

ENHANCING THE FEEDING VALUE OF CORN CROP RESIDUES
TO IMPROVE BEEF CATTLE PRODUCTION

BY

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THESIS

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ABSTRACT

Corn has been used in cattle diets for more the 50 years in the United States. However, since 2005 when the “Ethanol Era” started, the demand for corn to be converted in to ethanol has been increasing. The increased demand for corn to be converted into ethanol, led to increased corn prices. When corn prices peaked, alternative feeds for beef cattle become more popular, particularly co-products from corn industry. For many years, distillers grains and solubles (**DGS**) were used in order to replace corn in cattle diet. However, DGS prices followed corn prices, and soon became an expensive energy source in cattle diets as well. Another byproduct that can be included in cattle diets is corn stover. Corn stover is one of the most abundant crop residues in the United States. Corn stover is the material (husk, leaf, and stem) left on the field following a combine, after traditional corn harvest. However, corn stover is a poor quality forage, limiting energy and protein, and has functioned mainly as a source of bedding or as a fiber source in cattle diets. In recent years, more research has been conducted in order to increase the inclusion of corn stover in growing cattle diets. Most of that research has been focused on treating corn stover chemically or physically in order to improve the feeding value by breaking lignin-hemicellulose bonds to increase digestibility. However, there are extra costs and hazards to manage when chemically treating corn stover. These costs and hazards, in addition to the extra labor involved in both physical and chemical processing, create challenges when applying these techniques in small scale operations. Harvesting less mature plants yields a material that has less lignin, thus, less bonding with hemicellulose, and tends to improve digestibility and cattle feedlot performance. However, feeding immature corn crop residues to cattle has not been heavily investigated. Feeding immature residues lends itself to harvesting these residues wet and storing

them as silages. The use of forage additives, such as lactobacillus and propionic acid, improve the quality of ensiled whole corn plants and small grains; however, they have not been investigated as means to improve ensiling of corn crop residues.

Therefore, the objectives of this study were to test the feeding value of corn plant residues, harvested at 2 maturities, and the effects of additives, Silage SAVOR Plus (propionic acid-based additive) or Silo-King (lactobacillus-based additive), on in situ fiber disappearance, economic traits, and growth performance and carcass characteristics of growing feedlot cattle. Steers were fed 1 of 4 treatments: 1) corn stover wetted to 40% DM and ensiled (**SVT**), 2) corn stalklage, harvested at 40% DM and ensiled (**STK**), 3) corn stalklage plus Silo-King (**STKL**; Silo-King, Agri-King, Inc., Fulton, IL at 0.25 kg/ton), or 4) corn stalklage plus Silage SAVOR Plus (**STKP**; Silage SAVOR Plus, Kemin Industries, Inc., Des Moines, IA at 0.5 kg/ton). Corn stover (71.5% NDF, 6.12% CP, and 5.88% lignin) was harvested 186 d post planting, after dry corn (88% DM). Corn stalklage (68.3% NDF, 6.24% CP, and 5.39% lignin) was harvested 158 d post planting, after harvesting high moisture corn (**HMC**; 77% DM). Diets were fed for 85 d (growing phase of the feedlot), and contained 25% corn plant residue, 30% modified wet distillers grain with solubles (**MWDGS**), 35% HMC, and 10% supplement (DM basis). From d 86 to 186 (finishing phase of the feedlot), all steers were fed a common finishing diet that contained 20% silage, 20% MWDGS, 50% HMC, and 10% supplement (DM basis). In order to characterize corn stover composition a chemical, physical and in situ analysis were conducted. The in situ analysis was conducted in order to determine in situ DM disappearance (**DMD**) and NDF disappearance (**NDFD**). Corn plant residue samples (SVT, STK, STKL and STKP) were incubated in 2 ruminally fistulated steers for 12, 24, 36 and 48 h. There were no effects of treatment on DMD ($P = 0.40$) and NDFD ($P = 0.34$) over time. Average NDFD at 48 h were

27.39, 30.59, 32.50, and 29.45% for ST, STK, STKL, and STKP, respectively. Feeding wetted corn stover resulted in similar ruminal fiber degradation, and steer growth and carcass performance as feeding corn stalklage. There was a treatment effect ($P \leq 0.03$) on corn stover particle size (0.8 to 1.9 cm and >1.9 cm) for SVT and STKP treatments, which was not expected since all of the materials went through the same harvesting process; however, the difference in particle size did not impact another measurements on the current trial. During the first 85 d, when fed 25% of corn residue, there were no difference in ADG during the first 85 d on feed, steers gained on average 1.69, 1.80, 1.74, and 1.67 kg/d when fed SVT, STK, STKL, and STKP, respectively. There were no carry-over effects ($P \geq 0.66$) of treatment from d 86 to 186; thus, there were no effects ($P \geq 0.78$) of treatment on overall steer performance for the entire 186 d. Yield and quality grade distributions, HCW, marbling, back fat, ribeye area and dressing percentage also did not differ ($P \geq 0.14$) among treatments. Due to the similar results on performance and carcass characteristics, there were no effect ($P \geq 0.44$) of treatments on economics traits (feedlot cost, cost of gain, return per head, and break-even price to pay on stover) for any of the feeding phases (growing phase, finishing phase, and overall). However in the current trial, a 3 pass harvesting and bagging corn stover system was used for all of the treatments. Previous research suggests the use of a 3-pass method saves cost by not having to grind and treat corn stover previous to feeding (Vadas and Digman, 2013). Moreover, when this system is used for cattle feed, cattle growth performance improves when compared to cattle fed a conventional baled corn stover (Russell et al., 2011). The lack of differences in animal performance and corn residue characteristics in the current trial may be explained by the short window (28 d) between the 2 harvesting days, due to the weather issues faced on the fall of 2014, the harvest of HMC was delayed which impacted the fiber fractions of the plant more than was

expected. However, it is important to notice that all animals gained 12% more than predicted, suggesting a greater feed value of corn plant residues when fed in combination with DGS than NRC (1996) claims. Corn plant residues create another option to replace some corn in a feedlot diet during the growing phase.

DEDICATION

To my family, my parents Anisio and Laura, and my two sisters Athena and Ana.

Thank you all for all of your support and love!

Love you all!

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This is no doubt one of the hardest, but gratifying part of my writing. I'll probably forget somebody, because I have so much to thank.

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CHAPTER 1: LITERATURE REVIEW

INTRODUCTION

For 30 years, corn price remained fairly consistent (around \$2.37/25.40 kg⁻¹) in the United States (1975 to 2005; NASS, 2015), making corn an inexpensive source of energy in cattle diets (Wright, 2005). However, the expansion of corn ethanol industry in recent years, dubbed the “Ethanol Era”, increased competition for corn grain use, increased corn grain price, and limited availability of corn for livestock feed (Westcott, 2007). Thus, the livestock industry, in particular the cattle industry, turned to increased inclusion of co-products from corn processing in diets to meet cattle needs and reduce feed costs (Loy and Strohbehn, 2007; Chapple et al., 2015).

One of the most available co-products came from the ethanol industry as distillers grains with solubles (**DGS**). Corn grain is made up of two-thirds starch. That starch is fermented during ethanol production, thus, DGS contains nearly 3 times more protein, fiber, fat, and minerals than corn grain (on a DM basis; NRC, 1996). Therefore, the inclusion of DGS in feedlot diets was touted for its potential to increase cattle performance when compared to cattle fed traditional corn-based diets (Klopfenstein et al., 2008). Another alternative co-product that can be included in cattle diets in order to reduce feed costs is corn crop residues. Corn stover, is a corn crop residue co-product that includes the cobs, husks, leaves and stems and is gathered after dry corn harvest, typically by baling. Corn stover is one of the most abundant crop residues in the United States (Glassner et al., 1998). However, corn stover is a poor quality forage, limiting energy and protein, which has functioned mainly as a source of bedding or as a fiber source in cattle diets.

When corn prices were greater than \$6.00/bushel, the 2 co-products, corn stover and DGS, were heavily researched fed in combination as a “corn replacement feed” in cattle diets (Russell et al., 2011; Duckworth et al., 2014; Chapple et al., 2015; Shreck et al., 2015). However, the fact that corn stover is a poor quality forage remains.

Enhancing digestibility of a poor quality forages through physical or chemical processing has been practiced for many years. (Burdick et al., 1963; Kerley et al., 1985; Sewell et al., 2009; Duckworth et al., 2014; Chapple et al., 2015). Physical and chemical treatment disrupt intracellular bonds between cell wall components - cellulose, hemicellulose, and lignin - in order to increase surface area and microbial attachment (Gharpuray et al., 1983; Satter, 1983; Williams et al., 1995) and, ultimately, improve digestibility of the forage (Barton et al., 1971; Hunt et al., 1984; Gates et al., 1987). Applying both the physical and chemical treatment to corn stover has also been shown to increase its digestibility (Duckworth et al., 2014; Chapple et al., 2015). However, there are extra costs and hazards to manage when chemically treating corn stover. In addition to the extra labor involved in both physical and chemical processing, challenges arise when applying these techniques in small scale operations (Chaudhry, 2000). There are also costs associated with these treatment processes that may not always yield returns necessary to pay for them (Duckworth et al., 2014; Chapple et al., 2015). Research strategies to safely and economically include corn stover in feedlot diets without negatively impacting growth performance is imperative to increase corn stover opportunities in the beef industry.

Another way to improve digestibility of forages, that does not require any chemical treatment, is to harvest the forage at an earlier maturity. As the maturity of the forage increases, it becomes more lignified, reducing forage digestibility (Van Soest and Marcus, 1964). Hunt et al. (1989) harvested corn stover at 3 different maturities, concluding that increased maturity of

the corn plant increased NDF, ADF, cellulose, and lignin concentrations of the corn stover, making corn stover less digestible. Corn stalklage is similar to corn stover, it contains the same plants parts; however, it is harvested from less mature plants, because it is harvested after high moisture corn as opposed to dry corn like corn stover. Thus, corn stalklage is a less mature corn crop residue that may increase digestibility (Hunt et al., 1989). Despite the potential, however, corn stalklage research has been limited.

When interest in corn stover piqued, mature corn stover, gathered and baled after dry corn harvest, was researched in growing systems at 20% of the diet DM (Russell et al., 2011). Approximately one third of calves slaughtered in the U.S. go through a growing system prior to being fed an energy-dense feedlot diet (Klopfenstein et al., 2000). The growing phase, as it is commonly referred to, is characterized by feeding cattle less energy, typically achieved with a forage-based ration, for 60 to 100 d prior to the finishing phase (Vaage et al., 1998). One segment of beef production where forages may be used in greater abundance is for growing cattle prior to feedlot entry. However, it is not yet known if harvesting corn stover at different maturities would affect cattle performance when fed during the growing phase or whether the inclusion can be increased and still allow growth performance to remain economically feasible.

In short, alternative feeds are still needed for cattle producers in the face of ever variable corn costs. Co-products of the corn industry appear to be viable options to reduce costs in certain feedlot cattle settings. However, the viability of these co-products, particularly the immature corn stalklage, in growing systems, prior to feedlot entry, has not been extensively researched.

CORN PRODUCTION AND CORN USE IN THE UNITED STATES

Corn is the predominant cereal crop grown throughout the world. According to United States Department of Agriculture (NASS, 2015), the United States is the largest producer of corn on a global scale. In fact, more than 95 million acres (38.45 million hectares) of corn were planted in the U.S. in 2013. Of those acres planted, more than 90% of the total area planted, or 87.45 million of acres (35.21 million hectares), were harvested for grain, and produced 13.83 billion bushels (351 million of metric ton; **MT**) of corn. The remaining 6.28 million acres (2.54 million hectares), close to 7% of the area planted, was used for corn silage production (NASS, 2015). Most of the corn production in United States is concentrated in the Midwestern States. In fact, close to 60% of the total corn produced in United States in 2013 was grown in the five main corn producing states: Iowa, Illinois, Minnesota, Nebraska, and Indiana (15.5%, 15.2%, 11.7%, 9.4% and 7.5%, respectively). As the major contributors to corn production, these states make up the “American Corn Belt” (NASS, 2015).

One of the main reasons for the excellent corn production in the “Corn Belt” region is not only the soil and weather available on those areas, but also the agricultural improvement that has happened there since the second half of the 20th Century. Over the course of 50 years, the average corn production per acre increased more than 350%, going from 0.40 MT per hectare (39 bu/ac) produced in 1950 to 1.57 MT per hectare (153 bu/ac) of corn in 2000 (Fuglie et al., 2007). While many technological and mechanical factors attributed to the increased productivity, one of the major drivers was the improvement made in corn genetics. Genetic improvements allowed producers to grow corn in a shorter productive season and expand corn production on arid regions, areas that were previous filled by cattle producers (Corah, 2008).

Changes in corn industry have direct impacts on the beef cattle industry, in part because cattle are typically located on arid lands, previously not well suited for corn production.

Therefore, increased demand for land to be used for crop production has decreased the amount of land available to raise beef cattle (Corah, 2008). Although, Ball (1998) reported that corn has been used in cattle “fattening” diets since the late 1800s, this was not necessarily the historic norm. In reality, as late as the 1950s, cattle harvested directly from grass represented virtually all of the beef consumed in U.S. (Corah, 2008). Research showing the effect of feeding corn as a greater proportion of the diet, or even using all-concentrate diets, began to appear by the mid-1950s (Perry et al., 1956). In fact, since then, and especially in the ‘90s, when corn was considered a cheap energy source for cattle diets, corn grain has been included as the main ingredient in feedlot diets and also used as a supplemental energy source for cattle that are fed a forage-based diet (Galyean and Gleghorn, 2001; Samuelson et al., 2016). Considering that the majority of the cattle in the United States are finished on grain-based feedlot diets, and corn has been used for cow energy supplementation during periods when forage production is limited (i.e. winter; Loerch, 1996), changes in corn production directly affect the whole beef production system.

Despite the need for animal feed, corn is also the most researched, and used, grain as a source of renewable energy in United States. In the last decade, the amount of corn used to produce ethanol has increased tremendously, reaching 30.8% of the total corn harvested in 2012. During this same decade, ethanol production increased more than 600%, going from 8,101 million of gallons of ethanol produced in 2002 to 50,036 million of liters of ethanol produced in 2012 (U.S. EIA, 2016), thus, earning this decade the moniker: “the Ethanol Era”.

Since the Ethanol Era started, not only has more corn been directed to the ethanol industry, but corn prices have also substantially increased. Indeed, for 30 years (from 1975 to 2005) the average corn price remained virtually stable, around \$2.37/25.40 kg⁻¹. However, the average price of a bushel of corn more than doubled in only six years (\$4.89/25.40 kg⁻¹, average

of corn from 2006 to 2012), peaking at more than \$7.00/ kg⁻¹ (\$275.58/MT) in 2007 (NASS, 2015). According to Condon et al. (2015), every additional 1 billion-gallon in corn ethanol produced (or similarly, each 10% expansion in production) increases corn prices by approximately 2 to 3%, on average.

Over time, the Ethanol Era has reshaped the corn industry in America and the agriculture production in the Corn Belt, the increase in ethanol production faced in recent years led to an increased demand for corn to be converted into a renewable fuel. This demand was met by increasing numbers of ethanol plants in many areas around the country, especially in the Midwestern states such as Illinois and Iowa; and, in turn, caused an increase in the corn price and a decreased use of corn in livestock production (Westcott, 2007). The rise in corn prices faced in the last decade have spurred many producers to convert land that had previously been considered “marginal hay or pasture land” to crop fields.

Due to the increased demand for corn as energy source for the ethanol industry, and the use of arid grazing lands for even more corn production, land and feed for livestock production have been shrinking. In most livestock operations, feed represents the largest single expenditure (Seglar and Shaver, 2014). For the beef industry, the loss of the marginal grazing lands coupled with the worst drought in 3 decades, the drought of 2012, decreased the national beef cattle herd. From 2006 to 2012, the total cattle in the United States decreased by 5.1 million heads (cattle and calf; NASS, 2015). At the same time, cattle prices soared less in proportion to corn price, and demand for beef remained constant, pressuring the cattle industry to seek alternative feeds to avoid expensive corn and remain in business. The coupling of record feed prices and a shrinking cow herd created challenges for producers who were willing to stay in the beef industry, and pushed cattle producers to investigate new alternative feeds, including corn plant residue, to feed

their cattle (Meteer, 2014). In fact, Watson et al. (2015) stated that efficient usage of corn plant residue and co-products materials would be “crucial to the future viability of beef production”.

Due to the recognition of the value of using co-products from the corn industry for beef cattle production, the topic has been reviewed extensively in the past, in particular the usage of co-products of the corn ethanol industry (DGS; Ham et al., 1994; Klopfenstein et al., 2008). In brief, DGS were commonly used as a protein source in cattle diets, but more recently cattle producers have been using DGS as an energy source in cattle diet in order to replace corn and reduce ration costs. However, DGS prices followed corn prices up and this economic strategy was a short lived as a replacement for corn. Distillers grains could be purchased for \$79.31 per MT in 2002/03 but soared to \$232.14 per MT in 2012/13 (NASS, 2015). Another option used even more recently was corn stover. Corn stover is consider a poor quality roughage that can be fed in combination with DGS to build a ration comparable to corn for feedlot cattle (Shreck et al., 2015). These feeds were dubbed “corn replacement feed” by the industry. Therefore, the remainder of this review will focus on the use of co-products from corn and ethanol industries that can be included as corn replacer feed in beef cattle production systems.

REPLACING CORN IN FEEDLOT DIETS

Distillers Grains and Solubles

Distillers grains and Solubles (**DGS**) is a co-product from the ethanol industry. The production of DGS in U.S. followed the production of ethanol from corn. Therefore, since the Ethanol Era started, production of DGS increased tremendously. Between late 90’s and earlier 2000s the amount of DGS produced in this country was less than 2.27 million MT a year, *and*

only 50% of this production came from the ethanol industry. In the year 2005/06, DGS production reached more than 8.16 million MT a year, and only 5 years later, in 2010, 27.22 million MT of DGS were produced in United States. By 2010, 99% of the total DGS production in the U.S. came from the ethanol industry (Hoffman and Baker, 2011). Whether it is wet, modified, or dry, DGS has been one of the most researched options to replace corn in cattle diets (Klopfenstein et al., 2008; Schroeder et al., 2014).

Cattle present a unique opportunity for feeding DGS. One of the limitations surrounding DGS feeding for other livestock species is the amount of fiber (46% NDF; NRC 1996). However, the symbiotic relationship with microorganism in the rumen allow cattle to consume fiber sources which the microbes convert to energy (Van Soest, 1991). Even still, including DGS as the primary energy source in cattle diets has some other limitations, such as the nearly 3 times more protein, fat, and minerals when compared to corn (on a DM basis; NRC, 1996). These elevated nutrient concentrations when DGS is used as an energy source to replace corn can sometimes exceed optimal concentrations for cattle and create some issues (Felix and Loerch, 2011). Despite the concerns surrounding these issues, research has shown that DGS can be included from 10 to 40% of the diet without detrimentally impacting cattle performance (Klopfenstein et al., 2008).

More recent challenges surrounding DGS in the diet have focused on its inclusion at 50% or more of the diet DM. Schroeder et al. (2014) reviewed some of these newer challenges presented when DGS is fed to cattle, including: sulfuric acid issues, ruminal acidosis, feed intake, and the differences in performance between wet and dry DGS. Still critical to remember is that DGS composition varies from one ethanol plant to the next, and analysis prior to feeding is always recommended.

Another factor that influenced how much of DGS were included in cattle diet is the DGS price. Distillers grains prices follow corn price; therefore, rising corn price and the increasing demand for cheaper feed sources, increase demand and drives up prices of DGS. Most of the nutritional challenges in feeding DGS have been overcome, however, in order to overcome the increase diet costs due to the rise of corn and DGS prices, producers need to search for cheaper feedstuffs to be included in the diet without big economics and production impacts. The issues surrounding the feeding of greater concentrations of DGS and the increase in its price faced in recent years, opened opportunities for one other co-product from corn industry that can be included in cattle diets as a corn replacer, corn plant residues.

Corn Plant Residues

Corn plant residue, containing the husk, leaf, and stem and commonly referred to as corn stover, is the material left on the field following a combine, after a traditional harvest of corn. Interest in harvesting this material has grown in recent years (Ertl, 2013). Historically, if harvested, corn stover was used as a bedding source for cattle. However, in recent years with the increased demand for renewable energy sources, corn stover has also been used as an energy source for ethanol production (Ertl, 2013). Moreover, with the increase of the corn price, the opportunities to include corn stover as “corn replacer” source in cattle diets have been a research topic of interest for many (Russell et al., 2011; Duckworth et al., 2014; Chapple et al., 2015; Shreck et al., 2015).

According to Graham et al. (2007) the quantity of grain produced has a direct influence on the national supply of collectable stover. In order to estimate how much of corn stover is available to be harvested in United States, the harvest index is calculated. The harvest index is a

calculation of the ratio of grain yield to plant (husk, leaf, and stem), being usually around 1:1, ranging from 47 to 56 percent for corn and the other part would be composed of the corn stover left over above ground (Ertl, 2013). The USDA estimated 13.83 billion bushels of corn were harvested on 87.45 million of acres in 2013 (NASS, 2015). Using an equation created by Graham et al. (2007) to estimate corn stover production by including the corn production (13.83 billion bushels), and assuming that a bushel of corn weighs 56 pounds at 86% DM, it is estimated that more than 300 million dry MT of corn stover were available to be harvested in 2013 in United States.

The amount of stover to be collected, and the advantages and disadvantages of harvesting the corn residues, have been topics of research in recent years, and the findings about it are still ambiguous whether removing corn stover benefits or reduces corn yields. One of the potential negative impacts of removing residue includes removing nutrients from the soil (Ertl, 2013). In addition, removal of corn stover can decrease the soil carbon and nitrogen content, increase potential erosion, and drought stress in later crops (Mann et al., 2002; Ertl, 2013). Removing corn stover can also increase fuel, equipment and labor cost, and may lead to drier soils and decreased yield on lighter soils (Ertl, 2013).

However, there are also some benefits of harvesting corn crop residues. Removing corn residue from the field can increase the ease of planting using traditional equipment and practices, and facilitated the control of some diseases and insect pests by decreasing insect and microorganism proliferation (Mann et al., 2002), and may increase seed germination and emergence (Ertl, 2013).

In a 5 year study, Stalker et al. (2015) did not find any effect on subsequent corn yield when a traditional corn system, without corn residue removal, was compared to two grazing

systems or when corn stover was harvested as a bale. However, the conflicting reports have left some corn producers hesitant to harvest corn crop residues. A state-wide survey from Iowa, the state with the greatest corn residue production, in 2011 reported that only 17% of farmers were even interested in harvesting their corn residue (Tyndall et al., 2011). The lack of interest in harvesting corn residue was a major shift from earlier surveys throughout the state that suggested as many as 74% of farmers would be interested in selling corn residues if they were profitable. Predictably, willingness to harvest corn crop residues, on the corn farmer side, rely on corn price, but also change with perceptions about harvest and transportation costs. Viable concerns that must also factor in to the value considerations of corn stover for use by cattle producers.

Regardless of whether the corn residue is going to be used on-farm such as feed or bedding, or if sold, removing corn residue from the field generates an additional source of income from the corn crop (Ertl, 2013). Graham et al. (2007) estimates that over 50% of the total corn residue produced could be harvested every year without causing erosion to exceed the tolerable soil loss. With the roughly 300 million MT of dry corn residue produced in United States, we can estimate that 150 million MT of dry corn residue were available to be collected without impacting subsequent crop production in 2013.

Even though corn stover is considered a poor quality forage due to the elevated concentrations of NDF and lignin (68% NDF, 10.29% lignin; NRC, 1996), the inclusion of this material in cattle diets provides plenty of effective fiber and serves as a very inexpensive feedstuff for cattle (Seglar and Shaver, 2014), and the 150 million MT of available dry corn stover piqued the interest of beef cattle nutritionists. In a survey of feedlot consulting nutritionists published in 2007, Vasconcelos and Galyen (2007) did not indicate any nutritionists were using corn residue in their feedlots. However, in a similar survey conducted by Samuelson

et al. (2016), 29.2% of the nutritionist surveyed said that they used corn stalks as a primary roughage source in finishing cattle diets. This shift indicates how important corn crop residues have become in beef cattle systems. Such increase use of corn residue in feedlot cattle diet may not only be driven by the higher corn prices, but also by the growing attention that researcher have given to improve the feeding value of this poor quality forage (Duckworth et al., 2014; Chapple et al., 2015; Shreck et al., 2015).

IMPROVING CORN RESIDUE FEEDING VALUE

Ensiling

Johnson et al. (1984) suggested that when corn residue is harvested and ensiled, it may give producers more flexibility in when to feed the material when compared to grazing corn stalks system, the harvesting and ensiling process may also improve DMI, and reduce field and storage losses when compared to grazing or harvesting round bales (Smith et al., 1975; Jamalullail, 1976; Johnson et al., 1984).

Researchers have reported benefits in feed value of corn stover was simply wetted and ensiled (Russell et al., 2011; Duckworth et al., 2014). Ensiling forages is an ancient practice used to preserve forage grown during the summer months for use during the off-season. This process of storing the material under moist conditions with very little oxygen exposure, or ensiling, allows anaerobic microbes to work by modifying substrates in order to increase digestibility and quality of the ensiled material (Shao et al., 2010). The process of ensiling forage is usually divided into the following steps: harvesting, compacting, and storing in silos or in polythene bags for a period ranging from 20 to 200 days. During the storage period, lactic acid formation from

ensiled materials results in a pH drop, when silage pH drops to 4, the material is preserved from further microbial attack (Shao et al., 2010). However, when fermentation does not happen or pH does not drop, silage can spoil. In some cases, silage pH may actually increase. The increase in pH is usually initiated by yeasts that are able to metabolize lactic acid (Woolford, 1990), again increasing spoilage potential. Increasing silage spoilage may decrease animal production (Kung et al., 1998), which decreases net farm income (Kleinschmit and Kung, 2006).

The application of silage inoculants during the ensiling process can enhance the production of lactic acid for long-term storage of forages. A meta-analysis, conducted by Kleinschmit and Kung (2006), evaluated the effects of a lactobacillus additive on the fermentation and aerobic stability grass and small-grain silages. The authors concluded that in general, inoculation with lactobacillus decreased the pH and yeast, and increased aerobic stability of corn, grass, and small-grain silages. In addition, adding inoculants at ensiling period has the potential to improve digestibility of ensiled products (Casper, 2008). Applying a lactobacillus silage additive at ensiling of alfalfa haylage improved DM (61% for lactobacillus treated vs 56% for control) and NDF (43% for lactobacillus treated vs 28% for control) digestibility (Ayangbile et al., 2001).

In addition to lactobacillus, propionic acid is another additive to improve silage preservation and animal performance (Woolford, 1975). Treating forages with high rates of propionic acid in order to improve aerobic stability, and aid forage preservation, has been successfully used for many years. However, its relatively high application rate and cost has been a major limitation factors for its widespread use (Kung et al., 1998).

These type of silage inoculants have been well-tested in grass and corn silages. However, the efficacy of lactobacillus and propionic acid for ensiled corn crop residues, harvested without grains, have not been demonstrated.

Chemical Treatments

Methods of chemical treatment to improve corn stover quality have been researched in recent years (Russell et al., 2011; Duckworth et al., 2014; Chapple et al., 2015; Shreck et al., 2015). Improving corn residue quality is not a new topic. Research conducted in late 70's tested many methods to include stover in cattle diets (Klopfenstein, 1978; Berger et al., 1979). One method used included chopping corn stover and filling a wagon to be transported into the silo area, where chemicals and water were added to reach 65% moisture before ensiling the material (Klopfenstein and Koers, 1973). The chemicals, or alkali treatments, of poor quality forages have been developed for almost a century. Beckman (1921) developed the first methodology, which would be improved by Wilson and Pigden (1964). These original techniques applied sodium hydroxide (NaOH) to roughages prior to feeding. Chemically treating corn residues breaks the bonds between lignin and hemicellulose, usually without changing lignin concentration (Duckworth et al., 2014). Years later Wilson and Pigden (1964) had improved Beckman's technique, Berger et al. (1979) revisited the treating of poor quality forage with NaOH as an effective method to improve forage digestibility. Numerous chemical treatments throughout the years, such as, sodium oxide (Na₂O), ammonium oxide (NH₃), calcium hydroxide (Ca(OH)₂), potassium hydroxide (KOH) and calcium oxide (CaO), have been used to increase corn stover digestibility (Klopfenstein, 1978; Klopfenstein and Owen, 1981, Klopfenstein et al., 1987). According to Klopfenstein (1978), in order achieve the best chemical treatment responses,

chemical substances, in particular NaOH, must be treated at levels from 3 to 5% of residue DM. Options that are nearly as effective as NaOH to treat poor quality forages, including $\text{Ca}(\text{OH})_2$ or CaO, are considered safer and less expensive when compared to NaOH treatment (Rounds and Klopfenstein, 1974; Chaudhry, 1998).

More recently, both physical (Shreck et al., 2015) and chemical (Duckworth et al., 2014; Chapple et al., 2015; Shreck et al., 2015), methods have been evaluated to improve corn stover feed value. The physical treatment of corn stover is more simplified. In order to evaluate grind size of corn stover, Shreck et al. (2015) fed treated (5% CaO) and untreated corn stover (20% DM inclusion) ground at 2 different sizes (2.54 cm and 7.62 cm) and stated that reducing grind size improved cattle performance in 3.5%; however, no interaction with chemical treatment and grinding size was observed. The use of CaO has been more researched with corn stover in recent years because of its relative safety and cheaper cost, compared to NaOH for example.

In order to test CaO treatments to corn residue, Russell et al. (2011) fed steers a traditional corn-based diet (70% corn and 20% DGS; DM basis) and compared them to steers fed a corn replacement diet, containing DGS (40% of diet DM) and corn stover (20% of diet DM; treated with 5% CaO), and reported that both groups had similar ADG (1.77 kg/day for control and 1.71 kg/day for the corn replacer diet) during the 112 d of the growing phase. These authors stated that feeding corn stover treated with CaO was a cost-effective replacer for a portion of the corn in the cattle diet. Another experiment conducted by Shreck et al. (2015), replaced 15% (DM basis) of dry rolled corn with a treated (5% CaO) corn stover when diet contain 40% (DM basis) of modified distillers grain and solubles (MWDGS) and concluded that feeding chemically treated crop residues and DGS was an effective strategy for replacing a portion of corn grain and roughage in feedlot diets. While Duckworth et al. (2014) reported no benefit to feedlot

performance when corn stover was ensiled versus when it was treated with 5% CaO and then ensiled, they did report that 48 h ruminal in situ fiber disappearance (measured as NDF) increased by 39% when corn stover was treated with CaO. In addition, the increased ruminal degradation increase total tract apparent DM digestibility by 10.6% in cattle fed CaO-treated corn stover compared to those fed ensiled corn stover without treatment (Duckworth et al., 2014). Authors had anticipated the increased digestibility would increase cattle feedlot performance, which did not happen in the Duckworth et al. (2014) experiment.

While the method of applying chemical or physical treatments to corn stover has yielded somewhat variable performance results, there is another alternative to treating (chemical or physical) corn crop residues. As stated by Klopfenstein and Owen, 1981, corn crop residue feed value may also be altered by manipulating the harvesting time.

Corn Residue Maturity and Corn Stalklage

Cone et al. (2007) concluded that corn stover maturity alters analyzed composition, digestibility, and in vitro fermentation characteristics. Cone et al. (2007) reported that the corn stover that was harvested early (103 days) had a greater gas production parameters when compared to corn stover in a later stage of maturation (147 days), which indicates a greater rates of fermentation for the less mature corn stover. Furthermore, the authors mentioned that environmental conditions would influence the corn plant development, such as day length, sunshine, temperature, water availability and plant density. In the same study, the authors reported a greater organic matter digestibility (67.2% vs. 62.1%) for the 103 d vs 147 d harvested stover, they also conclude that NDF degradability of corn stover decreased for a 147 d plant when compared to the plant that was harvested at 103 d (49.1 vs. 56.2%, respectively).

In addition, Arias et al. (2003) reported that increasing the maturity of the corn plant did not affect cob weight, leaf, or stem DM yield per plant; but, the leaf:stem ratio decreased with an increasing in maturity (0.97 at harvest age of 130 d vs 0.82 at harvest age of 148 d). However, the advanced maturity increased NDF and decreased of in vitro DMD, CP, and water-soluble carbohydrates in the corn residue harvested on 130 d when compared to the residue harvested on 147 d, these authors also concluded that, regardless of maturity, both corn residues were poorly degraded in the rumen. The short 17 d difference in harvest window, compared with the 44 d difference in the previous trial (Cone et al., 2007), might explain the difference in results between these trials. Harvest age may, therefore, be a more appropriate means of discussing corn residue.

While recent articles have focused on corn stover (Shreck et al., 2015), less mature corn residue material is often referred to as corn stalklage, to distinguish it from the more mature corn stover. Corn stalklage is similar to corn stover in its plant part composition. However, it is harvested in a less mature plant, after harvesting a high moisture corn. Increasing maturity of the forage, results in an increment of the cells walls that are highly lignified and decrease in cell soluble, which creates a negative effects in forage digestibility (Van Soest and Marcus, 1964). Therefore, harvesting corn residue directly after high moisture corn may be one opportunity to obtain the less mature corn residue.

Berger et al. (1979) harvested and ensiled corn stalklage 3 to 7 days after high moisture corn was harvested, and suggested that ensiling corn residue gave producers more flexibility to when the material is going to be include in a cattle diet in comparison to the grazing system. In addition, the authors also concluded that ensiling corn stalklage may reduce field losses and improve palatability (Berger et al., 1979).

Berger et al. (1979) fed ensiled corn stalklage (40% DM; harvested October 8th) or ensiled corn stover (40% DM; harvested November 10th) at 78% of the diet DM for 112 days during the finishing phase and reported that cattle fed corn stalklage had an increase in 0.21 kg ADG and were 28% more efficient when compared to cattle that were fed the corn stover diet. In a second trial conducted by the same authors with duration of 120 days, calves fed corn stalklage (harvested and ensiled after harvesting HMC) had an increase of 0.14 kg ADG compared to calves fed a corn stover-based diet (40% DM; harvested and ensiled 3 weeks after corn stalklage). The authors concluded that since most of the production cost can be charged against the corn grain, corn stalklage may be a relatively cheap source of energy for finishing cattle (Berger et al., 1979). However, there has been no recent research on the use of immature corn stalklage in growing cattle diets.

FEEDING GROWING CATTLE

Most beef cattle in the U.S. that are fed in confinement are fed a grain-based diet to increase efficiency of gain (Samuelson et al., 2016). In addition, most cows in the U.S. are grazed on forages because allowing the cow to harvest her own feed is often the least expensive means of feeding the cow. There is, however, a period in the calves' life referred to as the growing phase. The growing phase is a period between weaning and beginning of the finishing feedlot phase, and the goal of this phase is to allow to develop the frame of cattle and put on gain with less expensive feed before fattening (Sainz et al., 1995).

Growing systems can be used to add value to homegrown feeds, take advantage of grazing opportunities, delay finishing to target a specific market, acclimate calves to eat from bunks and drink from a fountain waterer, or promote skeletal growth of small-framed cattle

(Anderson, 1991). Restricting energy intake before feedlot can create a compensatory gain during finishing phase, improving ADG, DMI and G:F previous to slaughter (Sharman et al., 2013).

Schoonmaker et al. (2004) compared the use of a forage-based diet vs an grain base diet for early-weaned steers during the growing phase (d 0 to 153) of the feedlot, and finished in a similar grain-based diet. They reported that total ADG and final weight from d 0 to slaughter (d 334) did not differ between the systems when calves were fed the same grain-based feedlot diet during finishing (154 to 334 d). Using corn plant residues, Russell et al. (2011) fed 20% corn stover (treated with 5% CaO and ensiled) for 112 d during a growing phase and then fed a grain-based diet, for the final 71 d, and compared these cattle to those fed a grain-based diet throughout the entire feedlot period (183 d). The authors reported greater results in DMI (7.79 kg/day vs 8.55 kg/day) for animals fed chemical treated (5% CaO) corn stover (20% DM) based diet during the growing phase, and similar total ADG (1.70 kg/day vs 1.77 kg/day) and G:F (0.219 vs 0.207) for both groups. The efficacy of corn stalklage for use in growing diets has not been determined.

CONCLUSION

With the increased corn priced faced in recent years, the search for alternative feeds has been increasing in United States. Distillers grains and solubles have been the greatest and main ingredient used to replace corn in feedlot diets. However, DGS inclusions in cattle diets are not without limitations (i.e. sulfur issues). In addition, increasing corn prices increased DGS price, leading researchers and producers to look for other alternative feeds, such as corn stover.

Corn stover is the most abundant residue produced in U.S.; however, as a poor quality forage, this material has been limited in its inclusion in beef cattle diets. Still, it is a cheap alternative feed source. Corn stover treatments (chemical and physical) have been used to increase its inclusion in cattle diets in recent years. Costs and human health risks are limitations faced when a chemical or physical treatments are applied. Less mature plants are generally considered to be more digestible for cattle; therefore, feeding a less mature plant may increase cattle performance. However, the use of immature corn crop residues in beef cattle production systems are not well researched. More information on dietary inclusion, economics, and harvest technique are needed.

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**CHAPTER 2: EFFECTS OF FEEDING CORN PLANT RESIDUES DURING THE
GROWING PHASE ON STEER GROWTH PERFORMANCE AND FEEDLOT
ECONOMICS**

ABSTRACT

Objectives were to test the feeding value of corn plant residues, harvested at 2 maturities, and the effects of silage additives, Silage SAVOR Plus (propionic acid-based additive) or Silo-King (lactobacillus-based additive), on in situ fiber disappearance, growth performance, carcass characteristics, economic traits, of growing feedlot cattle. In Exp. 1, steers were allotted to 1 of 4 treatments: 1) corn stover wetted to 40% DM and ensiled (**SVT**), 2) corn stalklage, harvested at 40% DM and ensiled (**STK**), 3) corn stalklage Silo-King (**STKL**; Silo-King, Agri-King, Inc., Fulton, IL at 0.25 kg per MT), or 4) corn stalklage plus Silage SAVOR Plus (**STKP**; Silage SAVOR Plus, Kemin Industries, Inc., Des Moines, IA at 0.5 kg per MT). Corn stover (71.5% NDF, 6.12% CP, and 5.88% lignin) was harvested 186 d post planting, after harvest dry corn (88% DM). Corn stalklage (68.3% NDF, 6.24% CP, and 5.39% lignin) was harvested 158 d post planting, after harvesting high moisture corn (HMC; 77% DM). Diets were fed for 85 d, and contained 25% corn plant residue, 30% modified wet distillers grain with solubles (MWDGS), 35% HMC, and 10% supplement (DM basis). From d 86 to 186, all steers were fed a common finishing diet that contained 20% silage, 20% MWDGS, 50% HMC, and 10% supplement (DM basis). Composite corn plant residue samples (ST, STK, STKL and STKP) from the growing trial were incubated in 2 ruminally fistulated steers for 12, 24, 36 and 48 h to determine in situ DM disappearance (DMD) and NDF disappearance (NDFD). There were no treatment effects ($P \geq 0.19$) on ADG, DMI and G:F from d 0 to 85. During the first 85 d, when fed diets containing

25% corn residue, steers gained 1.69, 1.80, 1.74, and 1.67 kg/d when fed ST, STK, STKL, and STKP, respectively. There were no carry-over effects ($P \geq 0.66$) of treatment from d 86 to 186; thus, there were no effects ($P \geq 0.78$) of treatment on overall steer performance for the entire 186 d. Yield and quality grade distributions, HCW, marbling, back fat, ribeye area and dressing percentage also did not differ ($P \geq 0.14$) among treatments. There were no effects of treatment on DMD ($P = 0.40$) and NDFD ($P = 0.34$) over time. Average NDFD at 48 h were 27.39, 30.59, 32.50, and 29.45% for ST, STK, STKL, and STKP, respectively. Feeding wetted corn stover resulted in similar ruminal fiber degradation, and steer growth and carcass performance as feeding corn stover, despite 28 d difference in harvest window.

INTRODUCTION

In order to replace the expensive corn faced in recent years, alternative feeds such as corn stover have been researched (Russell et al., 2011; Duckworth et al., 2014; Chapple et al., 2015; Shreck et al., 2015). Vadas and Digman (2013) calculated economics for a number of different corn stover harvest and storage systems and concluded that storing baled, dry corn stover is more economical than ensiling. However, in addition to harvesting cost, baled corn stover requires additional processing (grind) in order to be included in a total mixed ration (**TMR**; Russell et al., 2011) for feedlot cattle. Berger et al. (1979) fed corn stover harvested after high moisture corn harvest and compared it to a corn stover harvested after dry corn harvest and reported an improvement of 19% on cattle efficiency for cattle receiving an earlier maturity corn stover diet. Furthermore, Russell et al. (2011) fed corn stover at 20% of the diet DM and reported an improvement on carcass value return per head for cattle fed ensiled corn stover in comparison to cattle that received baled and ground corn stover. In small grain and grass silages, silage

inoculants may be used to enhance the production of lactic acid and improve the stability of silage during long-term storage (Kleinschmit and Kung, 2006). In addition, adding inoculants at ensiling period has the potential to improve digestibility of ensiled products when compared to those that are not inoculated (Casper, 2008), potentially improving the feeding value of ensiled forages. However, the efficacy of inoculants has not been evaluated in corn plant residues harvested after corn harvest. We hypothesized that harvesting and ensiling a less mature corn stover would improve digestibility and cattle performance and carcass characteristics when the material is fed during the growing phase of the feedlot, in addition, a silage additive would improve digestibility and cattle performance of the immature corn residues. Therefore, the objectives of this study were to test the feeding value of corn plant residues, harvested at 2 maturities, and the effects of silage additive, Silage SAVOR Plus (propionic acid base additive) or Silo-King (lactobacillus base additive), on in situ fiber disappearance growth performance, carcass characteristics, and economic traits of growing feedlot cattle.

MATERIALS AND METHODS

All animals used in this trial were managed according to guidelines recommended in the Guide for the Care and Use of Agriculture Animals in Agriculture Research and Teaching (FASS, 2010). The University of Illinois Institutional Animal Care and Use Committee approved all experimental procedures prior to the initiation of this study.

Animal and Diet Management

One hundred and twenty eight Angus x Simmental crossbred steers (9 mo, initial BW = 327 ± 40 kg) were used for this experiment at the University of Illinois Beef Cattle and Sheep Field Research Laboratory in Urbana, IL. Steers were housed in a confinement barn constructed with a wood frame with ribbed metal roofs, and siding on the north, west, and east sides. The south side is covered with $1.27 \text{ cm} \times 1.27 \text{ cm}$ wire mesh bird screen and has retractable curtains. The barn is divided in to 20 pens where each pen measures $4.9 \text{ m} \times 4.9 \text{ m}$ constructed of 5.08 cm galvanized steel tubing, on a concrete slatted floor that is covered with 1.9 cm thick rubber matting.

Steers were weighed, using a Flying W squeeze chute equipped with a Tru-Test (Tru-Test Incorporated, Mineral Wells, Texas) weighing system, on 2 consecutive d (d 0 and d 1) to determine initial BW. Steers were blocked by BW into heavy (BW = 364 ± 7 kg) and light (BW 304 ± 11 kg) blocks. Steers within block were stratified by d 0 BW and allotted to treatment pens on d 1, such that each pen within block had the same initial starting pen weight. Hence, there were 8 heavy block pens (2 pens per treatment) and 12 light block pens (3 pens per treatment). Steers were implanted with Component TE-IS (80 mg trenbolone acetate, 16 mg of estradiol, and 29 mg tylosin tartrate; Elanco Animal Health, Greenfield, IN) at the start of the trial (d 0).

Pens within blocks were randomly assigned to 1 of 4 treatments: 1) Wetted, bagged corn stover (**SVT**), 2) Corn stalklage (**STK**), 3) Corn stalklage plus Silo-King (**STKL**), or 4) Corn stalklage plus Silage SAVOR Plus (**STKP**). All growing diets included 25% of the forage residue (SVT; STK; STKL; STKP), 30% MWDGS, 35% high moisture (**HM**) corn, and 10% supplement (DM basis) and were fed for 85 d. Corn stalklage treatments, STK, STKL, and STKP, were harvested 158 d after planting. Corn stover, CS, was harvest 186 d after planting. After the growing phase, all steers were fed a common finishing diet containing 20% corn silage,

20% MWDGS, 50% HM corn and 10% supplement (DM basis) for a 100 d finishing phase. Diets were mixed in a mixer wagon (Knight Reel Auggie 3130; Kuhn Agricultural Machinery, Brodhead, WI) and delivered to pens once daily. Steers were fed in 3 m concrete bunks per pen. The ration was delivered at 0800 h and pens were managed for slick bunks. Bunks were read at 0630 h and were considered slick if less than 0.2 kg of feed per steer remained. If bunks were considered slick for 2 consecutive d, feed delivery was increased by 0.91 kg/head. Samples of each dietary ingredient were collected every 14 d to adjust for 100° DM inclusion of ingredients and subsamples were composited at the end the trial for nutrient analysis.

Steers were weighed every 28 d throughout the trial. At diet switch, steers were weighed again on 2 consecutive days (d 85 and 86) and reimplanted (d 85) with Component TE-S (120 mg trenbolone acetate, 24 mg of estradiol, and 29 mg tylosin tartrate Elanco Animal Health). For the last 28 d on feed, all steers were fed 300 mg/hd d⁻¹ of Optaflexx45 (100 g ractopamine hydrochloride/kg; Elanco Animal Health). Steers were then weighed off test on 2 consecutive days (d 185 and 186) to record final BW.

After the trial was completed, net energy for gain and net energy for maintenance were back calculated based on animal performance (IBW, FBW, ADG, DMI) using NRC (1996) equations.

Harvesting and Treating Corn Residues

Corn storklage was harvested after harvesting a high moisture (**HM**) corn using a 3 pass method, where the first step was preceded by a IH 5088 combine (6 rows; Case IH, Inc., Grand Island, NE) used to harvest the HM corn (77% DM) on September 22nd (158 d post planting), the

chaff spreader was turned off at the rear discharge of the machine, allowing the combine to deposit harvest trash in a windrow. The windrow consisted of primarily stalks, husks, cobs, and some leaf. Following the HM corn harvesting, a Speedrower 200 mower (New Holland, Inc., New Holland, PA) was used to mow the remaining stalk, characterizing the second step. A third step was realized by a FP 240 chopper (New Holland, Inc.) that was used to chop (2.5 cm) and harvest the windrow. The stalklage was harvested into wagons which were used to transport the product to the bagging site. At ensiling time, stalklage (40%DM) was treated by 3 methods: Untreated (**SVT**), Silo-King (Agri-King, Inc., Fulton, IL) at 0.25 kg per MT applied at bagging (**STKL**), or Silage SAVOR Plus (Kemin Industries, Inc., Des Moines, IA) at 0.5 kg per MT applied at bagging (**STKP**), all treatments were bagged in Ag-Bag Plastic SBAB08-150, Ag-Bag Plastic, Inc., Cottage Grove, MN.

Corn stover was harvested following the same procedures as corn stalklage (3 pass method); however, the process was done after harvesting a dry corn (88% DM) on October 20th (186 d), moreover an additional process was included in this method before the material was ensiled. In order to achieve the same dry mater (40% DM) as corn stalklage at the ensiling time, water was added to corn stover prior to bagging. No additive treatment was applied to this material. Corn stalklage and stover were harvested with the attempt to leave close to 50% of the material in the field as ground cover, thus, 2.18 DM per MT of corn stalklage DM were harvested per hectare, and 2.08 DM per MT of corn stover DM were harvested per ha.

Sampling and Analysis

Feed ingredient samples from entire trial were composited (650 g for growing and 650 g for finishing phase), freeze-dried (FreeZone, Labconco, Kansas City, MO), and then ground through a Wiley mill (1-mm screen, Arthur H. Thomas, Philadelphia, PA). All samples were analyzed for DM (24 h at 105°C) in a forced-air drying oven (Heratherm OMS100, Thermo Fischer Scientific Inc., Waltham, MA), ash and OM (500° C for 20 h, HotPack Muffle Oven, Model 770750, HotPack Corp., Philadelphia, PA), ADF and NDF (using Ankom Technology method 5 and 6, respectively; Ankom200 Fiber Analyzer, Ankom Technology, Macedon, NY), CP (Leco TruMac, LECO Corporation, St. Joseph, MI), and fat (ether extract method; Ankom Technology). Corn stover was analyzed for ADL using the method described by Van Soest et al. (1991). Samples were also sent to a commercial laboratory (Analab Inc. Fulton, IL) for chemical analyses (pH, lactic acid, acetic acid, butyric acid, and nitrate-N) . Physical composition of the corn residue was conducted using a Penn State Particle Size Separator Box following the guidelines for corn silage according to Heinrichs and Kononoff (2002).

Carcass Data Collection

On day 186, steers were shipped 301 km via commercial trucking to a commercial harvest facility and were humanely slaughtered under USDA inspection. On the same day HCW was collected. Then, carcasses were chilled for 24 h at -4°C. Approximately 24 h post-slaughter, the carcasses were ribbed between the 12th and 13th ribs and carcass data were collected via cameras including: 12th rib back fat thickness , kidney pelvic and heart fat (**KPH**), marbling score (**MS**), and LM area. The USDA Yield Grade (**YG**) was calculated using the equation:

$$YG = 2.5 + (6.35 \times \text{Back Fat(cm)}) + (0.2 \times \%KPH) + (0.0017 \times \text{HCW(kg)}) - (2.06 \times \text{LM area(cm}^2\text{)}).$$

Quality Grade was determined by USDA personnel at the plant.

Economics Analysis

Trial economics were divided in to 3 different phases, the growing phase that represents the first 85 days on feed when corn residue treatments were fed to the animals, the finishing phase that represents the last 100 days on feed where all animals were fed the same feedlot diet, and the overall economics that include the growing plus the finishing phase, or all 186 d of the trial, analyzing the whole system together.

Feedlot cost

In order to calculate feedlot cost, the following equation was used:

$$\text{Feedlot cost} = \text{NFC} + \text{YDC} + \text{HIC} + \text{HMCC} + \text{DGSC} + \text{SPC} + \text{CRC} + \text{SILC} + \text{EXC}$$

Where:

NFC = Non-feed costs were assessed at \$70.00/steer for whole period; \$31.99 growing phase and \$38.02 finishing phase (Beef Feedlot System Manual Iowa, 2015)

YDC = Yardage cost were assessed at \$0.71 steer/day (Beef Feedlot System Manual Iowa, 2015)

HIC = Hormone implant costs were \$1.88/steer (growing phase) + \$2.82/steer (finishing phase)

HMCC = High moisture corn costs were \$0.17 kg of DM

DGSC = Distillers grains with solubles costs were priced at 90% of the dry corn price on DM basis

CRC = Corn residue processing cost included: Cost of silo bag (\$400.00; 61m bag) + Cost of chopping cornstalks (\$29.41/ha) + Mowing cornstalks (\$35.21/ha) + Windrowing corn stalks (\$33.11/ha) + Farm labor (\$14.20/hour; Iowa Farm Custom Rate Survey, 2015)

SILC = Silage cost were assessed at 9 times the cost of a kg of corn harvested and stored on a wet basis (Pricing Forage in the Field - Ag Decision Maker, 2008)

EXC = Extra cost included \$10.47/kg of lactobacillus (Silo-King) for STKL; and \$1.44/kg of propionic acid (Silage SAVOR Plus) for STKP; and \$0.55/L of water for ST)

Cost of Gain

In order to calculate cost of gain, the following equation was used:

$$\text{cost of gain} = \frac{FLC}{DOF \times ADG}$$

Where:

FLC = Feedlot cost were explained in the equation above, applied for each specific phase (growing phase; finishing phase, overall).

DOF = Days on feed (85 d for growing phase and 100 days for the finishing phase).

ADG = Average daily gain for each phase based on final performance results

Return per Head.

In order to calculate return per head, the following equation was used:

$$\text{Return per head} = \text{MRH} - (\text{FLC} + \text{PHC})$$

Where:

MRH = Money received per steer (Growing phase used \$0.73 kg of live weight; Finishing phase used \$1.16 kg of carcass).

FLC = Feedlot cost were explained in the equation above, applied for each specific phase (growing phase; finishing phase, overall).

PHC = Purchase cost were assessed during the growing phase (Purchased at \$1.08 kg of live weight) and finishing phase (Purchased at \$0.73 kg of live weight).

Purchase prices and sale prices (money received per steer) were assessed at the start of both the growing and finishing phases and end of the growing and finishing phases, respectively, in order to separate the costs for the 2 phases.

Break-even price of corn residue (Kg/DM)

In order to calculate the break-even price for corn stover based on the steers' performance, the following equation was used:

$$\text{Break – even price of corn residue} = \frac{RTH}{GPDMI}$$

Where:

RTH = Return per head same as the equation explained above, applied for the growing phase only, where corn residue was fed.

GPDMI = Growing phase DMI.

In situ Disappearance

An in situ trial was conducted to further classify the composition of the corn crop residues used in this experiment. Two Angus-Simmental crossbred steers (BW = 635 ± 50 kg) fitted with rumen cannula, were used in an in situ digestibility trial at the University of IL Beef Cattle and Sheep Field Laboratory in Urbana, IL. Composite corn plant residue (ST, STK, STKL, and STKP) samples, collected during the trial, were incubated for 12, 24, 36, and 48 h in accordance with the procedures described by Felix et al. (2012). Bags were composited by animal and hour, analyzed for DM and NDF, and corrected for wash-out of these components.

Statistical Analysis

Performance, Carcass, and Economic Analysis

This experiment was a randomized complete block design. The growth performance, and economic data were analyzed using the MIXED procedures of SAS (SAS Institute, Cary, NC).

The model was:

$$Y_{ij} = \mu + B_i + T_j + (BT)_{ij} + e_{ij}$$

where, Y_{ij} = response variable; μ = mean; B_i = the fixed effect of BW block (light and heavy); T_j = the fixed effect of treatment; $(BT)_{ij}$ = the fixed effect of the interaction of BW block and treatment; and e_{ij} = the experimental error. Block was tested and deemed significant, therefore, it was left in the model. Pen was defined as the experimental unit. Degrees of freedom were adjusted using the Kenward-Rogers method. Categorical carcass characteristics were analyzed using the GLIMMIX procedure of SAS (SAS Institute; Cary, NC) using a binomial distribution and a Satterthwaite adjustment. Pen remained the experimental unit, and treatment and block remained fixed effects. Significance was declared at $P \leq 0.05$.

In situ analysis

To test the effects of in situ disappearance over time, data were analyzed using the MIXED procedures of SAS (SAS Institute, Cary, NC) using repeated measures. The covariance structure, compound symmetry, was selected based on the lowest Bayesian Information Criterion. Animal was consider an experimental unit, and treatment and hour were fixed effects. Significance was declared at $P \leq 0.05$.

Particle size analysis

The effects of particle size were tested using treatment as a fixed effect. Particle size analysis was done 4 times for a total of 4 reps within each size. Significance was declared at $P \leq 0.05$.

RESULTS AND DISCUSSION

We had hypothesized that harvesting corn crop residues after HMC would increase feed value, when compared to feeding corn crop residue harvested after dry corn, by increasing the DM and NDF digestibility. However, there were no treatment differences ($P \geq 0.15$) for in situ DM disappearance (**DMD**; 20.57%, 19.75%, 21.37%, and 21.54% for SVT, STK, STKL and STKP, respectively; Figure 1) or in situ NDF disappearance (**NDFD**; 27.57%, 30.59%, 32.50%, and 29.89% for SVT, STK, STKL and STKP, respectively; Figure 2) after 48h of incubation. Results from previous studies have been mixed. In some cases, results from the current study contradict previous studies that affirm increasing maturity decreases corn residue quality. For example, Hunt et al. (1989) harvested corn residue at 3 different maturities (early maturity, defined as a milk line 1/3 down from the top of the kernel; mid maturity, defined as a milk line 2/3 down from the top of the kernel; late maturity, defined as a black layer formation or physiological maturity) and reported that in situ DMD after 24 h of incubation decreased with increasing stage of maturity in corn stover (51.18%, 47.10%, and 45.91% for early, mid and late maturity corn residue, respectively), these authors concluded that the forage portion of the plant is subject to decreased quality with increased plant maturity. Furthermore, they proposed that in order to achieve the greatest quality, or feed value, corn residue should be harvested at the earliest maturity possible.

Lynch et al. (2012) reported that NDF, ADF, and hemicellulose concentrations increased in corn residues harvested at a later maturity (174 d vs 132 d), and also that DMD of corn stover decreased with increasing maturity (61.60% vs 56.87% DMD for 132 vs 174 d harvest, respectively). Similarly, Arias et al. (2003) concluded that in vitro DM digestibility decreased as maturity progressed (61.55% vs 54.35% DM digestibility for corn plants harvested 130 d vs 148 d after planting, respectively). Collecting weekly samples from the ensiling period until 10 wk

later, Berger et al. (1979) stated that corn stover digestibility decreased linearly over time (62.5% vs 42.5% in situ DMD from the first week and 10 wk after tasseling, respectively).

However, in agreement with the current trial, other studies have reported no differences in DMD for corn stover harvested at different maturities. Johnson et al. (1966) concluded that after the period of ear maturation (when the “black layer” develops at the tips of the kernels where they connect to the cob), minimal change happens in the cellulosic portion of the corn plant. According to Johnson et al. (1966), corn plant growth ceases after the plant reaches the vegetative point; therefore, ear formation is the major process taking place after that. These authors stated that from about 15 d after tasseling there was little change in in vitro cellulose digestibility of corn leaves and corn stalks after 48 h of incubation (74.75% to 70.55% for leaf, and 54.35% to 57.35% for stalks; planting and harvesting date were not mentioned in the trial).

While the research discussed above focused on maturity, there were also no effects of silage additives on corn residue 48 h in situ DMD and NDFD. The lack of difference in DMD and NDFD between ensiled forages treated with lactobacillus and propionic acid in comparison to an untreated forage have been reported (Mills and Kung, 2002; Filya, 2003). Filya (2003) stated that the inoculation of lactobacillus did not affect DMD of wheat (61.37% vs 60.6%, treated vs control), sorghum (58.83% vs 57.70%, treated vs control), or corn (53.70% vs 53.40%, treated vs control) silages. Adding propionic acid (0.1% of silage) immediately before ensiling barley silage, Mills and Kung (2002) concluded that there was no effect of additive on DMD after 48h of incubation (74.8% vs 71.7%, control vs treated). To our knowledge, this is the first trial that tested the efficacy of silage inoculants on corn stalklage.

It is important to note that regardless of treatment or maturity, corn residue DMD in the current study was less than in previous reports above (Johnson et al., 1966; Berger et al., 1979;

Hunt et al., 1989; Lynch et al., 2012). One explanation may be the variation in calculation techniques among papers. In the current study, the washout was estimated by rinsing bags that had not been incubated in the rumen. The DM and NDF in the bag was analyzed before and after rinsing and the disappearance due to rinsing was calculated. This washout then was the material (DM or NDF) that left the bag simply because of the rinsing technique, not due to any fermentation. Thus, washout averages were subtracted from the disappearance of the fermented bags to estimate the true disappearance due to microbial fermentation and not caused by washout. A similar technique was used by Duckworth et al. (2014). Results from Duckworth et al. (2014) for 48h in situ DMD of untreated corn stover were similar to the current results (25.46% average from Duckworth et al. (2014) experiment vs 20.52% average from the current experiment). Therefore, less DMD in the current trial compared to earlier reports may be caused by accounting for washout.

The lack of chemical and physical (Table 2) changes in composite samples of ensiled material collected over the 85 d feeding trial, explain the lack of treatment effect on ruminal disappearance of corn residue. Corn residue in the SVT and STKP groups had an increase ($P \leq 0.03$; 20.76% and 16.75% for samples >1.9 cm, and 16.82% and 17.45% for 0.8 to 1.9 cm, respectively) in the proportion of larger particles when compared to STK and STKL (11.13% and 10.55% for samples >1.9 cm, and 12.85% and 14.69% for 0.8 to 1.9 cm, respectively) treatments, while there was no difference among treatments when smaller particle sizes were analyzed ($P \geq 0.21$; 47.17%, 54.45%, 53.09%, 49.95% for 0.4 to 0.8 cm, 15.13% 21.44%, 21.67%, 15.86% for <0.4 cm on the respect treatments SVT, STK, STKL and STKP). However, these minute differences in particle size did not affect disappearance of the corn residues in situ and were likely not biologically relevant. Lactic acid ranged from 3.03 to 5.07 mmol and acetic

acid ranged from 0.55 to 0.58 mmol. These parameters are provided to characterize the corn crop residues in the current experiment and demonstrate that they adequately ensiled.

The lack of difference in forage characteristics and disappearance in the current trial is likely due to the narrow window between harvest dates in the current trial (28 d). When the experiment was designed, was expected to harvest corn storklage after a HMC with 65 to 70% DM was harvested. However, due to weather issues faced during the fall of 2014, HMC harvesting was delayed. Despite harvesting 158 d after planting September 22nd, the HMC was harvested at 77% DM. Greater window between HMC and harvesting dry corn (86% DM, 186 post planting) could affect future corn residue results.

We had hypothesized changes in forage characteristics among the treatments may affect the feed value of the corn residue treatments, thereby altering performance of cattle. However, as in the digestibility results, there was no treatment effects ($P \geq 0.15$) on cattle ADG, G:F and DMI when calves were fed corn residue at 25% of the diet (DM basis) during the growing phase of the feedlot (Table 3). Berger et al. (1979) reported a 19% increase in efficiency when feeding corn storklage (harvested at October 8th, after HMC harvest) to beef steers in a feedlot diet as opposed to more mature corn residues (harvested at November 10th, 32 d later later). While these authors had a similar harvest window to the current trial (28 in the current trial vs 32 d between harvesting materials for Berger et al. (1979)), cattle were fed a forage-based diet (78% of diet DM) throughout finishing while in the current study, corn residue was only included at 25% of the diet DM. Moreover calves fed by Berger et al. (1979) were fed for a longer period of time (112 d vs 85 d) and had substantially reduced ADG (0.65 kg/d) when compared to calves in the current trial (1.75 kg/d). Therefore the comparisons are quite different. Russell (1986) also fed ensiled corn stover at 2 different maturities (17 and 31 days after post-physiological maturity),

but, again, included it at 80% of the diet (DM basis) for 84 days. Russell (1986) reported that heifers fed the early-harvested stover silage (harvested when grain was 76.5% DM) had a similar intake (7.2 kg/day vs 7.5 kg/day) and ADG (0.47 kg/day vs 0.43 kg/day) as heifers fed the late-harvested stover silage (harvested when grain was 82.3% DM). Once again, the amount of stover fed and the difference in cattle sex, make Russell (1986) a poor comparisons to the current trial. Russell et al. (2011) reported similar animal performance (0.183 vs 0.192 on G:F for control [corn-based diet] vs corn stover treated diet, respectively) when diets were fed during the growing (112 d) feedlot phase, and animals were finished (71 d) on the same corn-based diet. There are no papers to the authors' knowledge comparing growth performance of cattle fed corn stalklage compared to corn stover at 25% of the diet DM.

Throughout the growing phase of the current trial, steers fed 25% corn residue gained better than was expected (1.71 kg/day vs 1.51 kg/day, respectively), regardless of treatment. Calculated NE_g and NE_m , based on the NRC (1996) tabular values for feeds (Table 1), projected cattle to gain less than 1.5 kg/day. However, cattle gained on average 1.7 kg/day. In fact, when NE_m and NE_g were back calculated based on cattle performance (NRC, 1996, iterative equations for medium framed steers) the energy values were on average 10.64% and 12.95% greater than book values for NE_m and NE_g , respectively (Figure 3)

When cattle were fed a common feedlot diet, during the finishing phase, performance increased relative to the growing phase, as expected with increased grain inclusion in the diet. However, due to the lack of differences in the growing and the finishing phases, overall ADG, DMI, and G:F results were not affected ($P \geq 0.36$) by growing phase treatment. The lack of differences in cattle growth performance overall also led to similar results in the carcass traits (Table 4). Cattle from the current experiment were killed with the same days on feed (186 d),

following similar feedlot performance results, there were no effects ($P \geq 0.10$) of corn residue treatments fed during the growing phase on carcass characteristics. Previous research has reported variable effects of feeding corn stover during the finishing phase on carcass characteristics (Duckworth et al., 2014; Chapple et al., 2015). There are no previous reports comparing carcass characteristics of cattle fed corn stalklage to those fed stover during the growing phase.

There were no treatment effects ($P \geq 0.20$) on feedlot cost, cost of gain, and return per head during the growing, finishing and overall feedlot trial (Table 5). There were also no treatment effects ($P = 0.84$) on break-even corn stover price, calculated during the growing phase, when corn residue was fed. In order to maintain similar material collection from the stalklage to the corn stover, the same 3 pass harvesting technique was used for all corn crop residues fed in the current study, as explained in the materials and methods, such that the only cost differential among treatments were the addition water to the residues harvested later, and additives to the stalklage treatments (average cost among treatments were \$77.75 per MT on DM basis), according to Vadas and Digman (2013), a similar harvest technique yielded corn stover silage that cost \$44.09 per MT (DM basis). In a conventional corn replacement diet, corn stover fed has been baled first, then processed, both ground and treated, after a period of bale storage (Duckworth et al., 2014; Shreck et al., 2015). Vadas and Digman (2013) reported that harvesting corn stover as a bale, as opposed to storing it in a silo bag, as silage, did reduce the cost of the corn stover product (\$36.22 per MT for wrapped bales, \$39.15 per MT for dry bales stored outdoors, \$43.05 per MT for dry bales stored indoor). However, Russell et al. (2011) reported that feed value, based on carcass net return per head, increased when cattle were fed corn stover silage compared to those fed baled corn stover that had been ground. In addition to the increased

feed value of corn stover silage, the additional processing (grinding) baled corn stover requires in order to be included in a TMR for feedlot cattle (Russell, 2011) adds \$11.68 per MT (Ag Decision Maker 2016) and must be considered in the total costs analysis. This additional cost increases the cost of feeding baled corn stover to \$54.73 per MT (if stored inside), making baled corn stover more expensive than the corn stover silage, valued at \$44.09 per MT, for feeding to growing cattle. The increased cost and decreased feeding value of baled corn stover when compared to corn stover silage, make it a less economical option for beef producers.

Interesting to note in the current study, however, was that all cattle gained more than expected (ADG less than 1.50 kg/day). In the current trial, cattle fed untreated corn stover silage at 25% DM of the diet for 85 d had an ADG of 1.70 kg/day and gained as well as cattle fed chemically (5% CaO) treated corn stover silage at 20% DM (ADG of 1.71 kg/day) in a prior experiment with different days on feed, and different cattle weight (Russell et al., 2011). Russell et al. (2011) reported that feeding a “corn replacement” diet (20% corn stover treated with CaO and 40% DGS, DM basis) became more favorable when corn price increased. When the current project was designed, the corn price was ~\$4.75 a bushel (~\$187.01 per MT). Using corn residue in the diet may be more economical when beef market conditions are not favorable to producers, such as high corn prices and low cattle prices.

IMPLICATIONS

Although we hypothesized that harvesting a less mature corn residue would improve digestibility and cattle growth performance, there were no effects of treatment on DMD, NDFD, growth performance, or carcass characteristics. Subsequently, there were no differences in

economics when corn stalklage or corn stover were fed during the growing phase. The short interval between harvesting dates and the use of similar harvest techniques may be the primary reasons for the lack of difference among treatments. However, cattle gained over 1.70 kg/d during the growing phase, despite being fed 25% of the diet DM as a poor quality roughage. This research suggests that feeding 25% corn crop residues to growing cattle then finishing them on grain-based diets may be a viable option for beef producers.

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TABLES AND FIGURES

Table 1. Composition of diets fed to cattle.

Item, % DM	Growing Phase ¹				Finishing Phase ²
	SVT	STK	STKL	STKP	
High moisture corn	35	35	35	35	50
MWDGS ³	30	30	30	30	20
Corn storklage	-	25	25	25	-
Corn stover	25	-	-	-	-
Corn silage	-	-	-	-	20
Supplement ⁴	10	10	10	10	10
Analyzed Composition					
NDF	33.60	33.04	33.08	32.14	21.48
ADF	16.07	15.45	15.59	15.05	8.96
CP	15.88	15.95	16.06	16.15	13.73
EE ⁵	4.00	4.01	3.95	3.98	3.52
NE _m , ⁶ Mcal/kg	1.77	1.80	1.80	1.80	2.19
NE _g , ⁶ Mcal/kg	1.16	1.18	1.18	1.18	1.50

¹Growing phase = d 0 to 85; SVT = Corn stover harvested at dry corn (86% DM) hydrated to 50% DM and ensiled in AG-BAG (AG-BAG, St. Nazianz, WI), STK = Corn storklage harvested at high moisture corn (77%DM) and ensiled in AG-BAG (AG-BAG, St. Nazianz, WI), STKL = Corn storklage treated with lactobacillus (Silo-King at 0.25 kg per MT), STKP = Corn storklage treated with propionic acid (Silage SAVOR Plus at 0.5 kg per MT).

²Finishing phase = d 86 to 186

³MWDGS = Modified wet distillers grains with solubles (38.21% NDF, 13.98% ADF, 29.13% CP, 7.9% EE).

⁴Supplement = 76.20% corn, 5.99% urea, 15.89% limestone, 0.15% Rumensin 90 (198g monensin/kg DM; Elanco; Greenfield, IN), 0.10% Tylosin 40 (88 g tylan/kg DM; Elanco; Greenfield, IN), 0.77% grease, 0.91% Dairy trace mineral salt (Trace mineral salt contains: 8.5% Ca (as CaCO₃), 5% Mg (as MgO and MgSO₄), 7.6% K (as KCl₂), 6.7% Cl (as KCl₂) 10% S (as S8, prilled), 0.5% Cu (as CuSO₄ and Availa-4 (Zinpro Performance Minerals; Zinpro Corp, Eden Prairie, MN), 2% Fe (as FeSO₄), 3% Mn (as MnSO₄ and Availa-4), 3% Zn (as ZnSO₄ and Availa-4), 278 ppm Co (as Availa-4), 250 ppm I (as Ca(IO₃)₂), 150 Se (Na₂SeO₃), 2,205 KIU/kg VitA (as retinyl acetate), 662.5 KIU/kg VitD (as cholecalciferol), 22,047.5 IU/kg VitE (as DL- α -tocopheryl acetate), and less than 1% CP, fat, crude fiber, salt.)

⁵EE = ether extractable fat

⁶NE = calculated based on book values of feeds from NRC, 1996

Table 2. Chemical and physical characteristics of corn residue fed to feedlot cattle.

Item	Treatment ¹				SEM	P-value ³
	SVT	STK	STKL	STKP		
Particle size ² , %						
Upper sieve, >1.9 cm	20.76	11.13	10.55	16.75	1.22	<0.01
Middle sieve, 0.8 to 1.9 cm	16.82	12.85	14.69	17.45	1.06	0.03
Lower sieve, 0.4 to 0.8 cm	47.17	54.45	53.09	49.95	2.50	0.21
Bottom pan, <0.4 cm	15.13	21.44	21.67	15.86	3.37	0.26
Analyzed composition						
NDF	71.48	68.32	69.39	68.61		
ADF	49.90	45.55	45.07	45.71		
ADL	7.73	6.52	7.59	7.98		
Hemicellulose	21.58	22.77	24.32	22.90		
Cellulose	42.17	39.03	37.48	37.73		
pH	4.1	3.9	4.1	4.1		
Lactic Acid	3.03	5.07	3.31	3.10		
Acetic Acid	0.81	0.90	0.58	0.55		
Butyric acid	0	0	0	0		
Nitrate-N, ppm	160	244	559	665		

¹SVT = Corn stover harvested at dry corn (86% DM) hydrated to 50% DM and ensiled in AG-BAG (AG-BAG, St. Nazianz, WI), STK = Corn stalklage harvested at high moisture corn (77%DM) and ensiled in AG-BAG (AG-BAG, St. Nazianz, WI), STKL = Corn stalklage treated with lactobacillus (Silo-King at 0.25 kg per MT), STKP = Corn stalklage treated with propionic acid (Silage SAVOR Plus at 0.5 kg per MT).

²Determined following the guidelines for corn silage according to Heinrichs and Kononoff (2002).

³Main effect of dietary treatment.

Table 3. Effects of feeding corn residue during the growing phase (d 0 - 85) on growth performance of feedlot cattle.

Item	Treatment ¹				SEM	P-value ²
	SVT	STK	STKL	STKP		
n, pens (animals)	5 (34)	5 (30)	5 (33)	5 (31)	-	-
Initial BW, kg ³	326	331	329	331	14	0.99
Middle BW d 86, kg ⁴	469	483	477	472	13	0.87
Final BW, kg ⁵	655	665	658	660	17	0.98
Growing phase, d 0 to 85 ⁶						
ADG, kg	1.70	1.81	1.75	1.68	0.05	0.30
DMI, kg/d	9.21	9.34	9.05	9.17	0.26	0.88
G:F	0.1856	0.1946	0.1940	0.1830	0.0077	0.63
Finishing phase, d 86 to 186 ⁷						
ADG, kg	1.88	1.83	1.83	1.90	0.06	0.83
DMI, kg/d	10.68	10.82	10.50	10.64	0.40	0.95
G:F	0.1770	0.1692	0.1748	0.1796	0.0058	0.64
Overall, d 0 to 186 ⁸						
ADG, kg	1.79	1.81	1.79	1.79	0.03	0.95
DMI, kg/d	10.00	10.14	9.83	9.96	0.32	0.92
G:F	0.1796	0.1788	0.1820	0.1802	0.0046	0.97

¹SVT = Corn stover harvested at dry corn (86% DM) hydrated to 50% DM and ensiled in AG-BAG (AG-BAG, St. Nazianz, WI), STK = Corn stalklage harvested at high moisture corn (77%DM) and ensiled in AG-BAG (AG-BAG, St. Nazianz, WI), STKL = Corn stalklage treated with lactobacillus (Silo-King at 0.25 kg per MT), STKP = Corn stalklage treated with propionic acid (Silage SAVOR Plus at 0.5 kg per MT).

²Main effect of dietary treatment.

³Initial BW = 2 d BW weight at allotment (d -1 and d 0).

⁴Middle BW d 86 = 2 d BW prior to the finishing phase (d 84 and d 85).

⁵Final BW = 2 d BW prior to slaughter (d 185 and d 186).

⁶Growing phase = d 0 to 85 on feed, animals were fed different corn residue at 25% (DM basis) of the diet.

⁷Finishing phase = d 86 to 186 on feed, all the animals were fed the same feedlot finishing diet.

⁸Overall = d 0 to 186 on feed.

Table 4. Effects of feeding corn residue during the growing phase (d 0 - 85) on carcass characteristics feedlot cattle.

Item	Treatment ¹				SEM	P-value ²
	SVT	STK	STKL	STKP		
n, animals (pens)	5 (34)	5 (30)	5 (33)	5 (31)	-	-
HCW, kg	403	409	406	405	11	0.99
LM area, cm ²	91.31	88.97	89.99	88.74	1.66	0.69
Calculated YG ³	2.98	3.33	3.50	3.40	0.16	0.17
Marbling score ⁴	502	461	474	478	23	0.67
Dressing percent, %	61.52	61.92	62.20	61.88	0.25	0.32
Back fat, cm	1.38	1.47	1.63	1.62	0.11	0.35
KPH	1.92	1.91	1.90	1.96	0.04	0.67
USDA Yield Grade ³						
1, %	2.94	0	0	0	2.90	1.00
2, %	35.29	40.00	33.33	36.67	8.20	0.96
3, %	44.12	50.00	60.61	50.00	8.52	0.60
4, %	17.65	3.33	6.06	13.33	6.54	0.27
5, %	0	6.67	0	0	0	1.00
USDA Quality Grade						
Prime, %	8.82	0	6.06	13.33	4.86	0.81
Choice, %	82.35	80.00	75.76	63.33	6.54	0.33
Select, %	8.82	20.00	18.18	20.00	4.86	0.58

¹SVT = Corn stover harvested at dry corn (86% DM) hydrated to 50% DM and ensiled in AG-BAG (AG-BAG, St. Nazianz, WI), STK = Corn stalklage harvested at high moisture corn (77%DM) and ensiled in AG-BAG (AG-BAG, St. Nazianz, WI), STKL = Corn stalklage treated with lactobacillus (Silo-King at 0.25 kg per MT), STKP = Corn stalklage treated with propionic acid (Silage SAVOR Plus at 0.5 kg per MT).

²Main effect of dietary treatment; Contrast between ST and SK.

³YG was calculated using the yield grade equation from the USDA beef grading standards (USDA, 1997).

⁴Marbling score: 300–399 = slight; 400–499 = small; 500–599 = modest.

Table 5. Economics of feeding corn residue during the growing phase to feedlot cattle.

Item	Treatment ¹				SEM	P-value ²
	SVT	STK	STKL	STKP		
Growing phase, d 0 to 85						
Feedlot Cost, \$/head ³	247.92	246.87	242.08	244.09	4.25	0.76
Cost of Gain, \$/kg ⁴	1.72	1.61	1.64	1.72	0.06	0.44
Return per Head, \$/head ⁵	-300.56	-279.03	-286.74	-313.00	36.05	0.91
Break-even Kg/DM, \$/kg ⁶	-1.52	-1.40	-1.48	-1.60	0.16	0.84
Finishing phase, d 86 to 186						
Feedlot Cost, \$/head ⁷	299.11	301.50	296.11	298.39	6.67	0.95
Cost of Gain, \$/head	1.59	1.65	1.62	1.57	0.05	0.64
Return per Head, \$/head	316.47	283.37	306.63	319.23	25.99	0.76
Overall phase, d 0 to 186						
Feedlot Cost, \$/head ⁸	552.88	554.22	544.03	548.33	10.41	0.90
Cost of Gain, \$/head	1.66	1.65	1.64	1.65	0.03	0.93
Return per Head, \$/head	10.00	-1.53	14.00	0.27	34.76	0.99
Break-even Kg/DM, \$/head	0.08	-0.01	0.08	0.01	0.18	0.97

¹SVT = Corn stover harvested at dry corn (86% DM) hydrated to 50% DM and ensiled in AG-BAG (AG-BAG, St. Nazianz, WI), STK = Corn stalklage harvested at high moisture corn (77%DM) and ensiled in AG-BAG (AG-BAG, St. Nazianz, WI), STKL = Corn stalklage treated with lactobacillus (Silo-King at 0.25 kg per MT), STKP = Corn stalklage treated with propionic acid (Silage SAVOR Plus at 0.5 kg per MT).

²Main effect of dietary treatment

³Feedlot cost during the growing phase (d 0 to 85) = Non-feed cost⁹ + Hormone implant cost (\$1.88) + Cost of high moisture corn (\$0.17 kg of DM; used price of dry corn \$0.15 kg of DM as basis) + Cost of MWDGS (\$0.16 kg of DM) + Supplement cost (\$0.33 kg of DM) + Cost of processing corn residue¹⁰ + Extra cost¹³.

⁴Cost of gain = Feedlot Cost/days on feed/ADG.

⁵ Return per Head = Money receive per head - Feedlot Cost³ + Purchase the animal¹².

⁶Break-even Kg/DM = Price to pay per Kg/DM of corn residue on the field.

⁷Feedlot cost during the finishing phase (d 86 to 186) = Non-feed cost⁹ + Ractopamine cost (\$0.50/d; last 30 days) + Hormone implant cost (\$2.82) + Cost of high moisture corn (\$0.17 kg of DM; used price of dry corn \$0.15 kg of DM as basis) + Cost of MWDGS (\$0.16 kg of DM) + Supplement cost (\$0.33 kg of DM) + Cost of silage¹¹.

⁸Overall feedlot cost = Non-feed cost⁹ + Ractopamine cost (\$0.50/d; last 30 days) + Hormone implant cost (\$1.88 growing phase, \$2.82 finishing phase) + Cost of high moisture corn (\$0.17 kg of DM; used price of dry corn \$0.15 kg of DM as basis) + Cost of MWDGS (\$0.16 kg of DM) + Supplement cost (\$0.33 kg of DM) + Cost of processing corn residue¹⁰ + Cost of silage¹¹ + Extra cost¹³.

⁹Non-feed cost = Non-feed operating cost for interest on veterinary and medicine, death loss, interest on feed and feeder, operating expenses for feeding equipment, and marketing costs is

Table 5. (Cont.)

\$70.00 (\$31.99 to the growing phase and \$38.01 to the finishing phase) for calves per head;
Yardage cost = \$0.71hd/day

¹⁰Cost of processing corn residue = Cost of silo bag (\$400.00; 61m bag) + Cost of chopping
cornstalks (\$29.41/ha) + Mowing cornstalks (\$35.21/ha) + Windrowing corn stalks
(\$33.11/ha) + Farm labor (\$14.20/hour)

¹¹Cost of silage = 9 times the cost of a kg of corn harvested and stored (wet basis); silage at
40% DM

¹²Purchase the animal; Growing phase = Purchase at \$1.08 kg and sold at \$0.73 kg of live
weight; Finishing phase = Purchase at \$0.73 kg of live weight and sold as carcass weight.

¹³Extra cost = \$10.47/kg of lactobacillus at the STKL; \$1.44/kg of propionic acid at the STKP;
\$0.55/l of water at ST.

Figure 1

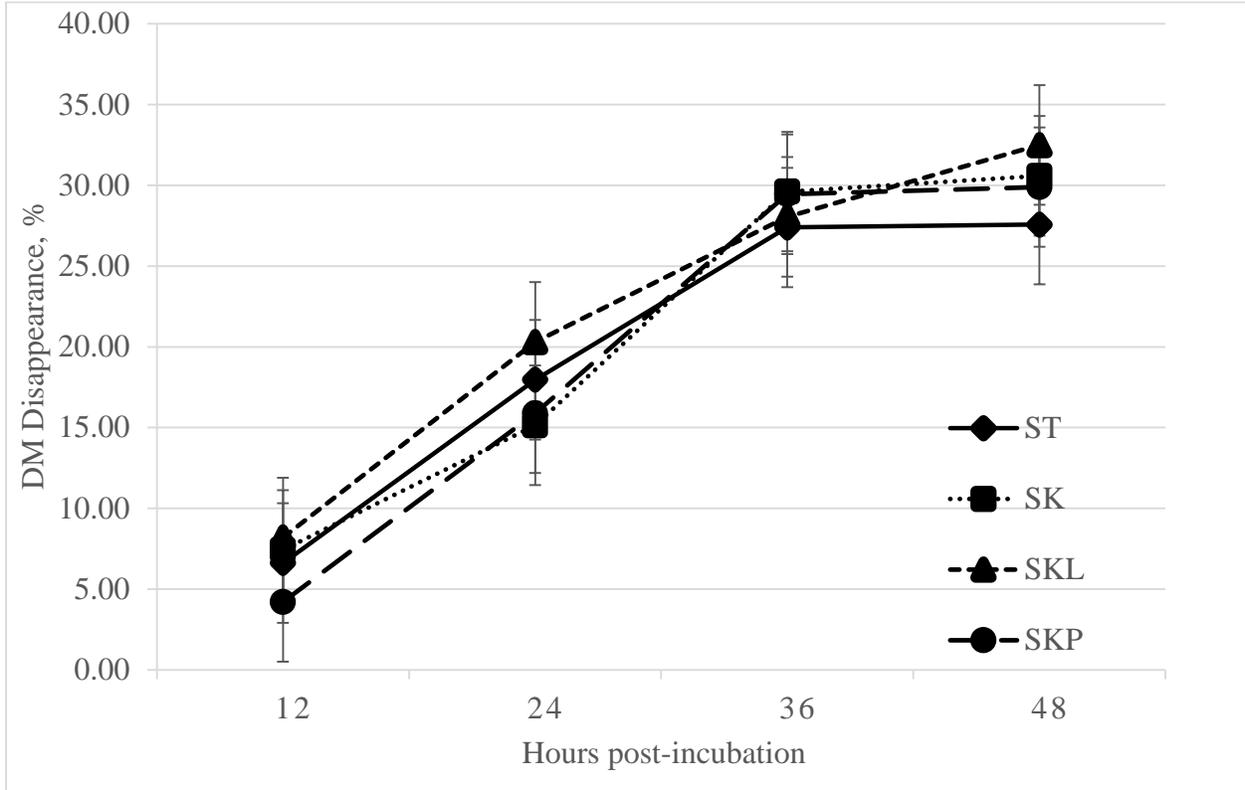


Figure 1. Effect of corn residue treatment on DM disappearance after 48h incubation. **SVT**, (♦) = Corn stover harvested at dry corn (86% DM) hydrated to 50% DM and ensiled in AG-BAG (AG-BAG, St. Nazianz, WI), **STK** (■) = Corn stalklage harvested at high moisture corn (77%DM) and ensiled in AG-BAG (AG-BAG, St. Nazianz, WI), **STKL** (▲) = Corn stalklage treated with Silo-King (0.25 kg per MT; Agri-King, Inc., Fulton, IL), **STKP** (●) = Corn stalklage treated with Silage SAVOR Plus (0.5 kg per MT; Kemin Industries, Inc., Des Moines, IA). There was no hour \times treatment interaction ($P = 0.40$) on DM disappearance. There was no effect of treatment ($P = 0.18$) on DM disappearance. The error bars reflect the SEM associated with the interaction of treatment \times hour (SEM = 3.70).

Figure 2

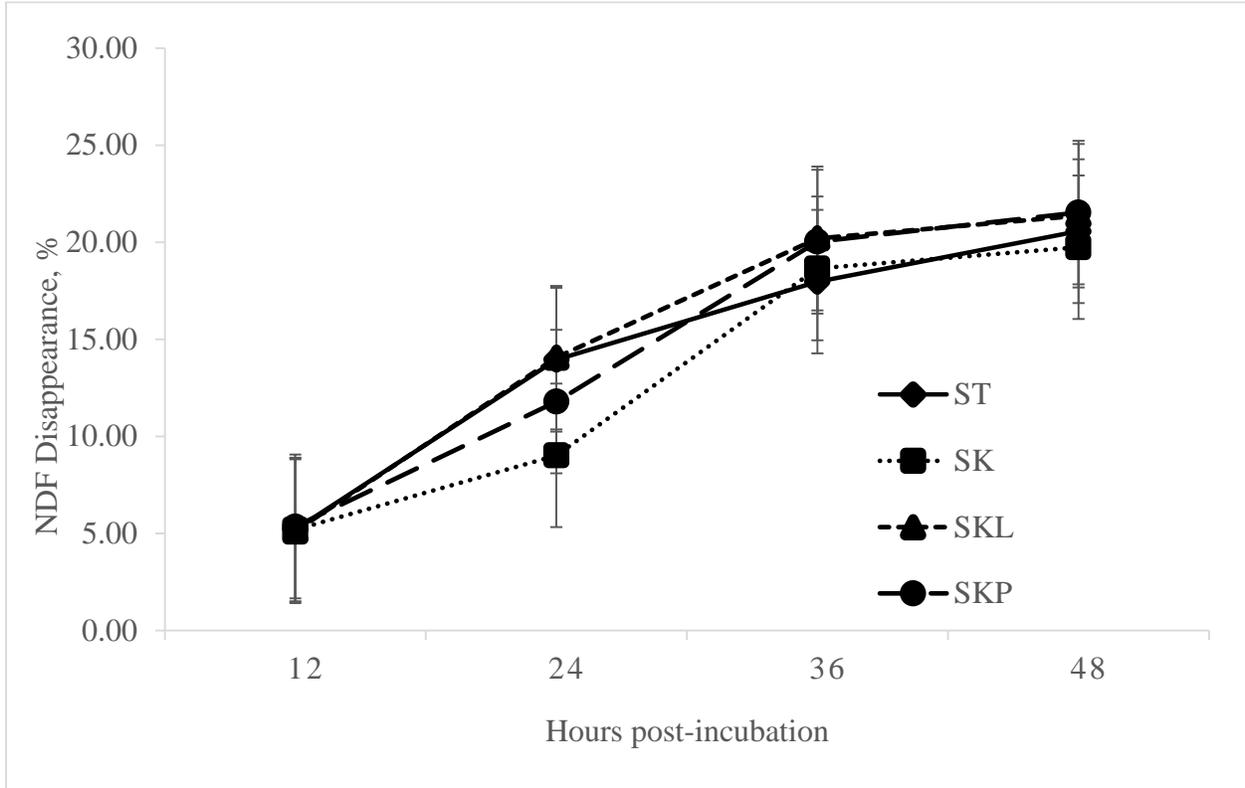


Figure 2. Effect of corn residue treatment on NDF disappearance after 48h incubation. **SVT**, (◆) = Corn stover harvested at dry corn (86% DM) hydrated to 50% DM and ensiled in AG-BAG (AG-BAG, St. Nazianz, WI), **STK** (■) = Corn stalklage harvested at high moisture corn (77%DM) and ensiled in AG-BAG (AG-BAG, St. Nazianz, WI), **STKL** (▲) = Corn stalklage treated with Silo-King (0.25 kg per MT; Agri-King, Inc., Fulton, IL), **STKP** (●) = Corn stalklage treated with Silage SAVOR Plus (0.5 kg per MT; Kemin Industries, Inc., Des Moines, IA). There was no hour × treatment interaction ($P = 0.34$) on NDF disappearance. There was no effect of treatment ($P = 0.15$) on NDF disappearance. The error bars reflect the SEM associated with the interaction of treatment × hour (SEM = 4.57).

Figure 3

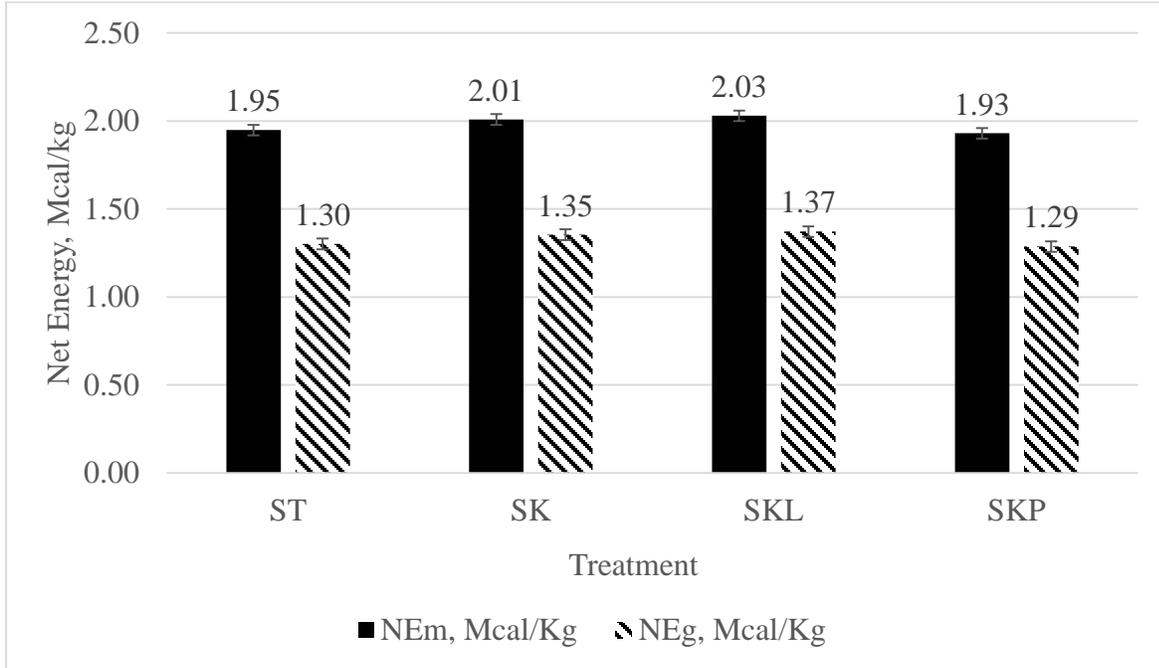


Figure 3. Effects of feeding corn residue during the growing phase (d 0 - 85) on back calculated NE_m and NE_g using NRC (1996) equations. **ST** = Corn stover harvested at dry corn (86% DM) hydrated to 50% DM and ensiled in AG-BAG (AG-BAG, St. Nazianz, WI), **STK** = Corn stalklage harvested at high moisture corn (77%DM) and ensiled in AG-BAG (AG-BAG, St. Nazianz, WI), **STKL** (\blacktriangle) = Corn stalklage treated with Silo-King (0.25 kg per MT; Agri-King, Inc., Fulton, IL), **STKP** (\bullet) = Corn stalklage treated with Silage SAVOR Plus (0.5 kg per MT; Kemin Industries, Inc., Des Moines, IA). Treatment did not affect ($P \geq 0.13$) NE_m or NE_g backcalculated values (SEM = 0.03).

CHAPTER 3: CONCLUSIONS

As the most abundant corn byproduct in United States, corn residue is a great option to be included into growing cattle feedlot diets in order to decrease costs in particular when corn prices increase. Replacing corn with corn residue and distillers grains and solubles (**DGS**), has been referred to as a corn replacer diet. Chemical and physical treatments have been applied in order to increase the feeding value of these co-products. However, chemical and physical treatments have additional costs, and labor, and potential hazards when applied. Thus, making it difficult to be applied, in particular in small scale operations. Another option to increase feeding value of corn residue, is to harvest it at an earlier maturity.

Although we had hypothesized that harvesting an earlier maturity corn residue would increase digestibility and animal performance, the short window (30 d) between the 2 harvesting dates may have prevented expected results. The addition of silage additives in the current trial did not effect cattle performance or digestibility. In the current trial, even though there were no differences among treatments, cattle fed diets containing 25% corn residue outperformed the expectations, which makes the combination of corn residue and DGS a great option in order to replace corn in growing cattle diets.

In conclusion, harvesting corn residue at 2 different maturities (with a 28 d window) did not result in differences in digestibility and cattle performance. Moreover, the application of silage additive in a less mature plant at the ensiled time, did not affect digestibility and cattle performance when corn residue was fed at 25% DM of the diet during the growing phase (85 d) of the feedlot.