Spring 2012

Effects of Feeding Insect-Protected Corn and Corn Residue to Cattle, and Evaluation of Distillers Grains Storage when Mixed with Crop Residue on Cattle Performance

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EFFECTS OF FEEDING INSECT-PROTECTED CORN AND RESIDUE TO CATTLE, AND EVALUATION OF DISTILLERS GRAINS STORAGE WHEN MIXED WITH CROP RESIDUE ON CATTLE PERFORMANCE

by

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A THESIS

Presented to the Faculty of

The Graduate College at the University of Nebraska

In Partial Fulfillment of Requirements

For the Degree of Master of Science

Major: Animal Science

Under the Supervision of Professors Galen E. Erickson and Terry J. Klopfenstein

Lincoln, NE

May 2012

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University of Nebraska, 2012

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Research has been conducted on genetically modified corn fed to livestock since the introduction of insect resistant hybrids. While the overwhelming conclusion of these trials demonstrate nutritional equivalency to corn from non-transgenic hybrids, the introduction of new transgenes and combinations of resistance traits necessitates continued evaluation of genetically modified corn hybrids. Expansion of the ethanol industry has resulted in the increased availability of co-products for use as a livestock feed, as well as an increase in crop residues that offer unique opportunities for use by cattle producers. A finishing trial was conducted with corn and corn silage from MON 89034, which incorporates two genes encoding for insect resistance. The presence of the transgenes in MON 89034 did not impact finishing performance or carcass characteristics when compared to steers fed corn and corn silage from a near isogenic, non-transgenic parental hybrid and two non-transgenic reference hybrids. Growing steers were fed

silage from corn hybrid MON 89034 and performance was compared to that of steers fed silage from the isogenic, non-transgenic parental hybrid and two non-transgenic reference hybrids. No differences in performance were observed. A grazing trial evaluated the performance of steers grazing corn residue from hybrid MON 89034 and its isogenic, non-transgenic parental hybrids, and no differences in performance were observed. An individual trial was conducted to determine the effects of ensiled (EN) or freshly mixed (FR) modified distillers grains with solubles (MDGS) blended with corn stalks (CS) or wheat straw (WS) at 30% or 50% diet DM. Steers offered EN blends had greater DMI, ADG, and G:F than steers fed FR blends. Growing steers were offered the same MDGS:crop residue blends as those in the individual trial, but as a supplement to a basal forage diet to determine palatability and forage intake replacement. Steers offered all mixes equaled or surpassed ADG and G:F of steers offered only the basal forage diet, with blends replacing 9.6% to 35.4% of the basal diet.

Acknowledgements

When I finally decided to return to school and obtain my M.S., I was cautious, not really knowing what to expect. Sure, I was excited, but being out of school for an extended period of time left me with doubts. All of them were erased, as this has been one of the most fulfilling experiences of my life on an intellectual and personal level.

I'd first like to thank my parents, Dennis and Diane, for understanding and encouraging what we like to refer to as my "pre-mid-life crisis." They've been patient and stood behind me and I'm indebted to them for it. My brother and sister-in-law, Matt and Sarah, along with my sister and brother-in-law, Susie and Ryan have supported me with minimal questions and I am thankful for their assistance when time became an issue.

To my advisors, Dr. Galen Erickson and Dr. Terry Klopfenstein, I can't thank you enough for giving me a chance and encouraging me. I'd also like to thank Dr. Rick Rasby and Dr. Paul Kononoff for serving on my committee and all of the technicians for their help in answering questions as well as planning and executing my trials.

I'm not even sure where to begin thanking the other graduate students who have become incredible friends. Brandon, Annie, Amy, Anna, Adam, Cody S., Cody N., Will, Josh, Kelsey, Jana, Curt, Alex, Ace, and Derek, you've made this experience so much more than I could have ever expected. Whether working all day at the feedlot or horsing around outside of our duties as graduate students, I've cherished every minute. Mallorie, simple words typed on paper in no way can express my appreciation and gratitude for the listening, the understanding, the great times, and for becoming my best friend.

Barry

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Introduction

The introduction of genetically engineered crops to the United States in 1996 has been met with great success and acceptance in conventional agriculture. The incorporation of genes providing insect protection and herbicide resistance has not only led to increased crop yields, but decreased herbicide and pesticide usage. Genetic modifications providing for insect resistance in corn are based upon the insertion of DNA from *Bacillus thuringiensis*, a native soil bacterium. The foreign DNA produces a crystalline protein that is toxic to several species of insects that harm yields and would otherwise necessitate pesticide applications and more intensive management. Insect protected corn, commonly called Bt corn, was planted on 73% of all corn acres in the United States in 2010 (USDA, 2010).

Because such a large percentage of domestic corn production is used as livestock feed, it is necessary to ensure that genetic modifications do not negatively affect the nutritional composition of the grain, silage, or residue. There have been multiple experiments evaluating livestock performance when fed Bt corn, and scientists have concluded that the incorporation of the insect protected gene results in animal performance similar to non-transgenic corn. Nonetheless, different combinations of genes in specific hybrids, often referred to as double or triple stacked hybrids, must be evaluated to ensure acceptance as a livestock feed.

The growth of the ethanol industry in the midwestern United States has resulted in the adoption of distillers grains with solubles as a staple in feedlot diets. Typically, cattle on feed numbers decrease in the summer months in the midwest, resulting in decreased demand for distillers grains and seasonally lower prices (Waterbury and Mark, 2008). Producers can take advantage of these lower prices and stockpile a high quality feed for use later in the year, but storage can be a concern.

Crop residues from grains are a relatively low cost and abundant feed resource for cattle producers located in close proximity to grain producing areas, because grain producing plants typically produce an equal or greater weight of vegetative material compared to grain (Vetter and Boehlje, 1978). In the midwest, it is common practice for dry cows or weaned calves to graze corn residues over the winter months. All of the residues are available on the first day of grazing and are subject to deterioration of quality due to animal selectivity and adverse weather (Klopfenstein et al., 1987). Wheat straw provides bulk in the form of fiber, but it is low in nutritional value and digestibility (Saenger et al., 1983). Cattle struggle to maintain weight on untreated wheat straw alone, making it necessary to supplement protein and energy (NRC, 1983).

By combining low quality forages such as crop residues with high protein, high energy ethanol co-products, nutritional requirements for growing calves are more easily met. Adams et al. (2007) concluded that WDGS mixed with roughages, including cornstalks or wheat straw, could be successfully stored in silo bags. Several studies (Wilken et al., 2009; Buckner et al., 2010) examined the effects of stored or freshly mixed distillers grains and crop residue diets on growing calf performance with mixed results. Nuttelman et al. (2008) determined that stored blends of distillers grains and wheat straw reduced grazed forage intake. However, no studies have compared the combination of storage method, residue type, and moisture content of these blends on growing calf performance and forage intake.

REVIEW OF LITERATURE

History of Genetically Modified Corn

The role of biotechnology in modern production agriculture has been responsible for a myriad of advances in management practices. Since their initial availability in the United States in 1996, crops containing genetically modified or transgenic traits have grown to account for the majority of corn, soybean, and cotton acres planted. Herbicide tolerant or insect resistant traits reduce pesticide use and increase yield and quality of the crop, resulting in substantial increases in profit (Marra et al., 2002). Specifically, 88% of all corn acres planted in 2011 contained at least one genetically modified trait, with insect resistant hybrids accounting for 75% of all domestic acres (USDA ERS, 2011). When comparing yields from genetically modified corn to non-transgenic hybrids, Marra et al. (2002) observed 6.7 bu/ac greater yields for insect protected corn varieties.

Recombinant DNA technology enables a trait or traits expressed in one organism to be transferred to an entirely different organism through the targeting of specific genes or gene sequences. The desired foreign DNA sequence is inserted into the T-DNA of plasmids to create a recombinant plasmid, after which the T-DNA from the plasmid is transferred to the host organism and the target DNA sequence is assimilated into the host genome (Wisniewski et al., 2002).

Transgenic corn encoded for insect resistance has been genetically altered by the insertion of genes from *Bacillus thuringiensis*, which is a native soil bacterium that produces crystalline proteins that are toxic to Lepidopteran insects (Ortman et al., 2001). Commonly called Bt corn, incorporation of genetic sequences from *Bacillus thuringiensis* into the corn plant DNA encode for production of specific insecticidal proteins known as delta endotoxins. The endotoxins bind to the epithelium of the insect's midgut and create cation selective channels, resulting in cell lysis due to an influx of water and eventual death of the insect (English and Slatin, 1992).

Toxicity to various insects is dependent upon which specific crystalline (Cry) protein is produced. Inclusion of Cry1A.105 and Cry2Ab2 proteins, both of which are exclusive to MON 89034, provide protection against *Ostrinia* species such as European and Asian corn borer and *Diatraea* species like southwestern corn borer (GM Crop Database, 2011).

Transgenic Corn as a Livestock Feed

Due to the large portion of corn grown in the United States used as a livestock feed and the successful adoption of genetically modified crops into modern production agriculture, there is a need to determine nutritional equivalency of the transgenic product to that of the non-transgenic counterpart. The use of grain, silage, and crop residue in the beef industry demands similar performance responses from the whole corn plant across a variety of management scenarios.

To examine any nutritional differences, Jung and Sheaffer (2004) compared six corn hybrids containing the *cry*1Ab protein to their near isogenic non-transgenic controls. Each hybrid was replicated in four different growing locations and whole plants were harvested at silage maturity. Samples were analyzed for CP, starch, NDF, ADF, 24 and 96 h in vitro NDF digestibility, and lignin. Means of Bt vs. non-Bt hybrid analyses are as follows: 7.4% vs. 7.5% CP; 32.5% vs. 32.7% starch; 44.0% vs. 43.8% NDF; 23.4% vs.

23.2% ADF; 35.6% vs. 35.2% 24 h NDF digestibility; 56.3% vs. 56.3% 96 h NDF digestibility; and 10.1% vs. 10.2% lignin. Though slight differences were observed among locations, comparisons of Bt hybrids to their non-Bt hybrid pairs showed no significant differences in nutritional quality, NDF digestibility, and lignin content.

Wiedemann, et al. (2006) compared the rate and extent of ruminal degradation of the recombinant *cry*1Ab protein to that of the native and abundant Rubisco gene in whole plant and ensiled corn. The ensiling process decreased the presence of the recombinant protein to 10% of the levels detected in whole plant samples, which the authors attributed to low pH conditions and microbial activity. Whole plant samples showed a decrease to 28% of initially detectable values of the recombinant protein after only 2 hours of fermentation, with a decrease to only 2.6% of initial values after 48 hours. Furthermore, ensiled samples of the *cry*1Ab protein were not detectable in its full length form after 8 hours in the rumen, with no recombinant protein fragments amplifiable by PCR after 48 hours, indicating that ruminal fermentation degrades the transgenic protein such that it is not functional after a relatively short period in the rumen.

Transgenic Corn in Finishing Feedlot Diets

Vander Pol et al. (2005) conducted two experiments in finishing steers were fed corn grain and corn silage from a corn rootworm protected hybrid (event MON 863), a nearly identical, non-transgenic control hybrid (CON), and two commercially available reference hybrids. In Exp. 1, steers fed MON 863 had greater ADG (P = 0.04) and heavier final BW (P = 0.03) than steers fed CON hybrids. When comparing performance of steers fed MON 863 to the average of steers fed the two reference hybrids, steers fed

MON 683 had increased G:F (P = 0.05), but all other finishing performance and carcass measurements were similar.

In Exp. 2, neither feedlot performance (P > 0.50) nor carcass characteristics (P > 0.15) differed in a preplanned contrast between steers fed MON 863 or CON. Likewise, similar performance (P > 0.11) was observed when MON 863 and the average of the two reference hybrids were contrasted. In both experiments, the authors concluded that the Bt hybrid had no negative effects on performance and that any slight differences observed were due to nutritional composition of the hybrids rather than the presence of the transgene.

Huls et al. (2008) evaluated finishing performance and carcass characteristics of steers fed corn grain from a transgenic hybrid containing two genes (*cry*34Ab1 and *cry*35Ab1) encoding for corn rootworm resistance and one gene providing herbicide tolerance. Steers were individually fed corn grain based diets containing either the double-stacked transgenic hybrid (DAS-59122-7), a near isogenic non-transgenic parental hybrid (Control), or a non-transgenic commercially available reference hybrid (Reference). In terms of ADG, DMI, and G:F, no statistical differences (P > 0.33) were observed when comparing steers fed corn from 59122 to steers fed corn from Control. Similarly, no differences were detected when comparing performance of steers fed 59122 to those fed Reference. Carcass characteristics were also similar across treatments (P > 0.29), with a subtle tendency (P = 0.07) for higher dressing percentage in steers fed the Control diet. Due to nearly indistinguishable HCW between all treatments, the authors attributed this slight difference to inaccurate measurement of final live weight before slaughter and ultimately concluded that the presence of genes encoding for corn rootworm protection and herbicide tolerance had no negative effect on the feeding value of 59122.

An experiment performed by Sindt et al. (2007) evaluated feedlot performance and carcass quality of heifers fed steam-flaked corn sourced from a Bt variety containing the *cry*1F protein, which provides resistance to several species of corn borer, cutworm, and armyworm. Diets were based upon flaked corn sourced from the transgenic Bt variety (TC1507), a near isogenic conventional hybrid (Control), and two non-transgenic commercial hybrids (33J56 and 33R77). Nutritional analysis of diets indicated diets containing corn from TC1507 showed no difference ($P > 0.05$) in value to the diets based upon non-transgenic corn, which support the similarities in both live and carcass adjusted final BW, ADG and G:F across all treatments. Carcass data indicated no differences in HCW, marbling score, or USDA calculated yield grade based upon hybrid, leading the authors to conclude that the presence of the transgene in TC1507 did not affect the feeding value of the corn when steam-flaked.

Three separate trials were conducted by Erickson et al. (2002) in which feedlot performance and carcass characteristics were compared between steers fed diets containing corn from a glyphosate tolerant Roundup Ready® (RR) hybrid, a near-isogenic control hybrid (CON), and two non-transgenic reference hybrids (REF). In Experiment 1, effects of diets consisting of corn containing the glyphosate tolerant gene were compared against the control and the average of the two reference hybrids. Similar feedlot performance (DMI, ADG, G:F) was observed in RR and CON treatments ($P > 0.29$) as well as between RR and REF ($P > 0.30$). No differences were observed when carcass characteristics between RR and CON were contrasted ($P > 0.07$). However, steers fed the RR treatment had more subcutaneous fat (P = 0.04) than steers fed REF treatments. The authors concluded that this was not attributable to corn hybrid.

In Experiment 2, variation was observed for DMI between treatments, but was not significant. Average daily gain and feed efficiency were not different for steers fed diets containing RR corn when compared to CON and the average of the reference hybrids. Carcass data produced similar results to those of Experiment 1, indicating no differences among treatments and leading the authors to conclude the presence of the RR gene did not affect the feeding value of the corn.

In Experiment 3, steers fed CON tended to be more efficient (P = 0.08) than steers fed the RR hybrid, while the contrasts between the RR hybrid and the average of the two reference hybrids showed no differences in gain:feed ratio. In both comparisons, ADG, DMI, HCW, marbling, and REA of steers fed the RR hybrid were similar to those of steers fed CON or REF hybrids. Steers fed REF hybrids had significantly more (P = 0.05) 12^{th} rib fat than their counterparts fed the RR hybrid. However, all steers in Experiment 3 were considerably fatter (1.5 cm fat depth) than steers in Experiment 1 (0.9 cm) and Experiment 2 (1.0 cm).

Transgenic Corn Silage in Cattle Diets

Folmer et al. (2002) evaluated the effect of corn silage from two Bt corn hybrids (event Bt-11, producing the *cry*1Ab protein) and two near-isogenic non-Bt hybrids on the performance of growing beef steers. Steers fed diets containing 90% silage from Bt hybrids had greater intakes (P = 0.02) than steers fed non-Bt silage. Interestingly, an interaction was observed between presence or absence of the Bt trait and corn hybrid when comparing average daily gain ($P = 0.03$) and feed efficiency ($P = 0.01$). The authors concluded that these differences were attributable to compositional differences in the corn silage (NDF, ADF, lignin, and starch), rather than incorporation of the Bt gene.

Hendrix et al. (2000) also evaluated growing steer performance when fed diets based upon corn silage from either a transgenic Bt hybrid or an isogenic counterpart without the Bt gene. In consecutive years, 56 steer calves were assigned to one of the two treatments consisting of a growing ration containing Bt or non-Bt corn silage. No differences ($P > 0.10$) in DMI (8.88 vs 8.67 kg/d) and ADG (1.30 vs 1.34 kg/d) were observed when comparing the performance of steers fed the transgenic or non-transgenic corn silage, respectively. Interestingly, steers fed the Bt corn silage showed a slight advantage ($P < 0.05$) in feed conversion over those fed the non-Bt silage (0.154 vs 0.146, respectively). With these results, the authors concluded that silage from Bt corn has no measureable detrimental nutritional qualities when compared to silage from a nearly isogenic non-transgenic hybrid.

To further examine the nutritional aspects of silage from corn containing the Bt gene, Folmer et al. (2002) fed 16 (12 intact, 4 ruminally fistulated) lactating dairy cows diets containing 40% corn silage and 28% corn grain from one of the four previously mentioned hybrids in a replicated 4 x 4 Latin Square. Milk production, milk protein, and milk fat percentage did not differ between Bt and non-Bt hybrids. Additionally, DMI was unaffected by presence of the transgene, leading to similar fat-corrected milk production (FCM/DMI, kg/kg) for cows fed diets containing Bt or non-Bt corn and corn silage. Results collected from the fistulated cows showed no differences in ruminal pH or acetate:propionate ratio, further leading the authors to conclude that the transgenic corn hybrids had no impact on lactational performance.

Calsamiglia et al. (2007) evaluated milk production and presence of transgenic DNA in milk in 8 lactating dairy cows fed diets containing 45% corn silage from a hybrid containing 2 transgenes encoding for insect resistance (*cry*1Ab protein) and herbicide tolerance. No differences in DMI, milk production, or fat-corrected milk production were observed. However, cows fed diets including the transgenic corn silage had slightly higher milk protein and lactose contents. In addition to similar lactational performance, no traces of the transgenic DNA were detected in milk from the cows fed the genetically modified corn silage.

Grazing Transgenic Corn Residue

A study conducted by Folmer et al. (2002) compared performance and grazing preference of growing steers grazing a corn residue pasture consisting of equal areas (2.8 ha) of a Bt hybrid and a genetically similar non-Bt hybrid. Presence or absence of the Bt trait had no effect ($P = 0.12$) on daily gain of steers. Due to low European corn borer pressure, there was much less residual corn than typically observed, resulting in much lower gains than expected. Daily observations were made on how many animals were grazing the Bt or non-Bt portion of the residue. Grazing distribution was not different ($P = 0.51$) between Bt and non-Bt residues, with 47.5% of steers observed grazing Bt corn residue and 52.5% of steers observed grazing non-Bt residues.

Vander Pol et al. (2005) performed a grazing trial in which growing steers grazed corn residue from a Bt hybrid or a near isogenic, non-transgenic parental hybrid.

Presence of the transgene did not influence final BW or ADG (P > 0.25) of steers grazing the residues. Samples of the residues were collected in the field, separated into leaf, husk, and stem fractions, and analyzed for IVDMD prior to and at the end of the grazing period. Results indicated no effect (P > 0.45) of the transgene when compared to the control hybrid.

Hendrix et al. (2000) evaluated grazing patterns and weight change of dry, pregnant cows grazing corn residue from Bt or non-Bt hybrids. Cows grazing fields with Bt corn residue did not differ (P > 0.10) in ending weight change from those grazing the non-transgenic residues (-2.29 vs -2.34/kg cow, respectively). In a separate experiment, cows were given access to adjoining fields of either Bt or non-Bt corn residue. Grazing pattern and preference were noted three times daily, with cows observed grazing the Bt field 46% of the time and the non-Bt field 54% of the time. Despite the slight difference of time spent grazing the non-Bt field, similar performance led the authors to conclude that grazing quality of corn residue is unaffected by the presence of the Bt gene.

Transgenic Corn in Swine and Poultry Diets

Hyun et al. (2005) conducted two studies on the growth performance and carcass characteristics of growing and finishing pigs fed diets containing YieldGard Rootworm Bt corn (MON 863). In each experiment, a 2 x 4 factorial arrangement included barrows and gilts and diets consisting of corn sourced from the transgenic test hybrid (MON 863), a non-transgenic genetically similar hybrid (RX670), or two conventional non-transgenic hybrids (DK647 and RX740). In both experiments, ADFI, ADG, and G:F were unaffected by corn hybrid. Carcass characteristics in Exp. 1 were not affected by corn hybrid, and slight differences in LM composition between hybrids in Exp. 2 were not attributed to corn source. In both studies, barrows performed better than gilts. These data led the authors to conclude that YieldGard Rootworm corn is nutritionally equivalent to non-transgenic corn in growing and finishing pig diets.

Similar results were observed by Stein et al. (2009) in a similar experiment. Growth performance and carcass characteristics of pigs fed corn hybrid DAS-59122-7 corn hybrid, which contains transgenes encoding for corn rootworm resistance and glufosinate tolerance, was compared to performance of pigs fed corn from a non-transgenic near isoline hybrid (control) and a commercially available non-transgenic hybrid (35P12). Performance from growing (37 to 60 kg), early finishing (60 to 90 kg), and late finishing (90 to 127 kg) phases were compared across hybrids, with no differences in ADFI, ADG, and G:F in any of the feeding period comparisons. Lack of differences in growth performance as well as similarities in dressing percentage, LM area, 10^{th} rib back fat, and carcass lean content suggest that the presence of both the rootworm resistant and herbicide tolerance did not affect nutritional quality of DAS-59122-7 when fed to growing-finishing pigs.

Transgenic corn containing the Bt-11 gene was fed to broiler chickens by Brake et al. (2003) with similar growth rates and feed conversion ratios to chickens fed diets containing non-transgenic isoline or commercially grown corn. Jacobs et al. (2008) observed no detrimental effects in egg production and egg quality in laying hens fed diets consisting of corn containing the *cry*34Ab1 and *cry*35Ab1 genes when compared to those hens fed the two non-transgenic control diets.

Research Objectives

There has been much research conducted to evaluate the feeding value of transgenic corn to livestock. The overwhelming conclusion is that the genetic modifications to the crop, whether for insect protection or herbicide tolerance, do not affect the growth, carcass, or lactational performance negatively. However, the technological advances in the genetic modification of the crops are continually evolving, so new genes and combinations of genes must be evaluated to ensure acceptance as a livestock feed.

The objectives of this research reported herein is to 1) compare performance and carcass characteristics of finishing steers fed corn and corn silage from MON 89034 to a non-transgenic parental hybrid and two non-transgenic reference hybrids, 2) compare performance of growing steers fed corn silage from MON 89034, a non-transgenic parental hybrid, and two non-transgenic reference hybrids, and 3) evaluate performance of steers grazing corn residue from MON 89034 and a non-transgenic parental hybrid. The hypothesis is that finishing, growing, and grazing performance will be unaffected by the presence of the gene encoding for production of Cry1A.105 and Cry2Ab2 proteins.

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REVIEW OF LITERATURE

Ethanol Co-Products

Growth of the ethanol industry in Nebraska has led to an increased supply of co-products such as distillers grains with solubles. As demand and therefore supply of corn grain for corn in ethanol production have risen, so too has acres planted to corn, resulting in more crop residues available for grazing or feeding. Increases in the quantity of low quality forages and distillers grains provide opportunities for producers to utilize these feedstuffs to lower costs or increase production.

Because the DM of wet distillers grains with solubles (WDGS) is low (30-35% DM), it is challenging to store in bunkers or silo bags. The addition of crop residues to WDGS adds bulk in the form of fiber and results in more manageable storage (Adams et al. 2008). Waterbury and Mark (2008) determined that seasonal prices of ethanol co-products are lowest during the summer months when fewer cattle are on feed. Stockpiling distillers grains at seasonally low prices can be advantageous to smaller producers, but storage can be a concern. Adams et al. (2008) summarized six experiments evaluating storage methods of ethanol byproducts blended with cornstalks or wheat straw in an attempt to find optimal use of low quality forages and WDGS. Successful storage levels of wheat straw with WDGS in silo bags ranged from 12.5% to 67% (DM) wheat straw. The authors also determined that cornstalks and wheat straw have similar storage characteristics in silo bags. Wilken et al. (2009) and Buckner et al. (2010) successfully used silo bags to store ethanol co-product and crop residue blends, while Warner et al. (2011) stored WDGS and ground cornstalk in bunkers with no detrimental effects.

Usage of Crop Residue

Crop residues fed to ruminants provide the potential to use essentially a left over product from the production of grains. Vetter and Boehlje (1978) concluded that grain producing plants normally produce a greater than or equivalent weight in vegetative material than as grain, leaving an abundant supply of available feed in areas where grain is grown. Because the plants have reached physiological maturity, the residual vegetation is low in digestibility and protein content (3.5 and 6.5% CP for wheat straw and cornstalks, respectively; NRC. 1996) and necessitates supplementation in many scenarios (Klopfenstein et al. 2008).

Typically, corn residues are grazed in the field where they stand, most commonly by cows. The problem with grazing, however, is that all of the feed is available immediately and is susceptible to deterioration due to trampling, and weather (Klopfenstein et al., 1987). Mechanized harvesting of corn residue adds cost, but allows for the residue to be used outside of the typical winter grazing season and into the corn growing season.

Wheat straw is typically baled after harvest and ground for use as an ingredient in diets. It is low in available protein and digestible energy (Saenger et al., 1983), but can be used to add bulk to other ingredients. In separate experiments, Coombe et al., (1979) and Lesoing et al., (1980) showed that chopped untreated wheat straw is of very little nutritional value to growing calves.

Supplementation of Cattle with Ethanol Co-Products

Supplementation of distillers grains with solubles (DGS) at levels of 15% or lower is a common method of providing additional protein (Klopfenstein et al. 2008). In systems where low quality forages such as winter range or corn residue are the primary feed source, protein is often the limiting factor. Protein deficiencies are especially greater for growing calves, as this period of skeletal and muscular growth requires more metabolizable protein.

In forage based diets, intake is limited by gut fill rather than a chemostatic response to energy. This is especially magnified in low quality forages with lower protein content and degradability. Microbial protein can be sufficient to meet the entire MP requirement of calves or cows at maintenance. With low quality forages, reduced passage rate associated with gut fill limited intake can reduce microbial efficiency. Because the bacterial crude protein is the major source of MP in low quality forages, a MP deficiency can exist, resulting in little or no gains in growing calves (Klopfenstein, 1996).

Protein in DGS is 65% ruminally undegradable, and if fed at supplemental levels (< 15%) in low quality forage based diets, will not meet DIP requirements of growing calves. However, the abundance of MP in UIP form can supply the DIP deficiency through the adaptation of MP into urea in the liver (Klopfenstein, 1996).

To examine the effects of the UIP fraction of DDG on DIP deficiencies, Stalker et al. (2007) fed heifers a forage based diet and supplemented them with DDG at 30% of diet DM. Diets were formulated to have DIP deficiencies greater than 100g/d, but with excess MP. As supplemental DIP was incrementally supplied in the treatments (0, 33, 67, 100, or 133% of DIP deficiency), intake, daily gain, and gain efficiency were unaffected ($P > 0.33$). Furthermore, no differences in allantoin to creatine ratios were noted ($P > 0.84$), indicating similar microbial crude protein production across dietary urea supplementation levels. Similarities between treatments imply that the excess MP provided by DDG negates the need for additional DIP in a forage based diet.

Further research on the effects of DDGS on DIP deficiencies was conducted by Jenkins et al. (2011). Individually fed heifers were fed diets containing 10% or 20% DDGS with or without supplemental urea. While all treatments had positive MP balances, those without supplemented urea were DIP deficient. Neither urea inclusion ($P > 0.40$) nor the urea x DDGS level interaction ($P > 0.38$) were significant, leading the authors to conclude that a 10% replacement of DDGS in a DRC finishing diet provided enough urea through MP recycling that DIP needs were met. In a second experiment, steers were fed diets containing 25% WDGS and 0.0%, 0.5%, or 1.0% urea (DM basis). All diets had positive MP balances, with a designed DIP deficiency for steers fed 0.0% urea. No differences in performance or carcass characteristics were observed, further proving the conclusions from the first experiment that the DIP deficiency was met through MP recycling.

MacDonald et al. (2007) demonstrated a positive response to UIP supplementation to heifers grazing smooth bromegrass pastures. Corn gluten meal was used as a source of UIP equivalent to UIP provided in DDGS and resulted in gains greater than heifers fed no additional UIP, but only 39% as great as those supplemented with DDGS. Corn oil was also supplemented in another treatment to provide an equal amount of EE to that contained in the DDGS treatment, with no difference in ADG (P = 0.25) from unsupplemented CON heifers. Due to greater ADG (P < 0.01) of heifers supplemented with DDGS and similar forage intakes between equal levels of UIP supplementation. (P = 0.63), the authors attributed 39% of the gain increase to meeting the MP deficiency and the remaining ADG increase for heifers supplemented DDGS to a positive associative effect of fat and UIP.

Supplementation of ethanol co-products in forage based diets not only provides additional CP and energy, it also improves the extent of forage digestion. Gilbery et al. (2006) evaluated the effects of corn condensed distillers solubles (CCDS) supplementation on intake and digestion site of steers consuming low quality grass hay. As CCDS supplementation levels increased, CP intake and total tract CP digestibility increased along with microbial CP synthesis (P ≤ 0.06). Organic matter (P = 0.003), NDF (P = 0.008), and ADF (P = 0.02) digestion in the rumen all improved, while intestinal and total tract digestion were unaffected (P > 0.37). However, microbial efficiency was not affected (P = 0.43), indicating that the increase in available ruminal CP resulted in more microbial synthesis and improved nutrient availability.

Data from Gilbery et al. (2006) agree with results observed by Summer and Trenkle (1998) in an experiment intended to determine the digestibility of low or high quality forage when corn or corn co-products were supplemented. Dry rolled corn, corn gluten feed (CGF), or dry distillers grains were supplemented to basal diets of either ground corn stover or ground alfalfa. The addition of CGF or DDG to corn stover based diets improved NDFD and DMD (P < 0.05) when compared to no supplement or DRC diets. However, DRC added to alfalfa based diets resulted in greater DMD than CGF or

DDG supplements. Positive associative effects observed when corn co-products were supplemented in low quality forage diets were attributed to the greater CP content of CGF or DDG, whereas DRC supplied more digestible energy when CP was not limited by forage quality, inferring that BCP was the limiting factor in DRC diets.

Loy et al. (2008) conducted a similar study to determine the feeding value of dry distillers grains relative to dry rolled corn in a grass hay based diet. When dry rolled corn and dry rolled corn:corn gluten meal supplements were compared to dried distillers grains at two different levels (0.21% and 0.81% BW), the authors observed improved performance with increased supplementation rates. The data indicated dried distillers grains have 118% to 130% of the feeding value of corn in a high forage diet.

Grazed Forage Replacement with Distillers Grains

In addition to improving ADG, supplementation of distillers grains in grazing systems to reduces forage intake and thereby increases stocking rate. Greenquist et al. (2009) observed gains of 0.92 kg/d for steers receiving a DDGS supplement at 0.5% of BW daily while grazing smooth bromegrass, compared to 0.67 kg/d for steers not receiving the supplement. The experiment was designed to maintain equivalent grazing pressure across treatments so that animal productivity per hectare could be observed. The resulting improvement in steer performance coupled with a denser stocking rate led to a 105% increase ($P < 0.01$) in BW gain per hectare for supplemented steers compared to the non-supplemented treatment.

In another study designed to determine the effects of DDGS supplementation on ADG and grazed forage replacement, Gustad et al. (2006) fed DDGS to calves grazing corn residue. As supplements of DDGS increased from .29% to 1.27% of BW, ADG of steers increased ($P < 0.01$) from 0.9 lb/d to 1.8 lb/d, with the authors suggesting optimal supplementation at 1.1% of BW. A control group of steers was fed hay as a measureable proxy substitute to the grazed residue and supplemented DDGS at amounts corresponding to those grazing cornstalks. A linear decrease ($P < 0.01$) in forage intake was observed as supplementation increased, resulting in a 27% reduction in forage intake for steers supplemented at 1.27% of BW compared to the hay only control group. Using these data, the authors theorized that stocking rates could be increased by 27% when following this DDGS supplementation protocol.

Nuttelman et al. (2008) conducted an experiment to determine if forage DMI could be replaced with a blend of WDGS and low quality forage. A mixture of 67% WDGS and 33% ground wheat straw was stored in silo bags and supplemented to individually fed growing steers along with a blend of sorghum silage and alfalfa hay. Steers offered the mixture had lower DMI ($P = 0.05$) compared to steers supplemented with only WDGS or DDGS and did not affect F:G ($P = 0.32$). The decrease in DMI in steers supplemented the mixture resulted in 0.9 lb of forage replaced for every lb of mixture offered, suggesting that the wheat straw supplied enough rumen fill to limit forage intake, and leading the authors to conclude that feeding stored blends of wheat straw and WDGS are palatable and can effectively reduce grazed forage intake.

Storage Methods of Distillers Grains

The feeding value of stored vs. fresh wet distillers grains was evaluated by Abrams et al. (1983) in four separate experiments. Growing lambs and finishing steers were fed diets containing wet distillers grains ensiled with ground corn cobs or the same ratio of ingredients mixed fresh daily. Lab analysis showed a tendency for increased soluble N in ensiled WDG compared to fresh samples. While results of the lamb and steer trials conflicted due to differences in diet composition and rumen degradable protein, the data showed neither an advantage nor a detriment to feeding ensiled WDG.

A similar experiment was performed by Muntifering et al. (1985) in which wet corn stillage mixed with tall fescue hay was fed to growing lambs. Diets mixed fresh daily were more digestible ($P < 0.05$) and retained more dietary N ($P < 0.05$) than ensiled blends of co-product and hay.

Wilken et al. (2009a) performed an experiment in which growing steers were fed either ensiled or freshly mixed diets containing a 30:70 (DM basis) ratio of WDGS and ground cornstalks. Steers fed the ensiled mixture consumed significantly more (14.1 vs. 12.2 lb/d) and gained more (1.43 vs. 1.02 lb/d) than steers fed the diet mixed fresh daily ($P < 0.01$) and tended to be more efficient (9.83 vs. 11.95 F:G) than those offered the non-ensiled diet.

The improved performance of steers fed ensiled diets in the Wilken experiment was not observed by Peterson et al. (2009). Steers offered ensiled WDGS and wheat straw diets were paired by BW with steers offered freshly mixed diets with the purpose of limiting intake to that of the steer fed the non-ensiled diets. While the steers fed non-ensiled rations tended to gain more ($P = 0.08$) and be more efficient ($P = 0.09$), the comparable performance between storage methods conflicts with previously presented data.

Because steers fed the ensiled mixtures had greater DMI, it was not clear whether the increase in ADG and efficiency were due to greater intake or a nutritional advantage of the ensiled blends. Buckner et al. (2010) performed a follow up study to compare ensiled WDGS and wheat straw diets to those mixed fresh daily. Steers consuming the freshly mixed diets were matched by similar BW to steers fed the ensiled diets and were limited to equivalent DMI throughout the study. Steers consuming the ensiled diets gained more ($P = 0.02$) and were more efficient ($P < 0.01$) than those fed freshly mixed diets, suggesting that the ensiling process improved the rate or extent of the fiber in the wheat straw.

Moisture of Diets

Worley et al., (1986) fed corn silage harvested at two different dry matters (31% and 44%) and conducted one lamb and three calf trials to analyze animal performance and diet digestibility. Though lambs offered silage with 44% DM consumed more when offered the feed ad libitum, the authors observed no changes in apparent digestibility or animal performance relative to the dry matter content of the diet.

Wilken et al., (2009b) conducted an experiment to analyze the effects of wet or dry forage fed with either dry or modified distillers grains plus solubles to growing calves. No differences in growth performance were observed between steers fed diets containing dry or modified distillers grains, which agree with data reported by Nuttelman et al. (2008). However, steers fed diets containing wet forage (corn silage) gained more and were more efficient than steers offered the dry forage (oat hay and oat straw blend).

Research Objectives

There has been research conducted on many facets of ethanol co-product supplementation, storage method, moisture level, and crop residue usage, but the challenge of matching market advantages with specific production scenarios remains fluid depending on individual operations. The research reported herein was conducted the University of Nebraska-Lincoln. The objectives of these experiments were to 1) evaluate storage method, moisture level, and forage type in crop residue and MDGS diets on growing steer performance; and 2) evaluate growing steer performance and replacement of forage with supplement blends of crop residue and MDGS.

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Effects of feeding corn grain and corn silage or grazing residues from a second generation insect protected hybrid (MON 89034) compared to parental and reference hybrids on animal performance and carcass characteristics[1]

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ABSTRACT: One grazing and two feeding experiments were conducted to compare the feeding value of corn grain, corn silage, or corn residue from a second generation insect protected (Bt) hybrid (MON 89034) developed by Monsanto including two proteins (Cry1A.105 and Cry2Ab2) with a non-transgenic parental hybrid (PAR), and two commercially available non-transgenic reference hybrids (REF1 and REF2). Diets for all three experiments were formulated to meet NRC (1996) protein requirements. In Exp. 1, two hundred forty crossbred steer calves (290 ± 14 kg) were fed a dry rolled corn and corn silage based (65 and 15% of diet DM, respectively) finishing diet in 24 pens, with six pens per corn hybrid. Dry matter intake ($P = 0.48$) and ADG ($P = 0.90$) were similar between MON 89034, CON, REF1, and REF2 treatments. Steers fed diets containing corn and corn silage from REF1 were more efficient ($P = 0.05$) than steers fed REF2 and PAR treatments. Carcass characteristics (HCW, marbling score, 12^{th} rib fat thickness, LM area, calculated USDA yield grade, and percent graded choice) did not differ ($P > 0.36$) with regards to diets from transgenic, parental, or reference hybrids. In Exp. 2, two hundred forty crossbred steer calves (279 ± 20 kg) were fed a corn silage based (80% of diet DM) growing diet in 20 pens with five pens per corn hybrid. Ending BW, DMI, ADG, and G:F were not different ($P > 0.32$) based on corn silage source. In Exp. 3, two 12.4 ha fields containing corn residue from either MON 89034 or a near isogenic, non-transgenic parental hybrid (PAR) were divided into four equal sized paddocks. Sixty-four crossbred steer calves (249 ± 8 kg) were stratified by BW and assigned randomly to one of the eight paddocks. Protein supplement was fed at 1.14 kg/d to ensure protein intake did not limit performance. Ending BW and ADG were similar for steers grazing each hybrid ($P > 0.20$). Based on these results, incorporation of insect resistant genes had

no significant effect on the nutritive value of MON 89034 as compared to non-transgenic counterparts.

Key Words: Cattle, Corn Residue, Corn Silage, Finishing, Transgenic Corn

INTRODUCTION

Usage of insect protected corn hybrids, commonly called Bt corn, reached 73% of all acres planted in 2010 (USDA, 2010). With a large portion going to the beef industry in the form of grain, silage, or crop residue, it is important to determine the nutritive value of insect protected hybrids compared to conventional, non-transgenic hybrids. Insertion of DNA from *Bacillus thuringiensis,* a common soil bacterium, encodes for the production of crystalline proteins toxic to lepidopteran insects, several species of which damage corn plants and reduce yield (Wright et al., 1999). Inclusion of Cry1A.105 and Cry2Ab2 proteins, both of which are exclusive to MON 89034 provide protection against *Ostrinia* species such as European and Asian corn borer and *Diatraea* species like southwestern corn borer (GM Crop Database, 2011).

Previous research by Sindt et al. (2007) observed similar performance in feedlot cattle fed conventional corn varieties and transgenic corn incorporating the Cry1F protein, while Vander Pol et al. (2005) found similar results in performance of finishing steers and steers grazing transgenic corn residue. While Cry1A.105 and Cry2Ab2 proteins provide insect protection similar to Cry1F, their inclusion in MON 89034 needs to be examined to determine nutritional equivalency relative to non-transgenic feeds.

The objectives of these experiments were to 1) compare performance and carcass characteristics of finishing steers fed corn and corn silage from MON 89034 to a non-transgenic parental hybrid and two non-transgenic reference hybrids, 2) compare performance of growing steers fed corn silage from MON 89034, a non-transgenic parental hybrid, and two non-transgenic reference hybrids, and 3) evaluate performance of steers grazing corn residue from MON 89034 and a non-transgenic parental hybrid. The hypothesis is finishing, growing, and grazing performance will be unaffected by the presence of the gene encoding for production of Cry1A.105 and Cry2Ab2 proteins.

MATERIALS AND METHODS

Steers used in these experiments were managed according to guidelines approved by the University of Nebraska Institute for Animal Care and Use Committee.

All corn was grown at the University of Nebraska Agricultural Research and Development Center (ARDC) near Mead, NE under identity preserved methods. All hybrids were cut for silage at similar moisture levels (34.2% DM ± 2.1%) and stored in silo bags by hybrid. Corn grain was stored in bins by hybrid prior to dry rolling, delivered as needed, rolled, and stored in separate commodity bays. Samples of all hybrids were collected and tested for the presence or absence of the genetically modified proteins.

Prior to initiation of the study, samples of corn and corn silage were collected and sent to a commercial laboratory (Romer Labs, Union, MO) to test for the presence of mycotoxins. Small amounts of Zearalenone were detected in MON 89034 (297 ppb) and PAR (304 ppb) corn silage. Deoxynivalenol (Vomitoxin) was found in MON 89034 (0.6 ppm) and PAR (0.3 ppm) corn silage, as well as whole corn samples from all hybrids (1.1 to 1.9 ppm). Whole corn from REF1 tested positive for Zearalenone (644 ppb), Fumonisin B1 (1.1 ppm) and Fumonisin B2 (0.2 ppm). The maximum allowable levels of these mycotoxins are: Zearalenone at 0.5 ppm, Deoxynivalenol at 10 ppm, and Fumonisin at 50 ppm. In all samples, the detected levels of mycotoxins were well below the level of concern (Current Guidelines for Mycotoxins, 2011).

Experiment 1

Animals. Two hundred forty crossbred steer calves (initial BW = 290 ± 14 kg) were used in a RCBD design to evaluate the effect of second generation insect protected corn grain and corn silage (MON 89034) on performance and carcass characteristics of finishing cattle. Steers were received at the University of Nebraska Agricultural Development and Research Center (near Mead, NE) during the fall of 2009. Steers were weighed, processed, and weaned on smooth bromegrass pasture. Initial processing protocol included vaccination with a modified live virus vaccine for protection against IBR, BVD Types I & II, PI3, and BRSV (Bovishield Gold 5; Pfizer Animal Health, New York, NY) and prevention of *Haemophilus somnus* (Somubac; Pfizer Animal Health), injection with a paraciticide (Dectomax; Pfizer Animal Health), and an antimicrobial (Micotil; Elanco Animal Health, Greenfield, IN). Prior to initiation of the experiment, steers were limit-fed (5.8 kg/steer daily at 2% of BW; DM basis) a 50% wet corn gluten feed:50% alfalfa hay (DM basis) diet for 5 d in pens to minimize the effect of gastrointestinal fill on initial BW (Stock et al., 1983). Steers were weighed two consecutive days in the morning before feeding to reduce BW variation due to gastrointestinal fill. Steers were stratified by BW, blocked (one heavy block with one replication and one light block with five replications), stratified within block based on d 0 BW, and assigned randomly to one of 24 pens (four treatments, six replications per treatment, 10 steers per pen). Pen dimensions were 41.5 m long x 15.2 m wide and consisted of clay-based soil with a 2% slope from front to back, with cement aprons around bunks and waterers. Each pen provided 63.2 m^2 per steer and was equipped with a 7.3 m fence line feed bunk, which provided 73.2 cm of bunk per steer.

Steers were implanted with Revalor-IS (Merck Animal Health, Desoto, KS) on d 1 and re-implanted with Revalor-S (Merck Animal Health) on d 84. All steers were slaughtered on d 175 based on BW and visual appraisal. Steers were harvested at a commercial abattoir (Greater Omaha, Omaha, NE) where HCW was recorded on the day of slaughter. After a 48-h chill, USDA marbling score was called by a USDA grader and 12^{th} rib fat thickness and LM area were measured. Calculated USDA Yield Grade was derived from HCW, 12^{th} rib fat thickness, KPH, and LM area using the equation determined by Boggs and Merkel (1993). Hot carcass weights were used to calculate adjusted final BW, ADG, and G:F using a common dressing percent of 63.

Treatments. Treatments consisted of corn grain and corn silage from four hybrids, second generation insect protected corn MON 89034 (MON), near isogenic, non-transgenic parental hybrid DKC 63-78 (PAR), reference hybrid DKC 61-42 (REF1), and reference hybrid DKC 62-30 (REF2). Prior to trial initiation, each hybrid was assigned a letter, and treatments were blinded to feedlot personnel.

All diets were formulated to meet or exceed NRC (1996, Level 1) requirements for DIP, Ca, P, and K. Steers were adjusted to the final diet over 21 days, with corn replacing ground alfalfa hay. Adaptation to the high-concentrate diet consisted of alfalfa hay levels decreasing from 37.5%, 27.5%, 17.5%, and 7.5% for 3, 4, 7, and 7 d, respectively. Diets were formulated to contain 300 mg/steer/d monensin (Elanco Animal Health) and 90 mg/steer/d tylosin (Elanco Animal Health). Ingredient and diet samples were collected weekly, composited by month, and analyzed for nutrient composition at a commercial laboratory (Dairy One, Ithaca, NY). Samples were analyzed for CP (Leco FP-528 Nitrogen/Protein Analyzer), crude fat (Ether Extraction), starch (YSI 2700 SELECT Biochemistry Analyzer), NDF (ANKOM Technology Method 6), and Ca, P, and K (Thermo IRIS Advantage HX). The supplement was formulated based on the lowest CP value from the four hybrids, so overfeeding of protein ensured differences would be due to energy or transgene presence and not other nutrients. Final diet compositions are in Table 1.

Experiment 2

Animals. Two hundred forty crossbred steer calves (initial BW = 279 ± 20 kg) were used in a randomized block design to evaluate the effect of feeding corn silage from a second-generation insect protected (Bt) corn hybrid (MON 89034) on growing steers. Steers were received at the ARDC during the fall of 2009. Steers were weighed, processed, and weaned on smooth bromegrass pasture for 30 d. Initial processing protocol included vaccination with a modified live virus vaccine for protection against IBR, BVD Types I & II, PI3, and BRSV (Bovishield Gold 5; Pfizer Animal Health) and prevention of *Haemophilus somnus* (Somubac; Pfizer Animal Health), injection with a paraciticide (Dectomax; Pfizer Animal Health), and an antimicrobial (Micotil; Elanco Animal Health). After receiving, steers grazed corn residues and were supplemented with wet corn gluten feed (Sweet Bran, Cargill) for 90 d. In February 2010, steers were limit-fed (5.6 kg/steer daily at 2% of BW; DM basis) a 50% wet corn gluten feed:50% alfalfa hay (DM basis) diet for 5 d in pens to minimize gastrointestinal fill on initial BW. Steers were weighed two consecutive days in the morning before feeding to obtain an accurate initial BW. Steers were stratified by BW, assigned to block (one heavy block with one replication and one light block with four replications), stratified within block based on d 0 BW and randomly assigned to one of 20 pens (four treatments, five replications per treatment, 12 steers per pen). Pen dimensions were 49.9 m long x 14.5 m wide and consisted of clay-based soil with a 2% slope from front to back. Each pen provided 60.3 m^2 per steer and was equipped with a 9.1 m fence line feed bunk, which provided 76.1 cm of bunk/steer.

Treatments. Treatments consisted of silage from four corn hybrids; second generation insect protected corn (MON 89034), near isogenic non-transgenic parental hybrid DKC 63-78 (PAR), reference hybrid DKC 61-42 (REF1), and reference hybrid DKC 62-30 (REF2). Prior to trial initiation, each hybrid was assigned a letter, and treatments were blinded to feedlot personnel.

All diets were formulated to meet or exceed requirements outlined by the NRC (1996, Level 1) for DIP, Ca, P, and K. Final diet composition is presented in Table 2. All diets contained monensin (200 mg/steer daily; Elanco Animal Health). Ingredients and diets were sampled weekly, composited by month, and sent to a commercial laboratory (Dairy One, Ithaca, NY) for nutrient analysis. Samples were analyzed for CP (Leco FP-528 Nitrogen/Protein Analyzer), crude fat (Ether Extraction), starch (YSI 2700 SELECT Biochemistry Analyzer), NDF (ANKOM Technology Method 6), and Ca, P, and K (Thermo IRIS Advantage HX). Silage was tested for pH, VFA, and organic acid concentration. The common supplement was formulated based on the lowest CP value from the 4 hybrids, so overfeeding of protein ensured differences would be due to energy and not other nutrients.

Experiment 3

Animals. Sixty-four crossbred steer calves (initial BW = 249 ± 8 kg) were used in a CRD to evaluate the effects of grazing corn residue from a second generation insect protected hybrid (MON 89034) or a near isogenic non-transgenic parental hybrid. Steers were received at the ARDC during the fall of 2009. Steers were weighed, processed, and weaned on smooth bromegrass pasture. Initial processing protocol included vaccination with a modified live virus vaccine for protection against IBR, BVD Types I & II, PI3, and BRSV (Bovishield Gold 5; Pfizer Animal Health) and prevention of *Haemophilus somnus* (Somubac; Pfizer Animal Health), injection with a paraciticide (Dectomax; Pfizer Animal Health), and an antimicrobial (Micotil; Elanco Animal Health). In early November, steers were held in pens and limit-fed (5.0 kg/steer daily at 2% of BW; DM basis) a 50% wet corn gluten feed, 50% alfalfa hay (DM basis) diet for 5 d in pens to minimize gastrointestinal fill effect on initial BW. Steers were weighed two consecutive days in the morning before feeding to obtain an accurate initial BW. Due to adverse weather conditions, the trial concluded on d 40 in late December when heavy snowfall and blizzard conditions prevented steers from grazing the corn residue. At this time, steers were again held in pens and limit-fed the 50% wet corn gluten feed:50% alfalfa hay diet at 2% of BW (DM basis) for 5 d. After the limit-feeding period, steers were weighed individually on two consecutive days to determine final BW. Steers were supplemented with 1.14 kg/d (DM basis) of a protein supplement (supplement contained: 93.8% DDGS, 4.7% limestone, 0.8% tallow, 0.1% monensin-80, 0.3% trace minerals, 0.2% selenium, and 0.1% vitamin A-D-E) formulated to meet metabolizable protein (MP) and degradable intake protein (DIP) requirements (NRC, 1996; Level 1), to ensure protein intake did not limit performance.

Treatments. Steers were assigned randomly to treatment by stratification of d 0 BW and assigned to one of eight 3.1 ha paddocks within two 12.4 ha fields (eight steers per paddock; 32 steers per field). Fields contained corn residues from either the second generation insect protected hybrid MON 89034 (MON) or the near isogenic non-transgenic parental hybrid DKC 63-78 (PAR). Steers were stocked at a rate of 0.39 ha/steer. Paddock was the experimental unit.

Residual corn from each paddock was estimated by sampling three random 91.44 x .76 m strips in each paddock. Whole and partial ears were collected and shelled. Shelled corn was dried in a 60˚ C oven to determine DM/ha of residual corn grain.

Data were analyzed using the MIXED procedures of SAS (SAS Institute, Cary, NC). Exp. 1 and Exp. 2 were analyzed as randomized block designs, with block treated as a fixed effect and pen as the experimental unit. In each of these experiments, least square means are not presented due to adjustment for unequal replication within blocks. Arithmetic means are presented by treatment. Exp. 3 was analyzed as a completely randomized design with paddock as the experimental unit. In all experiments, an alpha level of 0.05 was assumed for significance.

RESULTS AND DISCUSSION

Experiment 1

Diets averaged 13.1% CP and 5.6% crude fat, with REF1 diets lowest in both categories at 12.3% and 5.1%, respectively. REF1 diets contained 58.0% starch, which was higher than the average of 55.0% across all treatments (Table 1). Diets had very similar values for NDF, Ca, P, and K regardless of corn source. Dry rolled corn varied in CP from 7.9% to 9.4% and in crude fat from 3.8% to 5.9%, with corn from REF1 hybrid lowest in both categories (Table 3). Average starch percentages in dry rolled corn from each hybrid ranged from 68.0% for PAR to 70.7% for REF1. These similar compositional values agree with a study done by Jung and Sheaffer (2004), who noted no significant differences in the CP content or starch content of six separate Bt hybrids grown at four locations alongside their near-isoline parental hybrids lacking a transgene.

Two steers died (bloat, pneumonia) and one steer was removed (footrot) from the trial due to non-treatment related issues. Initial BW (290 kg) differed by 1.3 kg between treatments but was found to be statistically different ($P = 0.02$), therefore was used as a covariate in the analysis. Results are shown in Table 4. Final BW ($P = 0.91$) was not impacted by corn source, nor was DMI ($P = 0.48$). Average daily gains were not affected by treatment ($P = 0.90$). However, steers fed diets from the REF1 treatment were more efficient ($P = 0.05$) than steers fed corn sourced from REF2 and PAR hybrids. This difference in G:F can be attributed to the higher starch and lower NDF composition of the REF1 diets relative to other treatments and is not related to the presence or absence of the transgenes. These observations are similar to previous research by Sindt et al. (2007), and Huls et al. (2008), in which feedlot cattle fed diets containing corn from insect protected transgenic hybrids performed similarly to their experimental counterparts fed diets containing non-transgenic corn. In a similarly conducted experiment, Vander Pol et al. (2005) reported similar ADG and DMI, with slightly better gain efficiency in steers fed diets containing insect protected corn. Equivalent DMI, ADG, and G:F responses to insect protected transgenic corn have also been found in swine (Stein et al., 2009; Hyun et al., 2005), and poultry (Jacobs et al., 2008; Brake et al., 2003). Donkin et al. (2003) and Folmer et al. (2002) used lactating Holstein cows to evaluate the DMI, milk production, and milk composition of animals fed corn grain and corn silage from Bt hybrids when compared to non-transgenic control treatments and concluded that no differences exist.

As with feedlot performance, carcass characteristics were similar across treatments (Table 3). Hot carcass weights varied by only 2.1 kg and were not different ($P = 0.90$.) Marbling score ($P = 0.36$) and 12th rib fat thickness ($P = 0.55$) were also similar, suggesting that cattle were finished to comparable endpoints regardless of corn source in the diet. No differences were observed in LM area ($P = 0.87$). Due to like amounts of fat deposition and thickness, combined with similar LM area, calculated USDA YG was not different ($P = 0.72$) based on treatments. The lack of differences in carcass characteristics of feedlot cattle fed corn grain from an insect protected hybrid are in agreement with observations reported by Vander Pol et al. (2005) and Huls et al. (2008), as well as results noted by Erickson et al. (2003) in an experiment evaluating transgenic glyphosate-tolerant corn grain. Likewise, carcass composition in swine (Hyun et al., 2005) and broilers (Taylor et al., 2005) showed no difference when fed diets including insect protected corn in comparison to genetically similar non-transgenic corn based diets

Experiment 2

Diets ranged from 12.6% to 13.4% CP and averaged 0.61% Ca, 0.29% P, and 0.82% K (Table 2). Corn silages varied from 34.1% to 35.9% DM, 7.9% to 8.2% CP, and 40.1% to 41.5% NDF, with similar Ca, P, and K values across all hybrids (Table 3). Slight differences in DM are attributed to weather delays in harvesting the silage. These similarities in nutritional composition are supported by Jung and Sheaffer (2004). In their study, lignin concentration was not different when comparing all Bt/non-Bt pairs, and NDF digestibility differed significantly in only one of the pairs.

Steers weighed 279 kg at the beginning of this trial, with a range of 1.7 kg between treatments. Initial BW was significantly different (P = 0.01), so it was used as a covariate in the final statistical analysis. Results are listed in Table 5. Ending BW varied from 418 to 421 kg and was not different (P = 0.78) for steers fed MON 89034. Dry matter intakes were numerically less for MON 89034, but not statistically different (P = 0.40), which agrees with previous research performed by Folmer et al. (2002), Faust et al. (2007) and Donkin et al. (2003) using lactating dairy cows fed diets containing corn silage from transgenic hybrids and genetically similar non-transgenic control hybrids. Gain was not affected by treatment (P = 0.71), as well as G:F (P = 0.32), although steers fed MON 89034 were numerically more efficient. The lack of differences in gain and efficiency are in agreement with Folmer et al. (2002) who, in a study related to the lactating dairy cow experiment, evaluated the performance of the same Bt corn silage fed to growing beef steers and observed no differences in average daily gain or gain efficiency when comparing the same hybrids, but did find a 3.5% greater intake for steers fed diets containing Bt silage.

Experiment 3

There were no differences in initial BW (P = 0.07) or ending BW (P = 0.89) between treatments. Average daily gains were impacted by adverse weather conditions and snow cover, but were not different (P = 0.20), with steers grazing MON 89034 residue gaining 0.24 kg compared to 0.18 kg for steers assigned to PAR residue.

Residual corn estimates were 113.2 kg/ha in paddocks containing MON 89034 residue, and 115.9 kg/ha in paddocks with PAR residue.

Research by Jordon et al. (1997) positively correlates (r = 0.79) ADG in corn residue grazing systems to residual corn. Therefore, the nearly identical observations of residual corn between the test and control residues in our study support the similar ADG and ending BW we observed. Similarly constructed experiments were conducted by Vander Pol et al. (2005) and Folmer et al. (2002) compared performance of steers grazing Bt vs. non-Bt corn residues and found no differences in average daily gain. While steers in this experiment were assigned to a specific treatment, it should be noted that when Folmer et al. (2002) allowed steers to graze freely between Bt and non-Bt residues, no preference in grazing distribution was observed. It should also be noted that the study had to be terminated early (40d) due to exceptional snow and ice cover, but likely had no impact on the results between the two treatments.

Similarities in growing performance can be explained by data observed by Weidemann et al. (2006) in which ruminal degradation of the transgenic Cry1Ab protein and the rubisco gene was compared with both whole plant and chopped ensiled samples. After 8 h of rumen incubation, neither the transgene nor rubisco were able to be amplified in the ensiled samples by PCR to quantifiable amounts, leading the authors to conclude that microbial digestion did not differ between Bt corn silage when compared to an isogenic counterpart. When the same whole plant and ensiled samples were tested prior to ruminal digestion, the authors observed Cry1Ab protein levels in ensiled samples at only 10% of levels found in whole plant samples, which they attributed to low pH and microbial activity.

These data suggest that inclusion of the Bt trait and presence of Cry1A.105 and Cry2Ab2 proteins in MON 89034 had no effect on growth performance or carcass characteristics of cattle fed corn silage, grain, or residue. Based on these results, the second generation insect protected hybrid is nutritionally equivalent to conventional, non-transgenic corn hybrids and should be treated as such with regards to cattle diets.

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Table 1. Diet and nutrient composition of diets fed to finishing steers in Exp. 1 (%DM).

	Treatments[1]			
Item	MON	PAR	REF1	REF2
Corn X	65.0			
Corn Y		65.0		
Corn Z			65.0	
Corn W				65.0
Corn Silage X	15.0			
Corn Silage Y		15.0		
Corn Silage Z			15.0	
Corn Silage W				15.0
WDGS	15.0	15.0	15.0	15.0
Supplement[2]				
Fine Ground Milo	2.3005	2.3005	2.3005	2.3005
Limestone	1.6810	1.6810	1.6810	1.6810
Salt	0.3	0.3	0.3	0.3
Urea	0.4	0.4	0.4	0.4
Potassium Chloride	0.099	0.099	0.099	0.099
Tallow	0.125	0.125	0.125	0.125
Trace Mineral[3]	0.05	0.05	0.05	0.05
Vitamin A-D-E[4]	0.015	0.015	0.015	0.015
Rumensin-80[5]	0.01875	0.01875	0.01875	0.01875
Tylan-40[6]	0.010701	0.010701	0.010701	0.010701
Nutrient Composition[7], % of diet DM				
CP	13.5 (0.6)	13.1 (0.9)	12.3 (0.6)	13.6 (0.5)
Crude Fat	5.9 (0.4)	5.8 (0.4)	5.1 (0.4)	5.4 (0.3)
Starch	54.3 (4.0)	54.4 (3.9)	58.0 (3.0)	53.3 (3.2)
NDF	15.5 (1.4)	16.6 (3.9)	14.9 (1.6)	16.5 (1.5)
Ca	0.58 (0.15)	0.64 (0.16)	0.56 (0.86)	0.62 (0.09)
P	0.35 (0.02)	0.36 (0.02)	0.36 (0.01)	0.32 (0.01)
K	0.53 (0.03)	0.56 (0.04)	0.55 (0.03)	0.58 (0.04)

[1]REF1 = reference hybrid DKC 61-42, REF2 = reference hybrid DKC 62-30, PAR = non-transgenic parental hybrid, MON = corn rootworm resistant hybrid MON 89034.
[2]Supplement formulated to be at 5% of diet DM.
[3]Premix contained (g/kg of premix): 130 Ca, 1 Co, 15 Cu, 100 Fe, 2 I, 80 Mn, and 120 Zn.
[4]Premix contained (per kg of premix): 30,000 kIU of vitamin A, 6,000 kIU of vitamin D, and 7 kIU of vitamin E.
[5]Premix contained 176 g/kg monensin.
[6]Premix contained 88 g/kg tylosin.
[7]All samples analyzed at Dairy One, Ithaca, NY. Values in ( ) are standard deviations.

Table 2. Diet and nutrient composition of diets fed to growing steers in Exp. 2 (%DM)

	Treatment[1]			
Ingredient	MON	PAR	REF1	REF2
Corn Silage X	80.0			
Corn Silage Y		80.0		
Corn Silage Z			80.0	
Corn Silage W				80.0
WDGS	15.0	15.0	15.0	15.0
Supplement[2]				
Fine Ground Milo	3.0061	3.0061	3.0061	3.0061
Limestone	0.916	0.916	0.916	0.916
Salt	0.3	0.3	0.3	0.3
Urea	0.574	0.574	0.574	0.574
Tallow	0.125	0.125	0.125	0.125
Trace Mineral[3]	0.05	0.05	0.05	0.05
Vitamin A-D-E[4]	0.015	0.015	0.015	0.015
Rumensin-80[5]	0.0139	0.0139	0.0139	0.0139
Nutrient Composition[6], % of diet DM				
CP	13.3 (0.7)	12.6 (0.4)	12.7 (0.3)	13.4 (0.7)
Crude Fat	5.9 (0.8)	5.9 (0.7)	5.0 (0.4)	5.2 (0.5)
Starch	30.1 (1.4)	32.8 (1.9)	32.5 (2.8)	30.4 (1.5)
NDF	39.4 (4.1)	35.7 (2.4)	33.0 (1.3)	36.3 (2.0)
Ca	0.67 (0.23)	0.53 (0.08)	0.54 (0.03)	0.70 (0.06)
P	0.28 (0.01)	0.27 (0.01)	0.27 (0.02)	0.36 (0.01)
K	0.78 (0.04)	0.78 (0.06)	0.89 (0.07)	0.82 (0.05)

[1]REF1 = reference hybrid DKC 61-42, REF2 = reference hybrid DKC 62-30, PAR = non-transgenic parental hybrid, MON = corn silage containing Cry1A.105 and Cry2Ab2 proteins (MON 89034).

[2]Supplement formulated to be at 5% of diet DM.

[3]Premix contained (g/kg of premix): 130 Ca, 1 Co, 15 Cu, 100 Fe, 2 I, 80 Mn, and 120 Zn.

[4]Premix contained (per kg of premix): 30,000 kIU of vitamin A, 6,000 kIU of vitamin D, and 7 kIU of vitamin E.

[5]Premix contained 176 g monensin/kg. Formulated to provide 200 mg/head/d.

[6]All samples analyzed at Dairy One, Ithaca, NY. Values in ( ) are standard deviations.

Table 3. Nutrient composition of corn and corn silage composited monthly in Exp. 1 and Exp. 2 (%DM).

	Treatments[1]			
Item	**MON**	**PAR**	**REF1**	**REF2**
Dry Rolled Corn[2], % of ingredient DM				
DM	87.7 (0.7)	86,0 (1.1)	89.3 (0.5)	89.3 (0.4)
CP	9.2 (0.2)	9.1 (0.2)	7.9 (0.6)	9.1 (0.2)
Crude Fat	5.3 (2.0)	5.8 (0.4)	5.9 (2.2)	3.8 (0.6)
Starch	69.1 (2.5)	68.3 (3.6)	70.9 (4.6)	71.0 (3.7)
NDF	10.2 (2.2)	10.3 (2.2)	9.9 (2.5)	9.1 (1.2)
Ca	0.02 (0.024)	0.01 (0.004)	0.02 (0.012)	0.01 (0.004)
P	0.32 (0.117)	0.34 (0.119)	0.25 (0.032)	0.28 (0.016)
K	0.33 (0.010)	0.36 (0.010)	0.33 (0.040)	0.32 (0.020)
Silage[2], % of ingredient DM				
DM	34.2 (1.2)	35.2 (1.1)	34.4 (1.5)	33.9 (1.4)
CP	8.2 (0.4)	8.1 (0.5)	8.0 (0.2)	8.3 (0.3)
Crude Fat	4.0 (0.3)	3.9 (0.3)	3.8 (0.6)	3.4 (0.1)
Starch	34.2 (2.5)	37.4 (3.8)	35.5 (1.9)	34.4 (3.3)
NDF	40.5 (1.7)	40.0 (3.5)	39.0 (2.5)	40.4 (3.2)
ADF	25.6 (0.7)	23.1 (1.0)	22.7 (1.5)	22.9 (1.3)
Ca	0.22 (0.027)	0.20 (0.031)	0.20 (0.035)	0.20 (0.023)
P	0.17 (0.018)	0.17 (0.028)	0.18 (0.012)	0.18 (0.007)
K	0.79 (0.040)	0.80 (0.071)	0.95 (0.059)	0.84 (0.047)

[1]REF1 = reference hybrid DKC 61-42, REF2 = reference hybrid DKC 62-30, PAR = non-transgenic parental hybrid, MON = corn rootworm resistant hybrid MON 89034.

[2]All samples analyzed at Dairy One, Ithaca, NY. Values in ( ) are standard deviations.

Table 4. Performance and carcass characteristics of steers fed finishing diets for 175 d containing different corn hybrids as dry-rolled corn & corn silage in Exp. 1.

	Treatment[1]					
Variable	MON	PAR	REF1	REF2	SEM	P-value
Performance						
Initial BW, kg[3]	290	291	290	291	5	0.02
Final BW, kg[4]	588	586	588	585	5	0.91
DMI, kg/d	10.14	10.27	9.96	10.21	0.14	0.48
ADG, kg	1.70	1.69	1.70	1.68	0.03	0.90
G:F	0.168[ab]	0.164[a]	0.171[b]	0.165[a]	0.002	0.05
Carcass Characteristics						
HCW, kg	370.5	369.4	370.3	368.4	2.9	0.90
Marbling score[5]	573	561	581	565	12	0.36
12th rib fat, cm	1.31	1.25	1.34	1.32	0.04	0.55
LM area, cm^2	84.2	84.4	84.2	83.5	0.84	0.87
Calculated YG[6]	3.21	3.13	3.24	3.22	0.07	0.72

[a-b]Within a row, means without common superscript letter differ ($P \leq 0.05$).

[1]REF1 = reference hybrid DKC 61-42, REF2 = reference hybrid DKC 62-30, PAR = non-transgenic parental hybrid, MON = corn and corn silage containing Cry1A.105 and Cry2Ab2 proteins (MON 89034).

[2]P-value significant at 0.05.

[3]Initial BW used as covariate.

[4]Final BW calculated as hot carcass weight divided by 0.63.

[5]500 = Small 0, 600 = Modest 0.

[6]Yield grade calculation = 2.50 + (2.5 * fat thickness) – (0.32 * LM area) + (0.2 * KPH (2.5)) + (0.0038 * HCW).

Table 5. Growing performance of steers fed diets containing different corn hybrids as corn silage for 86 d in Exp. 2.

	Treatment[1]					
Item	MON	PAR	REF1	REF2	SEM	P-value[2]
Initial BW[3], kg	279	280	278	278		0.01
Ending BW, kg	420	421	421	418	3	0.78
DMI, kg/d	9.28	9.45	9.51	9.46	0.10	0.40
ADG, kg	1.65	1.65	1.65	1.61	0.03	0.71
G:F	0.178	0.174	0.174	0.170	0.003	0.32

[1]REF1 = reference hybrid DKC 61-42, REF2 = reference hybrid DKC 62-30, PAR = non-transgenic parental hybrid, MON = corn silage containing Cry1A.105 and Cry2Ab2 proteins (MON 89034).

[2]P-value significant at 0.05.

[3]Initial BW used as covariate.

Effects of Forage Type, Storage Method, and Moisture Level in Crop Residues Mixed with Modified Distillers Grains

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ABSTRACT

Two growing experiments were conducted to evaluate diets consisting of wheat straw (WS) or cornstalks (CS) mixed with modified distillers grains with solubles (MDGS) when ensiled (EN) or mixed fresh daily (FR). Wheat straw based diets were also compared at different DM levels (50 and 30) when ensiled or mixed & fed fresh. In Exp. 1, 60 individually fed crossbred steers (289 ± 10 kg) were used in a CRD and analyzed as 2 separate 2 x 2 factorials. Steers fed ensiled diets had greater DMI ($P = 0.03$) than steers fed diets mixed fresh daily. Storage method x residue type interactions ($P < 0.02$) were observed for ADG and G:F. Steers fed ensiled WS blends gained 0.59 kg/d and were similar to fresh CS (0.54 kg/d) and ensiled CS (0.50 kg/d) diets. Steers fed fresh WS blends gained the least (0.42 kg/d). Steers fed fresh MDGS:CS diets were more efficient (0.116) than those fed ensiled MDGS:CS mixtures (0.097), while ensiled MDGS:WS blends were more efficient (0.108) than fresh WS treatments (0.084). Dry matter level did not affect performance. In Exp. 2, 510 crossbred steers (316 ± 23 kg) were used in a randomized block design (3 blocks into 30 treatment pens and 4 CON pens) to evaluate growth performance and forage replacement of feeding MDGS mixed with forages. Residue:MDGS mixtures and a basal forage diet (60:40 alfalfa:grass hay) were offered *ad libitum* each day in separate feedings. Forage type x storage method interactions ($P < 0.05$) were observed for supplement DMI, forage DMI, and percent of basal diet replaced. Steers offered supplemental MDGS:CS and freshly mixed MDGS:WS diets had greater intakes than those offered ensiled MDGS:WS blends and a greater replacement of basal forage. Diets mixed fresh daily resulted in greater ADG ($P \leq 0.01$) and G:F ($P \leq 0.02$) compared to ensiled mixtures, while diet DM had no effect. All

treatments except for 30% DM ensiled WS replaced 22.2% or more of the basal forage intake and improved ADG and G:F relative to steers receiving only the basal diet.

Key Words: cattle, growing, crop residue, distillers grains

INTRODUCTION

The growth of the ethanol industry in the United States has led to a large increase in the amount and availability of ethanol byproducts such as distillers grains, which are nutritionally dense and valuable feedstuffs for all types of cattle operations (Klopfenstein et al., 2008). Seasonally low ethanol byproduct prices during the summer months can be advantageous for smaller producers. Stockpiling these byproducts enables those who may not use larger or semi-load quanties fast enough to prevent spoilage to take advantage of the seasonal low prices (Waterbury and Mark, 2008). At the same time, increased production of grains for ethanol results in an abundance of crop residues, which can be mixed with distillers grains and packed to store for periods (Erickson et al, 2008).

While stockpiling and storing distillers grains with crop residues makes economic sense in seasonal situations, the effect of storage on the nutritive value of the feedstuffs must be considered. Ensiling cornstalks (Wilken et al., 2009) with WDGS in silo bags resulted in greater DMI, ADG, and G:F compared to diets mixed fresh daily. Because the steers consumed more of the ensiled blends, Buckner et al. (2010) performed a follow up study in which steers fed ensiled WDGS and wheat straw blends were limited to the intake of those receiving similar diets mixed fresh observed greater ADG and G:F in the steers fed ensiled blends. By using cornstalks or wheat straw in combination with readily available ethanol byproducts, grazed forage intake may be reduced through gut fill provided by crop residues and growing performance enhanced by the nutrient dense distillers grains. A mix of wheat straw and WDGS reduced grazed forage intake without affecting growing steer performance (Nuttelman et al., 2008). The objectives of these experiments were to 1) evaluate storage method, moisture level, and forage type in crop residue and MDGS diets on growing steer performance; and 2) evaluate growing steer performance and replacement of forage with supplement blends of crop residue and MDGS.

MATERIALS AND METHODS

Experiment 1

Thirty days prior to trial initiation, ground cornstalks or ground wheat straw were blended with MDGS (Archer Daniels Midland, Columbus, NE) in a 70:30 (DM basis) ratio. Based upon previous loads, DM of ingredients was estimated to be 58% for MDGS, 81% for wheat straw, and 88% for cornstalks. Ingredient DM determinations at trial initiation were 60.5% for MDGS, 82.9% for WS, and 87.6% for CS, and feedsheets were adjusted based upon weekly DM values. Water was added to the blends to achieve the targeted DM of either 30% or 50% of the respective blend prior to storage in silo bags (AG-BAG Systems Inc., St. Nazianz, WI) at the University of Nebraska Research Feedlot near Mead, NE. Modified distillers grains with solubles used to mix fresh diets was also stored in silo bags, while wheat straw and corn stalks were ground through a 12.7 cm screen and stored in open bays of a commodity shed. The wheat straw and corn stalks used in ensiled and freshly mixed treatments were from the same source. Modified distillers grains with solubles that were fed in freshly mixed diets were stored in silo bags.

After bagging, DM analysis was performed using a 60˚C forced air oven. Samples were taken from the top, middle, and bottom levels of each silo bag to determine if added water had settled and created uneven layers of moisture. The DM values for EN CS 30, EN WS 30, and EN WS 50 were 32.7 (± 3.0), 31.7 (± 1.6), and 45.8 (± 5.8), respectively, indicating acceptable consistent DM throughout the bags.

By storing these feedstuffs in a silo bag, a traditional ensiling process did not occur. While there was minimal anaerobic fermentation and lowering of pH due to the presence of oxygen, the term ensiling is used to describe lack of exposure to the atmosphere and the packing process used to store the blends of crop residue and corn byproduct.

Sixty crossbred steers (initial BW = 289 ± 10 kg) were used in a completely randomized design experiment. Steers were received at the University of Nebraska Agricultural Development and Research Center (ARDC) during the fall of 2010. Steers were weighed and vaccinated with a modified live virus vaccine for protection against IBR, BVD Types I & II, PI3, and BRSV (Bovishield Gold 5; Pfizer Animal Health, New York, NY) and prevention of *Haemophilus somnus* (Vision 7-Somnus; Pfizer Animal Health), and injection with a paraciticide (Dectomax; Pfizer Animal Health). Steers were revaccinated with a modified live virus vaccine for protection against IBR, BVD Types I & II, PI3, and BRSV (Bovishield Gold 5; Pfizer Animal Health) and prevention of *Haemophilus somnus* (Vision 7-Somnus; Pfizer Animal Health), and injection with a paraciticide (Dectomax; Pfizer Animal Health) after 14 d and trained to use individual Calan gates (American Calan Inc., Northwood, NH). Prior to initiation of the trial, steers were limit fed a diet of 50% alfalfa hay and 50% wet corn gluten feed (Sweet Bran, Cargill Inc, Blair, NE) at 2% of BW (5.8 kg DM) to minimize variation in gastrointestinal fill. Following the limit feeding period, steers were weighed on three consecutive d, with the average BW from d -1 and 0 used to assign steers randomly to treatments. Ten steers were assigned to one of six treatments. While there were six treatments, using 2 treatments in both comparisons enabled the data to be analyzed as 2 separate 2 x 2 factorials. Forage type (CS or WS) and storage method (EN or FR) were compared in the first factorial, with the diet DM constant across diets. Storage method and diet DM (50 or 30) were compared in the second factorial, with only WS mixed with MDGS in the diets. All treatments received the same supplement at 5% of diet DM. Supplement contained fine ground corn (37.8%), urea (27.6%), limestone (24.6%), salt (6.0%), tallow (2.5%), trace minerals (1.0%), vitamin A-D-E (0.3%), and monensin (0.3%). Diet was formulated to provide 200 mg/steer/d monensin.

Steers were individually fed their respective diets *ad libitum* for 84 d using Calan gates and housed in an open front barn with 30 steers per pen, with 30.5 cm. of bunk space and 2.32 m^2 of space for each steer. Feed was adjusted daily based on individual refusals to maintain *ad libitum* intakes. Feed refusals were collected daily and feed samples were collected weekly. Refusals and weekly samples were analyzed for DM using at 60˚C at 48 h using a forced air oven. Steers were limit fed a diet of 50% alfalfa hay and 50% wet corn gluten feed at 2% of BW (6.6 kg DM) for 5 d at trial completion and weighed three consecutive d to obtain ending BW.

Data were analyzed using the MIXED procedure of SAS (SAS Inst. Inc., Cary, NC) as a completely randomized design with steer as the experimental unit. Separate 2 x 2 factorials were used to compare growth performance. The first factorial compared type of crop residue (CS and WS) and storage method (EN or FR), with all blends at 30% DM. The second factorial compared MDGS:WS blends ensiled (EN) or mixed fresh daily (FR) and DM (50 or 30) of the mix. If interactions were significant ($P \leq 0.05$), simple effects of individual treatment are reported. If interactions were not significant, main effects of forage, DM level, and storage method are reported.

Experiment 2

Thirty days prior to trial initiation, ground cornstalks or ground wheat straw were blended with MDGS (Archer Daniels Midland, Columbus, NE) in a 70:30 (DM basis) ratio. Based upon previous loads, DM of ingredients was estimated to be 58% for MDGS, 81% for wheat straw, and 88% for cornstalks. Ingredient DM values at trial initiation were 61.0% for MDGS, 82.1% for WS, and 85.8% for CS Water was added to the blends to achieve the targeted DM of either 30% or 50% of the respective blend prior to storage in silo bags at the University of Nebraska-Lincoln Agricultural Research and Development Center (ARDC) near Mead, NE. Modified distillers grains with solubles used to mix fresh diets was also stored in silo bags, while wheat straw and corn stalks were ground through a 12.7 cm screen and stored in open bays of a commodity shed.

Five hundred and ten crossbred steers (initial BW = 316 ± 23 kg) were used in a randomized complete block design experiment to compare forage replacement and growing performance. Steers were received at ARDC during the fall of 2010. Steers were weighed and vaccinated with a modified live virus vaccine for protection against IBR, BVD Types I & II, PI3, and BRSV (Bovishield Gold 5; Pfizer Animal Health) and prevention of *Haemophilus somnus* (Vision 7-Somnus; Pfizer Animal Health), and injection with a paraciticide (Dectomax; Pfizer Animal Health) on arrival. Steers were revaccinated with a modified live virus vaccine for protection against IBR, BVD Types I & II, PI3, and BRSV (Bovishield Gold 5; Pfizer Animal Health) and prevention of *Haemophilus somnus* (Vision 7-Somnus; Pfizer Animal Health), and injection with a paraciticide (Dectomax; Pfizer Animal Health) after 14 d, and placed onto bromegrass pastures for 30 d. After receiving, steers grazed corn residues and were supplemented with wet corn gluten feed (Sweet Bran, Cargill Inc., Blair, NE) for 90 d. In February 2011, steers were moved to pens and were limit-fed a diet consisting of 50% alfalfa hay and 50% wet corn gluten feed at 2% BW (6.3 kg DM) to minimize the effect of gastrointestinal fill prior to initiation of the trial. Following the 5 d limit-feeding period, steers were weighed on 2 consecutive d, with d 0 BW used to block by BW, stratify within block, and assign randomly to pen.

Treatments were supplements containing 70% crop residue and 30% MDGS (DM). The treatments were arranged in two separate 2 x 2 factorials. The first factorial compared type of crop residue (CS and WS) and storage method (EN or FR), with all blends at 30% DM. The second factorial compared MDGS:WS blends ensiled (EN) or mixed fresh daily (FR) and DM (50 or 30) of the mix. Treatments were offered as a supplement to a basal diet consisting of 60% grass hay and 40% alfalfa hay, which served as a proxy for grazed forage. Steers were offered supplements *ad libitum* at 0700 h. At 1200 h, prior to feeding the basal forage diet, bunks were evaluated based on supplement intake and adjustments for the subsequent day's supplement offering were made. The basal diet was offered at 1300 h and adjustments to each afternoon's feeding were made prior to the 0700 h feeding of the residue and MDGS supplement. Trace mineral blocks were placed in each bunk. Feed refusals were weighed and removed at the time of each bunk evaluation. Four pens were used as a control (CON) group and were only offered the 60% grass hay:40% alfalfa hay basal diet. Steers were limit fed 5 d at trial completion and weighed on two consecutive days for ending BW.

Data were analyzed using the MIXED procedures of SAS (SAS Inst. Inc., Cary, NC) as a randomized block design, with block as a fixed effect and pen as the experimental unit. Separate 2 X 2 factorials were evaluated to test the intake and growth performance of steers. The first factorial compared type of crop residue (CS and WS) and storage method (EN or FR), with all blends at 30% DM. The second factorial compared MDGS:WS blends ensiled (EN) or mixed fresh daily (FR) and DM (50 or 30) of the mix. If interactions were significant ($P \leq 0.05$), simple effects are reported. If interactions were not significant, main effects are reported.

RESULTS AND DISCUSSION

Experiment 1

The performance results of steers fed different crop residues (CS vs. WS) with different storage methods (EN vs. FR) are shown in Table 1. No interaction was observed between storage method and residue type for DMI. Dry matter intake was greater for steers consuming ensiled diets ($P = 0.02$) compared to those mixed fresh daily (5.4 kg/d vs. 4.9 kg/d, respectively), and those offered wheat straw tended ($P = 0.07$) to have greater DMI than steers offered cornstalk blends (5.3 kg/d vs. 4.8 kg/d, respectively).

Interactions were observed between residue type and storage method for ADG (P = 0.02) and G:F (P < 0.01), with steers fed the EN MDGS:WS mix gaining 0.59 kg/d compared to 0.42 kg/d for steers consuming the FR MDGS:WS diet. However, the positive effect ensiling had on ADG of steers fed wheat straw blends was not observed in steers fed cornstalk blends, as the FR (0.54 kg/d) and EN (0.50 kg/d) diets did not differ (P = 0.77) for cornstalks blended with MDGS. Steers fed diets containing cornstalks mixed fresh daily were more efficient than those fed ensiled cornstalk mixes (0.116 and 0.097, respectively). Due to lower average daily gains and DMI, steers consuming freshly mixed wheat straw diets had lower G:F (0.084) than those fed ensiled wheat straw blends (0.108).

In the other analysis of the 2 x 2 factorial with diets containing only wheat straw, no interactions (*P* = 0.10, Table 2) were observed between storage method and diet DM, so only main effects are discussed. No differences (P ≥ 0.71) were observed when comparing the performance of steers fed diets of different moisture levels. Steers fed ensiled diets had greater ending BW (*P* = 0.03) and ADG (*P* = 0.01) with similar DMI (P = 0.11), and consequently greater G:F (*P* = 0.03) than those fed diets mixed fresh daily.

The performance advantages for steers fed ensiled diets in this experiment are supported by previous comparisons of ensiled and freshly mixed diets. Wilken et al. (2009) observed greater ADG (0.65 vs. 0.46 kg/d) and G:F (0.102 vs. 0.084) in steers fed ensiled blends of WDGS and cornstalks when compared to those offered diets mixed fresh daily. Similar results were noted by Buckner et al. (2010) when ensiled WDGS and wheat straw were compared to fresh diets. Steers consuming the ensiled diets gained more and were more efficient than those fed freshly mixed diets. However, the trial performed by Wilken et al. (2009) noted greater DMI in steers fed ensiled diets (6.4 vs. 5.5 kg/d, respectively). Consequently, the steers in the Buckner et al. (2010) experiment were pair fed to similar DMI to determine if improved performance was due to the ensiling process providing greater nutrient availability. The increased intakes of ensiled blends are in agreement with data observed in this experiment, which suggests that the ensiling process improves palatability and nutritional quality.

Contrasting data were reported by Peterson et al. (2009) in an experiment similar to Buckner et al. (2010). Steers fed non-ensiled blends of WDGS and wheat straw showed tendencies to gain more ($P = 0.08$) and be more efficient ($P = 0.09$) than those fed the same ingredients that had been ensiled. Apparent advantages in freshly mixed blends compared to ensiled blends agree with results from an experiment conducted by Muntifering et al. (1985), in which ensiled and non-ensiled diets consisting of wet corn stillage and tall fescue hay were fed to lambs and steers. Diets mixed fresh were more digestible and retained more dietary N than the ensiled mixes of co-product and hay.

Increased performance of steers fed ensiled wheat straw blends when compared to those consuming the non-ensiled diets suggest that the ensiling process increased the rate and extent of fiber digestion in the straw, which is supported by greater intakes of ensiled diets. However, steers fed freshly mixed cornstalk diets had lower intakes yet comparable daily gains, resulting in greater efficiency than steers offered ensiled cornstalk blends. These results may be attributed to animal selectivity of MDGS and more digestible and nutrient dense portions of the ground residue.

Experiment 2

This experiment was designed to test the palatability and potential forage intake replacement of MDGS and crop residue mixes, therefore, DMI of the supplements relative to the hay was the important measure. As with Exp. 1, the results of storage method (EN vs. FR) x residue type (CS vs. WS) diets were analyzed separately from diet DM (50 vs. 30) x storage method (EN vs. FR) results (Table 3).

Interactions were observed between residue type and storage method when comparing supplement DMI ($P < 0.01$) and forage DMI ($P = 0.05$). Steers offered the ensiled wheat straw blend consumed only 0.6 kg/d of the supplemented mixture, as opposed to 2.1 kg/d for the freshly mixed wheat straw blend and 2.4 kg/d of the cornstalk blends, either FR or EN. Steers supplemented with ensiled MDGS:WS mixtures consumed 5.7 kg/d of the forage offered, which was significantly more than steers offered the non-ensiled MDGS:WS mix (5.1 kg/d). Steers offered EN MDGS:CS blends were not different in terms of forage DMI from those offered FR MDGS:CS blends. The reduction in supplement DMI and increase in forage DMI of steers offered the EN MDGS:WS mixes was due to spoilage in the silo bag. Pockets of oxygen became present when the mix was bagged, causing mold to grow. Warm spring weather also contributed to the spoilage, whereas the colder temperatures during the winter inhibited mold growth in Exp. 1. This spoilage reduced DMI, leading to a slower rate of feeding and subsequently allowing further spoilage once exposed to more oxygen.

The differences in supplement and forage intake resulted in an interaction (P < 0.01) for residue type by storage method when comparing percentage of basal diet replaced by MDGS:residue mixes. Ensiled and non-ensiled MDGS:CS supplements replaced (35.4% and 33.7%, respectively) of the total DMI, while the MDGS:WS supplement mixed fresh daily constituted 29.0% of total DMI for steers fed that treatment. However, ensiled wheat straw and MDGS accounted for only 9.6% of total DMI in steers offered that treatment. Because the forage blend was offered as a proxy for grazed forage, these data suggest that MDGS blended with cornstalks, either ensiled or mixed fresh daily, could replace a greater percentage of grazed forage than either of wheat straw mixtures.

No interactions were observed between storage method and residue type when comparing ADG and G:F (Table 3). Steers fed diets mixed fresh daily gained more (P < 0.01) and were more efficient (P = 0.01) than those offered ensiled blends of MDGS and residue. These results conflict with data from Wilken et al. (2009) and Buckner et al. (2010). In both experiments, the researchers observed greater ADG and gain efficiency in steers consuming ensiled crop residue and corn co-product diets compared to those receiving equivalent non-ensiled rations. However, Peterson et al. (2009) fed ensiled and non-ensiled blends of WDGS and wheat straw and noted trends for greater gains and gain efficiency in steers fed the non-ensiled diets. The difference in these experiments, though, is that steers were only offered the distillers grain and crop residue diets, whereas this experiment was designed to give steers the choice between a grazed forage substitute and the corn co-product and crop residue blend.

Previous studies have also demonstrated forage intake replacement with ethanol co-product supplementation. To examine grazed forage replacement, Gustad et al. (2006) supplemented DDGS from 0.29% to 1.27% of BW to steers grazing corn residue and observed a linear increase in ADG. A control group of steers was fed hay and supplemented DDGS at amounts corresponding to steers grazing corn residue, with the objective of comparing forage intakes at increasing supplementation levels. A linear decrease in forage intake was observed (P < 0.01) as supplementation levels were increased, with steers fed DDGS at 1.27% of BW consuming 27% less hay compared to the hay only control group. These data led the authors to suggest that not only could improvements in ADG be achieved with co-product supplementation, stocking rates could be increased by 27%.

Nuttelman et al. (2008) observed similar results in forage intake replacement by feeding DDGS, WDGS, and an ensiled blend of 67% WDGS and 33% ground wheat straw at increasing levels to steers fed a basal diet of sorghum silage and alfalfa hay. The co-product was supplemented at 0, 0.33%, 0.67%, and 1.0% of BW. Steers offered the mixture had similar G:F (P = 0.32) to steers fed corresponding levels of co-product, but lower DMI (P = 0.05) than steers receiving only DDGS or WDGS, leading the authors to theorize the straw provided enough rumen fill to effectively reduce forage intake without negative effects on gain efficiency or palatability.

An interaction was observed for supplement (MDGS, residue mix) DMI ($P <$ 0.01, Table 3) and percentage of total DMI ($P < 0.01$) when comparing storage method and residue type. Intakes were lower for steers fed ensiled wheat straw than fresh wheat straw and both cornstalk blends resulting in a lower percentage of forage replacement for the ensiled wheat straw blend.

Interactions between supplement DMI ($P < 0.01$, Table 4), forage DMI ($P = 0.01$) total DMI ($P = 0.01$), and percentage of total DMI ($P < 0.01$) were found when moisture level and storage type were analyzed. Steers fed the 30% DM fresh MDGS:WS supplement consumed more kg daily, resulting in the greatest percentage of total DMI. Steers offered the 30% DM ensiled supplement had decreased supplement intakes and consequently had the lowest percentage of forage replacement when compared to all other MDGS:WS blends. Slow rates of feeding contributed to spoilage within silo bags, which negatively affected the palatability of the 30% ensiled MDGS:WS blend. There were no interactions when comparing G:F. The main effects of both ADG ($P = 0.01$) and G:F ($P = 0.02$) showed an advantage of diets mixed fresh daily over ensiled diets, which contradicts the results of Exp. 1 and previous studies. However, this experiment presented steers with a choice between supplemented treatment and a basal forage diet rather than offering only the crop residue and MDGS blend. Increased palatability of fresh diets compared to spoilage in an ensiled diet resulted in greater intakes of supplemented blends and a subsequent increase in amount of MDGS consumed.

With the exception of the 30% DM ensiled wheat straw supplement, supplemented steers showed greater ADG and G:F than steers fed the control diet, while effectively replacing 22% to 35% of forage intake. Decreased intakes of the 30% ensiled wheat straw supplement can be attributed to spoilage within the silo bag due to slow rates of feeding. Despite the effects of spoilage, steers offered the MDGS:WS mixes still equaled or surpassed the performance of the control steers that were only offered the basal forage mix. These data suggest that MDGS mixed fresh daily with cornstalks will not only increase growing steer performance relative to a forage only situation, but the supplement can replace a greater proportion of hay, which was used as a proxy for grazed forage in this experiment.

CONCLUSIONS

By blending MDGS and crop residues, lower cost feed ingredients can be successfully fed to growing steers with satisfactory gains and efficiency. When steers were only offered MDGS:crop residue blends, ensiled mixes resulted in greater DMI and showed no preference or performance advantages between diet DM or crop residue type. However, when given the choice of a proxy grazed forage, steers offered freshly mixed blends had greater ADG and G:F than those offered ensiled blends. Despite the spoiled EN WS, supplemented mixes resulted in 9.6% to 35.4% replacement of the basal diet with equal or greater performance, which indicates that feeding MDGS:crop residue blends are advantageous to growing calf performance and effective for forage intake replacement.

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Table 1. Effects of forage type and storage method on performance of individually fed growing steers fed MDGS:crop residue blends for 84 d in Exp. 1

	Corn Stalks		Wheat Straw			P-Value		
	Fresh	Ensiled	Fresh	Ensiled	SEM	Trt[1]	Forage[2]	Trt*Forage[3]
Initial BW, kg	288.2	288.8	288.5	289.1	3.2	0.85	0.92	0.99
Ending BW, kg	333.2	330.9	324.1	339.1	4.9	0.20	0.92	0.09
ADG, kg	0.54[ac]	0.50[abc]	0.42[b]	0.59[ac]	0.04	0.10	0.77	0.02
DMI, kg/d	4.6	5.2	5.1	5.5	0.2	0.02	0.07	0.83
G:F	0.116[a]	0.097[bc]	0.084[c]	0.108[ab]	0.007	0.76	0.14	<0.01

[abc]Means without common superscript differ ($P \leq 0.05$).

[1]Storage method, ensiled or freshly mixed.

[2]Crop residue type, corn stalks or wheat straw.

[3]Interaction between storage method or forage type.

Table 2. Effects of diet DM and storage method on individually fed growing steer performance fed MDGS:wheat straw blends for 84 d in Exp. 1.

	30% DM		50% DM			P-Value		
	Fresh	Ensiled	Fresh	Ensiled	SEM	Trt[1]	DM	Trt*DM
Initial BW, kg	288.5	289.1	287.6	289.8	3.3	0.66	0.96	0.81
Ending BW, kg	324.1	339.1	327.4	332.9	4.4	0.03	0.74	0.29
ADG, kg	0.42	0.59	0.47	0.51	0.04	0.01	0.71	0.10
DMI, kg/d	5.1	5.5	5.1	5.3	0.2	0.11	0.74	0.49
F:G	0.084	0.108	0.092	0.097	0.006	0.03	0.76	0.16

[1]Storage method, ensiled or freshly mixed.

Table 3. Growing steer performance when offered fresh or ensiled supplements containing corn stalks or wheat straw and MDGS in Exp 2.

		Corn Stalks		Wheat Straw			P-Value		
	CON	Fresh	Ensiled	Fresh	Ensiled	SEM	Trt[1]	Forage[2]	Trt*Forage[3]
Initial BW, kg	308.5	316.5	317.0	316.9	316.6	10.2	0.99	0.99	0.97
Ending BW, kg	325.1	342.9	336.3	345.2	330.8	7.5	0.18	0.83	0.61
Supplement DMI, kg/d	-	2.4[a]	2.4[a]	2.1[a]	0.6[b]	0.1	<0.01	<0.01	<0.01
Forage DMI, kg/d	-	4.7[ab]	4.4[a]	5.1[bc]	5.7[c]	0.2	0.46	<0.01	0.05
Total DMI, kg/d	7.1	7.1	6.8	7.2	6.3	0.1	<0.01	0.11	0.08
Basal diet replaced[4], %	-	33.7[a]	35.4[ab]	29.0[b]	9.6[c]	2.0	<0.01	<0.01	<0.01
ADG, kg	0.32	0.51	0.37	0.54	0.27	0.06	<0.01	0.63	0.32
G:F	0.045	0.071	0.054	0.076	0.043	0.009	0.01	0.71	0.36

[abc]Means without common superscript differ ($P \le 0.05$).

[1]Storage method, ensiled or freshly mixed.

[2]Crop residue type, corn stalks or wheat straw.

[3]Interaction between storage method or forage type.

[4]Percentage of basal 60:40 alfalfa hay:grass hay diet replaced by MDGS:crop residue blends.

Table 4. Growing steer performance when offered fresh or ensiled supplements at differing diet DM containing wheat straw and MDGS in Exp 2.

		30% DM		50% DM			P-Value		
	CON	Fresh	Ensiled	Fresh	Ensiled	SEM	Trt[1]	DM	Trt*DM[2]
Initial BW, kg	308.5	316.9	316.6	316.8	317.4	10.3	0.99	0.97	0.96
Ending BW, kg	325.1	345.2	330.8	341.1	335.8	7.5	0.21	0.96	0.55
Supplement DMI, kg/d	-	2.1^{a}	0.6^{b}	1.5^{c}	1.6^{c}	0.1	<0.01	0.08	<0.01
Forage DMI, kg/d	-	5.1^{a}	5.7^{b}	5.4^{ab}	5.2^{a}	0.1	0.22	0.55	0.01
Total DMI kg/d	7.1	7.2^{a}	6.3^{b}	7.0^{a}	6.8^{a}	0.1	<0.01	0.15	0.01
Basal diet replaced[3], %	-	29.0^{a}	9.6^{b}	22.2^{c}	23.7^{ac}	1.8	<0.01	0.06	<0.01
ADG, kg	0.32	0.54	0.27	0.47	0.35	0.07	0.01	0.98	0.27
G:F	0.045	0.076	0.043	0.067	0.051	0.009	0.02	0.97	0.36

[abc]Means without common superscript differ ($P \leq 0.05$).

[1]Storage method, ensiled or freshly mixed.

[2]Interaction between storage method or diet DM.

[3]Percentage of basal 60:40 alfalfa hay:grass hay diet replaced by MDGS:crop residue blends.