement types, with no added enzyme (CON), *S. cerevisiae bouldarii* CNCM 1079-Levucell SB (LEV), or Amaferm (AMF); and two corn processing methods, dry whole shelled corn (DWSC) or high-moisture corn (HMC). Diets included LEV and AMF supplements at 0.5 and 3.0 grams per head per day, respectively. A corn processing × supplement interaction was observed for G:F ($P = 0.03$). Cattle supplemented with AMF with DWSC had a 7.2% increase in G:F; however, no difference was observed when HMC was fed. When evaluating the main effect of supplement type, no significant differences were observed for final BW, DMI, or ADG ($P \geq 0.30$). Furthermore, no differences were observed for any steer carcass characteristics for the main effect of supplement type, or the corn processing × supplement interaction ($P \geq 0.33$).

Three feedlot and one digestibility trial were conducted to evaluate the effect of Syngenta Enogen Feed Corn (SYT-EFC; Syngenta Seeds Inc., Minnetonka, MN) on feedlot performance, site and extent of digestion, and ruminal fermentation parameters (Jolly-Breithaupt, 2018). Syngenta Enogen Feed Corn is a new corn hybrid containing an α-amylase enzyme trait, and feeding the hybrid to feedlot cattle was hypothesized to improve performance. Experiment one utilized 384 calf-fed steers, with six treatments arranged in a 2 × 2 × 2 factorial. Treatments included corn hybrid [SYT-EFC or negative

isoline control (NEG)], corn processing (DRC or HMC), and byproduct type [modified distillers grains plus solubles (MDGS) or Sweet Bran (SB); Cargill Milling]. No interactions were observed for the three way corn hybrid × corn processing × byproduct type interaction for any performance or carcass parameters ($P \geq 0.21$). A corn hybrid × corn processing interaction was observed for final BW ($P = 0.02$) and ADG ($P = 0.04$), where steers fed SYT-EFC as DRC displayed greater final BW and ADG compared to NEG; however, the NEG treatment resulted in greater final BW and ADG than SYT-EFC when fed as HMC. No interaction was observed for G:F; however, steers were more efficient when fed SYT-EFC DRC compared to NEG DRC ($P = 0.05$). Experiment two utilized four ruminally and duodenally cannulated steers, in a 2 × 2 + 1 factorial. Treatments were DRC based, and included corn hybrid (SYT-EFC or NEG), byproduct type (MDGS or SB) and a 50:50 blend of SYT-EFC and NEG hybrids with MDGS. No interactions were observed for DM, OM, or starch digestibility ($P \geq 0.19$); however, steers fed SYT-EFC had greater total tract OM, post-ruminal starch, and total tract starch digestibility, compared to NEG ($P \leq 0.08$). Steers fed SYT-EFC observed a 2.2% increase in total tract starch digestion compared to those fed the NEG hybrid. Finally, evaluation of ruminal pH parameters presented no differences for the interactions or main effects of corn hybrid ($P \geq 0.22$). Experiments three and four utilized 300 calf-fed steers, at two locations, for a total of 600 head. Treatments included SYT-EFC or NEG hybrids as DRC fed with wet distillers grains plus solubles (WDGS). No corn hybrid × location interactions ($P \geq 0.13$), and no main effects of hybrid ($P \geq 0.17$) were observed for all performance and carcass characteristics. Furthermore, steers fed SYT-EFC possessed greater backfat thickness, smaller LM area, and thus greater calculated YG compared to

NEG ($P \leq 0.02$); however, HCW and marbling scores were not different among treatments ($P \geq 0.33$). Unlike experiment one, feeding SYT-EFC hybrid corn in experiments three and four did not significantly improve G:F.

Feedlot performance results have varied when exogenous amylase has been included in feedlot rations. Differences observed by Jolly-Breithaupt (2018) indicate that feeding beef cattle corn containing an α-amylase trait as a DRC may provide a slight improvement in feed efficiency, due to an increase in total tract starch digestion. However, it appears that no additional response is gained in animal performance when diets contain rapidly fermentable grains, such as HMC or SFC. Lack of additional response could be attributed to a greater extent of starch digestion already occurring with these processing types. The varying response observed in less processed diets warrants further research on the utilization of amylase enzymes in less fermentable diets of feedlot cattle, and their impact on beef cattle performance.

Amylase in Dairy Rations

While an improvement in digestion in feedlot cattle would result in increased performance in the form of feed efficiency, the use of exogenous enzymes within dairy cattle could result in increased milk production and improvement in milk-yield components. The application of fibrolytic enzymes in dairy rations in order to increase ruminal fiber digestion has been evaluated in several studies. However, the impact of amylases on starch digestion has not been thoroughly examined. The impact of Amaize (Alltech Inc., Nicholasville, KY), a commercial α-amylase product, on milk composition and production, ruminal starch disappearance and fermentation, and metabolite concentrations was conducted by Tricarico et al. (2005) on Holstein dairy cows. The

experiment utilized 20 intact and four ruminally cannulated cows, in a 4 × 4 Latin square design. Amaize was provided at four inclusions, 0, 240, 480, or 720 DU/kg. Milk production increased quadratically, with the 240 DU/kg treatment resulting in the greatest milk yield ($P = 0.02$). Furthermore, a quadratic increase in fat corrected and energy corrected milk was observed ($P = 0.01$), as well as a tendency for increased milk protein ($P = 0.06$). Results from the 6 or 24 hour *In situ* incubation for ruminal starch disappearance showed no differences due to enzyme supplementation. Volatile fatty acid evaluations observed an increase in molar proportions of butyrate ($P = 0.05$), and a tendency for an increase in acetate ($P = 0.06$), resulting in a greater acetate to propionate ratio with the enzyme supplementation compared to the control ($P = 0.04$). Tricarico et al. (2005) observed increased serum concentrations of BHBA ($P = 0.01$) and NEFA ($P = 0.03$) with the addition of amylase supplementation. Similarly, DeFrain et al (2005), observed greater BHBA and NEFA concentrations when an amylase supplement was provided at 0.1% of the diet (DM basis; $P \leq 0.01$). Nonetheless, blood glucose concentrations linearly decreased compared to the controls ($P = 0.01$; Tricarico et al., 2005). This is in contrast to results from DeFrain et al. (2005), who observed a tendency for an increase in blood glucose with enzyme supplementation ($P = 0.08$). Results from DeFrain et al. (2005) suggest an improvement in energy balance and ability to maintain blood glucose concentrations when Holstein cows are provided an amylase supplement. Furthermore, Tricarico et al. (2005) concluded that optimal inclusion of Amaize is achieved at 240 DU/kg, as seen by increased milk production, and milk fat and protein contents.

A large case study, utilizing 45 commercial dairy herds (8,150 cows) evaluated the commercial use of an *Aspergillus oryzae* product on lactational performance (Amaize; Harrison and Tricarico, 2007). Dairy herd improvement (DHI) test records were collected and examined for number of cows, days in milk, milk production, and milk composition prior to supplementation. Cows received 12 grams per head per day after the first DHI monthly testing, and received supplementation through the second DHI test. Overall milk production tended to increase during the supplementation phase on a herd (P = 0.059), and individual cow basis (P = 0.097). Furthermore, on a herd basis, milk protein tended to increase when cows were supplemented with Amaize (P = 0.062). However, milk fat was not different on a herd or individual cow basis with the supplementation of amylase, which is in contrast to results from Tricarico et al. (2005). The application of exogenous alpha amylase in dairy rations has been variable. An increase in milk production, milk components (fat and protein), and butyrate have been shown to increase as a result of supplementation. However, the exact mechanism responsible for these increases remains unclear, and results tend to be inconsistent.

CORN SILAGE PRODUCTION

The implementation of corn silage in beef cattle diets allows feeders to take advantage of the entire corn plant at a time of maximum quality and tonnage, while securing substantial quantities of roughage/grain inventory (Burken et al., 2017a). Substantial yields, grain production, and the preservation of corn silage make it a beneficial year-round feed resource for beef and dairy producers (Heguy et al., 2016). Corn silage has been a key staple in dairy operations, as well as growing and finishing rations of beef cattle since the early 1900’s. Its use has primarily been as a roughage

source; however, because it is approximately 50% corn grain, silage is a moderately high energy (67.7% TDN), low protein (8.24%) feed product (NASEM, 2016). These nutrient characteristics makes corn silage a supplemental energy source in cow/calf systems, and allows flexibility in growing and finishing beef cattle rations (Allen, 2003).

As with any feed ingredient, there are some clear advantages and disadvantages when including corn silage in an operation. First, silage provides a large yield of a single harvested crop annually, which can be stored and used throughout the course of the year, whereas other forages require multiple harvests throughout the growing season. Due to the substantial dry matter yields corn silage provides, less land is needed for forage production. This allows acres that would normally be used for forage production to be planted into other crops. Furthermore, corn silage is harvested earlier than traditional corn grain, providing flexibility in planting and harvesting dates in the instance of bad weather, and spreading labor out during the harvest period. Additionally, based on economic market conditions, corn can be harvested for forage or grain. Crop producers have the ability to harvest and market their corn as dry grain during periods of great corn yields, or when economic incentives are present (Allen et al., 2003).

Unfortunately, corn silage production results in some agronomic disadvantages. Due to a vast majority of corn residue being removed, plant organic matter and nutrients, primarily nitrogen (N) and phosphorus (P) which would normally remain in the field with grain harvest are removed. Removal of these nutrients results in lower soil organic matter levels for subsequent crop production. Additionally, removal of corn residue leaves little to no ground cover, increasing the risk of soil erosion; however, application of livestock

manure and planting of cover crops can aid in mitigating these disadvantages (Allen et al., 2003).

Corn Silage Fermentation

The process of ensiling takes two to six weeks, and is the rapid conversion of plant soluble sugars into organic acids in an anaerobic environment, resulting in a fermented, stored feed product (Wilkinson et al., 2003). Lactic acid bacteria (LAB) present on the surface of the plant at harvest metabolize the plant sugars, resulting in the production of organic acids, and thus a drop in silage pH (Der Bedrosian et al., 2012; Pahlow et al., 2003). According to a review by Pahlow et al. (2003), the fermentation process of corn silage occurs in four primary phases: 1) initial anaerobic phase, 2) main fermentation phase, 3) stable phase, and 4) the feed-out phase.

The initial anaerobic phase (1) usually lasts 12-24 hours with the death of the plant, and initiation of plant part degradation via enzymatic processes. In order to limit the risk of mold and harmful yeast growth, length of the anaerobic phase should be minimized as much as possible. Oxygen within the packed silage allows the plant to respire until all of the oxygen is consumed, creating heat and an anaerobic environment (Pahlow et al., 2003). During this initial phase, lactic acid production decreases the overall pH of the silage from seven to four, preserving the corn (Merry and Davies., 1999; Pahlow et al., 2003). Additionally, proteases and carbohydrases produced from bacteria decompose proteins to amino acids and increase the quantity of soluble carbohydrates available for the bacteria (Pahlow et al., 2003).

Upon depletion of all available oxygen in the silage, the main fermentation phase (2) officially begins. While LAB, other anaerobic bacteria, and yeast further degrade

soluble carbohydrates and compete for nutrients, the drop in pH results in LAB outcompeting other harmful bacteria (Pahlow et al., 2003). During the second phase, ideally 4 to 6% of the total silage DM will be converted to lactic acid, further stabilizing the fermented forage (NASEM, 2016). Proper fermentation is indicated by a 3:1 or greater lactic acid and acetic acid ratio, ideally with lactic acid comprising 65-70% of the total organic acid production. Effluent and gas are released, and readily available nutrients are consumed by anaerobic bacteria, resulting in some shrinkage (Pahlow et al., 2003). The main fermentation phase can last for 7 to 28 d after initial harvest, with temperatures rising to 80 - 100°F, and pH dropping to four or lower.

Once the metabolic processes of the silage cease, the stable phase (3) occurs, resulting in little change as long as the silage remains free from oxygen. The acidic environment causes only acid tolerant enzymes to actively degrade structural carbohydrates (hemicellulose), increasing NDF digestibility, while proteases degrade the zein protein matrix binding starch (Pahlow et al., 2003; Der, Bedrosian et al., 2012). During the stable phase, temperature and pH remain stable at or below four (Pahlow et al., 2003).

Feed-out of the fermented silage is the fourth and final stage of the ensiling process. During feed-out the silage bunker or bag is opened, and oxygen has the capacity to seep up to 1 m beyond the surface face (Honig, 1991). Exposure to oxygen promotes yeast and bacteria populations to reactivate and grow, leading to heat production, mold spoilage, reduction in lactic acid concentration, and increased pH. Aerobic bacteria begin to consume the ensiled material, damaging the highly digestible water soluble carbohydrates within the silage (Darby et al., 2002). Charley (2016) recommends

removing 0.15 to 0.30 m per day from the silage face in order to reduce losses during the feed-out phase.

Ensiling corn silage is challenging and consistency in silage production is a major concern. During fermentation, issues can arise with the slow removal of oxygen, inadequate drops in pH, and length of harvesting periods. Many of the challenges of silage production include oxygen, temperature, dry matter content, and production of organic acids within the silage (Pitt and Muck, 1993). Silage quality can be impacted by management factors, including hybrid type, maturity at harvest, length of storage, chop length, mechanical kernel processing, and pack density (Johnson et al., 1999; 2002; 2003). Corn silage can be a valuable feed resource in beef and dairy rations and if properly put up, can be a great roughage or energy source.

Kernel Processing Corn Silage

Increasing the energetic density and digestibility of forages is key to achieve maximal returns within the beef and dairy sectors. Corn hybrid, theoretical length of cut, and maturity at harvest are all management tools that can impact animal performance. However, corn silage producers also have the opportunity to kernel process silage prior to fermentation. Kernel processing is done during harvest, in which the corn kernel, cob, and stover portions of the plant are disrupted via an onboard roller mill (Johnson et al., 1999). Disruption of the grain increases the surface area of the kernels, increasing starch availability for ruminal microbes, and thus, increasing starch digestion. Previous research by Rojas-Bourrillon et al. (1987) indicates processing decreases kernel particle size 15-30%, thus increasing surface area for rumen bacteria to degrade starch (Schurig and Rodel, 1993). In addition to cracking the kernel, crushing of the entire corn plant likely

affects some of the fiber particle availability as well. According to Owens (1997), starch digestibility is greater for kernel processed corn silage, with added benefits for silage harvested at a later maturity. However, kernel processing adds associated costs to silage production, in the form of additional fuel requirements and the acquisition of a processing unit (Johnson et al., 2003).

Research has primarily been evaluated in dairy rations, and conflicting results with kernel processing silage have been observed. Cooke and Bernard (2005) evaluated the effects of kernel processing corn silage when included at 38% of diet DM in the rations of lactating dairy cows. Silage was kernel processed to either 2 or 8 mm, resulting in increased starch digestibility from 75.6% to 85.4% ($P < 0.01$; respectively). Furthermore, NDF and ADF digestibility of the silage increased by 32.4% and 50.5% respectively ($P < 0.01$). No differences in DMI were observed when kernel processing to either 2 or 8 mm ($P > 0.05$). However, previous research has also observed either decreased (Andrea et al., 2001) or no differences (Rojas-Bourrillon et al., 1987) in fiber digestion with the implementation of kernel processing. Increased fiber digestion is hypothesized to be attributed to greater available surface area for ruminal fibrolytic microbe species (Cooke and Bernard, 2005).

Feedlot rations typically possess lower inclusions of corn silage, thus, further evaluation is needed to determine the impact on performance of cattle fed kernel processed silage. One finishing and one digestibility trial were conducted to evaluate the effect of kernel processing and use of brown midrib corn silage hybrids in silage based finishing diets (Ovinge, 2019). Experiment one utilized 380 yearling steers, in a 2 × 3 factorial design. Treatments included corn silage kernel processed or not, and three corn

hybrids, included in the diet at 40% of diet DM. Evaluation of the main effect of kernel processing observed decreased DMI ($P = 0.02$), with similar ADG ($P = 0.93$), resulting in a 2.9% improvement in G:F ($P = 0.10$) for cattle fed kernel processed corn silage diets. When included in the diet at 40%, a 7.3% (2.9% / 0.40) improvement in G:F is observed due to kernel processing. Experiment two utilized six ruminally cannulated steers, in a 6 × 6 Latin Square design. Dietary treatments were the same as for experiment one. Kernel processing had no effect on nutrient digestibility ($P \geq 0.49$), or VFA concentration ($P \geq 0.37$).

Inclusion of Corn Silage in Beef Cattle Diets

Corn silage has been included in beef cattle diets for a long time, and its application in finishing and growing systems has been extensively evaluated. The adoption of increasing inclusion levels has primarily been evaluated as a means to reduce ration costs during times of expensive corn (Goodrich et al., 1974). With the vast supply and knowledge around byproducts from the ethanol industry, recent research conducted at the University of Nebraska-Lincoln has explored the economic advantages to feeding high concentrations of corn silage with DGS included in the diet (Burken et al. 2017b). Previous research, without the inclusion of DGS has observed poorer cattle performance, with decreased ADG and G:F, as the inclusion of corn silage increased in the diet (Goodrich et al., 1974; Hammes et al., 1964; Klosterman et al., 1965; Jesse et al., 1976; Brennan et al., 1987; DiCostanzo et al., 1997; Erickson, 2001: McEwen, 2002a,b). Owens et al. (2018) recently summarized that inclusions up to 21% and 29% of diet DM had no effect on ADG and DMI, respectively. Reduction in performance has been somewhat mediated with the inclusion of DGS. Burken et al. (2017a) included modified

distillers grains plus solubles (MDGS, 47% DM, 31% CP; NASEM, 2016) in the diet at either 20 or 40%, and included corn silage at either 15 or 45% of diet DM. Average daily gain was observed to be 13.6% poorer when MDGS was included at 20%, and DMI was reduced 14.6% as silage increased in the diet from 15 to 45%. However, when MDGS was included at 40%, ADG was reduced only 5.0%, with no difference in DMI when silage inclusion increased from 15 to 45% (Burken et al., 2017a).

Although high concentrations of corn silage in beef cattle diets can result in poorer animal performance, the 50% corn grain 50% roughage make-up of the feedstuff makes it a high energy product compared to other forage sources, like grass hay. Corn silage contains a very low amount of ruminally undegradable protein (RUP; 13.1%) as a percent of total crude protein (CP), additionally the digestibility of that RUP is quite low (50%; Oney et al., 2019). A majority of the protein within silage is degraded in the bunker and the rumen. Fermentation of the protein reduces the amount of protein and amino acids that reach the small intestine for use by the animal (Owens et al., 2018). Thus, amount and type of protein included in the ration has a large impact on growing steer performance. Inclusion of DGS in corn silage diets offers some protein relief, as it is a high protein (29.1-30.8% CP) energy source (89-98% TDN), that is high in RUP (63%; Castillo-Lopez et al., 2013). Previous research supplying adequate metabolizable protein (MP) to growing beef cattle has shown a growth performance benefit in corn silage based diets. Hilscher et al. (2019) evaluated increasing levels of RUP (0.4, 1.7, 301, 4.2, or 5.5%) when corn silage was included in the diet at 88% DM. Cattle supplemented with 5.5% RUP displayed the heaviest ending BW, as MP requirements of the growing calves were met with increasing RUP in the silage diets. Furthermore, ADG and G:F linearly

increased as RUP increased in the diet (*P* < 0.01; Hilscher et al., 2019). Similarly, Oney et al (2019) included silage in the diet at 85% DM, with supplemental RUP increasing in the diet at 0, 3.25, 6.5, 9.75, and 13%. Ending BW and ADG linearly increased with increasing RUP supplementation (Oney et al., 2019). Results from Hilscher et al. (2019) and Oney et al. (2019) display the importance of adequate RUP and MP supply for growing beef cattle, particularly when diets contain high levels of corn silage.

Ovinge (2019) evaluated the impact of varying inclusion of silage in corn based finishing diets on cattle performance and carcass characteristics. The experiment utilized 288 steers, with six treatments in a 2 × 3 factorial. Treatments included two corn silage hybrids fed at three inclusions, 15%, 45%, or 75/15%. The 75/15% treatment included 75% corn silage in the diet up to d 70 then reduced to 15% for the remainder of the trial, resulting in an average corn silage inclusion of 45% throughout the entirety of the feeding period. Cattle on the 15% silage treatment were fed for 153 d, while those on the 45% and 75/15% were fed for 181 days. Due to greater days on feed, steers fed 45% and 75/15% had greater final BW; however, displayed poorer G:F compared to steers fed the 15% corn silage (0.162 vs. 0.170 respectively; *P* < 0.01). Furthermore, LM area was greater for cattle on the 75/15% treatment; with the 45% and 75/15% treatments producing lower dressing percentages (*P* < 0.01). Ovinge (2019) concluded that feeding corn silage at a consistent 45% throughout the feeding period to finishing beef cattle resulted in similar performance to cattle fed an average 45% corn silage in the 75/15% treatment.

GRAZING DOUBLE-CROPPED ANNUAL FORAGES

Advantages of Double-Cropped Forages

Double-cropped annual forages, commonly known as cover crops, have increased in popularity recently in Nebraska and much of the Midwest (SARE/CTIC, 2016). Utilization of forage cover crops provide agronomic benefits to crop producers with the improvement of soil conservation, soil erosion and weed control, and nutrient cycling, as well as providing a feed source for livestock (Sulc and Tracy, 2007; Sulc and Franzluebbers, 2014; SARE/CTIC, 2016). A recent survey of Nebraska producers indicated that brassicas and small grains, such as oats, are most commonly utilized for late-summer planted cover crops (Drewnoski et al., 2015). The recent push towards planting cover-crops into agronomic practices has stimulated a vast need for research into the benefits and disadvantages of their adoption. Research has primarily evaluated the agronomic impacts of cover crops following cash crop harvest without harvesting or grazing the above ground forage biomass (Brandsaeter and Netland, 1999). However more recently, an interest in the concept of grazing late-summer planted annual forages as an economic opportunity to add body weight to livestock has led to the increased need for further research (Koch et al., 2002; Fae, 2009). Many questions still remain regarding the logistics of planting and grazing double-cropped forages, such as forage type and planting date, as well as their impacts on animal performance and subsequent crop yields.

Effects of Planting Date

Planting date plays a major role in the overall forage quality and yield potential of double-cropped annual forages (DCAF), ultimately determining the economic viability of their implementation. The ability to extend the grazing season from summer grazing

through late fall, until winter feeding can have a positive impact both economically, and on animal performance prior to the feedlot phase (Koch et al., 2002). However, planting in late-summer limits the number of growing degree days, and may decrease the yield potential of these forages. Nonetheless, forages produced from later planting dates are more likely to be higher quality, due to being less mature (Wiedenhoeft and Barton, 1994).

Corblentz et al. (2011 and 2012), demonstrated the importance of planting and harvest date on oat forage yield and nutritive value of oats planted in North Carolina. Oats were planted on three different dates (July 15th, August 1st, and August 15th), and were harvested on five different dates between September 15th and November 15th. Corblentz at al. (2011) observed the greatest forage yields with the oats planted on July 15th linearly and quadratically increasing over time from 4,501 to 8,100 kg DM / ha with the different harvest dates. The August 1st planting had a linear increase in forage yield over time, with a maximum yield of only 5,175 kg DM / ha by the November 15th harvest date. Finally, oats planted on the 15th of August had significantly reduced yields compared to the earlier planting dates, with the maximum yield never exceeding 1,934 kg DM / ha (Corblentz et al., 2011). Furthermore, Corblentz et al. (2012) evaluated the nutrient content of the oats based on the three planting dates via 48 h incubation on in vitro neutral detergent fiber digestibility (NDFD), with 48 h total digestibility decreasing over time. Results from Corblentz et al. (2011 and 2012) suggest that earlier planted oat forages typically have increased DM yields, but are more mature with a poorer nutritive value than later planted oats.

In agreeance with previous research, Wiedenhoeft and Barton (1994) outlined that earlier planted forages possess greater NDF concentrations compared to later planted forages, primarily a function of the plant's maturity. Results from Wiedenhoeft and Barton (1994) show NDF content of brassica species ranged from 14 to 42%, and ADF ranged from 11 to 36% across planting dates. Once forage is cut, the subsequent regrowth possesses greater protein and lower fiber concentrations. Furthermore, later planting of brassicas tends to lead to an increase in protein concentrations up to 8% (Wiedenhoeft and Barton, 1994). Regardless of planting date, late-summer or early-fall planted forages provide livestock producers with a high quality feed source.

Koch et al. (2002) planted turnips and radishes in July and August, and collected samples in mid-October in Powell, WY, to evaluate the effects of planting date, tillage practice, and animal performance. No yield differences were observed between brassica species; however, the researchers concluded that planting date was the greatest factor in affecting yield potential. Turnips planted in July produced an average yield of 3,900 kg DM / ha, while those planted in August averaged only 2,500 kg DM / ha. Each week after July 20^{th} that planting was delayed resulted in an average yield reduction of 700 kg DM / ha, or approximately 25% of the potential productivity.

Livestock Grazing Cover Crops

Aside from the agronomic benefits planting cover crops provides, the ability of livestock to achieve body weight gains and extend the summer grazing season is an important benefit for livestock producers. Brassicas contain a high concentration of water soluble carbohydrates (WSC) which are rapidly fermentable within the rumen, increasing the risk of the onset of subacute acidosis (Barry, 2013; Westwood and Mulcock, 2012).

Koch et al. (2002), observed similar gains were attained for each brassica species grazed, with Rambouillet crossbred lambs averaging 0.18 kg / d of BW gain. However, when comparing planting dates, lambs grazing the July planted forages gained 41% more than those grazing the August planted species. This increase in gains is attributed to the increased forage production of the July planted brassicas (Koch et al., 2002). Furthermore, Fae et al. (2009) evaluated the impacts of grazing cover crops planted after corn silage harvest, on subsequent corn silage yield, and soil characteristics. Forages were planted in early-September, upon corn silage harvest, and dairy heifers were turned out to graze. The authors observed no differences in subsequent corn silage yields, while heifers gained 0.81 kg / d. The forage cover provided an average of 105 animal grazing days per hectare (Fae et al., 2009).

A study by Cox-O'Neill (2017) was conducted to evaluate different fall backgrounding strategies. The three treatments included grazing corn residue with distillers grains (DGS) supplementation (0.86% of BW / d), grazing an oat-brassica forage planted after corn silage harvest, and feeding a corn silage based ration in a drylot setting. Calves in the two grazing treatments grazed for 65 d, and spent 21 d on the corn silage ration in order to meet a target end weight of 364 kg. Over the entire trial period calves in the drylot had the greatest gains (1.48 kg / d), with calves grazing the corn residue and DGS gaining the least (0.87 kg / d), and those grazing the oat-brassica forage falling intermediate (1.05 kg / d). However, during the grazing period calves grazing the oat-brassica forage displayed greater gains (0.72 kg / d) compared to calves grazing corn residue with DGS (0.45 kg / d) (Cox-O'Neill, 2017).

Finally, a multi-year study was conducted to evaluate the potential of grazing an oat monoculture planted after either corn silage (CS) or high-moisture corn (HMC) harvest (Ulmer, 2016; Hansen, 2017). Ulmer (2016) observed differences in oat forage yield, with those planted following CS harvest yielding 3,200 kg DM / ha, while oats drilled after HMC harvest produced only 586 kg DM / ha by late-October. Steers grazed for 62 d, beginning in mid-November, and averaged 0.59 kg /d on oats following CS, and 0.33 kg / d when grazing oats following HMC harvest (Ulmer, 2016). Similarly, Hansen (2017) observed differences in oat forage yields, with those following CS harvest producing 2,547 kg DM / ha, while oats planted after HMC harvest yielded 1,973 kg DM / ha. Calves grazed for 42 d, and those grazing CS oats gained 1.10 kg / d, while daily gains of 0.84 kg / d were observed when grazing following HMC harvest (Hansen, 2017). These results would suggest that planting and grazing a late-summer or early-fall cover crop can provide livestock producers with relatively good gains, with the greatest gains coming from earlier planted forages.

Economics

Economically, the opportunity to plant and utilize a second crop offers producers a more efficient alternative use for land and capitol, by providing an inexpensive high quality forage (Koch et al., 2002). However, many producers perceive labor and the associated costs of planting and managing cover crops as a major challenge (Drewnoski et al., 2015). In the study by Koch et al. (2002), turnips and radishes were seeded from July 17th to August 12th, at 2 to 3 kg / ha, and 25 to 28 kg / ha, respectively. The authors noted that the cost to grow and graze the turnip-radish forage was approximately $220 to $250 per hectare, calculating to $0.72 to $0.79 per kg of BW gain (Koch et al., 2002).

Furthermore, Cox et al. (2016) performed an economic analysis of three different fall backgrounding systems, which included grazing corn residue with distillers grains (DGS) supplementation (0.86% of BW / d), grazing an oat-brassica forage planted after corn silage harvest, and feeding a corn silage based ration in a drylot setting. The least cost of gain was observed for calves grazing corn residue with DGS supplementation ($0.77 / kg), followed by calves in the drylot ($0.88 / kg), and lastly those grazing the oat-brassica forage had the greatest cost of gain ($1.01 / kg). Cox et al. (2016) attributed approximately 40% of the costs for the oat-brassica grazing system to inorganic nitrogen application during seeding. The costs associated with planting and grazing cover crops vary largely based on available resources, environmental conditions, and achieved body weight gains.

CONCLUSIONS

Based on this review of the literature, it is apparent that in order to improve beef cattle efficiency and maximize production, starch digestion must be exploited. Corn processing has been proven to increase the rate and extent of total tract starch digestion, and the more recent use of distillers grains has stimulated numerous questions around its impact on postruminal starch digestion. Furthermore, the use of exogenous enzymes has been widely adopted within the poultry and swine industries; however, its value in the diets of beef cattle has not been fully characterized. A new corn hybrid, Syngenta Enogen Feed Corn (SYT-EFC) contains a thermotolerant alpha amylase enzyme, which becomes activated at increased temperatures. Originally developed for use in the dry milling ethanol industry, SYT-EFC reduces the need for alpha amylase addition during the fermentation process to convert starch to glucose. This corn hybrid may work as an

exogenous amylase supplement when fed to beef cattle, increasing starch digestion and animal performance. Furthermore, corn silage has recently started to be viewed as an energy source in feedlot rations. Cattle feeders need to derive as much from their silage as possible, and kernel processing during harvest may provide some performance benefits.

Additionally, the concept of planting and grazing a fall double crop forage for both agronomic and economic benefits has stimulated a need for further research. Crop producers may benefit from the practice by removing unwanted residue, spreading out cost of production, and improving soil characteristics of their fields. Likewise, producers in the cow/calf, backgrounding, or feedlot industries could benefit from the utilization of crop ground to achieve favorable fall gains. Annual forages and brassicas have been shown to produce adequate biomass and nutritive quality for animal grazing, while also providing agronomic benefits within a cropping system. Previous research has observed greater benefits and reduced risk when annual forages are planted in late summer or early fall, as well as little to no impacts to subsequent crop yields. Finally, adoption of this practice can be an economical way to add BW gains to livestock. The objectives of the research presented in this thesis were to:

1. Determine the effects of SYT-EFC fed as corn silage or grain on growing beef cattle performance, digestion, and ruminal parameters.
2. Evaluate the impact of SYT-EFC as dry-rolled corn, high-moisture corn, or a blend of the two on feedlot cattle performance.
3. Evaluate SYT-EFC when fed with titrating inclusions of wet distillers grains plus solubles on finishing beef cattle performance.

4. Determine calf gains and forage production of double-cropped annual forages following corn production, as well as their impact on subsequent crop yields and the total cost of gain for these systems.

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CHAPTER II. Effect of Syngenta Enogen Feed Corn Containing an Alpha Amylase Trait Fed as Corn Silage or Grain on Growing Feedlot Cattle Performance and Digestibility[1]

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ABSTRACT

One growing and one digestion experiment evaluated the effect of a corn hybrid which contains an alpha amylase enzyme trait, Syngenta Enogen Feed Corn (SYT-EFC), in corn silage or forage based growing diets. Experiment one utilized 576 crossbred, steer calves (306 ± 23 kg) in a 2×2+2 factorial treatment arrangement, with factors of corn hybrid (SYT-EFC or a conventional corn hybrid CON), corn silage kernel processed or not, and the two corn hybrids as dry-rolled corn (DRC) with grass hay. Silage was included in the diet at 80% while DRC was included in the diet at 40%, with 40% grass hay on a DM basis. Experiment two utilized four ruminally and duodenally cannulated heifers in a 4×4 replicated Latin Square design (each heifer received each treatment twice). Factors included the two silage hybrids included at 80% in the diet, either kernel processed or not. For Exp. 1, only tendencies for interactions were observed between corn silage hybrid and kernel processing ($P > 0.06$) for any performance characteristics. Feeding CON hybrid silage decreased DMI compared to SYT-EFC ($P = 0.01$). Average daily gains were similar between the two silage hybrids ($P = 0.29$), thus, G:F was greater for cattle fed the CON silage ($P < 0.01$). Kernel processing of silage decreased DMI ($P = 0.05$), increased ADG ($P = 0.03$), and G:F ($P < 0.01$). There were no statistical differences in performance characteristics when cattle were fed either CON DRC or SYT-EFC DRC with grass hay ($P \geq 0.24$). For experiment 2, no interaction ($P \geq 0.21$) and a tendency for differences in total tract digestibility between the silage hybrids or kernel processing were observed for any nutrients ($P \geq 0.07$). While heifers consuming the non-kernel processed silage had a greater ADF intake ($P < 0.01$), no digestibility differences were observed. Feeding kernel processed corn silage at 80% of diet DM in

Exp. 1 resulted in a 5.2% improvement in efficiency, suggesting the silage was improved by 6.5% (5.2/0.80) compared to non-kernel processed silage. Feeding kernel processed corn silage at high inclusions can provide a benefit to producers; however, SYT-EFC corn did not provide an improvement in cattle performance when fed as corn silage or dry-rolled corn in a forage based diet.

Key Words: amylase, corn silage, digestibility, dry-rolled corn, feedlot, growing cattle

INTRODUCTION

Inclusion of corn silage in beef cattle diets allows producers to take advantage of the entire corn plant, securing substantial tonnage of roughage and grain at maximum quality (Burken et al., 2017a). Corn silage has primarily been used as a forage source; however, it is a moderately high energy, low protein feedstuff (Allen et al., 2003). These characteristics offer producers flexibility when included in cattle growing and finishing diets. Due to the entire corn plant being harvested and ensiled, corn silage contains roughly 50% corn grain (Burken et al., 2017a), giving it a total digestible nutrients (TDN) value of 75% that of corn (NASEM, 2016).

Since the early 2000s demand for corn has increased as a result of increased ethanol usage, thus, competition for corn as a feedstuff has increased. As the price of corn increases, corn silage has been shown to be an economical roughage and energy source in feedlot diets (Goodrich et al., 1974). One limitation to feeding increased concentrations of corn silage in feedlot diets is a reduction in G:F as more corn is replaced (Goodrich et al., 1974; Erickson, 2001). Recent research suggests less of a reduction in G:F than previously observed if distillers grains plus solubles is included in diets with increased silage inclusions. Burken et al. (2017ab) observed reductions in G:F of only 5% as corn silage increased from 15 to 45% of diet DM when modified distillers grains plus solubles (MDGS) were included in the diet, compared to previous observations of an 8-10% reduction in G:F.

In order to maximize feed conversion in beef cattle, starch digestion must be optimized. A new corn hybrid, Syngenta Enogen Feed Corn (SYT-EFC; Syngenta Seeds, LLC) has been genetically enhanced to contain a thermotolerant α-amylase enzyme trait.

This enzyme becomes activated at increased temperatures, reducing the need for exogenous enzymes during the dry milling ethanol fermentation process, to convert starch to sugar. Inclusion of the enzyme may result in improved animal performance by increasing post-ruminal starch digestion. Previous research has observed an increase in G:F, and an increase in post-ruminal starch digestion when SYT-EFC was fed as DRC, compared to cattle fed corn not containing the α-amylase enzyme trait (Jolly-Breithaupt, 2018).

Therefore, the objective of these two experiments was to compare SYT-EFC corn to commercially available corn without the α-amylase enzyme trait when used as corn silage, and also how SYT-EFC grain will work in forage-based diets when fed as dry-rolled corn.

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.

Corn cultivation, harvest, and chemical composition

Two hybrids of corn silage were grown in a single irrigated field at the Eastern Nebraska Research and Extension Center (ENREC) near Mead, NE. The two hybrids included a conventional commercial corn hybrid which served as the control (CON), and Syngenta's Enogen Feed Corn (SYT-EFC; Syngenta Seeds, LLC). The SYT-EFC hybrid has been created to contain a thermotolerant and pH tolerant α-amylase enzyme. Syngenta Enogen Feed Corn has been primarily utilized by the dry milling ethanol industry. The internal enzymes become activated at increased temperatures, thus reducing

the need for the addition of α-amylase to convert starch into glucose prior to fermentation. Corn silage was harvested using a self-propelled forage harvester (JD 5400, John Deere, Moline, IL) set for a 1.27-cm theoretical chop length. Half of each hybrid type was harvested with a kernel processing unit, and half was harvested without.

Corn silage harvest initiation occurred on September 6, 2017 and continued until September 8, 2017. Harvest was targeted for approximately ¾ milkline, and whole plant corn silage samples were 37% DM, determined prior to harvest by a moisture tester (Koster Crop Tester, Inc., Brunswick, OH). Each treatment silage (4) was packed and stored in separate side-by-side 3-m diameter by 61-m long plastic silos (AgBag, St. Nazianz, WI) and allowed to ferment for 144 d prior to feeding. Pre-trial samples of each silage hybrid, dry-rolled corn, and grass hay were taken and sent off for analysis at a commercial lab. Silage samples were taken with a core sampler at various locations along the Ag-Bag®, composited, and frozen prior to analysis. Pre-trial corn silage, dry-rolled corn, and grass hay samples were analyzed for dry matter (DM), crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), and minerals at Ward Laboratories, Inc.® (Kearney, NE; Table 2.1) Additionally, weekly corn silage samples were taken from the face of each silage pile, composited, and frozen for monthly analysis (n = 4). Monthly fermentation analysis of the silage hybrids was performed by Dairy One Laboratories® (Ithaca, NY), and were averaged over the entire feeding period (Table 2.2).

Experiment 1 – Cattle Growing Experiment

An 84-d growing study, utilizing 576 crossbred, steers (initial BW = 306 kg; SD = 23 kg) was conducted at the Eastern Nebraska Research and Extension Center (ENREC) feedlot near Mead, NE. Steers were received as calves in the fall of 2017, and the trial

was conducted utilized from January to April 2018. Upon arrival into the feedlot, calves were individually identified, weighed, and vaccinated. Vaccinations were administered to aid in the prevention of bovine viral diarrhea virus Type I and II, infectious bovine rhinotracheitis, parainfluenza$_3$, bovine respiratory syncytial virus, *Mannhemia haemolytica*, and *Pasteurella multocia* (Bovi-Shield Gold 5, Zoetis, Inc.; Kalamazoo, MI), *Heamophilus somnus* (Sumobac, Zoetis, Inc.), and parasite control (Dectomax, Zoetis, Inc.). Approximately 14 d following initial vaccination, steers were revaccinated for *Heamophilus somnus* (Ultrabac-7, Zoetis, Inc.) and *Mannhemia haemolytica* (Bovi-Shield Gold One Shot, Zoetis, Inc.). Animals were mass-treated for bovine respiratory disease (Micotil, Elanco Animal Health; Greenfield, IN) and wintered on corn stalks from October 15th to trial initiation (108 d).

Steers were limit fed a diet consisting of 50% alfalfa hay and 50% Sweet Bran (Cargill Wet Milling; Blair, NE; DM basis) at 2.0% of BW for 5 consecutive days to equalize gut fill prior to initiation of the trial (Watson et al., 2013). Steers were weighed for 2 consecutive days (0 and 1) and the average of those 2 days was used to establish initial BW (Stock et al., 1983). Cattle were implanted with 36 mg Zeranol (Ralgro®, Merck Animal Health, Madison, NJ) on d 1. Steers were blocked by BW into light, medium, and heavy BW blocks (n = 2, 4, and 2 replicates, respectively) based on d 0 BW, stratified by BW within block, and assigned randomly to one of 48 pens. Pens were then assigned randomly to 1 of 6 treatments (Table 2.1), with a total of 12 steers per pen and 8 replications per treatment.

Dietary treatments (Table 2.2) were arranged in a 2 × 2 + 2 factorial, and included 1) conventional commercial corn silage with kernel processing (CON KP), 2)

CON corn silage without kernel processing (CON NKP), 3) Syngenta Enogen Feed Corn silage with kernel processing (SYT-EFC KP), 4) SYT-EFC silage without kernel processing (SYT-EFC NKP), 5) CON dry-rolled corn with grass hay (CON DRC), and 6) SYT-EFC dry-rolled corn with grass hay (SYT-EFC DRC). All of the corn silage based diets contained 80% corn silage, 15% modified distillers grains plus solubles (MDGS), and 5% supplement, all on a DM basis. The DRC based diets included corn at 40%, grass hay at 40%, MDGS at 15%, and supplement at 5% of the diet on a DM basis. Diets were formulated to meet or exceed NRC requirements for metabolizable protein (MP) and minerals (NRC, 1996). The final growing diets provided 200 mg / steer daily of Rumensin (Elanco Animal Health, Greenfield, IN).

Cattle were fed *ad libitum* and feed bunks were evaluated daily at approximately 0530 h for feed refusals, so that trace amounts of feed were left in the bunk at the time of feeding. Feed was delivered once daily at 0800 h with a truck mounted mixer and delivery unit (Roto-Mix, Dodge City, KS). All feed refusals were subsampled and dried for 48 h in a 60°C forced-air oven for determination of DM and calculation of refusal DM weight. Dietary ingredients were sampled weekly for DM analysis. As-fed dietary ingredient inclusions were adjusted weekly. Ending BW was determined similar to initial BW. Steers were limit fed a diet consisting of 50% alfalfa hay and 50% Sweet Bran (Cargill; Blair, NE) at 2.0% BW for 5 consecutive days and weighed 2 consecutive days. Ending BW was determined by averaging the 2-d weights.

The energy value of the dietary treatments were calculated using pen data in the Galyean (2009) Net Energy calculator based on the NRC (1996) equations. Calculated energy values utilized the heaviest final BW of each block and the individual initial BW,

DMI, and ADG of each pen, with a target endpoint of USDA Choice. Feeding values were calculated based on G:F using the following equation: $(((G{:}F_{TRT} – G{:}F_{CON}) / G{:}F_{CON}) / \text{corn silage inclusion, \%}) * 100$. Feed efficiency of the SYT-EFC hybrid is denoted $G{:}F_{TRT}$, while $G{:}F_{CON}$ represents the feed efficiency of the control hybrid.

Performance (BW, DMI, ADG, G:F, and energy value) data were analyzed using the MIXED procedure of SAS (SAS Inst., Inc., Cary, N.C.) with pen as the experimental unit. Data were analyzed as a 2 × 2 + 2 factorial. Within corn silage treatments, the interaction was tested between corn trait and kernel processing. If no interaction was detected, then main effects are discussed. If an interaction occurred, then simple effects of kernel processing within corn silage trait will are discussed. A preplanned pairwise comparison was made between hybrids when fed at 40% of the diet as DRC. Significance was declared at $P < 0.05$, and tendencies were considered between $P > 0.05$ and $P \leq 0.10$.

Experiment 2 – Cattle Digestion Experiment

A 112-d digestion study was conducted to evaluate the effects corn hybrid and kernel processing of corn silage on extent of digestion and rumen parameters in growing beef cattle diets. Both SYT-EFC and CON corn hybrids were from the same corn crop utilized in Exp. 1. Four ruminally and duodenally cannulated heifers were utilized in a 4 × 4 replicated Latin Square design. Using four heifers in a 4 × 4 design allowed for eight observations per treatment. The study consisted of eight periods that were 14 d in length with a 9 d adaptation period and a 5 d collection period. Heifers were housed in individual 3.7 m × 1.8 m, rubber slatted floor pens. Heifers were assigned randomly to the same four corn silage growing diets as described in Exp. 1 (CON KP, CON NKP,

SYT-EFC KP, and SYT-EFC NKP; Table 2.2). The final growing diets provided 200 mg / heifer daily of Rumensin (Elanco Animal Health, Greenfield, IN).

Diets were mixed twice weekly and stored in a cooler held at 4°C to ensure fresh feed was maintained. Heifers were fed once daily at 0800 h and had *ad libitum* access to feed and water. Individual ingredient samples were collected at the time of mixing, were composited by period, freeze dried (Virtis Freezemobile 25ES, SP industries, Warminster, PA), and ground through a 1-mm screen using a Wiley Mill (No. 4, Thomas Scientific, Swedesboro, NJ). Ingredients offered were analyzed for dry matter (DM; AOAC, 1999, Method 4.1.03), organic matter (OM; AOAC, 1999, Method 4.1.10), crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), starch (Megazyme International, AOAC International, 2000; Method 996.11; AACC Method 76.13), fat, and gross energy (GE). Ash was evaluated by placing samples in a muffle furnace for 6 h at 600°C. Crude protein was determined using a combustion-type N analyzer (FlashSmart N/Protein Analyzer, CE Elantech, Inc., Lakewood, NJ). Neutral detergent fiber was determined using the procedure described by Van Soest et al. (1991), using α-amylase and sodium sulfite, with modifications described by Buckner et al. (2011) for MDGS. Acid detergent fiber content was determined using the procedure described by Van Soest (1963). Furthermore, lipid content was determined by a biphasic lipid extraction processes (Bremer et al., 2010). Finally, gross energy of ingredient and fecal samples was determined utilizing bomb calorimetry (Parr 6400 Automatic Isoperibol Calorimeter, Parr Instrument Co., Moline, IL). These gross energy values were used to calculate digestible energy (DE), by subtracting fecal energy from total energy intake, calculated from the ingredient GE and DMI. Corn silage was sent to a commercial

lab for fermentation analysis, and four samples based on monthly composites as well as a pre-trial composite were sent for analysis at a commercial laboratory (Dairy One Labs, Ithaca, NY; Mertens, 2005; Table 2.2).

Titanium dioxide was dosed ruminally twice daily at 0700 and 1900 h at a rate of 7.5 g / heifer for the duration of the trial. Fecal grab samples, approximately 250 g each, were collected d 10 through d 13, four times daily at 0700, 1100, 1500, and 1900 h. Individual fecal samples were composited by day on a wet weight basis and lyophilized (Virtis Freezemobile 25ES, SP industries, Warminster, PA). Daily fecal composites were then composited by heifer within period to create a period composite from the freeze-dried samples. Period fecal composite samples were analyzed for DM, OM, NDF, ADF, starch, and gross energy using the same procedures described above. Furthermore, fecal samples were analyzed for titanium dioxide concentration (Spectra MAX 250, Molecular Devices, LLC, Sunnyvale, CA; Myers et al., 2004). Concentration of TiO_2 was then used to calculate fecal DM output using the following equation: [(g TiO_2 dosed per d) / (concentration of TiO_2 in feces)] (Meyers et al., 2004).Total tract digestibility was calculated using the following equation: [(kg of nutrient fed – kg of nutrient refused – kg of nutrient in feces) / (kg of nutrient fed – kg of nutrient refused)] × 100.

Wireless ruminal pH probes were inserted into the rumen on d 7 at 1500 h and recorded ruminal pH every minute until removed on d 14 at 1500 h (Dascor, Inc., Escondido, CA). Rumen pH data were analyzed for days 10 through 13 to capture the collection period, and get four full days of rumen pH measurements. Rumen fluid samples were taken on d 10 through d 13 at 0700, 1100, 1500, and 1900 h, and were

analyzed for ruminal volatile fatty acid profiles (VFA; Trace 1300, Thermo Fisher Scientific, Inc., Waltham, MA) using procedures outlined by Ehrlich et al. (1981).

In situ NDF digestibility of each of the corn silages in the rumen was evaluated. Dacron bags (5 cm × 10 cm Ankom *in situ* bags (R150) with a 50 μm pore size; Ankom Technology, Macedon, NY) were filled with 1.25 g of one of the four experimental corn silages utilized in the experiment, or dry corn bran (Cargill Wet Milling, Blair, NE) that had been lyophilized (Virtis Freezemobile 25ES, SP industries, Warminster, PA). All samples were ground through a 2 mm screen using a Wiley Mill (No. 4, Thomas Scientific, Swedesboro, NJ) before being weighed into the Dacron *in situ* bags. On d 13, four bags of each feed type were placed in mesh bags with weights to keep samples in the ventral sac of the rumen, and incubated in the rumen of each heifer for a period of 24 hours. Bags were removed at the same time (1500 h) on d 14. Additionally, four bags of each feed type were not incubated to provide a zero hour or no incubation sample. All bags, in addition to the zero hour bags, were rinsed five times in a washing machine (39°C), through a 1-minute agitation and 2-minute spin cycle (Whittet et al., 2002), and then frozen prior to analysis. Prior to analysis, bags were rinsed with distilled water. Neutral detergent fiber disappearance was determined for corn silage and bran samples by refluxing bags in neutral detergent solution with α-amylase and sodium sulfite, in an ANKOM 200 Fiber Analyzer (ANKOM Technology). Bags were agitated in NDF solution for 1 h at 100°C and then rinsed with distilled water for five minutes, four separate times. Neutral detergent fiber disappearance of the corn bran and experimental corn silage samples were calculated by subtracting the remaining residue after 24 h of

incubation from the initial NDF sample value minus any washout from the zero time point sample bags, and dividing by the original NDF of the sample.

Total tract nutrient intake, excretion, and digestibility data were analyzed using the MIXED procedure of SAS (SAS Inst., Inc., Cary, N.C.), with period and treatment as fixed effects, and heifer within period as a random effect. The interaction effect between corn silage hybrid and kernel processing was analyzed prior to analysis of main effects of either corn silage hybrid or kernel processing. In-situ data were analyzed using the MIXED procedure of SAS, with heifer within period as a random effect, and treatment fed and ingredient incubated analyzed as fixed effects. Ruminal pH data were analyzed using the MIXED procedure of SAS with day as the repeated measure. Treatments were considered fixed effects and heifer within period was considered a random effect. Volatile fatty acid data were analyzed using the MIXED procedure of SAS with heifer within period a random effect and time and treatment as fixed effects. Treatment differences were considered significant when $P \leq 0.05$. A tendency was declared when $P > 0.05$ and $P \leq 0.10$.

RESULTS AND DISCUSSION

Corn Silage

Corn silage was targeted to be harvested at 37% DM (Table 2.1). Fermentation analysis shows the four silage samples had a pH at or below 4.1, indicating proper fermentation. Total acids for the CON silage were greater than 7.12% and were greater than 5.79% for the SYT-EFC silage. Acid detergent fiber and neutral detergent fiber were numerically lower for the SYT-EFC KP silage. Additionally, starch was numerically lower for the SYT-EFC NKP silage, and greatest for the SYT-EFC KP silage, with the

CON hybrid silages falling intermediate. Differences in starch are likely due to increased availability with kernel processing of the corn silage.

Experiment 1 – Cattle Growing Experiment

Corn Silage Hybrids

There were no interactions between corn silage hybrid and kernel processing for ending BW, ADG, or G:F ($P \geq 0.19$; Table 2.3). An interaction was observed between corn silage hybrid and kernel processing for initial BW ($P = 0.03$) which was due to very small differences in BW (less than 1 kg between treatments) when assigned. Additionally, a tendency for an interaction between hybrid and kernel processing was observed for DMI ($P = 0.06$) where cattle fed CON silage tended to have reduced DMI when silage was kernel processed, but no change in DMI was observed due to kernel processing for the SYT-EFC silage hybrid. Net energy of the diet was calculated from the performance data. A tendency for a corn silage hybrid × kernel processing interaction was observed for both net energy available for maintenance and for gain ($P \leq 0.07$). Control hybrid silage tended to have greater net energy available when kernel processed, but no difference was observed due to kernel processing for the SYT-EFC silage hybrid.

For the main effects of corn silage hybrid (Table 2.4), ADG between the two hybrids was similar, with cattle on the CON silage averaging 1.73 kg / d and cattle fed the SYT-EFC silage averaging 1.71 kg / d ($P = 0.29$). Due to the tendency for an interaction on DMI, resulting in a reduction when fed CON KP, steers fed the CON silage had a greater G:F at 0.1807 compared to SYT-EFC at 0.1737 ($P < 0.01$). Previous research evaluating supplementation of exogenous α-amylase observed an increase in ADG (Burroughs et al., 1960; Jolly-Breithaupt, 2018; and Tricarico et al., 2007), with

increased DMI and G:F (Jolly-Breithaupt, 2018). However, other studies have observed contradicting results, with no differences in DMI, ADG, or G:F (Tricarico et al., 2007; and DiLorenzo et al., 2011) when α-amylase was supplemented.

Ensiling of α-amylase containing corn, such as SYT-EFC silage, may result in the amylase enzyme being degraded by microbial populations prior to utilization by the animal. Enzymes are proteins that are produced by living cells, and act to catalyze biochemical reactions. Previous research by Benton et al., (2005) evaluated the impact of ensiling corn on ruminal degradable protein (RDP) content and observed a linear increase in RDP as the length of the ensiling period increased. Therefore, it is possible that as a result of increased RDP, the α-amylase enzyme within the corn itself is degraded within the rumen by the microbial population. When corn silage is harvested the kernel is typically 60 to 70% DM; however, during ensiling, the grain will absorb moisture, becoming similar to HMC. Furthermore, ensiling corn grain disrupts the starch containing endosperm, increasing the availability of starch during ruminal fermentation (Huntington et al., 2006). Thus, starch present in corn silage is rapidly degraded in the rumen, resulting in little bypassing to the small intestine for digestion by the animal. Ensiling of SYT-EFC hybrids likely results in little α-amylase enzyme and starch available for post-ruminal digestion by the animal.

Kernel Processing

For the main effect of kernel processing, steers fed kernel processed silage tended to have greater ending weights than steers fed silage that was not processed (453 vs. 449 kg; $P = 0.06$; Table 2.5). Additionally, cattle fed kernel processed silage had lower DMI (0.30 kg / d less) than those fed silage that was not processed ($P = 0.05$). The effect of

kernel processing on DMI has been variable, based on the maturity of the corn silage at the time of harvest. Studies by Bal et al. (2000) saw an increase in DMI by 0.6 kg / d ($P <$ 0.01) due to kernel processing when fed at 67% of the diet to lactating dairy cattle. Bal et al. (2000) evaluated the impacts of kernel processing silage that had been harvested at 50% milkline, whereas the current study utilized silage that was more mature at ¾ milkline and 37% DM. Furthermore, heifers consuming a diet including corn silage (31% DM) at 61% of the diet displayed no difference in intake due to kernel processing in a study conducted by ZoBell et al. (2002).

In the current study, ADG was greater for steers fed silage with kernel processing (1.75 kg / d) than steers fed silage that had not been processed (1.70 kg / d; $P = 0.03$). Due to decreased DMI, and increased ADG, G:F was greater for cattle fed kernel processed silage (0.1817 vs. 0.1727; $P < 0.01$). Kernel processing corn silage when fed at 80% of the diet appears to have a positive effect on G:F of growing steers, when compared to non-kernel processed silages. Feeding kernel processed corn silage resulted in a 5.2% improvement in efficiency when diets included silage at 80%, suggesting the silage was improved by 6.5% (5.2 / 0.80) compared to not kernel processing silage. Reduction in dry matter intake and an increase in average daily gain in the current study indicates cattle were obtaining more energy from the kernel processed silage, and ate to a metabolic endpoint, instead of to gut fill.

Dry-rolled corn and grass hay

Control and SYT-EFC DRC when included at 40% of the diet with 40% grass hay were not statistically different from one another for any of the performance characteristics measured ($P \geq 0.24$; Table 2.3). Cattle fed SYT-EFC DRC had

numerically lower DMI (0.20 kg / d less) than those fed CON DRC (*P* = 0.24). With no differences in ADG (*P* = 0.92), G:F was numerically greater for the cattle fed SYT-EFC DRC (0.1444) than those fed CON DRC (0.1419; *P* = 0.37). Gain to feed was increased by 1.8% when diets included the SYT-EFC hybrid as dry-rolled corn at 40%, suggesting a 4.5% improvement (1.8 / 0.40) compared to the control hybrid, although not significant. Previous research evaluating the effect of SYT-EFC processed as DRC in finishing diets, and as the sole grain source in the diet observed an increase in G:F when compared to commercially available corn (Jolly-Breithaupt, 2018). Jolly-Breithaupt (2018) also observed an increase in feed efficiency of 5.7% when SYT-EFC DRC was fed with wet distillers grains plus solubles (WDGS) compared to commercially available corn. However, Schoonmaker et al. (2014) included SYT-EFC as ground corn at either 10 or 20% of the diet, with 45.2% rolled corn, 20% WDGS, and 12% bromegrass hay. The authors reported no differences in ADG or G:F when SYT-EFC was fed as ground corn at either 10 or 20% of the diet (Schoonmaker et al., 2014). Nonetheless, previous research evaluating feeding an exogenous α-amylase enzyme has observed either an increase in ADG, DMI, and G:F (Burroughs et al., 1960; Jolly-Breithaupt, 2018; Tricarico et al., 2007) or no difference in any of the performance characteristics (Tricarico et al., 2007; and DiLorenzo et al., 2011). Although not significant, DiLorenzo et al. (2011) observed a 9.5% improvement in G:F when α-amylase was included in DRC based diets (Rumistar; DSM Nutritional Products Inc., Kaiseraugust, Switzerland). Regardless of a numerical improvement, the current trial suggests that SYT-EFC had no statistical benefit over the CON when fed as dry-rolled corn in forage based growing diets.

Experiment 2 - Cattle Digestion Experiment

There were significant corn silage hybrid by kernel processing interactions on apparent total tract nutrient intake, fecal output, or digestibility for DM, OM, or NDF ($P \geq 0.23$). Unlike in Exp. 1, dry matter intake across corn silage hybrids was not different ($P = 0.99$; Table 2.7), and was unaffected by kernel processing ($P = 0.82$; Table 2.8). However, a hybrid by processing interaction was observed for ADF intake, where heifers consuming SYT-EFC KP consumed less ADF ($P = 0.03$). This reduction in ADF intake is likely due to a lower concentration of ADF in the SYT-EFC KP silage compared to the SYT-EFC NKP or either CON hybrid silages. Despite the decrease in intake, no interactions were observed for ADF fecal output, or total tract ADF digestibility ($P \geq 0.22$), although, numerically SYT-EFC KP had the lowest ADF digestibility of the four silages.

Additionally, a corn silage hybrid by kernel processing interaction was observed for starch intake ($P = 0.02$). Heifers fed the SYT-EFC KP silage consumed significantly more starch (2.78 kg / d) than the unprocessed SYT-EFC silage (2.42 kg / d) with the CON KP and NKP silages falling intermediate (2.52 and 2.54 kg / d; respectively). In contrast to the ADF concentration, the SYT-EFC KP silage contained the greatest proportion of starch (38.03%), whereas the SYT-EFC NKP silage contained the least (32.55%). Similarly to ADF, despite the increase in starch intake, no differences were observed for fecal starch output or total tract starch digestibility ($P \geq 0.21$).

Corn Silage Hybrids

Corn silage hybrid had no effect on DM, OM, or starch intake ($P \geq 0.47$; Table 2.7). These results are similar to those found by Jolly-Breithaupt (2018), when evaluating

digestibility of SYT-EFC and control (NEG) hybrids fed as dry-rolled corn with MDGS in finishing diets ($P \geq 0.15$). Furthermore, in the current study, no differences were observed for fecal output of DM, OM, or starch ($P \geq 0.38$). Fecal OM excretion was significantly different as observed by Jolly-Breithaupt (2018), where cattle fed SYT-EFC excreted 25.8% less OM compared to NEG, suggesting a greater extent of OM digestion ($P = 0.05$). Jolly-Breithaupt (2018) also observed less fecal starch output when feeding the SYT-EFC hybrid ($P = 0.01$). Post-ruminal digestion was increased in cattle fed SYT-EFC, resulting in greater total tract DM, OM, and starch digestibility compared to a control ($P \leq 0.08$; Jolly-Breithaupt, 2018).

A tendency for a main effect of corn silage hybrid was observed for NDF intake ($P = 0.10$), where heifers consuming CON hybrid silage (3.65 kg / d) had a greater NDF intake compared to SYT-EFC (3.46 kg / d). Corn hybrid did not change NDF excreted ($P = 0.59$), thus, total tract NDF digestibility was not different based on corn silage hybrid ($P = 0.77$). Furthermore, a tendency for a difference in ADF intake was observed, with the CON silage hybrid increasing fiber intake ($P = 0.08$); however, excretion was not different ($P = 0.85$). Although not statistically different, ADF digestibility was 3 percentage units greater when heifers were fed CON (39.7%) silage compared to SYT-EFC (36.7%) silage.

No differences were observed for starch intake, excretion, and total tract starch digestion due to the corn silage hybrids ($P \geq 0.23$). Jolly-Breithaupt (2018) observed an increase in total tract starch digestion from 90.0% when their control was fed to 93.8% when SYT-EFC was fed with either MDGS or Sweet Bran ($P = 0.01$). An improvement in live animal performance was also reported when finishing cattle were fed DRC based

diets with SYT-EFC hybrid, likely due to the increase in total tract starch digestion observed by Jolly-Breithaupt (2018). Previous research has observed conflicting results when evaluating the effect of supplemental α-amylase on total tract nutrient digestibility. Hristov et al., (2008) observed no differences in DM, OM, or starch total tract digestibility when lactating dairy cows were fed a control diet or an amylase containing supplement. In contrast, lambs fed supplemental α-amylase from *Bacillus licheniformis* had a quadratic increase in total tract digestibility for DM ($P = 0.03$), OM ($P = 0.04$), and starch ($P = 0.05$; Rojo et al., 2005).

Kernel Processing

The main effects of kernel processing on nutrient intake, excretion, and digestibility are presented in Table 2.8. Kernel processing of the corn silages did not impact DM intake, excretion, or DM digestibility ($P \geq 0.34$). Furthermore, OM intake, excretion, and digestibility were significantly different when the corn silages were kernel processed ($P \geq 0.34$). Previous research evaluating DM and OM digestibility of kernel processed corn silages showed no differences in apparent total tract nutrient digestibility, when silage was included in the diet at 55% (DM basis; ZoBell et al., 2002). Nonetheless, Wilkinson et al. (1978) fed corn silage *ad libitum*, observing an increase in DM digestibility of 1.8% when corn silage was kernel processed.

A main effect of kernel processing was observed for neutral detergent fiber intake ($P = 0.04$), where NDF intake was lower for the kernel processed treatments. Fecal NDF excretion was not different ($P = 0.55$), resulting in only a numerical reduction in apparent NDF digestibility for the kernel processed silages compared to non-kernel processed (45.5 vs 50.8%; $P = 0.12$). The numerical decrease in NDF digestibility is in contrast to

results observed by ZoBell et al. (2002), who observed an increase in NDF digestibility and no change in ADG ($P = 0.39$) or DMI ($P = 0.33$) when feeding kernel processed corn silages. Furthermore, previous research evaluating the effects of kernel processing corn silage has observed improvements in NDF digestibility (Cooke and Bernard, 2005; and Johnson et al., 2003). In the current study, intake of ADF was lower for the kernel processed silages ($P < 0.01$); however, there was no difference in ADF excretion ($P = 0.76$), resulting in a tendency for a decrease in ADF digestibility when kernel processed (34.4 vs 42.0%; $P = 0.07$). Similarly, Andrae et al. (2001) included corn silage at 60% (DM basis) in a finishing ration, and observed a reduction in NDF and ADF digestibility ($P < 0.01$), along with an improvement in starch digestibility ($P < 0.01$), with no difference in DM digestibility ($P = 0.11$). Johnson et al. (2003; exp. 1) and Bal et al. (2000) observed no change in NDF digestibility due to kernel processing; however, when processing was used Bal et al. (2000) observed a reduction in ADF total tract digestibility ($P < 0.01$). Kernel processing of corn silages in previous research has presented conflicting results. This has largely been attributed to differences in cattle sorting the diet, and an increase in passage rate, decreasing the exposure of the fiber particles to fibrolytic bacteria. It is also speculated that improvements in starch digestion in the rumen result in a less hospitable environment for the fibrolytic bacteria (Andrae et al., 2001). No diet sorting was observed in the current study; however, increased passage rate may contribute to some of the differences in digestibility.

A tendency for increased starch intake was observed for the kernel processed silages ($P = 0.06$). Starch intake ranged from 2.65 kg / d for kernel processed silages to 2.49 kg / d for unprocessed silages. This difference in intake is likely due to the kernel

processed silages possessing a greater starch content (Table 2.1). Fecal starch output was not different ($P = 0.25$), resulting in no change to total tract starch digestibility when kernel processing was applied (94.3 vs 94.9%; $P = 0.36$). This is in contrast to previous research which observed a 3.5 percentage units improvement in starch digestion when corn silage was kernel processed (Dhiman et al., 2002). No differences in starch digestibility imply that improvements in ruminal starch digestion did not inhibit the digestibility of neutral or acid detergent fiber.

Energy Intake

No significant corn hybrid by kernel processing interactions were observed for gross energy (GE) intake, GE excreted, or digestible energy (DE) ($P \geq 0.31$; Table 2.6). Corn silage was included at 80% in all diets, and was the only dietary ingredient changed among treatments. Therefore, due to no differences in gross or digestible energy, the energetic densities of the corn silages were similar. While not statistically different, when DE was measured as Mcal / kg of diet consumed, a numerical increase in DE was observed for the SYT-EFC hybrid diets compared to the CON (3.81 vs. 3.60 Mcal / kg; $P = 0.39$; Table 2.7). A similar numerical increase in DE was observed when evaluating the effect of kernel processing the silages, where the non-kernel processed silage possessed greater DE than the kernel processed corn silage (3.76 vs. 3.65 Mcal / kg; $P = 0.67$; Table 2.8). The numerical increase in DE for both the main effect of corn hybrid and kernel processing agrees with the numerical increase in DM and OM digestibility data, which were not statistically different ($P \geq 0.32$; Table 2.6). However, none of the digestibility measures were significant in Experiment 2. This difference contradicts the reduction in

performance response observed in Experiment 1, where cattle fed the SYT-EFC hybrid and non-kernel processed silage were out performed by their counterparts (Table 2.3).

In Situ

In the *in situ* experiment, there were no interactions between the ingredient incubated in the rumen, and corn silage hybrid by kernel processing treatment ($P \geq 0.96$; Table 2.9). Furthermore, when evaluating the NDF disappearance of each individual ingredient incubated in the rumen for 24 h, no effect of dietary treatment was observed ($P \geq 0.15$). Neutral detergent fiber disappearance (NDFD) for ingredients was lower when incubated in heifers consuming SYT-EFC silages; however, this reduction is not statistically different from heifers consuming the CON silages. Burken et al. (2017b) evaluated *in situ* NDFD after a 30 h incubation for corn silage that was harvested at ½ milkline, and observed a NDFD of approximately 35%. Furthermore, as corn silage maturity increased, NDFD of the silage at 30 h decreased to approximately 25% (Burken et al., 2017b), which is still greater than, although more similar to the NDFD observed in the current trial. Frequently, corn bran is used as a fiber fermentation indicator, to determine the rumen environment influences due to differences in dietary treatments the ingredient is incubated in (Burken et al., 2017b). Corn bran that has been incubated for either 24 or 30 hours has typically observed NDFD ranges from 36 to 49%, whereas, the current trial observed an average NDFD of 33.5% when incubated for 24 h.

Ruminal pH

No significant corn silage hybrid by kernel processing interactions were observed for any of the ruminal pH variables measured ($P \geq 0.12$; Table 2.10). Maximum pH was

significantly lower for heifers on the non-kernel processed treatments as compared to kernel processing of the silages ($P = 0.05$). Furthermore, no differences between treatments were observed for average ruminal pH ($P \geq 0.12$). However, the SYT-EFC hybrid treatments resulted in significantly lower minimum pH compared to CON ($P < 0.01$). Similarly, the SYT-EFC hybrid silage treatments resulted in greater pH variation, compared to heifers consuming the CON silages ($P = 0.05$). The CON treatment tended to have a greater amount of time (minutes) with a pH below 5.6 per day ($P = 0.09$); however, there was no difference in the area below 5.6 among treatments ($P \geq 0.40$).

VFA Concentration

No interactions between corn silage hybrid and kernel processing were observed for any of the VFA concentration parameters measured ($P \geq 0.14$; Table 2.10). Total VFA concentration was not impacted by corn hybrid or kernel processing treatments ($P \geq 0.18$). However, acetate concentration as a percentage of total VFA concentration was significantly lower for heifers consuming the SYT-EFC hybrid silage ($P = 0.02$), as well as when corn silage was not kernel processed ($P = 0.04$). Proportions of propionate and butyrate were unaffected by either corn silage hybrid or kernel processing treatments ($P \geq 0.24$). Differences in acetate concentration, with no difference in propionate concentration resulted in a lower acetate : propionate ratio when SYT-EFC hybrid silages were fed ($P = 0.02$).

Our results suggest that feeding growing cattle Syngenta Enogen Feed Corn silages does not improve any of the performance or digestibility characteristics when compared to a traditional corn silage hybrid, when fed at 80% of the diet. In Exp. 1, traditional corn silage had lower DMI, similar ADG, and greater G:F compared to SYT-

EFC. Using kernel processing in corn silage did not interact with the corn hybrid type. However, kernel processing silages resulted in heaver ending BW, deceased DMI, increased ADG, and thus, improved G:F compared to non-kernel processed silages. Furthermore, in Exp. 1, feeding growing cattle Syngenta Enogen Feed Corn as dry-rolled corn did not have any effect on performance characteristics when compared to traditional dry-rolled corn, when fed at 40% of the diet with 40% grass hay. Furthermore, results from the digestibility trial (Exp. 2) suggested no differences in digestibility due to corn silage hybrids or the use of kernel processing. While heifers consuming the kernel processed silage had a greater starch intake, no differences were observed for total tract starch digestibility when compared to non-kernel processed silages. In the feedlot trial, kernel processing improved feed efficiency by 5.2% when fed at 80% inclusion (DM), suggesting a 6.5% improvement in the silage as a feed (5.2 / 0.8). This improvement in the value of corn silage due to kernel processing may offset the additional costs associated with processing the corn at harvest. When corn silage is included at elevated levels in growing diets, kernel processing silage can provide a benefit to producers; however, the same response was not observed when corn containing an α-amylase was utilized.

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Table 2.1. Nutrient and fermentation analysis of corn silage hybrids (DM basis; Exp. 1)

	CON[1]		SYT-EFC[2]	
Item	KP	NKP	KP	NKP
DM at harvest	37.37	38.70	38.78	37.75
DM	35.48	35.85	36.78	36.08
CP	8.08	8.23	8.13	8.05
NDF, %	38.83	41.96	36.17	39.11
ADF, %	25.92	26.51	22.11	26.94
Starch, %	34.24	34.57	38.03	32.55
pH	4.03	4.08	4.13	4.03
Lactic Acid, %	3.99	3.57	4.14	4.22
Acetic Acid, %	3.06	3.05	1.74	1.35
Propionic Acid, %	0.41	0.46	0.24	0.17
Butyric Acid, %	0.02	0.04	0.03	0.04
Total Acids, %	7.49	7.12	6.15	5.79

[1]CON = Commercially available corn grain without the alpha amylase enzyme trait.
[2]SYT-EFC = Syngenta Enogen Feed corn provided by Syngenta under identity-preserved procedures, stored, processed as corn silage.
Note: Fermentation analysis in this table are from monthly composited silage samples (n=6). Sample analysis was performed at Dairy One® (Ithaca, NY). All values are presented on a DM basis.
DM at harvest from green cop samples taken at harvest.

Table 2.2. Dietary treatment compositions (% DM basis) to evaluate corn hybrid and kernel processing on growing cattle performance (Exp. 1)

	Treatments[1]					
	Corn Silage				Dry-rolled Corn	
	CON		SYT-EFC		CON	SYT-EFC
Ingredient, % DM	KP	NKP	KP	NKP	-	-
CON KP Corn Silage	80	-	-	-	-	-
CON NKP Corn Silage	-	80	-	-	-	-
SYT-EFC KP Corn Silage	-	-	80	-	-	-
SYT-EFC NKP Corn Silage	-	-	-	80	-	-
CON Dry-rolled Corn	-	-	-	-	40	-
SYT-EFC Dry-rolled Corn	-	-	-	-	-	40
Grass Hay	-	-	-	-	40	40
MDGS[2]	15	15	15	15	15	15
Supplement[3]						
Fine Ground Corn	2.099	2.099	2.099	2.099	2.099	2.099
Limestone	1.5	1.5	1.5	1.5	1.5	1.5
Urea	0.9	0.9	0.9	0.9	0.9	0.9
Salt	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
Beef Trace Mineral[4]	0.05	0.05	0.05	0.05	0.05	0.05
Vitamin ADE[5]	0.015	0.015	0.015	0.015	0.015	0.015
Rumensin 90[6]	0.011	0.011	0.011	0.011	0.011	0.011
Nutrient Composition[7]						
NDF, %	41.6	44.1	39.5	41.8	39.0	39.8
ADF, %	23.3	23.7	20.2	24.1	20.1	20.1
CP, %	13.1	13.7	13.0	13.4	15.2	15.2
Starch, %	29.7	29.9	32.7	28.3	30.9	29.8

[1]Treatments were corn silage hybrids: CON = commercially available corn grain without the alpha amylase enzyme trait, SYT-EFC = Syngenta Enogen Feed Corn provided by Syngenta under identity-preserved procedures; KP = kernel processed, NKP = not kernel processed.
[2]MDGS = Modified distillers grains plus solubles.
[3]Supplement formulated to be fed at 5% of diet DM.
[4]Premix contained 6.0% Zn, 5.0% Fe, 4.0% Mn, 2.0% Cu, 0.29% Mg, 0.2% I, 0.05% Co.
[5]Premix contained 30,000 IU vitamin A, 6,000 IU vitamin D, 7.5 IU vitamin per gram.
[6]Formulated to provide 22.0 mg/kg Monensin (Rumensin-90®; Elanco Animal Health, Indianapolis, IN).
[7]Based on monthly composites, analyzed nutrients for each ingredient. Sample analysis was performed at Ward Laboratories (Kearney, NE). All values presented on a DM basis.

Table 2.3. Effect of corn silage hybrid and kernel processing on growing cattle performance (Exp. 1)

	Corn Silage[7]				Dry-rolled Corn[8]			*P*-Values				
	CON[1]		SYT-EFC[2]		CON[1]	SYT-EFC[2]	SEM	F-Test	Hybrid[3]	Kernel[4]	Int.[5]	SYT-EFC as DRC[6]
Item	KP	NKP	KP	NKP	-	-						
Initial BW, kg	306	307	307	306	307	307	0.4	0.28	0.48	0.79	0.03	0.87
Ending BW, kg	452[a]	450[ab]	453[ab]	446[abc]	439[c]	439[bc]	2.1	<0.01	0.47	0.06	0.28	0.96
DMI, kg/d	9.4[c]	9.8[b]	9.9[b]	9.8[b]	11.2[a]	11.0[a]	0.12	<0.01	0.01	0.05	0.06	0.24
ADG, kg	1.74[a]	1.71[ab]	1.74[ab]	1.67[abc]	1.58[c]	1.58[bc]	0.027	<0.01	0.29	0.03	0.46	0.92
Gain:Feed	0.1864[a]	0.1747[ab]	0.1768[b]	0.1703[b]	0.1419[c]	0.1444[c]	0.00120	<0.01	<0.01	<0.01	0.19	0.37
NEm, Mcal/kg	1.42[a]	1.35[b]	1.36[b]	1.34[b]	1.18[c]	1.19[c]	0.010	<0.01	<0.01	<0.01	0.06	0.43
NEg, Mcal/kg	0.83[a]	0.78[b]	0.78[b]	0.76[b]	0.63[c]	0.64[c]	0.009	<0.01	<0.01	<0.01	0.07	0.43

[abc] Means with different superscripts differ (*P*-value ≤ 0.05).
[1]CON= Commercially available corn grain without the alpha amylase enzyme trait
[2]SYT-EFC = Syngenta Enogen Feed Corn provided by Syngenta under identity-preserved procedures, stored, processed as corn silage.
[3]Effect of corn silage variety.
[4]Effect of kernel processing.
[5]Interaction effects of corn silage and kernel processing.
[6]Pairwise comparison of SYT-EFC and CON processed as DRC.
[7]Corn silage included in the diet at 80%, 15% MDGS, 5% supplement.
[8]Dry-rolled corn included in the diet at 40% with 40% grass hay, 15% MDGS, and 5% supplement.

Table 2.4. Main effect of corn silage hybrid on growing cattle performance (Exp. 1)

	Treatment			
Item	CON[1]	SYT-EFC[2]	SEM	*P*-value[3]
Pens	16	16		
Initial BW, kg	306	306	0.3	0.48
Ending BW, kg	452	450	1.3	0.37
DMI, kg/d	9.6	9.9	0.07	0.01
ADG, kg	1.73	1.71	0.014	0.29
Gain:Feed	0.1807	0.1737	0.00152	<0.01

[1]CON= Commercially available corn hybrid without the alpha amylase enzyme trait, processed as corn silage
[2]SYT-EFC = Syngenta Enogen Feed Corn provided by Syngenta under identity-preserved procedures, stored and processed as corn silage.
[3]*P*-value for the main effect of corn silage hybrid.

Table 2.5. Main effect of kernel processing on growing cattle performance (Exp. 1)

	Treatment[1]			
Item	KP	NKP	SEM	*P*-value[2]
Pens	16	16		
Initial BW, kg	306	306	0.3	0.79
Ending BW, kg	453	449	1.3	0.06
DMI, kg/d	9.6	9.9	0.07	0.05
ADG, kg	1.75	1.70	0.014	0.03
Gain:Feed	0.1817	0.1727	0.00152	<0.01

[1]Treatments were kernel processed (+KP) or not kernel processed (-KP) as corn silage was harvested
[2]*P*-value for the main effect of kernel processing

Table 2.6. Effect of corn silage hybrid and kernel processing on intake and digestibility of nutrients in growing cattle diets (Exp. 2)

	Treatments[1]					*P*-value[2]			
	CON		SYT-EFC						
Item	KP	NKP	KP	NKP	SEM	F-Test	Hybrid	Kernel	Int.
DM									
Intake, kg / d	8.50	8.50	8.51	8.55	0.266	1.00	0.99	0.82	0.95
Excreted, kg / d	3.70	3.35	3.26	3.35	0.030	0.45	0.38	0.47	0.26
Digestibility, %	56.7	60.6	61.5	61.4	2.6	0.40	0.34	0.34	0.30
OM									
Intake, kg / d	7.96	7.91	7.95	7.96	0.247	1.00	0.95	0.94	0.98
Excreted, kg / d	3.19	2.89	2.83	2.91	0.203	0.51	0.45	0.48	0.27
Digestibility, %	60.1	63.4	64.2	64.0	2.4	0.50	0.41	0.34	0.32
NDF									
Intake, kg / d	3.53	3.74	3.36	3.57	0.109	0.11	0.10	0.04	0.90
Excreted, kg / d	1.98	1.81	1.79	1.85	0.149	0.58	0.59	0.55	0.23
Digestibility, %	44.4	51.5	46.6	48.7	3.8	0.42	0.77	0.12	0.33
ADF									
Intake, kg / d	1.99[a]	2.03[a]	1.73[b]	2.07[a]	0.062	<0.01	0.08	<0.01	0.03
Excreted, kg / d	1.28	1.17	1.17	1.24	0.083	0.63	0.85	0.76	0.22
Digestibility, %	36.1	42.2	32.7	40.7	4.0	0.30	0.46	0.07	0.92
Starch									
Intake, kg / d	2.52[b]	2.54[ab]	2.78[a]	2.42[b]	0.080	0.03	0.47	0.06	0.02
Excreted, kg / d	0.17	0.13	0.13	0.13	0.029	0.40	0.43	0.25	0.39
Digestibility, %	93.4	94.8	95.1	94.9	1.1	0.25	0.23	0.36	0.21

Energy									
GE Intake, Mcal/d	37.79	38.27	37.94	39.94	1.370	0.67	0.52	0.38	0.59
GE Excreted, Mcal/d	15.62	14.20	13.96	14.30	0.912	0.52	0.37	0.53	0.31
DE, Mcal/d	29.98	31.17	30.96	32.79	2.199	0.84	0.56	0.49	0.88
DE, Mcal/kg	3.53	3.67	3.77	3.84	0.243	0.82	0.39	0.67	0.89

[ab] Means with different superscripts differ (*P*-value ≤ 0.05).

[1]Treatments were corn silage hybrids: CON = commercially available corn hybrid without the alpha amylase enzyme trait, SYT-EFC = Syngenta Enogen Feed Corn provided by Syngenta under identity-preserved procedures; KP = kernel processed, NKP = not kernel processed at harvest .

[2]Int = *P* –value for the interaction of corn silage hybrid × kernel processing. Hybrid = P-value for the main effect of corn silage variety. Kernel = *P*-value for the main effect of kernel processing.

Table 2.7. Main effect of corn silage hybrid on intake and digestibility of nutrients in corn silage growing cattle diets (Exp. 2)

	Treatments			
Item	CON	SYT-EFC	SEM	*P*-value[2]
DM				
Intake, kg / d	8.54	8.53	0.182	0.99
Excreted, kg / d	3.50	3.31	0.164	0.38
Digestibility, %	59.1	61.5	1.8	0.34
OM				
Intake, kg / d	7.97	7.96	0.170	0.95
Excreted, kg / d	3.01	2.87	0.145	0.45
Digestibility, %	62.3	64.1	1.6	0.41
NDF				
Intake, kg / d	3.65	3.46	0.075	0.10
Excreted, kg / d	1.88	1.82	0.121	0.59
Digestibility, %	48.6	47.7	2.8	0.77
ADF				
Intake, kg / d	2.02	1.90	0.043	0.08
Excreted, kg / d	1.22	1.20	0.062	0.85
Digestibility, %	39.7	36.7	2.8	0.46
Starch				
Intake, kg / d	2.54	2.60	0.055	0.47
Excreted, kg / d	0.15	0.13	0.025	0.43
Digestibility, %	94.2	95.0	0.95	0.23
Energy				
GE Intake, Mcal/d	38.03	38.94	0.968	0.52
GE Excreted, Mcal/d	14.91	14.13	0.692	0.37
DE, Mcal/d	30.58	31.88	1.555	0.56
DE, Mcal/kg intake	3.60	3.81	0.172	0.39

[1]Treatments were corn silage hybrids: CON = commercially available corn grain without the alpha amylase enzyme trait, SYT-EFC = Syngenta Enogen Feed Corn provided by Syngenta under identity-preserved procedures.
[2]*P*-value for the main effect of corn silage hybrid.

Table 2.8. Main effect of kernel processing on intake and digestibility of nutrients in corn silage growing cattle diets (Exp. 2)

	Treatments			
Item	KP	NKP	SEM	*P*-value
DM				
Intake, kg / d	8.50	8.57	0.182	0.82
Excreted, kg / d	3.48	3.32	0.164	0.47
Digestibility, %	59.1	61.5	1.8	0.34
OM				
Intake, kg / d	7.95	7.97	0.170	0.94
Excreted, kg / d	3.01	2.87	0.145	0.48
Digestibility, %	62.2	64.2	1.6	0.34
NDF				
Intake, kg / d	3.44	3.67	0.075	0.04
Excreted, kg / d	1.88	1.81	0.121	0.55
Digestibility, %	45.5	50.8	2.8	0.12
ADF				
Intake, kg / d	1.86	2.06	0.043	<0.01
Excreted, kg / d	1.22	1.20	0.062	0.76
Digestibility, %	34.4	42.0	2.8	0.07
Starch				
Intake, kg / d	2.65	2.49	0.055	0.06
Excreted, kg / d	0.15	0.13	0.025	0.25
Digestibility, %	94.3	94.9	0.95	0.36
Energy Intake				
GE Intake, Mcal/d	37.87	39.11	0.968	0.38
GE Excreted, Mcal/d	14.79	14.25	0.692	0.53
DE, Mcal/d	30.47	31.98	1.555	0.49
DE, Mcal/kg	3.65	3.76	0.172	0.67

[1]Treatments were kernel processing (KP) and no kernel processing (NKP) at harvest of corn silage.
[2]*P*-value for the main effect of kernel processing.

Table 2.9. Effect of corn silage hybrid and kernel processing on 24-h *in situ* NDF disappearance from corn bran and corn silage hybrids (Exp.2)

	Treatment[1]				
	CON		SYT-EFC		
Item, % NDFD	KP	NKP	KP	NKP	*P*-Value
CON KP	22.4	19.7	14.5	17.4	0.15
CON NKP	19.6	21.2	17.1	15.9	0.45
SYT-EFC KP	22.8	17.0	16.5	18.3	0.28
SYT-EFC NKP	19.8	19.9	13.1	16.3	0.17
Bran	35.9	33.4	31.6	33.2	0.68

SEM = 2.88
Corn hybrid × kernel processing interaction; $P \geq 0.96$
[1]Treatments were corn silage hybrids: CON = commercially available corn grain without the alpha amylase enzyme trait, SYT-EFC = Syngenta Enogen Feed Corn provided by Syngenta under identity-preserved procedures; KP = kernel processed, NKP = not kernel processed.

Table 2.10. Effect of con silage hybrid and kernel processing on rumen pH and ruminal volatile fatty acid profiles (Exp. 2)

	Treatment[1]							
	CON		SYT-EFC			*P*-Values[2]		
Item	KP	NKP	KP	NKP	SEM	Hybrid	Kernel	Int.
Ruminal pH								
Maximum pH	6.92	6.86	6.93	6.84	0.048	0.80	0.05	0.71
Average pH	6.43	6.42	6.38	6.33	0.058	0.12	0.48	0.63
Minimum pH	5.81	5.96	5.74	5.70	0.083	<0.01	0.37	0.12
Variance	0.081	0.051	0.094	0.085	0.015	0.05	0.12	0.40
Time < 5.6, min / d	122	210	78	91	56.8	0.09	0.25	0.38
Area < 5.6[3]	19.46	40.14	12.45	21.70	21.959	0.49	0.40	0.74
Ruminal VFA[4]								
Total, mM[5]	116.55	108.22	109.07	108.44	3.477	0.27	0.18	0.25
Acetate, %	62.80	62.13	61.21	58.59	2.295	0.02	0.04	0.53
Propionate, %	22.11	22.04	23.42	23.91	1.533	0.42	0.50	0.32
Butyrate, %	11.40	12.28	12.18	12.26	0.853	0.31	0.24	0.14
A:P[6]	3.08	3.02	2.81	2.72	0.190	0.02	0.54	0.88

[1]Treatments were corn silage hybrids: CON = commercially available corn hybrid without the alpha amylase enzyme trait, SYT-EFC = Syngenta Enogen Feed Corn provided by Syngenta under identity-preserved procedures; KP = kernel processed, NKP = not kernel processed at corn silage harvest.
[2]Int = *P* –value for the interaction of corn silage hybrid × kernel processing. Hybrid = P-value for the main effect of corn silage variety. Kernel = *P*-value for the main effect of kernel processing.
[3]Area < 5.6 = ruminal pH units below 5.6 by minute.
[4]Ruminal volatile fatty acids (VFA).
[5]VFA concentration in mol/100 mol.
[6]Acetate:Propionate.

CHAPTER III. Effect of Syngenta Enogen Feed Corn Containing an Alpha Amylase Trait Fed as Dry-Rolled Corn, High-Moisture Corn, or a Blend on Finishing Cattle Performance and Carcass Characteristics[3]

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ABSTRACT

Three hundred thirty-six crossbred steers (initial BW = 416 ± 17 kg) were used to evaluate the effect of a new corn hybrid containing an alpha amylase enzyme trait (Syngenta Enogen Feed Corn; SYT-EFC) and corn processing methods on performance and carcass characteristics of finishing beef cattle. Seven treatments with six pens per treatment (8 steers / pen, n = 6) were used in a generalized randomized block design, with two BW blocks. Corn hybrids included a conventional commercial corn hybrid (CON), and Syngenta's Enogen Feed Corn (SYT-EFC). Treatments were designed as a 2 × 3 + 1 factorial with corn hybrids fed as 100% dry-rolled corn (DRC), 100% high-moisture corn (HMC), a 50/50 blend of DRC and HMC (BLEND), or a 50/50 blend of SYT-EFC DRC and CON HMC (SYT-EFC/CON BLEND). Corn was included at 70%, along with 20% distillers grains, 5% wheat straw, and 5% supplement (DM basis). Linear and quadratic interactions, as well as the main effects of hybrid and corn processing method were evaluated using orthogonal contrasts. Pre-planned contrasts compared CON BLEND to SYT-EFC BLEND and SYT-EFC/CON BLEND. A quadratic interaction was observed for ADG when steers were fed SYT-EFC when cattle consuming the BLEND gained more than the cattle fed DRC or HMC alone, but steers consuming CON had similar ADG on the DRC and BLEND diets, with increased gain when fed HMC (P = 0.10). Additionally, a linear interaction was observed for G:F, with linearly increased efficiency for steers fed the CON hybrid; however, no additional response was observed as diets shifted from the BLEND to HMC for the SYT-EFC hybrid (P = 0.09). For the main effects of corn hybrid, DMI was greater for steers fed the CON hybrid versus SYT-EFC (P = 0.03). Furthermore, a linear effect of processing method on DMI was observed, with

steers fed DRC consuming significantly more than those fed HMC, and the BLEND falling intermediate ($P < 0.01$). Steers fed DRC based diets consumed significantly more when fed the CON hybrid compared to the SYT-EFC hybrid ($P = 0.01$). A significant hybrid effect was observed for final BW and HCW in cattle fed HMC diets, with those fed CON weighing significantly more than those fed SYT-EFC ($P = 0.03$). Finally, cattle fed CON HMC displayed greater ADG than those fed SYT-EFC HMC ($P = 0.03$). Feeding Syngenta Enogen Feed Corn as DRC, HMC, or a BLEND resulted in no significant improvement in any of the growth performance or carcass characteristics that were measured when feeding finishing beef cattle. While not significant, a numerical increase in G:F was observed, where steers fed the SYT-EFC hybrid as DRC had higher G:F than those fed the CON hybrid as DRC, resulting in a 4.3% numerical improvement in G:F due to the SYT-EFC hybrid ($P = 0.30$).

Key Words: amylase, beef cattle, high-moisture corn, dry-rolled corn, starch digestibility

INTRODUCTION

Supplementation of exogenous enzymes in ruminant diets as a means to increase digestion and improve animal performance has yielded variable results (Beauchemin et al., 2003). Primarily, research has evaluated the utilization of fibrolytic enzymes, in order to improve forage utilization and feed efficiency of ruminants (Beauchemin et al., 2003). Starch is the major energy component of feedlot diets, and maximizing starch digestion should improve G:F. Starch digestion primarily occurs in the rumen; however, research has shown that as small intestinal carbohydrate concentration increases, pancreatic α-amylase secretion decreases (Harmon, 1993). Thus, exogenous α-amylase may provide improved animal performance by increasing the supply of amylase to the small intestine for starch digestion.

A new corn hybrid, Syngenta Enogen Feed Corn (SYT-EFC; Syngenta Seeds, LLC) has been genetically enhanced to contain a thermotolerant α-amylase enzyme trait. This enzyme becomes activated at increased temperatures, reducing the need for exogenous enzymes during the dry milling ethanol fermentation process to convert starch to sugar. Inclusion of the enzyme may result in improved animal performance by increasing post-ruminal starch digestion. Previous research evaluating SYT-EFC in feedlot diets has observed an improvement in feed efficiency of 1.6 to 10.1% (Jolly-Breithaupt, 2018). This response has been variable when SYT-EFC was fed as dry-rolled corn, and no improvement in performance has been observed when processed as high-moisture corn. A majority of producers that utilize HMC feed it as a ratio with DRC; therefore, the objective of this study was to evaluate SYT-EFC when fed at different ratios as either 100% DRC, 100% HMC, or a 50:50 blend of DRC and HMC.

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.

Corn harvest, storage, and chemical composition

Two hybrids of corn were grown in a single irrigated field at the Eastern Nebraska Research and Extension Center (ENREC) near Mead, NE. The two hybrids included a conventional commercial corn which served as the control (CON), and Syngenta's Enogen Feed Corn (SYT-EFC; Syngenta Seeds, LLC). The SYT-EFC hybrid has been modified to contain a thermotolerant and pH tolerant α-amylase enzyme. Syngenta Enogen Feed Corn has been primarily utilized by the dry milling ethanol industry. The internal enzymes become activated at increased temperatures, thus reducing the need for the addition of α-amylase to convert starch into glucose prior to fermentation.

Corn grain was harvested between September 10 and October 10, 2017. Dry-rolled corn (DRC) was stored in separate grain bins, and high-moisture corn (HMC) was stored in silo bags at the time of harvest. At harvest, dry matter samples were taken from each truckload of HMC and dried in a 60°C forced-air oven for 48 h to determine dry matter (DM) of the corn at harvest. All feeds were sampled weekly for DM, and monthly composites were analyzed for DM (Gales, 1990), crude protein (CP; LECO Co.), acid and neutral detergent fiber (ADF and NDF; ANKOM Technology 1996 & 1998; Mertens, 1992), starch (YSI Inc., 2000), and minerals (Campbell and Plank, 1991; Kovar, 2003) at a commercial laboratory (Ward Laboratories, Inc., Kearney, NE; Table 3.2).

Eastern Nebraska Research and Extension Center

A 148-d finishing study, utilizing 336 crossbred yearling steers (BW = 416 ± 17 kg) in a randomized block design, was conducted at the Eastern Nebraska Research and Extension Center (ENREC) feedlot near Mead, Nebraska. Steers were received as calves in the fall of 2017, and were placed in a winter backgrounding program. Upon arrival into the feedlot, calves were given individual identification, weighed, and vaccinated. Vaccinations were administered to aid in the prevention of bovine viral diarrhea virus Type I and II, infectious bovine rhinotracheitis, parainfluenza$_3$, bovine respiratory syncytial virus, *Mannhemia haemolytica*, and *Pasteurella multocia* (Bovi-Shield Gold 5, Zoetis, Inc.; Kalamazoo, MI), *Heamophilus somnus* (Sumobac, Zoetis, Inc.), and parasite control (Dectomax, Zoetis, Inc.). Approximately 14 d following initial vaccination, steers were revaccinated for *Heamophilus somnus* (Ultrabac-7, Zoetis, Inc.) and *Mannhemia haemolytica* (Bovi-Shield Gold One Shot, Zoetis, Inc.). Animals were mass-treated for bovine respiratory disease (Micotil, Elanco Animal Health; Greenfield, IN) and wintered on corn stalks. Steer calves were then placed on an 84-d silage growing trial prior to trial initiation.

Steers were limit fed a diet consisting of 50% alfalfa hay and 50% Sweet Bran (Cargill Wet Milling; Blair, NE; DM basis) at 2.0% BW for 5 consecutive days to equalize gut fill prior to initiation of the trial (Watson et al., 2013). Steers were weighed for 2 consecutive days (0 and 1) and the average of those 2 days was used to establish initial BW (Stock et al., 1983). Cattle were implanted with 200 mg trenbolone acetate and 20 mg estradiol (Revalor 200®, Merck Animal Health, Madison, NJ) on d 1 of the trial. Steers were blocked by BW into light and heavy BW blocks (n = 3 replicates for each BW block) based on d 0 BW, stratified by BW within block, and assigned randomly to

one of 42 pens. Pens were then assigned randomly to one of 7 treatments (Table 3.1), with a total of 8 steers per pen and 6 replications per treatment.

Dietary treatments (Table 3.1) were arranged in a 2 × 3 + 1 factorial, and included 1) conventional commercial corn processed as DRC (CON DRC), 2) CON processed as HMC (CON HMC), 3) a 50/50 blend of CON DRC and CON HMC (CON BLEND), 4) Syngenta Enogen Feed Corn processed as DRC (SYT-EFC DRC), 5) SYT-EFC processed as HMC (SYT-EFC HMC), 6) a 50/50 blend of SYT-EFC DRC and SYT-EFC HMC (SYT-EFC BLEND), and 7) a 50/50 blend of SYT-EFC DRC and CON HMC (SYT-EFC/CON BLEND). Steers were adapted to the finishing diets over a 21-d period with 10% corn replacing 10% alfalfa hay; while inclusion of modified distillers grains plus solubes (MDGS), wheat straw, and supplement remained constant in the diets. Corn grain was included in the final diets at 70%, with blends containing 35% DRC and 35% HMC on a DM basis. All diets contained MDGS included at 20%, along with 5% wheat straw and 5% supplement, on a DM basis. Supplements were formulated to provide 33 mg / kg of Rumensin® (Elanco Animal Health) and 9.7 mg / kg of Tylan® (Elanco Animal Health) on a DM basis.

Cattle were fed *ad libitum* and feed bunks were evaluated daily at approximately 0530 h for feed refusals, so that trace amounts of feed were left in the bunk at the time of feeding. Feed was delivered once daily starting at 0800 h with a truck mounted mixer and delivery unit (Roto-Mix, Dodge City, KS). All feed refusals were subsampled and dried for 48 h in a 60°C forced-air oven for determination of DM and calculation of refusal DM weight (AOAC, 1999, method 4.1.03). Dietary ingredients were sampled weekly for DM analysis. As-fed dietary ingredient inclusions were adjusted weekly.

Steers were harvested on d 149 at a commercial abattoir (Greater Omaha Packing Co., Omaha, NE). On the day of shipping, steers were fed 50% of the previous day's DM offered. Steers were shipped in the evening and harvested the following morning at the local abattoir (Greater Omaha Packing Co., Omaha, NE). The day of harvest, hot carcass weight (HCW) and liver abscesses were recorded. Liver abscesses were scored using the Brink et al. (1990) method; with 0 (no abscesses), A^-, A, and A^+ scores for severely abscessed livers. Abscess scores were then combined to determine the total proportion of liver abscesses per pen. Following a 48-hr chill, 12th rib back fat thickness, *Longissimus* muscle (LM) area, and USDA marbling scores were recorded. 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 + (2.5 × 12th rib fat, cm) + (0.2 × 2.5 [2.5 Assumed average steer KPH]) + (0.0038 × HCW, kg) – (0.32 × LM area, cm^2) (USDA, 1997). The energy value of the dietary treatments were calculated using pen data in the Galyean (2009) Net Energy calculator based on the NRC (1996) equations. Calculated energy values utilized the heaviest final BW of each block and the individual initial BW, DMI, and ADG of each pen, with a target endpoint of USDA Choice.

Growth performance and carcass characteristics were analyzed using the PROC GLIMMIX procedure of SAS (SAS Institute, Inc., Cary, N.C.) as a generalized randomized block design. Pen served as the experimental unit, with the block considered the fixed effect. The treatment design was a 2 × 3 + 1 factorial. Linear and quadratic interaction effects of hybrid and grain processing were evaluated for the 2 × 3 factorial. If no significant interactions were detected, then main effects of hybrid and corn processing

were evaluated. If a significant interaction existed, then simple effects of hybrid within processing method were compared. Preplanned contrasts compared CON versus SYT-EFC within each processing method, and a preplanned contrast compared CON BLEND to SYT-EFC/CON BLEND. Treatment differences were considered significant when $P \leq 0.10$.

RESULTS AND DISCUSSION

Interactions

There were no interactions between corn hybrid and processing method for initial BW, DMI, LM area, marbling score, or calculated yield grade ($P \geq 0.16$, Table 3.3). A linear interaction was observed for G:F for both hybrids ($P = 0.09$; Figure 2.2). A linear increase in G:F was observed with steers fed DRC based diets being least efficient and those fed HMC based diets being most efficient, with cattle on the BLEND diets falling intermediate when the CON hybrid was fed. However, when steers were fed SYT-EFC no additional response was observed as diets shifted from the 50/50 BLEND to straight HMC (Figure 2.1). A tendency for a linear interaction ($P = 0.09$) and a linear interaction ($P = 0.02$) was observed for NEm and NEg values, respectively. A linear increase in NEm and NEg was observed within the CON treatments; however, SYT-EFC had a less dramatic increase as diets moved from the 50/50 BLEND to straight HMC.

A tendency for a quadratic interaction for final BW and HCW was observed ($P = 0.11$). Cattle consuming CON had a quadratic increase in weights as the diet shifted from straight DRC to HMC. However, those fed SYT-EFC displayed an increase as diets shifted from DRC to the BLEND, and a decrease in weights when fed straight SYT-EFC

HMC (P = 0.11). Additionally, a quadratic interaction was observed for ADG of steers on SYT-EFC (P = 0.10; Figure 2.2), as those consuming the BLEND diet gained more than the DRC or HMC steers (1.69, 1.64, and 1.63 respectively). In contrast, cattle consuming the CON hybrid had similar ADG on the DRC and BLEND diets but had increased ADG when fed the HMC treatment. Previous research evaluating the effect of SYT-EFC when fed as DRC or HMC observed a hybrid × processing method interaction for final BW (Jolly-Breithaupt, 2018). Jolly-Breithaupt (2018) saw greater final BW in cattle fed SYT-EFC as DRC compared to those on a negative isoline parental hybrid (NEG; control); however, the opposite was true when the hybrids were processed as HMC, where cattle consuming the NEG hybrid weighed more than those on SYT-EFC. Nonetheless, when Jolly-Breithaupt (2018) fed SYT-EFC as DRC or HMC gains were greatest for steers fed SYT-EFC as DRC and lowest for SYT-EFC HMC.

Finally, a quadratic interaction was observed for both hybrids (P = 0.07), with steers fed CON BLEND having less back fat than CON DRC or CON HMC (1.52, 1.68, and 1.65 respectively), and those fed SYT-EFC BLEND having greater back fat than SYT-EFC DRC or SYT-EFC HMC (1.70, 1.60, and 1.63 respectively).

Main Effect of Corn Hybrid

For the main effects of corn hybrid, DMI was greater for steers fed the CON hybrid (11.4 kg) versus SYT-EFC (11.2 kg; P = 0.03). No other performance differences were observed due to corn hybrid ($P \geq 0.25$). Schoonmaker et al., (2014) observed no difference in final BW, DMI, ADG, or G:F ($P \geq 0.18$) when feeding ground corn containing an α-amylase enzyme at 10 or 20% of the diet, with 45.2% rolled corn, 20%

WDGS, and 12% bromegrass hay. Lack of response in performance observed by Schoonmaker et al., (2014) could be due to the enzyme containing corn being processed as ground corn, increasing the rate of ruminal starch fermentation and the risk of acidosis, or may be attributed to the low inclusion of the corn containing enzyme at a small proportion of the diet. In two experiments by Jolly-Breithaupt (2018), where SYT-EFC DRC was fed as the sole dietary corn, an improvement of 1.3 to 10.1% was observed. Previous research evaluating an exogenous α-amylase enzyme in finishing diets have observed an increase in ADG (Burroughs et al., 1960; Jolly-Breithaupt, 2018; Tricarico et al., 2007), as well as an increase in DMI and G:F (Jolly-Breithaupt, 2018). However, in previous research, no significant differences in DMI, ADG, or G:F have been observed with the supplementation of exogenous α-amylase (Tricarico et al., 2007; and DiLorenzo et al., 2011).

No differences for the main effect of corn hybrid were observed for LM area, marbling score, back fat thickness, or calculated yield grade ($P \geq 0.63$). This agrees with Schoonmaker et al., (2014), who observed no significant differences in any of the carcass characteristic measurements. Tricarico et al., (2007) observed a quadratic increase in HCW, LM area, and yield grade with the supplementation of an α-amylase enzyme ($P \leq 0.04$). Jolly-Breithaupt (2018) observed an increase in LM area ($P = 0.03$), and a tendency for an increase in marbling score ($P = 0.08$) in finishing steers fed SYT-EFC. The authors speculated that feeding SYT-EFC increased the glucose concentration absorbed by the animal, as glucose absorption increases, a greater quantity of acetyl units are utilized for lipid synthesis in intramuscular adipose tissue (Smith et al., 2009).

Ensiling of α-amylase containing corn, such as SYT-EFC HMC, may result in the amylase enzyme being degraded by microbial populations prior to utilization by the animal. Enzymes are proteins that are produced by living cells, and act to catalyze biochemical reactions. Previous research by Benton et al., (2005) evaluated the impact of ensiling corn on ruminal degradable protein (RDP) content and observed a linear increase in RDP as the length of the ensiling period increased. Therefore, it is possible that as a result of increased RDP, the α-amylase enzyme within the corn itself is degraded within the rumen by the microbial population. Furthermore, ensiling corn grain disrupts the starch containing endosperm, increasing the availability of starch during ruminal fermentation (Huntington et al., 2006). Thus, starch present in HMC is rapidly degraded in the rumen, resulting in little bypassing to the small intestine for digestion by the animal. Ensiling of SYT-EFC hybrids likely results in little α-amylase enzyme and starch available for post-ruminal digestion by the animal.

Grain Processing Method

For the main effect of grain processing, there was a linear effect of processing method on DMI, with steers fed DRC consuming significantly more than those fed HMC or BLEND diets ($P < 0.01$). A reduction in intake of 7.8% was observed as diets shifted from straight DRC to HMC. As ruminal starch fermentation increases due to increased availability, the rate of volatile fatty acid (VFA) production increases (Owens et al., 1997). This increased production can result in a reduction in intake, as seen by Owens et al. (1997) who reported an average reduction in DMI of 8.5% when comparing HMC and DRC based diets. However, this reduction has not always been observed (Huck et al., 1998; Stock et al., 1991). In the current study, no difference in ADG ($P = 0.45$) was

observed, this resulted in the lowest G:F in cattle fed DRC ($P < 0.01$). Previous research comparing DRC to HMC has observed an increase in efficiency with the HMC (Corrigan et al., 2009; Harrelson et al., 2009, and Scott et al., 2003). Nonetheless, Mader et al. (1983) and Owens et al., (1997) have also reported no significant improvement in efficiency due to HMC.

Finally, no significant differences were observed between steers fed the different processing methods for final BW, HCW, marbling score, back fat thickness, or calculated yield grade ($P \geq 0.29$). This is in partial agreement with Jolly-Breithaupt (2018) who reported no significant differences in HCW, marbling score, LM area, back fat depth, or calculated yield grade when feeding SYT-EFC as DRC or HMC ($P \geq 0.12$). However, in the current study, a linear effect was observed for *longissimus* muscle (LM) area, with cattle fed HMC having larger ribeyes than those fed DRC or BLEND ($P = 0.02$). No quadratic effects were observed for any growth performance or carcass characteristics in cattle fed different processing methods ($P \geq 0.21$). Stock et al. (1991) observed no associative effects for any feedlot performance measurements when feeding combinations of 50% HMC and 50% DRC. However, results from the current study and those from Stock et al. (1991) are in contrast to results by Stock et al. (1987a,b), who saw a 5 to 7% improvement in G:F when diets included a blend of HMC and DRC.

Hybrid Effect on Grain Processing

The effect of hybrid type on grain processing was tested for each processing method using pairwise comparisons. For steers fed DRC based diets, there was a significant effect on DMI, with those consuming CON DRC eating more than those on SYT-EFC DRC (12.0 vs. 11.5 respectively; $P = 0.01$). While not significant, a numerical

increase in G:F was observed, where steers fed the SYT-EFC hybrid had higher G:F than those fed the CON hybrid (0.1425 vs. 0.1383, respectively; *P* = 0.30) This resulted in a 4.3% numerical improvement in G:F due to the SYT-EFC hybrid. This is in agreement with Jolly-Breithaupt (2018), where steers fed SYT-EFC DRC had numerically greater feed efficiency than CON DRC, resulting in a 3.7% change (0.183 vs. 0.179; 61% diet DM inclusion *P* = 0.21). Furthermore, DiLorenzo et al. (2011) observed a 9.5% numerical improvement in G:F when α-amylase was included in DRC based diets (Rumistar; DSM Nutritional Products Inc., Kaiseraugust, Switzerland; *P* = 0.55).

A significant effect was observed for final BW and HCW in cattle fed HMC diets, with those fed CON weighing significantly more than those fed SYT-EFC (671 vs. 657 and 423 vs. 414 kg respectively; *P* = 0.03). In the current study, there was no effect on intake due to hybrid when fed as HMC (*P* = 0.24), this is in contrast to observations by Tricarico et al. (2007), who tended to see an increase in DMI when supplying an exogenous α-amylase product in HMC finishing diets compared to steers fed a control hybrid (*P* = 0.12). Furthermore, Tricarico et al. (2007) observed an increase in ADG for steers fed an exogenous α-amylase product in cracked corn or HMC based diets, compared to those consuming the controls (*P* = 0.04). However, in the current study, cattle fed CON HMC displayed greater ADG than those fed SYT-EFC (1.72 vs. 1.63 respectively; *P* = 0.03). This resulted in a 5.3% numerical improvement in G:F due to the CON hybrid fed as HMC. Additionally, steers fed the CON hybrid displayed significantly greater back fat thickness compared to the SYT-EFC hybrid (1.65 vs. 1.63 cm, respectively; *P* = 0.08).

Finally, a significant effect of hybrid was observed on the BLEND diets, with steers fed SYT-EFC BLEND having greater back fat than those on CON BLEND (1.70 vs. 1.52 respectively; $P = 0.08$).

SYT-EFC/CON Blend vs. CON Blend

A blend of SYT-EFC DRC and CON HMC was compared to the blend of control DRC and HMC (CON BLEND). No significant differences between these blends were observed for any of the growth performance or carcass characteristic parameters measured ($P \geq 0.47$). While not significant, a numerical improvement in G:F was observed when SYT-EFC DRC was included in the blend ($P = 0.71$). The improvement in efficiency attributed to the partial inclusion of SYT-EFC as the DRC (35% inclusion DM basis) component resulted in a 2.9% change (0.1485 vs. 0.1470).

In conclusion, an increase in G:F has been observed in previous finishing trials when SYT-EFC was included as the main source of corn grain. However, results from this trial would suggest no significant improvement in any of the growth performance or carcass characteristics that were measured by feeding finishing cattle Syngenta Enogen Feed Corn as DRC, HMC, or a 50/50 blend. Although a numerical improvement in feed efficiency was observed, it was too small to detect for the DRC and BLEND treatments. The change in G:F for DRC was 3.0% due to the diet, which suggests an improvement of 4.3% due to the SYT-EFC hybrid (3.0 / 0.70, inclusion). This numerical improvement is in agreement with results from Jolly-Breithaupt (2018), who observed an improvement in feed efficiency of 1.6 to 10.1% when SYT-EFC was included as DRC in feedlot diets.

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Table 3.1. Dietary treatment compositions (% DM basis) to evaluate corn hybrid and processing on cattle performance and carcass characteristics

Trait	CON[1]			SYT-EFC[2]			CON/SYT-EFC[3]
Processing Method	DRC	Blend	HMC	DRC	Blend	HMC	Blend
Dry-Rolled Corn CON[1]	70.0	35.0	-	-	-	-	-
Dry-Rolled Corn SYT-EFC[2]	-	-	-	70.0	35.0	-	35.0
High-Moisture Corn CON[1]	-	35.0	70.0	-	-	-	35.0
High-Moisture Corn SYT-EFC[2]	-	-	-	-	35.0	70.0	-
Wheat Straw	5.0	5.0	5.0	5.0	5.0	5.0	5.0
MDGS	20.0	20.0	20.0	20.0	20.0	20.0	20.0
Supplement	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Fine Ground Corn	2.2825	2.2825	2.2825	2.2825	2.2825	2.2825	2.2825
Limestone	1.7	1.7	1.7	1.7	1.7	1.7	1.7
Tallow	0.1250	0.1250	0.1250	0.1250	0.1250	0.1250	0.1250
Urea	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Salt	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Beef Trace Mineral	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Vitamin ADE	0.015	0.015	0.015	0.015	0.015	0.015	0.015
Rumensin-90[4]	0.0165	0.0165	0.0165	0.0165	0.0165	0.0165	0.0165
Tylan-40[5]	0.011	0.011	0.011	0.011	0.011	0.011	0.011
Nutrient Composition, %							
CP	13.40	13.52	13.65	13.62	13.68	13.73	13.64
ADF	6.89	6.54	6.19	6.85	6.68	6.50	6.52
NDF	14.86	14.16	13.46	15.73	15.64	15.55	14.59
Starch	54.61	54.79	54.98	52.20	52.29	52.37	53.59
Fat	4.60	4.65	4.69	4.82	3.46	4.85	3.39

Ca	0.76	0.76	0.77	0.76	0.76	0.76	0.76
P	0.38	0.39	0.40	0.44	0.41	0.38	0.42
K	0.58	0.60	0.65	0.61	0.62	0.63	0.62
Mg	0.15	0.16	0.16	0.16	0.16	0.16	0.16

[1]CON= Commercially available corn grain without the alpha amylase enzyme trait.
[2]SYT-EFC = Syngenta Enogen Feed Corn provided by Syngenta under identity-preserved procedures, stored, processed as dry-rolled corn (DRC) or high-moisture corn (HMC), and fed separately.
[3]SYT-EFC/CON= 50/50 Blend of SYT-EFC DRC and CON HMC.
[4]Supplement formulated to provide 33.0 mg/kg Monensin (Rumensin-90®; Elanco Animal Health, DM Basis).
[5]Supplement formulated to provide 9.7 mg/kg Tylosin (Tylan®; Elanco Animal Health, DM Basis).

Table 3.2. Nutrient analysis of corn hybrids

Trait	CON[1]		SYT-EFC[2]	
Item	HMC	DRC	HMC	DRC
Nutrient Composition				
DM, %	66.81	94.29	66.24	94.26
CP, %	8.30	7.94	8.42	8.26
ADF, %	1.24	2.24	1.68	2.18
NDF, %	4.42	6.42	7.40	7.66
TDN, %	90.32	88.76	89.62	88.84
Fat, %	3.84	3.70	4.06	4.02
Starch, %	72.68	72.16	68.96	68.72
NEm, Mcal/cwt	101.96	99.94	101.06	99.98
NEg, Mcal/cwt	70.60	68.90	69.84	68.94
Ca, %	0.08	0.07	0.06	0.07
P, %	0.28	0.25	0.25	0.33
K, %	0.40	0.34	0.41	0.39
Mg, %	0.11	0.10	0.11	0.11

[1]CON= Commercially available corn grain without the alpha amylase enzyme trait
[2]SYT-EFC = Syngenta Enogen Feed Corn provided by Syngenta under identity-preserved procedures, stored, processed as corn silage or high-moisture corn (HMC), and fed separately
Note: Sample analysis in the table were analyzed on monthly composited samples. Samples were analyzed at Ward Laboratories, Inc.® (Kearney, NE). All values are presented on a DM basis. Note that DRC was previously oven dried so DM is not representative of what was fed.

Table 3.3. Effect of corn hybrid and processing on cattle performance and carcass characteristics

	Treatments[1]								P-Values								
	CON[2]			SYT-EFC[3]			SYT-EFC/ CON[4]	SEM	Int.[5]		Main Effects			Hybrid Effect[6]			CON/SYT-EFC[7]
	DRC	Blend	HMC	DRC	Blend	HMC	Blend		L	Q	Hybrid[8]	L Proc.[9]	Q Proc.[10]	DRC	Blend	HMC	Blend
Pens	6	6	6	6	6	6	6										
Performance																	
Initial BW, kg	417	417	417	418	417	417	417	0.3	0.66	0.44	0.28	0.30	0.27	0.21	1.00	0.53	1.00
Final BW, kg[11]	662	663	671	661	667	657	665	0.43	0.18	0.11	0.27	0.49	0.56	0.72	0.49	0.03	0.80
DMI, kg/d	12.0	11.3	11.0	11.5	11.3	10.8	11.3	0.13	0.33	0.16	0.03	<0.01	0.88	0.01	0.89	0.24	0.67
ADG, kg[11]	1.66	1.66	1.72	1.64	1.69	1.63	1.67	0.029	0.21	0.10	0.25	0.45	0.51	0.66	0.50	0.03	0.84
Gain:Feed[11]	0.1383	0.1470	0.1563	0.1425	0.1498	0.1507	0.1485	0.00280	0.09	0.47	0.85	<0.01	0.55	0.30	0.48	0.16	0.71
NEm, Mcal/kg	1.79	1.88	1.97	1.85	1.90	1.94	1.90	0.027	0.09	0.80	0.85	<0.01	0.55	0.15	0.60	0.32	0.60
NEg, Mcal/kg	1.17	1.24	1.38	1.28	1.26	1.29	1.26	0.045	0.02	0.88	0.71	0.02	0.48	0.08	0.73	0.14	0.79
Carcass Characteristics																	
HCW, kg	417	418	423	416	420	414	419	2.7	0.18	0.11	0.25	0.49	0.54	0.71	0.50	0.03	0.81
LM Area, cm²	87.7	89.7	92.9	89.0	89.7	91.0	91.0	1.35	0.23	0.84	1.00	0.02	0.67	0.44	0.87	0.87	0.47
Marbling Score[12]	525	493	526	497	511	526	489	15.0	0.38	0.22	0.78	0.32	0.21	0.20	0.40	0.40	0.84
Back Fat Thickness, cm	1.68	1.52	1.65	1.60	1.70	1.63	1.57	0.066	0.55	0.07	0.63	0.92	0.60	0.38	0.08	0.08	0.66
Calculated Yield Grade[13]	3.73	3.55	3.55	3.63	3.73	3.59	3.56	0.104	0.50	0.22	0.67	0.29	0.85	0.46	0.22	0.22	0.96

[1] DRC and HMC included in the diet at 70%, 20% MDGS, 5% wheat straw, and 5% supplement; blend included in the diet with 35% DRC, 35% HMC, 20% MDGS, 5% wheat straw, and 5% supplement.
[2] CON= Commercially available corn grain without the alpha amylase enzyme trait.
[3] SYT-EFC = Syngenta Enogen Feed Corn provided by Syngenta under identity-preserved procedures, stored, processed as DRC or HMC.
[4] SYT-EFC/CON= 50/50 Blend of SYT-EFC DRC and CON HMC.
[5] Interaction effects of hybrid type and grain processing.
[6] Effect of hybrid type on grain processing.
[7] SYT-EFC/CON blend compared to CON blend.
[8] Main effect of hybrid type.
[9] Linear effect of grain processing.
[10] Quadratic effect of grain processing.
[11] Calculated from hot carcass weight, adjusted to a common 63% dressing percentage.
[12] Marbling Score 400-Small00, 500 = Modest00.
[13] Calculated as 2.5 + (2.5 x 12th rib fat, cm) + (0.2 x 2.5 [KPH]) + (0.0038 x HCW, kg) – (0.32 x ribeye area, cm^2), (USDA, 1997).

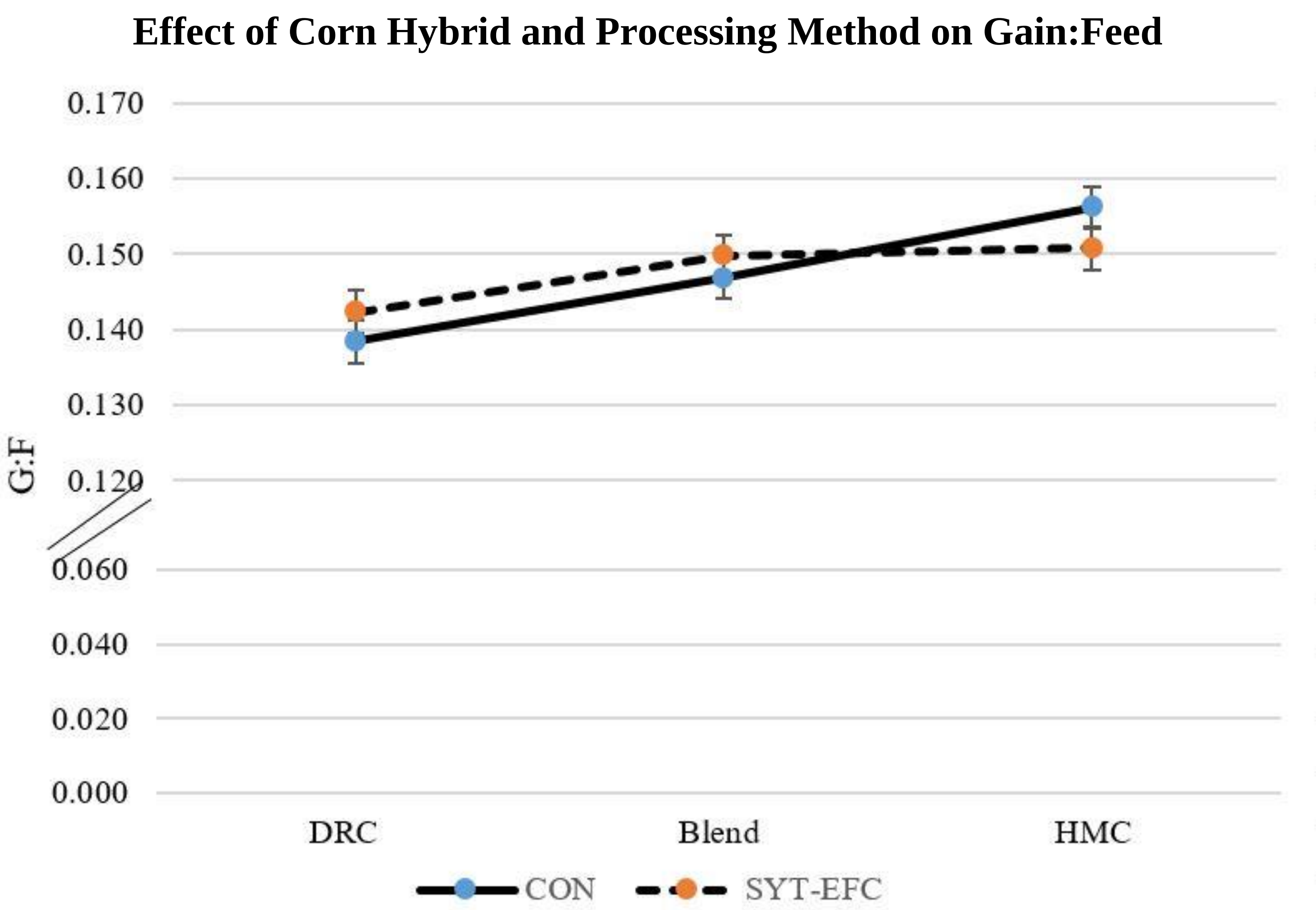

Figure 3.1. Effect of corn hybrid and processing method on feed efficiency (G:F) of finishing beef cattle. Treatments included commercially available corn hybrid (CON) and Syngenta Enogen Feed Corn hybrid (SYT-EFC); corn hybrids were fed as 100% dry-rolled corn (DRC), 100% high-moisture corn (HMC), or a 50/50 blend of DRC and HMC (BLEND) with 70% inclusion of corn grain in the diet.

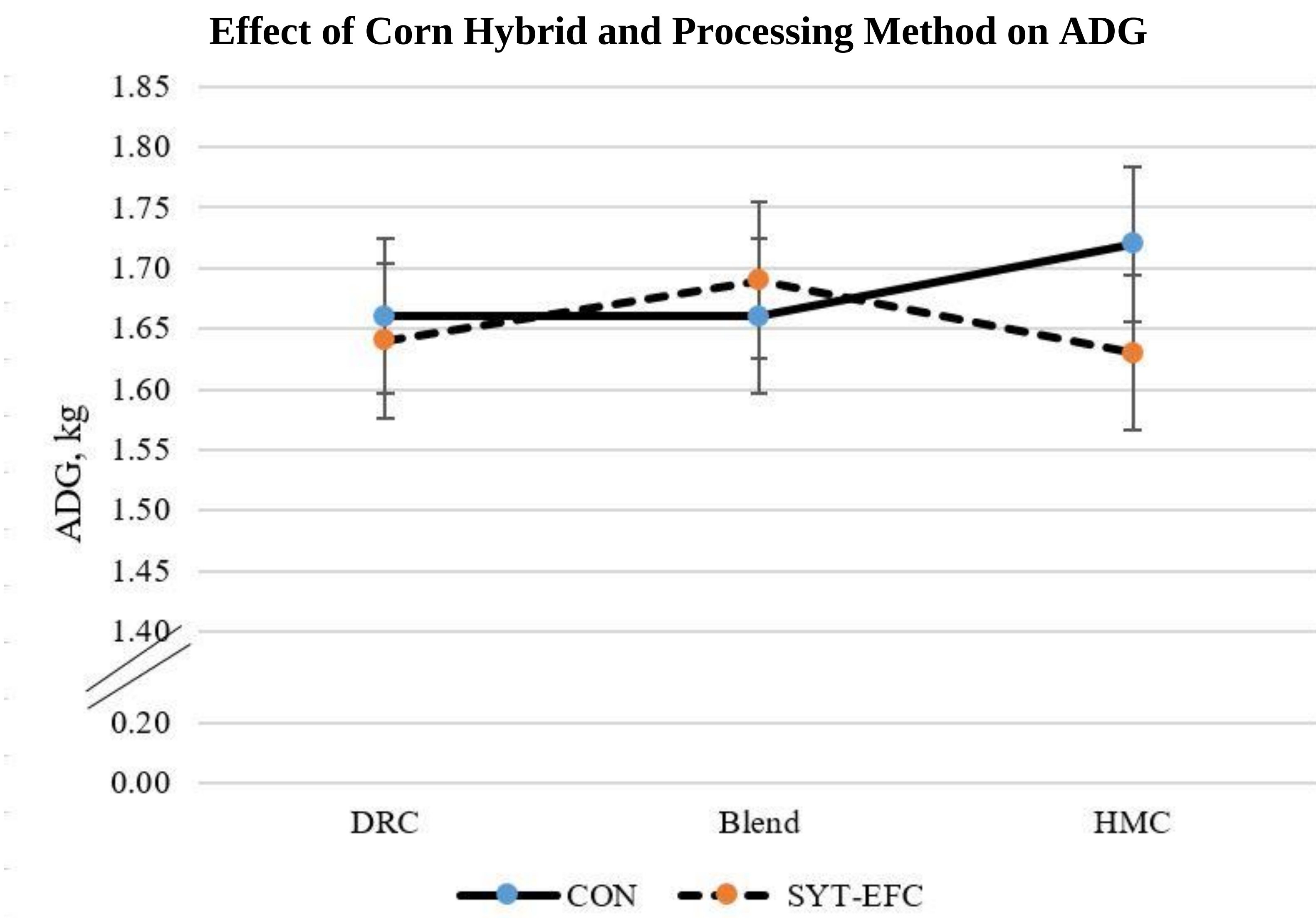

Figure 3.2. Effect of corn hybrid and processing method on average daily gain (ADG) of finishing beef cattle. Treatments included commercially available corn hybrid (CON) and Syngenta Enogen Feed Corn hybrid (SYT-EFC); corn hybrids were fed as 100% dry-rolled corn (DRC), 100% high-moisture corn (HMC), or a 50/50 blend of DRC and HMC (BLEND) with 70% inclusion of corn grain in the diet.

CHAPTER IV. Effect of Dose Titration of Wet Distillers Grains plus Solubles Replacing Syngenta Enogen Feed Corn Containing an Alpha Amylase Trait Fed as Dry-Rolled Corn and Interaction between Corn Hybrid and Distillers Inclusion[5]

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ABSTRACT

Four hundred eighty crossbred yearling steers (initial BW = 377 ± 31 kg) were used to evaluate the effect of a new corn hybrid containing an alpha amylase enzyme trait (Syngenta Enogen Feed Corn; SYT-EFC) with titrating levels of wet distillers grains plus solubles (WDGS) on performance and carcass characteristics of finishing beef cattle. Six treatments with eight pens per treatment (10 steers / pen, n = 8) were used in a generalized randomized block design. Steers were blocked by initial BW into light, medium, and heavy BW blocks (n = 2, 4, and 2 blocks, respectively). Corn hybrids included a conventional commercial corn (CON), and Syngenta's Enogen Feed Corn (SYT-EFC) which contains an alpha amylase enzyme trait. Corn was processed as dry-rolled corn (DRC) and WDGS inclusion was 0, 15, 30, or 45% with SYT-EFC and WDGS was included at 0 or 30% for CON diets. Increasing inclusion of WDGS with SYT-EFC linearly increased final BW, dry-matter intake (DMI), average daily gain (ADG; $P < 0.01$), and G:F ($P = 0.04$) for live performance characteristics. Furthermore, increasing WDGS inclusion linearly increased hot carcass weight (HCW), back fat thickness, and calculated yield grade in steers on SYT-EFC diets ($P < 0.01$). When comparing SYT-EFC to CON corn hybrids with 0% WDGS included in the diet, no statistical performance or carcass differences were observed ($P \geq 0.17$). Furthermore, a comparison of SYT-EFC and CON hybrids with an inclusion of 30% WDGS provided no significant differences in live performance; however, back fat thickness was greater for steers fed SYT-EFC ($P = 0.01$), and thus, calculated yield grade was greater ($P = 0.02$). Nonetheless, steers fed SYT-EFC with 0% WDGS had a 3.4% numerically better feed

conversion compared to CON; however, G:F was similar between the hybrids when WDGS was included in the diet at 30%.

Key Words: amylase, beef cattle, dry-rolled corn, wet distillers grains plus solubles

INTRODUCTION

Syngenta Enogen Feed Corn (SYT-EFC; Syngenta Seeds, LLC) has been genetically enhanced to contain an α-amylase enzyme trait. While SYT-EFC has been primarily utilized for ethanol production by the dry-milling industry, this trait may result in improved animal performance by increasing post-ruminal starch digestion in beef cattle. Previous research evaluating SYT-EFC in feedlot diets has observed an improvement in feed efficiency and an increase in post-ruminal starch digestion when SYT-EFC was fed as dry-rolled corn (DRC), compared to cattle fed corn not containing the α-amylase enzyme trait (Jolly-Breithaupt, 2018). However, this response has been variable across studies, and thus, warrants further research.

One question that remains unanswered is how SYT-EFC interacts with titrating levels of distillers grains included in the diet. Intestinal starch assimilation begins in the lumen of the small intestine with the secretion of α-amylase from the pancreas (Harmon, 2009; Harmon et al., 2004; and Owens, 1985). Protein entering the small intestine signals the pancreas to secrete α-amylase into the duodenum of the small intestine (Harmon, 2009; Harmon et al., 2004; Huntington, 1997). Due to the removal of starch from distillers grains, these byproducts contain high concentrations of protein in the form of ruminally undegradable protein (RUP). Ruminally undegradable protein bypasses microbial fermentation in the rumen and enters the small intestine to be digested and utilized by the animal (Holt et al., 2004; and Buckner et al., 2011). Thus, it is hypothesized that feeding distillers grains at higher inclusions naturally increases starch digestion. Supplying exogenous α-amylase enzymes, such as those present in SYT-EFC, may provide an increased benefit to the animal when distillers grains are included at

lower levels in the diet. The objective of this study was to evaluate SYT-EFC when fed with different inclusions of wet distillers grains plus solubles on finishing beef cattle performance.

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.

Corn storage and chemical composition

Corn grain was harvested and delivered to the Panhandle Research and Extension Center (PHREC) near Scottsbluff, Nebraska, prior to October 1, 2018. Dry-rolled corn was stored in separate grain bins, upon arrival at the PHREC. All feeds were sampled weekly for dry matter (DM), and monthly composites were analyzed for DM (Gales, 1990), crude protein (CP; LECO Co.), acid and neutral detergent fiber (ADF and NDF; ANKOM Technology 1996 & 1998; Mertens, 1992), starch (YSI Inc., 2000), and minerals (Campbell and Plank, 1991; Kovar, 2003) at a commercial laboratory (Ward Laboratories, Kearney, NE; Table 4.2).

Panhandle Research and Extension Center

A 154-d finishing study, utilizing 480 crossbred yearling steers (BW = 377 ± 31 kg) in a randomized block design, was conducted at the Panhandle Research and Extension Center (PHREC) feedlot near Scottsbluff, Nebraska. Steers were received as yearling calves in the spring of 2018. Upon arrival into the feedlot, calves were individually identified, weighed, and vaccinated. Vaccinations were administered to aid in the prevention of bovine viral diarrhea virus Type I and II, infectious bovine

rhinotracheitis, parainfluenza$_3$, bovine respiratory syncytial virus, *Mannhemia haemolytica*, and *Pasteurella multocia* (Bovi-Shield Gold 5, Zoetis, Inc.; Kalamazoo, MI), and parasite control (Safe-guard, Merck Animal Health, Madison, NJ). Cattle were implanted with 200 mg trenbolone acetate and 20 mg estradiol (Revalor 200®, Merck Animal Health, Madison, NJ) on d 35 of the trial. Additionally, on d 35 steers were branded for identification, and revaccinated to aid in the prevention of bovine viral diarrhea virus Type I and II, infectious bovine rhinotracheitis, parainfluenza$_3$, bovine respiratory syncytial virus, *Mannhemia haemolytica*, and *Pasteurella multocia* (Express 5-way, Boehringer Ingelheim, Ridgefield, CT), and parasite control (StandGuard, Elanco Animal Health, Greenfield, IN).

Steers were limit fed a diet consisting of 30% alfalfa hay, 40% corn silage, 25% wet distillers grains plus solubles (WDGS), and 5% liquid supplement (Blair, NE; DM basis) at 2.0% BW for 5 consecutive days to equalize gut fill prior to initiation of the trial (Watson et al., 2013). Steers were weighed for 2 consecutive days (0 and 1) and the average of those 2 days was used to establish initial BW (Stock et al., 1983). Steers were blocked by BW into light, medium, and heavy BW blocks (n = 2, 4, and 2 replicates respectively) based on d 0 BW, stratified by BW within block, and assigned randomly to one of 48 pens. Pens were then randomly assigned to one of 6 treatments (Table 4.1), with a total of 10 steers per pen and 8 replications per treatment.

Dietary treatments (Table 4.1) were arranged in an incomplete 2 × 4 factorial, and included 1) Syngenta Enogen Feed Corn processed as DRC with 0% WDGS (SYT-EFC 0), 2) SYT-EFC with 15% WDGS (SYT-EFC 15), 3) SYT-EFC with 30% WDGS (SYT-EFC 30), 4) SYT-EFC with 45% WDGS (SYT-EFC 45), 5) Conventional commercial

corn processed as DRC with 0% WDGS (CON 0), and 6) CON with 30% WDGS (CON 30). Steers were adapted to the finishing diets over a 21-d period with corn replacing alfalfa inclusion. Corn grain was included in the final diets at 79, 64, 49, or 34%, with WDGS inclusions of 0, 15, 30, or 45% respectively in all diets. Corn silage was included at 15% and a liquid supplement was included at 6% of diet DM for all diets. Supplements were formulated to provide 33 mg / kg of Rumensin® (Elanco Animal Health) and 9.7 mg / kg of Tylan® (Elanco Animal Health) on a DM basis.

Cattle were fed *ad libitum* and feed bunks were evaluated daily at approximately 0530 h for feed refusals, so that trace amounts of feed were left in the bunk at the time of feeding. Feed was delivered once daily starting at 0800 h with a truck mounted mixer and delivery unit (Roto-Mix, Dodge City, KS). All feed refusals were subsampled and dried for 48 h in a 60°C forced-air oven for determination of DM and calculation of refusal DM weight (AOAC, 1999, method 4.1.03). Dietary ingredients were sampled weekly for DM analysis. As-fed dietary ingredient inclusions were adjusted weekly.

Steers were harvested on d 155 at a commercial abattoir (Cargill, Fort Morgan, CO). Steers were shipped in the morning and harvested in the afternoon. The day of harvest, hot carcass weight (HCW) and liver abscesses were recorded. Liver abscesses were scored using the Brink et al. (1990) method; with 0 (no abscesses), A^-, A, and A^+ scores for severely abscessed livers. Following a 48-hr chill, 12^{th} rib back fat thickness, *Longissimus* muscle (LM) area, and USDA marbling scores were recorded. 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 + (2.5 x 12^{th} rib fat, cm) + (0.2 x 2.5 [KPH]) + 0.0038 x HCW, kg) – (0.32 x LM area, cm^2) (USDA,

1997). The energy value of the dietary treatments were calculated using pen data in the Galyean (2009) Net Energy calculator based on the NRC (1996) equations. Calculated energy values utilized the heaviest final BW of each block and the individual initial BW, DMI, and ADG of each pen, with a target endpoint of USDA Choice.

Fecal starch samples were collected on d 35 and 70, for analysis of fecal starch content. Three fecal samples were taken from the surface of each pen, bagged, and froze. The three pen samples were lyophilized (Virtis Freezemobile 25ES, SP industries, Warminster, PA), ground through a 1-mm screen using a Wiley Mill (No. 4, Thomas Scientific, Swedesboro, NJ) and composited by pen on a dry weight basis. Dry pen samples were analyzed for percent starch content (Megazyme International, AOAC International, 2000; Method 996.11; AACC Method 76.13).

Growth performance and carcass characteristics were analyzed using the PROC GLIMMIX procedure of SAS (SAS Institute, Inc., Cary, NC) as a generalized randomized block design. Pen served as the experimental unit, with the block considered the fixed effect. Data were analyzed as a 2 × 2 factorial, evaluating corn hybrid and WDGS inclusion interactions for CON and SYT-EFC with 0 or 30% WDGS. Additionally, linear and quadratic orthogonal contrasts evaluated the impact of replacing SYT-EFC DRC with 0, 15, 30, or 45% inclusion of WDGS. Treatment differences were considered significant when $P \leq 0.05$. Additionally, a tendency was declared when $P > 0.05$ and $P \leq 0.10$.

RESULTS AND DISCUSSION

Effects of WDGS inclusion with SYT-EFC

Orthogonal contrasts were used to evaluate the effect of WDGS inclusion when replacing 0, 15, 30, or 45% SYT-EFC DRC in the diet (Table 4.3). No differences were observed for initial BW, NEm and NEg values, or marbling score due to WDGS inclusion ($P \geq 0.17$). A linear increase ($P < 0.01$) was observed for carcass-adjusted final BW and HCW, with cattle consuming increased levels of WDGS possessing greater final live and carcass weights. There was a linear increase in DMI as WDGS inclusion increased from 0 to 45% ($P < 0.01$). Furthermore, ADG linearly increased, with steers gaining more as WDGS inclusions increased in the diet from 0 to 45% (1.73, 1.83, 1.86 and 1.89 kg respectively; $P < 0.01$). Daily gain increased at a greater rate than DMI, resulting in a linear increase in G:F as WDGS increased 0 to 45% ($P = 0.04$). These results are in agreement with observations by Corrigan et al. (2009) when evaluating the effect of increasing WDGS inclusions from 0 to 40% in DRC based diets. Corrigan et al. (2009) observed a linear increase in final BW, ADG, G:F, and HCW as WDGS increased in the diet ($P \leq 0.02$). Dry-matter intake was not different with varying levels of WDGS; however, cattle fed 27.5 and 40% WDGS consumed numerically less (Corrigan et al., 2009). Furthermore, a study by Watson et al. (2014) and a meta-analysis by Bremer et al. (2011) evaluated the impacts of increasing inclusions of WDGS in blended HMC and DRC feedlot diets. Watson et al. (2014) included WDGS at 0, 10, 20, 30, 40, or 50% of the diet, while Bremer evaluated trials that included 0, 10, 20, 30, or 40% WDGS. Results by Watson et al. (2014) observed a quadratic increase in final BW, HCW, ADG, G:F, as well as NEm and NEg values, with maximum weight, daily gain, and efficiency values occurring at 30 and 40% WDGS, and a decrease at 50% WDGS inclusion ($P \leq 0.01$). Additionally, DMI quadratically increased, with the greatest intake at 20% WDGS

($P < 0.01$). Similarly, results from Bremer et al. (2011) observed a quadratic increase for DMI, ADG, and G:F ($P < 0.01$). However, the greatest DMI was observed at 10 and 20% WDGS, greatest ADG at 30% WDGS, and the greatest G:F occurred at 40% WDGS inclusion.

In the current study, a tendency for a linear effect was observed for LM area, with cattle consuming 0 and 15% WDGS having a larger *Longissimus* muscle area than those consuming 30 or 45% WDGS (94.8, 94.8, 93.5, and 92.3 cm^2 respectively; $P = 0.09$). Finally, a significant quadratic effect was observed for back fat thickness. Cattle consuming increased levels of WDGS possessed significantly greater back fat, with back fat linearly increasing as WDGS moved from 0 to 30%; however, steers fed 45% WDGS possessed less backfat than those on the 30% treatment ($P < 0.01$). Similarly, Corrigan et al. (2009) observed a linear increase in back fat thickness as WDGS increased in the diet from 0 to 27.5%, but reduced backfat thickness for cattle fed 40% WDGS (1.47; $P < 0.05$). Results from Watson (2014) reported no additional differences in carcass characteristics. Nonetheless, similar to the current study, Bremer et al. (2011) observed a quadratic increase in backfat thickness, with the greatest amount observed when diets included either 30 or 40% WDGS ($P < 0.01$). In the current study, due to significantly greater back fat thickness, a quadratic ($P = 0.05$) increase was observed for calculated yield grade. As WDGS inclusion increased in the diet from 0 to 30%, calculated yield grade (YG) increased; however, YG decreased with inclusion of 45% WDGS. Corrigan et al. (2009) observed a linear increase in calculated YG until WDGS inclusions reached 40% ($P < 0.10$). While no difference was observed for marbling score in the current study ($P \geq 0.42$) or that conducted by Watson et al (2014), Bremer et al. (2011) observed a

quadratic increase in marbling, with the greatest score at 10, 20, or 30% WDGS inclusion.

Pen fecal samples were collected on d 35 and 70 of the trial, and analyzed for percent starch content. Starch content of the feces linearly decreased ($P < 0.01$) with increased WDGS inclusion. This is in agreement with the numerical decrease of starch content of the diet (Table 4.1). As DGS concentrations increase in the diet, the percent of starch from the DRC is displaced, resulting in a linear decrease of starch in the diet (Vander Pol, 2006). Thus, fecal starch content results in the current trial would be expected to decrease as WDGS displaces SYT-EFC DRC in the diet.

SYT-EFC vs. CON

No interactions for corn hybrid × WDGS inclusion were observed for any of the performance parameters, carcass characteristics or fecal starch content evaluated ($P \geq 0.15$; Table 4.4). Therefore, the main effects of corn hybrid and WDGS inclusion were tested. Marbling score was different between the two hybrids, with steers fed the CON hybrid displaying greater marbling scores than those fed SYT-EFC ($P = 0.03$). Additionally, starch content of the diets were similar for the two hybrids; however, fecal starch content was different among the two hybrids. Steers consuming SYT-EFC hybrid corn had a lower fecal starch content compared to the CON steers ($P < 0.01$).

Similarly to WDGS inclusion in SYT-EFC hybrid diets, the main effect of DGS inclusion resulted in no differences in initial BW or backfat thickness due to WDGS inclusion ($P \geq 0.46$). Final BW, HCW, DMI, ADG, G:F, NEm and NEg values, and calculated yield grade increased with increased WDGS inclusion ($P \leq 0.05$). These

results are consistent with previous research evaluating increased inclusions of DGS in feedlot diets (Klopfenstein et al., 2008; Watson et al., 2014; Bremer et al., 2011) Nonetheless, as WDGS increased in the diet, *Longissimus* area, marbling score, and fecal starch content decreased ($P < 0.01$).

Contrasts were used to evaluate the effect of corn hybrid type and WDGS inclusion for the 0% and 30% inclusion diets. No significant differences were observed for any of the performance parameters or carcass characteristics evaluated when comparing cattle fed SYT-EFC with those fed CON, with 0% WDGS ($P \geq 0.17$). However, steers fed the SYT-EFC hybrid with 0% WDGS had significantly lower fecal starch content than those consuming the CON hybrid (21.59 vs. 26.71%, respectively; $P < 0.01$). While starch digestion cannot be determined, this decrease in starch content indicates that SYT-EFC may improve total tract starch digestion. This is in agreement with digestibility results by Jolly-Breithaupt (2018) when feeding SYT-EFC or control hybrid as DRC. Jolly-Breithaupt (2108) reported a significant decrease in fecal starch content when feeding SYT-EFC resulting in a 61.3% reduction in fecal starch excretion compared to the control hybrid. This reduction in fecal starch suggests that a greater extent of starch digestion occurred when steers were fed the SYT-EFC hybrid. Cattle fed SYT-EFC with 0% WDGS had numerically greater ADG ($P = 0.51$) and G:F ($P = 0.17$) over those on the CON 0% diet (1.73 and 1.70 kg / d; 0.1503 and 0.1453, respectively). This improvement in G:F was 3.4% for the diet suggesting the SYT-EFC corn hybrid provided a 4.3% improvement (3.4/0.79, inclusion).

While this numerical response has been consistent across several experiments, previous research by Jolly-Breithaupt (2018) has observed varying results when

evaluating the SYT-EFC hybrid fed as dry-rolled corn. When comparing SYT-EFC to CON with WDGS included in the diet at 15% (DM basis), Jolly-Breithaupt (2018) observed heavier live final BW and HCW, as well as greater ADG and G:F in steers consuming SYT-EFC ($P < 0.01$). Dry-matter intake was not different among the corn hybrids ($P = 0.72$). Furthermore, marbling scores tended ($P = 0.08$) to be greater for SYT-EFC cattle; however, only numerical differences were observed for back fat thickness and calculated yield grades (YG; $P \geq 0.26$). A similar study by Jolly-Breithaupt (2018) included WDGS at 18% (DM basis) in SYT-EFC or control (NEG) DRC based diets. No statistical differences were observed for any of the live performance characteristics, HCW, or marbling scores evaluated due to corn hybrid ($P \geq 0.17$). Nonetheless, back fat thickness was greater for steers fed SYT-EFC ($P < 0.01$). Greater *Longissimus* muscle area was observed for NEG steers; however, steers consuming SYT-EFC displayed greater calculated yield grades ($P = 0.02$).

No significant differences were observed for any of the performance parameters evaluated when comparing steers consuming the SYT-EFC hybrid with those fed the CON hybrid with 30% WDGS ($P \geq 0.26$). Supplementation of exogenous α-amylase has displayed an increase in ADG (Burroughs et al., 1960; and Tricarico et al., 2007), G:F (Jolly-Breithaupt, 2018) or no difference in animal performance (Tricarico et al., 2007; and DiLorenzo et al., 2011). While not significant, DiLorenzo et al. (2011) observed a 9.5% numerical improvement in G:F when α-amylase was included in DRC based diets (Rumistar; DSM Nutritional Products Inc., Kaiseraugust, Switzerland; $P = 0.55$). Although G:F differences were not statistically different when comparing the two corn hybrids with either 0 or 30% WDGS, the numerical increase in G:F when SYT-EFC was

fed with 0% DGS and no response when fed with 30% suggests that SYT-EFC hybrid corn may have greater benefit at lower DGS inclusions.

Nonetheless, in the current study, back fat thickness was significantly different, with cattle consuming SYT-EFC having greater back fat thickness than those on the CON diet, when WDGS was included at 30% (1.78 and 1.63 cm respectively; $P = 0.01$). An increase in back fat thickness and no difference in LM area resulted in steers fed the SYT-EFC hybrid having significantly greater calculated yield grades compared to those consuming CON (3.57 vs. 3.29, respectively; $P = 0.02$). These results are in agreement with those observed by Jolly-Breithaupt (2018) when distillers grains were included in the diet at either 15 or 18% on a DM basis. Finally, in the current study, when WDGS was included at 30%, fecal starch content was significantly lower for steers fed SYT-EFC compared to the control ($P = 0.02$). This is in agreement with digestibility results by Jolly-Breithaupt (2018) when feeding SYT-EFC or control hybrid DRC with modified distillers grains (MDGS, 15% diet DM) or Sweet Bran (SB; 25% diet DM; Cargill Wet Milling, Blair, NE). The authors reported a significant decrease in fecal starch content when feeding SYT-EFC, regardless of byproduct type. Steers fed SYT-EFC displayed a 61.3% reduction in fecal starch excretion compared to the control hybrid. Jolly-Breithaupt (2018) suggests that this indicates a greater extent of starch digestion occurred when steers were fed the α-amylase containing corn.

In conclusion, feeding finishing beef cattle increasing inclusions of wet distillers grains plus solubles linearly increased final live BW, HCW, DMI, ADG, and G:F in diets containing SYT-EFC hybrid corn. Furthermore, an increase in WDGS inclusion resulted in an increased back fat thickness and calculated yield grade in steers fed SYT-EFC

based diets. Corn hybrid impacted steer fecal starch content, with less starch content observed for the SYT-EFC hybrid when diets contained either 0 or 30% WDGS. Decreased fecal starch content when steers were fed the SYT-EFC hybrid compared to CON suggests SYT-EFC may increase total tract starch digestion. When comparing the effect of corn hybrid, no statistical differences were observed among cattle consuming diets with 0% WDGS included, despite the observation of a 4.3% numerical increase in G:F when SYT-EFC was fed. No performance changes were observed between the corn hybrids when diets contained 30% WDGS, although, back fat thickness and calculated yield grades were greater for steers fed the SYT-EFC hybrid. Lack of improvement in efficiency when WDGS was included at 30% compared to that observed at 0% of the diet may be due to a greater proportion of the diet including the α-amylase enzyme (SYT-EFC) when no WDGS was fed. Therefore, as hypothesized, SYT-EFC may improve starch digestion when DGS is fed at lower inclusions, due to DGS naturally increasing starch digestion.

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Table 4.1. Dietary treatment compositions (% DM basis) to evaluate corn hybrid with titrating levels of WDGS

Trait:	SYT-EFC[1]				CON[2]	
WDGS Inclusion:	0[4]	15[5]	30[6]	45[6]	0[4]	30[6]
Control DRC[2]	-	-	-	-	79	49
SYT-EFC DRC[1]	79	64	49	34	-	-
WDGS	-	15	30	45	-	30
Corn Silage	15	15	15	15	15	15
Supplement	6	6	6	6	6	6
Nutrient Composition, %						
CP	12.01	15.32	14.33	14.29	11.80	14.20
ADF	4.85	6.86	8.86	9.23	4.99	8.95
NDF	10.75	15.04	19.33	19.77	10.22	19.00
Starch	55.97	45.34	34.72	24.09	55.77	34.59
Ca	0.72	0.73	0.73	0.73	0.71	0.73
P	0.21	0.31	0.41	0.41	0.24	0.42
K	0.48	0.60	0.72	0.71	0.47	0.71
Mg	0.11	0.14	0.18	0.18	0.11	0.18

[1]SYT-EFC = Syngenta Enhanced Feed Corn provided by Syngenta under identity-preserved procedures, stored, processed as dry-rolled corn (DRC).
[2]Control = Commercially available corn grain without the alpha amylase enzyme trait.
[3] Supplement formulated to provide 33 mg/kg Monensin (Rumensin-90®; Elanco Animal Health, DM Basis), 9.7 mg/ton Tylosin (Tylan®; Elanco Animal Health, DM Basis).
[4]Supplement formulated to provide 4.31% CP (1.5% urea), 0.64% Ca, and ≥ 10,820 IU Vitamin A.
[5]Supplement formulated to provide 1.44% CP (0.5% urea), 0.64% Ca, and ≥ 10,820 IU Vitamin A.
[6]Supplement formulated to provide 0.64% Ca, and ≥ 10,820 IU Vitamin A.

Table 4.2. Nutrient analysis of corn hybrids

Trait	SYT-EFC[1]	CON[2]
Nutrient Composition		
DM, %	84.41	84.66
CP, %	8.38	8.12
ADF, %	1.57	1.75
NDF, %	6.40	5.73
Starch, %	70.85	70.60
Ca, %	0.04	0.04
P, %	0.23	0.26
K, %	0.38	0.36
Mg, %	0.10	0.11

[1]CON= Commercially available corn grain without the alpha amylase enzyme trait
[2]SYT-EFC = Syngenta Enogen Feed Corn provided by Syngenta under identity-preserved procedures, stored, processed as dry-rolled corn (DRC)
Note: Sample analysis in the table were analyzed on monthly composited samples. Samples were analyzed at Ward Laboratories, Inc.® (Kearney, NE). All values are presented on a DM basis.

Table 4.3. Effect of Syngenta Enogen Feed Corn and distillers inclusion on cattle performance and carcass characteristics

	Treatments[1]				SEM	*P* – Values	
Hybrid	SYT-EFC[2]					Main Effects of WDGS	
Distillers Incl.	0	15	30	45		Linear[3]	Quadratic[4]
Pens	8	8	8	8			
Performance							
Initial BW, kg[5]	377	377	377	377	0.2	0.83	0.24
Final BW, kg	644	659	668	669	4.8	<0.01	0.12
DMI, kg/d	11.5	11.9	12.0	12.1	0.13	<0.01	0.29
ADG, kg[5]	1.73	1.83	1.86	1.89	0.031	<0.01	0.11
Gain:Feed[5]	0.1503	0.1538	0.1550	0.1562	0.00240	0.04	0.45
NEm, Mcal/kg	1.88	1.89	1.90	1.91	0.017	0.17	0.88
NEg, Mcal/kg	1.24	1.25	1.26	1.27	0.016	0.19	0.83
Carcass Characteristics							
HCW, kg	405	415	421	421	3.0	<0.01	0.12
LM Area, cm	94.8	94.8	93.5	92.3	1.13	0.09	0.58
Back Fat Thickness, cm	1.40	1.60	1.78	1.70	0.046	<0.01	<0.01
Marbling Score[6]	553	553	541	561	12.9	0.82	0.42
Calculated Yield Grade[7]	2.98	3.29	3.57	3.55	0.083	<0.01	0.05
Fecal Starch							
Starch, %[8]	21.59	18.52	14.60	12.35	1.369	<0.01	0.77

[1]DRC based diets with titrating levels of WDGS inclusions from 0 to 45%, all diets included supplement at 6% of diet DM.
[2]SYT-EFC = Syngenta Enhanced Feed Corn provided by Syngenta under identity-preserved procedures, stored and processed as dry-rolled corn (DRC).
[3] Linear effect of distillers grains inclusion levels on SYT-EFC.
[4] Quadratic effect of distillers grains inclusion levels on SYT-EFC.
[5]Calculated from hot carcass weight.
[6] Marbling score 400 = Small00, 500 = Modest00
[7]Calculated as 2.5 + (2.5 x 12^{th} rib fat, cm) + (0.2 x 2.5 [KPH]) + (0.0038 x HCW, kg) – (0.32 x ribeye area, cm^2) (USDA, 1997).
[8]Average percent of starch in fecal samples taken on day 35 and 70 from each pen.

Table 4.4. Effect of corn hybrid and distillers inclusion on cattle performance and carcass characteristics

	Treatments[1]				SEM	*P* – Values				
Hybrid	SYT-EFC[2]		CON[3]			Int.[4]	Corn Hybrid[5]	WDGS Incl.[6]	SYT-EFC vs. CON[7]	
Distillers Incl.	0	30	0	30					0 vs. 0	30 vs. 30
Pens	8	8	8	8						
Performance										
Initial BW, kg	377	377	377	377	0.2	0.80	0.33	0.46	0.41	0.62
Final BW, kg[8]	644	668	639	662	4.8	0.92	0.32	<0.01	0.49	0.41
DMI, kg/d	11.5	12.0	11.7	11.8	0.13	0.93	0.47	<0.01	0.40	0.26
ADG, kg[8]	1.73	1.86	1.70	1.85	0.031	0.21	0.85	0.05	0.51	0.42
Gain:Feed[8]	0.1503	0.1550	0.1453	0.1568	0.00240	0.92	0.32	<0.01	0.17	0.69
NEm, Mcal/kg	1.88	1.90	1.84	1.91	0.020	0.15	0.54	0.01	0.10	0.49
NEg, Mcal/kg	1.24	1.26	1.21	1.27	0.018	0.20	1.51	0.02	0.12	0.60
Carcass Characteristics										
HCW, kg	405	421	403	417	3.0	0.92	0.32	<0.01	0.49	0.41
LM Area, cm	94.8	93.5	94.8	94.8	1.13	0.25	0.53	<0.01	1.00	0.35
Back Fat Thickness, cm	1.40	1.78	1.32	1.63	0.046	0.51	0.51	0.71	0.37	0.01
Marbling Score[9]	553	541	546	556	12.9	0.26	0.03	<0.01	0.70	0.39
Calculated Yield Grade[10]	2.98	3.57	2.90	3.29	0.083	0.67	0.12	<0.01	0.51	0.02
Fecal Starch										
Starch, %[11]	21.59	14.60	26.71	18.93	1.546	0.79	<0.01	<0.01	<0.01	0.02

[1]DRC based diets with WDGS inclusions of 0 or 30%, all diets included supplement at 6% of diet DM.
[2]SYT-EFC = Syngenta Enhanced Feed Corn provided by Syngenta under identity-preserved procedures, stored and processed as dry-rolled corn (DRC).
[3]CON = Commercially available corn grain without the alpha amylase enzyme trait.
[4]Int = Corn hybrid by WDGS inclusion interaction
[5]Main effect of corn hybrid.
[6]Main effect of WDGS inclusion.
[7]Contrast comparison of SYT-EFC and CON DRC with 0 and 30% WDGS inclusion.
[8]Calculated from hot carcass weight.
[9]Marbling Score 500 = Modest00
[10]Calculated as 2.5 + (2.5 * 12t rib fat, cm) + (0.2 + 2.5 [KPH]) + (0.0038 * HCW, kg) – (0.32 * ribeye area, cm^2) (USDA, 1997).
[11]Average percent of starch in fecal samples taken on day 35 and 70 from each pen.

CHAPTER V. Forage Production and Calf Gains when Grazing Oats Following Corn Harvest

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ABSTRACT

A study was conducted to evaluate forage yield and grazing potential of double cropped annual forages (DCAF) following corn silage (CS) or high-moisture corn (HMC) harvest. An irrigated field enrolled in a corn-soybean rotation was utilized and the corn was harvested as either CS or HMC. Following CS or HMC harvest, an oat monoculture was planted at 108 kg / ha and a 32% ammonium nitrate fertilizer was applied at a rate of 44.8 kg / ha. Treatments included; DCAF followed by grazing (Cov-G), DCAF without grazing (Cov-NG), and no DCAF (NC-NG). Crop yields were measured to determine any effects on subsequent yield due to DCAF and grazing. Total forage production was greater for oats planted after CS (2,440 kg DM / ha) than those planted after HMC (1,231 kg DM / ha), likely due to differences in growing degree days (GDD; 972 vs. 665 respectively; $P < 0.05$). Furthermore, crude protein was greater in oats planted following HMC (20.5 vs 17.4 respectively; $P = 0.05$). Steer calves grazing oats planted following CS displayed greater ending body weight (BW) and average daily gain (ADG) compared to those on the HMC treatment ($P \leq 0.05$). Over the two grazing seasons, steers on the CS had an average ADG of 1.06 kg, while those on HMC averaged 0.45 kg ($P = 0.04$). No interaction was observed between corn treatment and cover crop treatment ($P = 0.41$) on subsequent soybean yields. Finally, subsequent soybean stover, CS, and HMC yields were not different due to treatment ($P \geq 0.10$). Planting cover crop forages following corn silage harvest provides producers opportunities for additional BW gain with greater forage production than planting after high-moisture corn, with no apparent impacts on subsequent yields.

Key Words: ADG, corn silage, cover crops, grazing cattle, high-moisture corn

INTRODUCTION

Grazing livestock on fall planted double-cropped annual forages may provide beneficial opportunities for producers looking to extend their grazing season between summer range and grazing winter residue. Double-cropped forages, commonly referred to as cover crops, have increased in popularity recently (SARE/CTIC, 2016). Cover crops provide numerous agronomic advantages for land owners, including, soil conservation, weed control, and economic incentives (grazing rent). Additionally, fall grazed cover crops possess the ability to provide substantial weight gains and economic benefits for livestock producers and land owners.

Planting date plays a major role in the yield potential of cover crops, and later planting dates result in limited yields due to fewer growing degree days (Wiedenhoeft and Barton, 1994). A 10-yr study conducted in Powell, WY evaluated the impact of planting date on turnip and radish yield, and determined brassicas seeded after July 20th produced 770 kg / ha less forage production per week (Koch et al., 2002). Koch et al. (2002) concluded that planting date was the single largest factor determining fall cover crop forage production. Corn and soybeans are the most common crops in Nebraska; however, due to limited growing degree days following harvest, they provide limited opportunities for cover crop production. Nonetheless, corn silage and high-moisture corn harvest may provide an opportunity for Nebraska producers to take advantage of late-summer planted double-cropped forages. Previous research grazing annual ryegrass and a winter rye-oat mix following corn silage observed daily gains of 0.81 kg, with no differences in subsequent corn yields (Fae et al., 2009). Few studies have evaluated calf performance when grazing oat monocultures. Economically, the ability to plant and

utilize a second crop may enable a producer to increase return per hectare and produce a high-quality grazing forage in the fall (Koch et al., 2002).

We hypothesized that early harvested corn systems will provide the opportunity for adequate fall forage production from double cropped annual forages. Increased forage production in these early crop systems may provide favorable calf gains and present producers with an economically favorable opportunity to extend the grazing season. Thus, the objective of this study was to determine calf gains and forage production of oats following corn silage or high-moisture corn harvest, as well as their impact on subsequent crop yields and the total cost of gain for these systems.

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.

Field and Planting Details

A pivot irrigated field located at the Eastern Nebraska Research and Extension Center (ENREC) near Mead, NE was utilized to determine oat forage production and calf gains while grazing oats planted following corn silage (CS) and high-moisture corn (HMC) harvest, as well as their effects on subsequent crop yield. The 42-hectare field was split into a corn and soybean rotation (21-ha each). In year 1 corn was planted on the west half, with soybeans planted on the east, and in year 2, corn was planted on the east and soybeans were planted on the west half. Corn and soybeans were planted with 76-cm row spacing. The half of the field planted to corn was split again into CS and HMC. In year 1, 10-ha of CS and 11-ha of HMC were planted; while in year 2, 11-ha of CS and

10-ha of HMC were planted on the corn half of the field. Each treatment (n = 6) contained 3 replications for sampling crops and 2 replications for forage sampling. Replication varied between crop and forage sampling in order to provide larger paddocks for grazing, and to increase statistical power in the crop sampling for a soil experiment not presented here.

Treatments were arranged in a complete 2 × 3 factorial, and included; double cropped annual forage (DCAF) followed by grazing (Cov-G), DCAF without grazing (Cov-NG), and no DCAF (NC-NG) for both CS and HMC. Treatments were initially applied in 2013; however, only data from 2017 (yr. 1) and 2018 (yr. 2) will be discussed. In 2013, corn was planted on the west half, double-cropped with wheat, and grazed; while soybeans were planted on the east half. In 2014, soybeans were planted on the west half, while corn was planted on the east half, and was double-cropped with an oat-brassica mix. Due to herbicide restrictions, no grazing occurred in 2014. In 2015, corn was planted on the west half, double-cropped with an oat monoculture, and grazed according to treatment. Soybeans were planted on the east half of the field in 2015. In 2016, soybeans were planted on the west half, while corn was planted on the east half, double-cropped with oats, and grazed according to treatment.

In 2017 (yr. 1), corn was planted on the west half, double-cropped with an oat monoculture, and grazed according to treatment. Soybeans were planted on the east half of the field. In year 1, Horsepower oats were drilled at 108 kg / ha on September 7, 2017 and September 22, 2017 following CS and HMC harvest, respectively. Upon seeding of oats, a 32% ammonium nitrate fertilizer was applied at a rate of 44.8 kg / ha. In 2018 (yr. 2), soybeans were planted on the west half, while corn was planted on the east half of the

field. The corn half was double-cropped with oats, and grazed according to treatment. In year 2, Horsepower oats were drilled at 108 kg / ha on August 29, 2018 and September 11, 2018 following CS and HMC harvest, respectively. In 2018, soil compaction from corn silage harvest and frequent rains resulted in limited oat growth on the CS side. Due to limited emergence of the oats planted on the CS, Horsepower oats were re-planted on the CS at 108 kg / ha on September 11, 2018, when oats were planted on the HMC. A 32% urea ammonium nitrate fertilizer was applied at a rate of 44.8 kg / ha following the seeding of oats to the entire field, including the NC-NG treatments.

Forage Production Measures

Initial oat biomass was sampled on October 27, 2017 (yr. 1) and on November 7, 2018 (yr. 2) to determine forage production, and thus stocking rates. Total biomass was measured by randomly selecting (0.91 × 0.57 m) areas within each treatment paddock that contained oats (CS Cov-G, CS Cov-NG, HMC Cov-G, and Cov-NG). Grazing paddock size ranged from 3.0 to 4.4 hectares. Due to differences in paddock size, grazed treatments were sampled in 5 locations / rep, while non-grazed treatments were sampled in 3 locations / rep. Forage was clipped at ground level, bagged, and dried for 48 h in a 60°C forced air oven to determine initial biomass. Based on previous research by Wilson et al. (2004), initial available corn stover was estimated by assuming 3.63 kg of leaf and husk residue per 25.4 kg of total corn grain with a corn yield of 13,860 kg per hectare. After the grazing period, forage biomass was sampled the same as initial forage biomass, and transects were taken to determine percent cover. Transects were taken using a 30.5 m tape stretched randomly across areas within each treatment. At each 0.30 m, it was determined whether the soil was covered or not, and the mean of these measurements was

used to determine the percentage of cover at each area. Similar to biomass samples, 5 transects / rep were taken in the grazed treatments and 3 transects / rep were taken in the non-grazed treatments. Furthermore, corn stover was sampled on the HMC side to account for the total amount of residue removed due to grazing.

Growing degree days (GDD) were calculated for each treatment to account for differences in planting date. Growing degree days are used to determine the number of days a plant has to grow based on the average temperature. Therefore, GDD are calculated by taking the maximum daily temperature (°C) minus the minimum daily temperature (°C) for each day, and summing them from the day the oats were planted, to the day initial biomass samples were taken. If the minimum daily temperature was below zero (°C), then the minimum temperature for that day was set at 0 (°C).

During initial biomass sampling, forage quality samples were taken for each treatment (2 rep / treatment) containing oats (CS Cov- G, CS Cov-NG, HMC Cov- G, HMC Cov-NG). Samples were taken by randomly clipping oats at ground level uniformly across each paddock. Forage samples were then freeze dried and ground through a 1-mm screen in a Wiley Mill. Additionally, samples were dried at 100°C for 24 h to determine DM and burned in a cool muffle furnace at 600°C for 6 h to determine OM. Samples were analyzed for neutral detergent fiber (NDF) as described by Van Soest et al. (1991) and acid detergent fiber (ADF) as described by Van Soest (1963). Sodium sulfite was added to all samples at 0.5 g for protein removal. Finally, sample crude protein (CP) was analyzed using a TrueSpec micro analyzer (LECO Corp.).

Crop Yield

Corn silage, high-moisture corn, and soybean yields were collected to determine subsequent crop yields following the previous years' imposed treatments. Treatments were the same as previously described (NC-NG, Cov-NG, and Cov-G) for both the CS and HMC, with 3 replications / treatment. Corn and soybean yields were collected by hand harvest methods (Lauer, 2002). Hand harvest of corn in year 1 occurred on September 5, 2017 and September 18, 2017 for CS and HMC respectively. Soybean hand harvest in year 1 occurred on October 2, 2017. In year 2, corn was hand harvested on August 28, 2018 and September 10, 2018 for CS and HMC, respectively, while soybeans were hand harvested on September 27, 2018.

Hand harvest of corn silage included cutting corn plants within a row at the first node for 5.33 m at 3 locations per replicate per treatment. Corn rows sampled were alternated within each replicate. Corn ears were then removed, weighed wet, shelled, dried in a 60°C forced air oven for 48 h, and weighed back to determine corn and cob DM. Dry cob weights were included in the dry stover yields. The remainder of the corn plant was ground through a chipper shredder (model #D11334 AC, Troy Built, MTD Products, Valley City, OH), weighed wet, and sub-sampled. Subsamples of the plant material were dried for 48 h in a 60°C forced air oven, and weighed back. Upon determination of DM, the corn ear DM and stalk DM was summed to determine corn silage yield per hectare.

High-moisture corn utilized a similar hand harvesting method, where corn was harvested at the second node level for 5.33 m at 3 locations per replicate within each treatment. Harvested rows were alternated within each replicate. Corn ears were removed, and the ear and remaining plant stover (husk, leaf, and stalk) were weighed

separately. Three corn plants and three ears were taken as a subsample from each 5.33 m bundle, and were dried in a 60°C forced air oven for 48 h to determine DM content. Corn kernel counts were completed on all three ears prior to shelling. Cobs and grain were placed back in the 60°C forced air oven for another 24 h, or until dry to determine corn grain yield. Cob weights were included in the dry stover yields. Dry matters were used to calculate corn grain and stover yield per hectare.

Soybean plants were hand harvested at ground level for 5.33 m at 3 locations / replication / treatment. Samples were then bundled, and dried in a drying room at 60°C until threshing. During threshing, grain and stover were collected, weighed wet, and dried for 48 h in a 60°C forced air oven to determine DM. Dry matter oven weights for the grain and stover were used to calculate soybean grain and stover yield per hectare.

Cattle Grazing and Management

Thirty-four steer calves (initial BW = 210 kg; SD = 13 kg) were utilized in 2017 (yr. 1) and thirty-six steer calves (initial BW = 230 kg; SD = 3 kg) were utilized in 2018 (yr. 2) for oat grazing. Prior to grazing, steers were limit fed a common diet of 50% Sweet Bran (Cargill Wet Milling; Blair, NE) and 50% alfalfa hay for 5 d, then weighed for 3 consecutive d to establish initial BW (Watson et al., 2013). Cattle were stratified by BW and assigned randomly to paddocks with two paddocks in the CS and HMC treatments. Due to differences in available forage, number of head varied between paddocks. In 2017, there were 9 steers / paddock, except for one HMC group which had 7 steers. In 2018 both CS groups contained 7 steers / paddock, while the HMC paddocks contained 10 and 12 head, respectively. In year 1 calves were implanted with 36 mg Zeranol (Ralgro, Merck Animal Health, Madison, NJ) and turned out into their respective

paddocks on November 1st, 2017. Steers grazed for 48 d and were pulled off on December 19th, 2017, due to limited oat forage remaining in the HMC treatments. Similarly, in year 2 cattle were implanted with Ralgro and were turned out into their respective paddocks on November 15th, 2018. Calves grazed for 30 d, and were removed on December 14th, 2018 due to winter weather impacting grazing. Oat forage remained on the CS side, as well as oat forage and corn residue on the HMC side; however, available forage was not accessible due to icy formation on the grazing treatments.

Stocking rates were calculated using a predetermined 70 d grazing period, with a 60% grazing efficiency, intakes estimated at 2.5% of BW, and initial oat biomass measurements of kg DM / ha within each grazing paddock. Additionally, 9.5 kg of total corn residue are assumed remaining in the field per 25.5 kg of HMC grain yield. Corn residue available for grazing was estimated by applying the 60% grazing efficiency to the total residue. This resulted in 13% of the total corn residue assumed available for grazing on the HMC treatment. Upon removal from the grazing treatments, steers were limit fed the same 50:50 alfalfa and Sweet Bran (Cargill Wet Milling; Blair, NE) diet for 8 d and were weighed for 3 consecutive d to limit differences in gut fill and determine ending BW (Watson et al. 2013).

Economics

A partial budget was established to evaluate costs associated with seeding and grazing oats planted after either CS or HMC harvest, in order to determine the total cost per kg of BW gain. The forage cost in the budget included oat seed plus seeding rate ($ / hd) and urea ammonium nitrate fertilizer plus application rate ($ / hd) for each oat system over the two years. Seed plus seeding rate and fertilizer plus application were based on

five year averages of each input for this trial. Furthermore, a yardage cost was included to account for fencing and water maintenance at $ 0.10 / hd / d. Additionally, a corn residue cost was included at $ 37.50 / ha, for calves grazing the HMC side. All values exclude vet costs, interest, and transportation costs which were assumed to be the same for all treatments. Average daily gain data was utilized from steer performance on each treatment (CS and HMC) for each year in the present study.

Statistical Analysis

The experiment was designed as a completely randomized block, with grazing treatments arranged in a 2 × 3 factorial including the two corn harvest methods and three cover treatments. Data were analyzed using the MIXED procedure of SAS (SAS Institute, Inc., Cary, N.C.). Paddock was the experimental unit for calf performance, oat forage quality data, and economic inputs. Treatment was analyzed as a fixed effect for steer performance, and subsequent corn and soybean yields. Analysis of the economic data included year in the model. Treatment means were separated using the pdiff statement when the F-test was significant. Data were considered to be significantly different at $P \leq 0.05$.

RESULTS AND DISCUSSION

Forage Production and Quality

Oat forage biomass production was greater following CS than HMC with 2,440 kg DM / ha compared to 1,231 kg DM / ha, respectively ($P = 0.01$, Table 5.1). Nonetheless, due to an abnormally wet harvest season, there was limited oat emergence on the CS in 2018. Thus, HMC oat biomass was more similar to CS than in previous

years. Furthermore, number of GDD was different for the two treatments, with oats planted on CS averaging 972 d and HMC averaging 665 d, respectively ($P = 0.05$). Greater forage production following CS is likely due to the difference in average GDD between the treatments and cover from the HMC residue.

Due to HMC residue, percentage ground cover after the grazing period estimated using transects, was significantly different between CS and HMC (59.1% and 93.0% respectively; $P < 0.01$; Table 5.1). Evaluating the simple effects of percentage ground cover, all treatments (Cov-G, Cov-NG, and NC-NG) within HMC had the greatest percent ground cover at 93.0, 95.4, and 95.4%, respectively (Table 5.2). Due to the corn residue, it is logical that the HMC treatments would possess greater ground cover. Furthermore, the limited oat biomass on the HMC treatments appears to have limited impact on ground cover. The NC-NG treatment within CS had the least cover at 36.6%, while the CS Cov-G and Cov-NG were intermediate with 59.1 and 75.2%, respectively. The presence of oats had a much greater impact on ground cover within the CS treatments compared to the HMC treatments. The implementation of grazing had no impact on the ground cover of HMC treatments; however, grazing lowered the percentage of cover within CS treatments.

Nutrient quality of oats (OM, CP, NDF, and ADF) is reported in Table 5.3. Oat OM was not different ($P = 0.25$) whether it was planted following CS or HMC harvest (86.9% and 87.5%, respectively). Nonetheless, CP was greater in the oats seeded following HMC compared to CS at 20.5 and 17.4%, respectively ($P = 0.05$). Oats planted following HMC harvest were less mature than those following CS, likely contributing to the increase in CP content. Both NDF and ADF content of oats were similar, whether

they were planted following CS or HMC harvest (34.4% vs 33.9% and 22.4% and 21.3%, respectively; $P \geq 0.26$). Due to differences in planting date, it would be expected that earlier planted CS oats would possess an increased NDF and ADF content, as they are more mature than the oats planted after HMC harvest. However, due to limited oat emergence in 2018, leading to re-seeding, oats planted after CS on year 2 were less mature. Wiedenhoeft and Barton (1994) demonstrated that earlier planted forages will have greater NDF content compared to forage planted later in the season. Additionally, as the plant matures and proportions of structural plant components increase, ADF content will increase (Van Soest, 1963).

Calf Performance

Calf initial and ending BW, average daily gain (ADG), and gain per ha is reported in Table 5.1. Steers grazing oats following CS had greater ending BW than those grazing after HMC (266 and 237 respectively; $P = 0.05$). Accordingly, calves grazing the CS treatment had greater ADG than steers grazing the HMC treatment ($P = 0.04$) with an ADG of 1.06 and 0.45 kg / d, respectively. Gain per hectare was numerically different between the two treatments, with calves grazing on the CS gaining 95 kg / ha while those grazing HMC oats gained 42 kg / ha ($P = 0.12$). Cox et al. (2017) reported an ADG of 0.72 kg / d when grazing an oat-turnip-radish mix planted after CS harvest for 71 d, which is similar to the gains observed in the current experiment.

Crop Yields

Subsequent soybean grain yields were significantly different ($P = 0.04$) based on the corn crop it followed, with soybeans succeeding CS yielding an average of 3,905 kg

DM / ha compared to 3,711 kg DM / ha for those following HMC (Table 5.3). Soybean grain yields were not significantly different due to the presence of DCAF (P = 0.18). No interaction was observed between corn treatment and DCAF treatment for soybean grain or stover yield ($P \geq 0.41$). Soybean stover yields were not affected by corn or DCAF treatments ($P \geq 0.80$).

Subsequent corn yields were compared across treatments for 2017 and 2018, to evaluate the impact of grazing in 2015 and 2016 respectively. Corn silage yields, HMC grain and HMC stover yields were not different among treatments ($P \geq 0.10$; Table 5.4). Fae et al., (2009) reported no impact on subsequent crop yields from cover crop forages with or without grazing of the forage.

Economics

A corn by year interaction was detected for ADG, stocking rate, seed plus seeding rate, fertilizer plus application rate, corn residue cost, and total cost ($P \leq 0.01$; Table 5.6). Calves grazing oats planted following CS harvest in 2017 (yr. 1) gained significantly more per day compared to those grazing HMC in 2017 (yr. 1), or oats planted after CS or HMC in 2018 (yr. 2) (1.53, 0.46, 0.59, 0.44 kg /d, respectively; $P \leq 0.01$). Furthermore, stocking rate for the HMC side in 2018 (yr. 2) was the greatest (2.69 hd / ha), while the CS in 2018 (yr. 2) was stocked the lightest (1.61 hd / ha; $P \leq 0.01$). Seed plus seeding costs were significantly greater when planting on the CS side in 2018 (yr. 2); however, planting oats on the HMC side in 2018 (yr. 2) cost the least, with seeding costs in 2017 (yr. 1) being intermediate ($P \leq 0.01$).

Furthermore, fertilizer and application costs were significantly greater when fertilizing oats planted after CS harvest in 2018 (yr. 2; $26.12), while fertilizing after HMC harvest in 2018 (yr. 2) was the least ($15.65; $P \leq 0.01$). Nonetheless, corn residue cost in yr. 1 was significantly higher than in yr. 2 ($16.37 vs. $13.74; $P \leq 0.01$). Differences in input costs between corn treatments and years are due to differences in number of head grazing, resulting in varying costs per animal. Finally, due to significantly higher seed plus seeding costs, and fertilizer and application costs; total costs ($ / hd) were greatest in 2018 (yr. 2) for the oats planted after CS harvest at $87.69 ($P \leq 0.01$). Total costs were least for oats planted after HMC in 2018 (yr. 2) and CS in 2017 (yr. 1), with costs for planting after HMC in 2017 (yr. 1) falling intermediate ($67.49, $68.22, and $81.64, respectively; $P \leq 0.01$).

No interaction was detected for cost per kg of gain; however, main effect of year was significant ($P = 0.01$; Table 5.6). Regardless of the corn treatment, costs associated with gaining one kg of BW was significantly greater in 2018 (yr. 2; $5.29 / kg for CS and $5.47 / kg for HMC) compared to 2017 (yr. 1; $0.93 / kg for CS, and $3.71 / kg for HMC; $P = 0.01$). From an economic standpoint, the number of animals and BW gains over the grazing period play a major role in the total cost per kg of BW gain. Limited gains and number of head can greatly impact the viability of using fall planted DCAF as an inexpensive feed source.

In conclusion, grazing double-cropped oats following corn harvest provides producers an opportunity to add additional weight to weaned calves, and may offer an economic incentive to cropping systems with no impact on subsequent crop yields. Due to fewer GDD, less forage production is observed following HMC harvest, leading to less

desirable gains compared to oats planted after CS. Furthermore, producers considering implementing late-summer cover crop systems need to consider the risks and limitations that seasonal weather may provide. In year 2 (2018) of the current study, abnormally wet weather conditions resulted in limited oat forage production on the CS treatment, and resulted in early termination of grazing. In this trial grazing was completely terminated; however, producers would have the opportunity to either supplement cattle through the inclement weather, or return calves to grazing upon availability of the forage. Seeding and grazing of oat forage following CS offers numerous benefits and opportunities for livestock and crop producers.

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Table 5.1. Two yr. averages of calf performance grazing oats seeded after corn silage or high-moisture corn harvest, forage production, growing degree days, and soil cover

	Treatment			
Item	CS[1]	HMC[2]	SEM	*P*-value
Calf Performance				
Initial BW, kg	220	220	10.4	0.75
Ending BW, kg	266	237	8.5	0.05
ADG, kg	1.06	0.45	0.262	0.04
Gain, kg / ha	95	42	38.5	0.12
Oat Forage Production				
Biomass, kg / ha[3]	2440	1231	229.8	0.01
GDD[4]	972	665	82.0	0.05

[1]Calf performance and forage production of oats seeded after corn silage harvest.
[2]Calf performance and forage production of oats seeded after high-moisture corn harvest.
[3]Biomass determined prior to the grazing period.
[4]GDD (growing degree days of oats) = [maximum temperature (°C) – minimum temperature (°C) (if min. temp. < 0, then set = 0] summed from d oats seeded to d initial oat biomass sampled.

Table 5.2. Two yr. simple effects of percentage of post-graze ground cover of oats after corn silage or oats and corn residue after high-moisture corn production[1]

	CS			HMC				
Item	Cov-G[2]	Cov-NG[3]	NC-NG[4]	Cov-G[2]	Cov-NG[3]	NC-NG[4]	SEM	*P*-value
Ground Cover, %	59.1[c]	75.2[b]	36.6[d]	93.0[a]	95.4[a]	95.4[a]	6.87	<0.01

[a,b,c,d] Means with different superscripts differ ($P \leq 0.05$).
[1]Crop × treatment interaction ($P < 0.01$).
[2]Cov-G = oats seeded after corn silage or high-moisture corn harvest and grazed.
[3]Cov-NG = oats seeded after corn silage or high-moisture corn harvest and not grazed.
[4]NC-NG = no oats seeded and no grazing.

Table 5.3. Two yr. averages of pre-graze forage quality of oats planted after corn silage and high-moisture corn harvest

	Treatment			
Item[1]	CS[2]	HMC[3]	SEM	*P*-value
Organic Matter	86.9	87.5	0.02	0.25
Crude Protein	17.4	20.5	0.85	0.05
Neutral Detergent Fiber	34.4	33.9	0.01	0.79
Acid Detergent Fiber	22.4	21.3	0.02	0.26

[1]All treatment means are percentages.
[2]Nutrient content of oats seeded after corn silage harvest.
[3]Nutrient content of oats seeded after high-moisture corn harvest.
[4] Forage quality samples taken prior to grazing, during initial biomass determination.

Table 5.4. Two yr. averages for subsequent soybean yields (kg DM / hectare) following oat forage production with and without grazing[1]

	Treatment[2]									
	CS[3]			HMC[4]				*P*-value		
Item[5]	Cov-G	Cov-NG	NC-NG	Cov-G	Cov-NG	NC-NG	SEM	Corn	Cover	Int.
Soybean Grain Yield	3,892	3,802	4,022	3,554	3,756	3,824	107.4	0.04	0.18	0.41
Soybean Stover Yield	3,757	3,830	3,864	3,915	3,814	3,807	163.5	0.80	0.99	0.71

[1]Average soybean yields from 2017, and 2018 following oats planted after corn silage or high-moisture corn harvest, with and without grazing by cattle.
[2]Cov-G = grazed oats, Cov-NG = ungrazed oats, NC-NG = ungrazed without oats drilled.
[3]Subsequent soybean yields in a rotation with corn silage.
[4]Subsequent soybean yields in a rotation with high-moisture corn.
[5]All treatment means are kg DM / hectare.

Table 5.5. Two yr. averages for subsequent corn yields (kg DM / hectare) following oat forage with and without grazing and no oat forage[1]

	Treatment[2]				
Item[3]	Cov-G	Cov-NG	NC-NG	SEM	*P*-value
Corn Silage Yield	19,207	16,285	19,609	1,092.9	0.10
HMC Grain Yield	13,966	13,234	12,778	684.2	0.48
HMC Stover Yield	9,207	8,931	8,100	435.9	0.21

[1]Average corn silage and high-moisture corn yields from 2017, and 2018 following oats planted after corn silage or high-moisture corn harvest, in 2016 and 2017.
[2]Cov-G = grazed oats, Cov-NG = ungrazed oats, NC-NG = ungrazed without oats drilled.
[3]All treatment means are kg DM / hectare.

Table 5.6. Cost of gain calculated for calves grazing oats seeded after corn silage or high-moisture corn harvest

	Treatment					*P*-value		
	2017		2018					
Item	CS	HMC	CS[1]	HMC	SEM	Corn	Year	Int.[6]
ADG, kg / d	1.53[a]	0.46[b]	0.59[b]	0.44[b]	0.090	<0.01	<0.01	<0.01
Stocking rate, hd / ha	2.16[b]	2.26[b]	1.61[c]	2.69[a]	0.067	<0.01	0.45	<0.01
Costs ($ / hd)								
Yardage[2]	4.80	4.80	3.00	3.00	-	-	-	-
Seed plus seeding[3]	43.86[b]	41.82[b]	58.57[a]	35.10[c]	1.220	<0.01	0.03	<0.01
Fertilizer plus application[4]	19.56[b]	18.65[b]	26.12[a]	15.65[c]	0.545	<0.01	0.03	<0.01
Corn residue[5]	0.00[c]	16.37[a]	0.00[c]	13.74[b]	0.234	<0.01	<0.01	<0.01
Total cost, $ / hd	68.22[c]	81.64[b]	87.69[a]	67.49[c]	1.890	0.15	0.23	<0.01
Cost of gain, $ / kg	0.93	3.71	5.29	5.47	2.486	0.21	0.01	0.26

[a,b,c] Means with different superscripts differ ($P \leq 0.05$).
[1]2018 seed plus seeding cost of oats only accounts for seeding once.
[2]Yardage includes fence and water at $0.10 / hd / d.
[3]Oat seed cost at $55.15 / ha ($22.32 / ac), and seeding at $39.54 / ha ($16.00 / ac).
[4] Nitrogen applied at a rate of 45 kg / ha at $0.86 / kg ($0.39 / lb) via Urea ammonium nitrate fertilizer, with application cost of $16.47 / ha ($6.67 / ac).
[5]Corn residue priced at $37.50 / ha ($15 / ac).
[6]Corn × Year interaction.