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Animal Performance and Diet Quality While Grazing Corn Residue

By

Jennifer A. Gigax

A THESIS

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L. Aaron Stalker and Terry J. Klopfenstein

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Animal Performance and Diet Quality While Grazing Corn Residue

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University of Nebraska, 2010

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Grazing cattle on corn residue as a winter feed source has become an integral part of many Nebraska producers' management plans. Utilizing corn residues extends the grazing season and is often more economical than grazing winter range or dry lot situations. Corn residue is high in OM and NDF, moderate in digestibility, and low in CP. Cattle grazing corn residues may need to be supplemented with a protein source to meet requirements.

The development and application of DNA technology to create new corn hybrids has improved yields with fewer inputs, leading to a continued low cost food supply for consumers. Previous research has demonstrated the safety of transgenic corn, silage, and corn residue as livestock feed sources. In all trials, transgenic corn is nutritionally similar to non-transgenic corn.

In the current trial, four treatments were applied to a 53 ha center pivot irrigated field of corn. Treatments included a control, light grazing (2.5 AUM/ha), heavy grazing (4.9 AUM/ha), and baling, Samples were collected from all treatment paddocks before and after grazing and analyzed for DM, OM, CP, NDF, IVDMD, and in vitro organic matter digestibility (IVOMD).

Leaf and husk material were consumed in the greatest amount on both grazing treatments. In general, leaf and husk residue had greater CP compared to cob and stem residue. Husk and cob residue had greater NDF content than leaf and stem residue. Digestibility of the residues ranged from 44 to 59%.. Undegradable intake protein digestibility of corn residue is low. Husk and leaf residue UIP digestibility was approximately 23%.

Leaf and husk residue from several transgenic hybrids grown in western Nebraska had greater CP compared to stem and cob residue. Cobs had greater NDF content compared to leaf, husk, and stem residue. Husk and leaf residue from all hybrids had greater digestibility compared to stem and cob residue. A relationship between husk and leaf yield per bushel of grain produced per hybrid was not observed in this trial.

Dedication

I would like to dedicate this thesis to my dad, Blake Gigax. You unknowingly started all of this with the gift my first heifer when I was in kindergarten (remember B9?). As it turned out, that was only the beginning of my interest in everything surrounding the cattle business. You encouraged me through rough times, taught me when I didn't know, and inspired me to be better than I thought I could be. You taught me everything I know about cattle and grasses (well almost) and I can't tell you how much that has meant to me. You always told me I could be anything I wanted to be when I grew up and all I've ever wanted was to be was just like you.

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My cousin Danny can take most of the credit for getting me to grad school in the first place. I did actually listen during all of our conversations and apparently some of it stuck. You have been there through thick and thin, answering questions and giving advice. Thank you doesn't really seem like enough, but it will have to do.

Last, but probably most important, I would like to thank my family supporting me through all of my crazy adventures. I am a person who likes to travel and even though I know you all didn't like me moving as far away as I was at times, it all played a part in my decision to pursue this degree. If it wasn't for your continual support, I wouldn't have made it to where I am today. Just think, I'll (hopefully!) never again have to live in a forest or a construction trailer in a barn. I'm finally well on my way to being what I want to be "when I grow up." Thank you so very much mom, dad, Becca, and Stephen.

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Introduction

The conversion of cellulose into useable products for humans has been and continues to be an integral part of societal development as it is the most abundant material on earth (Oltjen and Beckett, 1996). Ruminant animals have the unique ability to consume cellulose rich forages and translate them into valuable animal products for human use and consumption. The rumen contains vast amounts of cellulase, the only microbial enzyme capable of digesting cellulose. Approximately 40% of the earth's land mass is comprised of rangeland not suitable for cultivation or other use (Church, 1993). Ruminants allow land that is not suitable for other purposes to become productive. Ruminant production systems are also able to take advantage of the abundance of cereal grains raised in the United States, consuming approximately 37% of the grains fed to livestock yet producing 61% of human food energy from animal agriculture (Oltjen and Beckett, 1996).

Production animal agriculture is ever changing and producers must consider alternative options for the successful management of their operation. The most expensive component of raising beef cattle is winter feed sources (Reid and Klopfenstein, 1983). Therefore, finding a suitable way to manage and feed cattle during the winter months is critical to beef producers. For centuries, cattle producers utilized native range for grazing year round and would supplement cattle with grain, hay, or other stockpiled forages during times of extreme cold or snow cover. The land available for grazing beef cattle greatly decreased in the mid 1900's as the demand for corn grain greatly increased and vast amounts of land was tilled for crop production. Corn demand further increased in the early 1970's as United States agriculture exports increased which decreased the

surpluses of corn grain and increased the demand for and the prices of corn (Reid and Klopfenstein, 1983). With corn production increasing and land available for grazing cattle decreasing, many producers began to utilize the crop residues left in the field after harvest as a means for feeding cattle throughout the winter months.

Nebraska currently ranks 3rd in corn production, with 8.8 million acres planted in 2008, and 2nd in all cattle and calf production in the United States (Nebraska Department of Agriculture, 2010; Nebraska Corn Board, 2010a), making the utilization of corn residues for wintering cattle especially appealing and feasible. Nearly a quarter of the state is comprised of the Sandhills, approximately 20,000 square miles of sandy type soil and mixed grass prairie, a prime area for beef cattle production. Because much of Nebraska's crop production follows the Platte River Valley across the state, producers in the Sandhills often transport cattle south to graze corn residues if economically feasible.

Grazing corn residues presents a unique situation because all the forage available for consumption is present at the beginning of grazing. Corn is harvested when the nutritive value of the plant itself is at its lowest, creating a forage product with relatively low crude protein (CP) and digestibility. Models for nutrient requirements for beef cattle recognize that the nitrogen requirement for the rumen microbial population and the requirement for the animal must be separated to more precisely define dietary requirements. Crude protein can therefore be divided into categories of degradable intake protein (DIP) which is degraded in the rumen and undegradable intake protein (UIP) which escapes rumen degradation and is absorbed in the small intestine. Undegradable intake protein content of corn residue is an important factor to consider because bacterial crude protein (BCP) can supply essentially all of the protein required, but is dependent on

the UIP content of the diet (NRC, 1996). Research has not been conducted to determine the UIP content of corn residue, but previous research has shown that gestating beef cattle can be successfully maintained on corn residues with low levels of supplementation (Wilson et al., 2004).

Transgenic corn hybrids contain genes that have been artificially inserted into the plant. Common modifications include the addition of bacterial genes for insect resistance or herbicide resistance. Much research has been done to determine whether or not transgenic corn hybrids produce different amounts of residue with different nutrient quality compared to non-transgenic hybrids, however transgenic corn hybrids are ever evolving and data frequently become outdated.

The purpose of this review is to examine corn production in Nebraska, the practice of utilizing corn residues for grazing beef cattle and the nutrient quality of such residues, and the nutrient composition of current transgenic corn hybrids.

Literature Review

Wintering Systems for Beef Cattle

Grazing native range

Since being introduced into the United States in the 1500's by way of Texas, California, and Florida (Ball, 1998), beef cattle have grazed the abundant native range. Traditionally, cattle grazed these native ranges year round. However, as populations and demand for food products increased, less land was available for grazing and alternative management strategies evolved for the production of more beef on fewer acres. Many states maintain areas where soil types are unsuitable for other uses and remain today as prairies primarily used for beef production. Nearly a quarter of the state of Nebraska is comprised of the Sandhills, approximately 20,000 square miles of mixed grass prairie and a major area for large scale beef cattle production. The region is dominated by C_4 grass species (Schacht et al., 2000). Dominant grass species include sand bluestem (*Andropogon hallii* Hack), little bluestem (*Schizachyrium scoparium* (Michx.)), prairie sandreed (*Calamovilfa longifolia* (Hook) Scribn.), hairy grama (*Bouteloua hirsuta* Lag.), sand dropseed (*Sporobolus cryptandrus* (Torr.) A. Gray), and needle-and-thread (*Stipa comate* Trin. & Rupr.; Pool, 1914; Frolik and Sheperd, 1940; Tolstead, 1942). Many producers in Nebraska utilize this forage resource in year round grazing systems. The nutrient profile of the growing forages is adequate to meet cattle requirements. As forages mature, digestibility and CP content decrease while fiber and lignin content increase (Savage and Heller, 1947; Cook, 1972; Johnson et al., 1998). Dormant grasses are often deficient in nutrients that cattle need (Krysl and Hess, 1993).

Degradable intake protein is generally considered to be limiting in low-quality forages (Köster et al., 1996). Johnson et al. (1998) evaluated the effect of advancing season on dietary composition, forage intake, and digestion by beef steers grazing mixed-grass prairie from mid-June to mid-December. All forages were found to be dormant by mid-November. Decreases in CP (14.9 to 6.2%) and IVOMD (60.5 to 53.3%; $P < 0.01$) were observed from July to December. For the same time period, linear increases ($P < 0.01$) were observed for NDF (51.0 to 72.1%) and ADF (34.8 to 41.8%). Undegradable intake protein as a percent of CP increased from 23.1 to 30.8% ($P < 0.01$). Data from this trial indicate that dormant forages are deficient in DIP and would require protein supplementation to meet animal requirements.

A similar evaluation was conducted by Cline et al. (2010). They compared the effects of advancing season and grazing treatment on dietary composition, intake, site and extent of digestion, and microbial efficiency of native range. Treatments included season long grazing or twice over rotational (TOR) grazing in which the forage was grazed, rested and re-grazed within the same season. Dietary nitrogen content declined (112.7 to 77.1 g/d; $P \leq 0.07$) and fiber content increased ($P \leq 0.05$) during both years and both treatments with the exception of NDF in year 2 for the TOR grazing treatment. Total tract OM and apparent ruminal OM digestion decreased with advancing season ($P \leq 0.04$). Intake of DIP as a percent of CP decreased as forage matured (413.0 to 226.3 g/d; $P < 0.01$). These data suggest mixed-grass forages consumed late in the grazing season are deficient in N, particularly DIP, and forage intake may be insufficient to maintain lactating cows.

Because the cost of protein supplementation is a major cost for producers, it is important to identify actual amounts of DIP intake by animals grazing native range. The objective of Hollingsworth-Jenkins et al. (1996) was to determine the DIP requirement of gestating beef cows grazing native Sandhills range in Nebraska. Using different levels of DIP supplementation, they were able to conclude gestating cows grazing native Sandhills range need between 62 and 140 g/d of supplemental DIP to meet their daily requirement, or 7.1% of the digestible OM.

With the abundance of corn grown in Nebraska, many producers choose to utilize corn crop residue as a winter feed source to extend the grazing season and decrease the need for harvested forages. Griffin et al. (2010) evaluated the effect of wintering system on cow and calf performance. Cows were wintered on either native range or corn residue. Cow BW and BCS at pre-calving, pre-breeding, and weaning were not different ($P > 0.57$) between wintering systems. No differences were observed in calf birth weight ($P = 0.64$) or weaning weight ($P = 0.63$). Calf ADG from birth to weaning ($P = 0.72$) and adjusted 205-day weaning weight ($P = 0.77$) were not different. Percentage of cows to calve, rebreeding rate, and calves weaned per cow were not influenced be wintering system ($P > 0.65$). These data demonstrate that cows can be wintered on Sandhills range or cornstalks without affecting breeding performance or cow BW and BCS.

Grazing corn crop residues-corn production

Nebraska currently ranks 3rd in the United States for corn production and 2nd in all cattle and calves (Nebraska Department of Agriculture, 2010). In 2009, Nebraska produced over 40 billion kg of corn (Nebraska Corn Board, 2010a). Assuming 1 kg of

residue is produced for every kg of grain yield (Klopfenstein, 1978), over 18 million metric tons of corn residue were produced. Although corn production in Nebraska primarily follows the Platte river valley across the state, greater production occurs in the east due to the ideal climate and temperature. Eastern Nebraska averages 22.5 °C during the growing season and 76.2 cm annual rainfall compared to western Nebraska which averages 20.4 °C and only 45.7 cm of rainfall (Nebraska Corn Board, 2010b).

Crude irrigation systems, such as ditches dug to divert water from streams, have existed since the late 1800's. In 1947, Frank Zybach invented the first center pivot after viewing an irrigation demonstration using hand-moved pipe (Valmont). Zybach's first model was only a few feet tall, but was modified to be taller for corn production. A Nebraska owned company, Valley, bought the rights to his design in 1954 and engineers spent the next several years making the pivot stronger, taller, and more efficient (Valmont). Center pivot irrigation revolutionized crop production in the United States and vastly increased the amount of grain produced on fewer hectares. Nebraska sits on top of the Ogallala aquifer which provides the ground water for center pivot irrigation systems. Approximately 72% of the irrigated land in Nebraska is irrigated with center pivot systems and flood irrigation is used on about 28% (University of Nebraska-Lincoln). Subsurface irrigation systems apply water directly to the crop root zone using buried pipe line and only make up a very small portion of the irrigation systems used in Nebraska (University of Nebraska-Lincoln). The USDA 2007 census of agriculture estimates that approximately 3.5 million hectares (39.3%) of the cropland in Nebraska was irrigated (USDA, 2010b).

With the abundance of corn grown in Nebraska, there is opportunity for integration of crop residues and grazing systems. Utilizing corn crop residues as a winter forage source for cattle gained popularity in the 1970's and remains a vital part of production for many producers in the Midwest.

Grazing corn residues- nutritional components of corn residue

The biggest challenge in grazing corn residues is that all forage for consumption is available at the beginning of grazing. Because of the added costs incurred with harvesting, transporting, processing, storing, and feeding, grazing is the most economical use of corn crop residues (Klopfenstein et al., 1987). However, grazing does not maximize utilization. Utilization by beef cows has been estimated at 10-20% (Vetter et al., 1970), 15-20% (Ayers, 1973), and 20-30% (Vetter, 1973a; Lamm and Ward, 1981). More recent work estimates cattle will consume approximately 1/3 of the residue available (Wilson, 2004). Baling corn residue results in the greatest utilization; however, removing high quantities of residue is likely not sustainable. A portion of the residue organic matter that is not removed represents a replacement of nitrogen into the soil as it decomposes or is turned under by cultivation. Moisture from snow and rain is essential to creating a good planting environment and remaining residue acts as a barrier for water evaporation. Prewitt et al. (2007) used 3 different methods of baling corn residue and achieved removal rates of 32.1 to 94.5% of the available residue. The authors suggest that removing 74.1% of the residue seemed most economical and sustainable.

Cattle will select the most nutritious parts of the plant first, consuming grain first followed by husk, leaf, and some cob material (Vetter et al., 1970; Petriz et al., 1975;

Klopfenstein et al., 1987). Variation in quality of residue can be attributed to plant part, genetics, maturity, and plant growing conditions (Acock, 1978; White et al., 1981; Erickson, 1982; Klopfenstein et al., 1987; Rasby et al., 2008). Digestibility of residue decreases with weathering (Lamm, 1976) and the microbial activity involved with decomposition (Berger et al, 1979). A summary of nutrient quality analyzed in trials to date can be found in Table 1. Russell et al. (1993) estimated weathering losses accounted for 20.2-30.8% of OM loss over a 56 d grazing season. Due to improvements in harvesting methods and genetics of corn hybrids, very little grain remains in the field after harvest (Rasby et al., 2008). Irlbeck et al. (1991) estimated this amount to be approximately 4%.

Compositional changes in corn crop residues were evaluated by Lamm and Ward (1981). Residue was collected from fenced off enclosures (4.57m x 9.75m) inside each lot (8.1 ha) both before and after grazing and were analyzed for OM, CP, NDF, ADF, ADL, and IVOMD. Crude protein decreased over time for all plant parts except leaf and husk material ($P < 0.05$). In-vitro organic matter digestibility decreased over time for all plant parts ($P < 0.05$). Neutral detergent fiber, ADF, and ADL increased over time ($P < 0.05$).

Fernandez-Rivera and Klopfenstein (1989a) evaluated the residue yield, relative plant part composition and quality of plant parts in dryland and irrigated cornstalks as well as residue utilization by grazing calves. Dryland fields were stocked at either 1.3 or 2.3 AUM/ha while irrigated fields were stocked at 2.3 AUM/ha. Dryland corn had a higher proportion of leaf plus husk material and a lower proportion of stems compared to irrigated corn ($P < 0.05$). However, utilization was greater for irrigated fields ($P < 0.05$)

possibly due to greater consumption or increased trampling losses due to increased stocking rates. Crude protein of all plant parts was greater for dryland fields compared to irrigated fields ($P < 0.05$). Leaf plus husk IVDMD was not different between dryland and irrigated stalks but decreased over time ($P < 0.05$). The rate of decline of IVDMD increased ($P < 0.05$) as stocking rate increased which the authors attribute to the effect of selection by the animal of the more digestible husk and leaf fractions.

The same authors conducted a similar trial (Fernandez-Rivera and Klopfenstein, 1989b) and reported that extrusa CP content was higher than CP content of the forage available. This can be attributed to selection of plant parts with higher CP content and N added through saliva contamination (Van Dyne and Torell, 1964). As grazing continued, extrusa NDF content increased ($P < 0.05$). Digestibility of dietary roughage decreased with time ($P < 0.05$); this decrease was greater at higher stocking rates ($P < 0.05$). Irlbeck et al. (1991) also compared dryland and irrigated corn and found no difference in quantity of grain, leaf, and husk. At a high stocking rate (3.1 AUM/ha vs. 1.6 AUM/ha) however, a negative relationship was observed between performance and digestibility.

Grazing corn crop residues- stocking rate

On average, ruminants will consume approximately 2% of their BW daily. However, when consuming low quality forages this number may be closer to 1.5% (Holechek, 1988). Much research has been conducted to estimate forage intake on the basis of a standard animal. The term animal unit (AU) is commonly used in reference to grazing strategies but is inconsistently defined across publications. Several authors (SRM, 1989; Iowa State University, 1998; USDA NRCS, 2003) define the AU as a

mature, 454 kg cow, with or without a calf up to 6 months of age, consuming 11.8 kg (DM)/d or 354 kg/month. Waller et al. (1986) defined the AU as a mature 454 kg cow, with or without a calf up to 4 months, consuming 340 kg (DM)/month. This estimate is commonly used in Nebraska. The AU can also be thought of in terms of days (AUD), months (AUM), or year (AUY; Meyer, 2010).

Stocking rate refers to the amount of land area necessary to maintain an AU for a specific amount of time and is often expressed as AUM/ha. Stocking rate influences the amount of residue available per animal and, consequently, animal performance (Rasby et al., 2008). Russell et al. (1993) compared stocking rates of 0.57, 1.14, and 2.24 AUM/ha in a continuous grazing system and demonstrated cows grazing corn residues are less likely to gain BW at stocking rates below 2.2 AUM/ha. Fernandez-Rivera and Klopfenstein (1989a) compared the utilization of residue by beef calves at different stocking rates. Stocking rates were adapted from Lamm and Ward (1981) and adjusted for calf body size and irrigation of the field. In trial 1, irrigated fields were grazed at 2.3 AUM/ha and dryland fields at 1.3 or 2.3 AUM/ha. Trial 2 compared rates of 1.4, 1.9, and 2.5 AUM/ha for dryland fields and 2.5 and 4.8 AUM/ha for irrigated fields. No differences ($P > 0.05$) in utilization rate between treatments were observed in trial 1; however, dryland fields grazed at 2.3 AUM/ha tended to have greater utilization than fields grazed at 1.4 AUM/ha. In trial 2, irrigated fields had greater utilization ($P < 0.05$) than dryland fields. The authors hypothesized this was a result of the greater consumption and trampling losses associated with increased stocking rates. In-vitro dry matter digestibility of the residue decreased with time ($P < 0.05$) and this rate increased as stocking rate increased ($P < 0.05$).

The same authors conducted a similar trial (Fernandez-Rivera and Klopfenstein, 1989b) in which dryland fields were grazed at 1.4, 1.9, and 2.5 AUM/ha for 58 d or 2.8 AUM/ha for 44 d. Irrigated fields were grazed at 2.5 and 4.8 AUM/ha for 58d. Stocking densities were designed to exceed both upper and lower limits imposed in the previous experiment. Dietary CP content and IVDMD decreased ($P < 0.05$) with time and the rate of decrease was greater as stocking rate increased.

Predicting intake is an important factor in utilizing corn residues. Perry and Olson (1975) found a close relationship between corn grain and residue yield. In a summary of research, Wilson et al. (2004) reported approximately 7.3 kg (DM) of leaf and husk residue is produced for every bushel of grain yield. Nebraska corn production averaged 11,172 kg/ha in 2009. If we assume that 50% of the leaf and husk material is available for consumption (Rasby, 2008) and an AU consumes 340 kg (DM)/month (Waller, 1986), we can calculate an average Nebraska field has a potential stocking rate of 5.1 AUM/ha.

Forage Protein

Metabolizable protein system

The metabolizable protein system accounts for rumen degradation and separates dietary CP based on the needs of the rumen microorganisms and the needs of the animal (NRC, 1996). Degradable intake protein (DIP) includes the dietary protein and non-protein nitrogen needed for growth and maintenance of rumen microorganisms. The protein that escapes ruminal degradation and flows into the small intestine for absorption

is referred to as undegradable intake protein (UIP; NRC, 1996). Metabolizable protein (MP) that is absorbed in the small intestine is composed of bacterial crude protein (BCP) synthesized in the rumen and UIP from the diet. However, not all of this protein is available to the animal. Bacterial crude protein is assumed to be 80% true protein and 80% digestible which results in a 64% BCP efficiency (NRC, 1996). Undegradable intake protein is also assumed to be 80% digestible. The digestibility of UIP, however, is variable across, and even within, protein sources (Church, 1993).

Bacterial crude protein can supply anywhere from 50 to nearly 100% of the MP required by beef cows but is dependent on the UIP content of the diet (NRC, 1996). Synthesis of BCP is likely to be lower on low quality forage diets compared to concentrate based diets (NRC, 1996). Because of the decreased rate of passage associated with low quality forages, more digested energy is used for maintenance of the microorganisms which decreases the efficiency of BCP synthesis (Russell and Wallace, 1988; Russell et al., 1992).

Digestibility of undegradable intake protein

The NRC (1996) model assumes a constant UIP digestibility of 80% but states that this value is variable. The Dairy NRC (2001) recognizes the variability of UIP digestibility and now uses values ranging from 50-100% in the model. The length of incubation of forages in the rumen can significantly influence the digestibility of UIP. Von Keyserlingk (1996) found UIP digestibility estimates may be overestimated when incubation time in the rumen is too short. The digestibility of the UIP of forages is likely lower than the UIP digestibility of concentrates (Haugen et al., 2006). Frydrynch (1992) reports digestibilities of 88.2% for concentrates and 70.8% for forages.

Research at the University of Nebraska-Lincoln has found forages often have much lower UIP digestibilities than the 80% assumption of the NRC (1996), however, many feedstuffs also have a greater than 80% UIP digestibility. Benton et al., (2006) determined the CP, IVDMD, UIP (% DM), and UIP digestibility of subirrigated meadow and upland range in the Sandhills as well as several commercial feedstuffs (Table 2). From May to September, the CP decreased 39.8% (14.1 to 8.5%) for meadow ($P < 0.05$) and 22.7% (12.2 to 9.4%) for range ($P < 0.05$). For the same time period, IVDMD decreased 28.2% (70.2 to 50.4) for meadow ($P < 0.05$) and 22.4% (67.7 to 52.5) for range ($P < 0.05$). The UIP content decreased 32.9% from June to September for meadow. Undegradable intake protein was similar from May to July ($P > 0.05$) and from July to September, UIP increased 64.6%. From May to September, UIP digestibility decreased 85.1% (43.3 to 6.5%) for meadow and 67.5% (40.2 to 13.1%) for range.

Geisert et al. (2007), measured CP, IVDMD, UIP (% CP), and UIP digestibility of five hays, prairie, mature alfalfa, mature brome, immature brome, and immature alfalfa (PR, MAlf, MBro, IBro, and IAlf), for the comparison of invivo and invitro values; Table 2). Crude protein was 7.9, 16.3, 7.5, 9.3, and 17.6 for PR, MAlf, MBro, IBro, and IAlf respectively. Undegradable intake protein content ranged from 10.1 for IAlf to 37.2 for MBro. Digestibility of UIP was greatest for MAlf (62.4%) and lowest for IBro (34.0%). These values are similar to results from Haugen et al. (2006).

Mobile nylon bag method for analysis of protein degradability

The use of mobile bags containing feedstuffs for the determination of ruminal and intestinal protein degradability is not new. Quinn et al. (1938) used silk based bags for ruminal incubations. The material used for bags was changed with the advent of artificial

fabrics resistant to microbial degradation (Ørskov, 1982). Schowman et al. (1972) used polyester bags and Mehrez and Ørskov (1977) suggested the use of nylon bags. Nylon bags are not suitable for all feed materials, especially very finely ground material such as distillers grains. The bag must allow the entry of rumen microbes and the escape of accumulated gasses while keeping losses of sample to a minimum. Ørskov (1982) recommends using bags with a mesh size of 20-40 µm and pore sizes of 400-1600 μm^2. Sample size and bag size is dependent on the amount of residue required for analysis.

de Boer et al. (1986) evaluated the mobile nylon bag technique for estimating intestinal availability of UIP. They placed bags containing sample into a polyester mesh bag which was then inserted into the rumen for 0, 2, 4, 8, 12, and 24 hours for incubation. Zero hour bags were not inserted into the rumen but were mechanically washed for estimation of DM and CP. Two bags from each incubation time were inserted into the small intestine through a duodenal cannula at a rate of one bag per 45 minutes. Bags not inserted into the intestine were frozen and stored. Bags inserted into the intestine were not washed after ruminal incubation. Upon recovery from the rumen and feces, the bags were mechanically washed, dried in a 60°C forced air oven for 24 hours, weighed, and digested intact for nitrogen analysis. Rumen CP and DM disappearances increased with incubation time for all feeds tested.

The most popular method of estimating UIP digestibility is the mobile bag method; however, microbial contamination of in situ residue is a problem (Michalet-Doreau and Ould-Bah, 1992). Mass et al. (1999) evaluated the use of in situ neutral detergent insoluble nitrogen (NDIN) as an estimate of UIP relative to total in situ N and microbial corrected N. Several hay samples and solka floc were ruminally incubated for

analysis. The residue in each bag was subsamples and analyzed for three pools of N including total residual N (TN), microbial corrected N (MN), and neutral detergent insoluble N (NDIN). Neutral detergent insoluble N was measured by conducting the neutral detergent extraction procedure on the residue and then analyzing the residue for N. Total nitrogen estimates were higher (P = 0.05) than those calculated by using MN or NDIN. Microbial nitrogen and NDIN estimates were not different (P = 0.48). UIP estimates for TN are greater than those for MN and NDIN, indicating that correction for microbial contamination is necessary. The authors conclude the in situ NDIN method provides an accurate estimate of forage UIP.

Haugen et al. (2006) used a slightly different procedure for determining UIP digestibility of smooth bromegrass and birdsfoot trefoil. Bags containing sample were placed into a mesh bag with a 100g weight for ruminal incubation. Bags were weighted to ensure the samples did not float to the top of the mat layer which would likely hinder degradation. Time points for ruminal incubation included 0, 10 hour, 75% total mean retention time (TMRT), and 72 hours. After ruminal incubation, bags were washed in a washing machine for 15 minutes using 5 rinse cycles consisting of a one minute agitation and a two minute spin. Bags for duodenal insertion were frozen and stored. All other bags were refluxed in NDF solution for determination of neutral detergent insoluble nitrogen (NDIN). Ruminally incubated bags for duodenal insertion were put into a pepsin and HCl solution at 37°C for three hours to simulate abomasal digestion. Bags were inserted into the duodenum two hours after feeding at a rate of 1 bag per 6 minutes, for a total of 8 bags per steer daily. To correct for possible microbial contamination, bags collected in the feces were immediately frozen until all bags were collected. Bags were

then machine washed and refluxed in NDF solution, dried in a 60°C forced air oven for 48 hours, air equilibrated for 3 hours, and reweighed. Residue was then analyzed for N in a combustion analyzer for calculation of protein fractions and UIP digestibility. Digestibility of UIP decreased in smooth bromegrass (38.6 to 27.1%; $P < 0.01$) from June to July. For the same time period, UIP digestibility did not significantly differ for birdsfoot trefoil (21.1 to 25.1%; $P = 0.07$). The authors suggest the increase in UIP digestibility in birdsfoot trefoil might be attributed to tannins which offer some protection from rumen degradation.

Undegradable intake protein digestibility of corn residue has never been measured.

Transgenic corn hybrids

Development of transgenic hybrids

The development of new corn hybrids by selection to increase desired traits has been essential in influencing current hybrids. Transgenic technology was developed in the early 1980's and allows the transfer of genes from one organism to another. Transgenic plants have been genetically modified using recombinant DNA technology to introduce a gene from either the same or a different species (Persley et al, 1999). Application of this DNA technology allows for more rapid development of hybrids that contain new and desirable traits. Persley et al. (1999) acknowledged "the ability to transfer genes from any other plant or other organism into a chosen recipient means that the entire span of genetic capabilities available among all biological organisms has the potential to be genetically transferred or used in any other organism." The application of

biotechnology such as DNA modification can improve yields with fewer inputs, allow corn to be grown in a wider range of environments, help conserve natural resources, provide more nutrition in harvested products which keep longer in storage and transport, ultimately leading to a continued low cost food supply to consumers.

Corn makes up a large percentage of the transgenic crops grown in the U.S. and worldwide. In 2007, approximately 24% of the corn grown globally was genetically modified (ISAAA). The USDA (2010a) estimates that transgenic hybrids made up 86% of all corn planted in the U.S. in 2010. This has increased from 25% in 2000. There are several types of genetic modifications in corn plants. The most widely used contain a gene for insect resistance (Bt), herbicide resistance, or both. Bt corn has been modified to express a gene from a common soil bacterium, Bacillus thuringiensis (Saxena and Stotkzy, 2001; Vander Pol et al., 2005). Most commonly inserted into the plant is the cry1Ab gene for the control of the European corn borer (Saxena and Stotkzy, 2001) or the cry3Bb1 gene for the control of corn rootworm (Wright et al., 1999). Corn borers reduce the quality and yield of corn and increase the opportunity for fungal growth by damaging plant tissue (Clark and Ipharraguerre, 2001).

Nutritional composition of transgenic corn, silage, and corn residues

Concerns about the safety of transgenic hybrids for livestock feed led to several feeding trials comparing the nutrient quality and preference of grazing animals between transgenic and non-transgenic corn. Folmer et al. (2002) tested the utilization of residue by grazing steers and Bt corn silage and grain fed to growing beef cattle and lactating dairy cows. Four commercially available hybrids, two Bt and two non-Bt, were included in the trial. Preference of the Bt and non-Bt hybrids was also evaluated. Crude protein

content of the silages was not different between hybrids. Lignin content was slightly greater for Bt hybrids compared to non-Bt hybrids. The authors note these data agree with Faust and Spangler (2000) who evaluated Bt and non-Bt hybrids and found no difference in nutritional quality. Bt hybrids did not affect steer ADG ($P = 0.12$). Also, no significant preferences were observed between Bt and non-Bt corn residues. Hendrix et al. (2000) also found no effect of the Bt trait on preference.

Transgenic and non-transgenic corn was made into silage and used in digestion experiments with wethers and in long-term studies with growing and finishing bulls (Flachowsky et al., 2005). No significant differences were observed in nutritional quality, health of the animals, or carcass quality between the two hybrids.

Vander Pol et al. (2005) evaluated the effects of grazing residues or feeding corn from a Bt hybrid on animal performance and carcass characteristics. Steer ADG and final BW were not influenced ($P > 0.25$) by the presence of the Bt gene. Digestibility of husks, leaves, and stems were also not different at the beginning of the trial between the Bt and non-Bt hybrids. No differences ($P > 0.01$) were observed in initial BW, final BW, ADG, G:F, marbling score, 12th rib fat thickness, or LM area between hybrids.

Previous research has also indicated no differences when feeding transgenic corn to grazing cattle (Hendrix, 2000; Russell et al., 2001; Wilson et al., 2003), feedlot cattle (Kerley et al., 2001; Folmer et al., 2002; Erickson et al., 2003), or dairy cattle (Folmer et al., 2002; Grant et al., 2003).

Cattle will consume leaf and husk material first, cobs to a lesser extent, and very few stems. Variability of nutritional quality of corn residue can be attributed to plant part, genetics, maturity and growing conditions. Quality of residue and stocking rate can

affect cattle performance. Increased stocking rates tend to decrease animal performance because less high quality material is available per animal. The use of transgenic corn hybrids, specifically Bt hybrids, has greatly increased in the last decade. Nutritional quality of transgenic and non-transgenic corn and corn residues are very similar. Cattle do not exhibit preferences between transgenic and non-transgenic residues.

The objective of these studies was to examine diet quality of corn residue at different stocking rates and the impact of residue quality on animal performance as well as the nutrient quality of residue from several commercially available corn hybrids in Nebraska.

Literature Review Table 1. Summary of nutritional quality of corn residue found in extension and peer-reviewed publications.

Citation	CP,%	NDF,%	IVDMD,%	IVOMD,%	Comments
Rasby et al., 2008					
Grain	10.2			90.0	
Leaf	7.0			58.0	
Husk	3.5			68.0	
Cob	2.8			60.0	
Stem	*3.7*			51.0	
Fernandez-Rivera et al., 1989	6.6-5.0		71.5-51.3		All residue combined
Fernandez-Rivera and Klopfenstein, 1989a	5.6-4.8	84.2-81.9	45.2-40.8		All stalks, before and after, irrigated
Fernandez-Rivera and Klopfenstein, 1989b					
All stalks	3.0-7.0	80-86	44-51		
Leaf + husk	3.0-7.1	80-86	47-52		
Diet composition	6.0-10.0	51-67	58-71		
Klopfenstein et al., 1987					
All stalks	3.4	85.0	46.8		
Leaf	3.7	85.0	51.6		
Grain	9.6	23.3	91.4		
Stem	3.0	84.4	42.6		
Cob	2.6	94.1	33.6		
McDonnell, 1982					
Stem			48.4-58.0		
Leaf			54.7-57.8		
Cob			50.6-60.7		
Husk			63.8-68.9		
All Stalks			52.0-58.6		
Bartel et al., 1984					
Stem + leaf			42.4-61.2		
Husk			59.4-69.5		
Cob			36.3-47.7		
Leask and Daynard, 1973					
Leaf			48.0-64.0		
Stem			25.0-52.0		
Husk			49.0-70.0		
Roth et al., 1987					
Stem + leaf			48.0-63.0		
Husk			60.0-72.0		
Cob			32.0-46.0		

Lamm and Ward, 1981					All values given as a % of OM
Before					
Grain	12.6			95.2	
Cobs	6.8	71.5		62.2	
Stems	6.6	61.5		62.1	
Husk + leaf	7.3	68.4		66.2	
After					
Grain	12.2			92.5	
Cobs	5.6	85.8		37.7	
Stems	5.8	73.3		48.8	
Husk + leaf	7.6	78.6		47.9	
Vetter, 1973b					
Stalk	3.8				
Leaf	8.6				
Husk	3.7				
Cob	2.3				
Perry, 1973	3.6-5.7		36.0-50.0		
Vetter et al., 1970	4.24-3.31		48.2-42.3		

Literature Review Table 2. UIP digestibility of several feedstuffs found in Nebraska Beef Reports.

Item	CP, %	IVDMD,%	UIP, % CP	UIPDIG, % UIP[1]
UR, Sept[3]	9.4	52.5	2.44[2]	13.1
SIM, Sept[3]	8.5	50.4	1.26[2]	6.5
BM[3]	84.7	-	89.5	89.6
CGM[3]	70.1	-	69.7	94.9
DDGA[3]	29.7	-	55.7	90.0
DDGB[3]	31.0	-	51.3	88.9
Bran21[3]	14.4	-	18.6	31.3
Bran30[3]	14.4	-	16.6	35.4
SS[3]	8.9	61.6	19.9	36.3
Cobs[3]	3.8	47.0	91.1	51.6
Prairie[4]	7.9	52.8	27.9	40.1
MAlf[4]	16.3	58.6	14.9	62.4
MBrome [4]	7.5	54.5	37.2	58.9
IBrome[4]	9.3	60.1	22.6	34.0
IAlf[4]	17.6	67.1	10.1	46.0

[1] UIP digestibility.
[2] % DM
[3] Reproduced from Benton et al., 2006. Samples: UR Sept= Upland range tested in September; SIM=Sub-irrigated meadow tested in September; BM=bloodmeal; CGM=corn gluten meal; DDGA and DDGB=dried distillers grains from two sources; Bran21 and Bran30=corn bran ruminally incubated for 21 and 30 hours respectively; SS=sorghum silage; Cobs=corn cobs.
[4] Reproduced from Geisert et al., 2007. Samples: Prairie=prairie hay; MAlf=mature alfalfa hay; MBrome=mature brome hay; IBrome=immature brome hay; IAlf=immature alfalfa hay.

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Effect of Stocking Rate on Animal Performance and Diet Quality While Grazing Corn Residue

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Abstract

A grazing trial compared the effect of stocking rate on corn residue removal and nutrient quality over a 55 d period. Treatments included no removal (control), light grazing (2.5 animal unit months/ha), heavy grazing (4.9 animal unit months/ha), and baling (bale), that were applied to eight 6.6 ha paddocks (2 replications) on a 53 ha center pivot irrigated field of corn residue from mid-December to mid-February. Residue samples were collected prior to and after grazing at 10 locations within each paddock using a 1/2 m^2 quadrat. After collection, samples were sorted by plant part (leaf, stem, husk, cob, and grain), and analyzed for DM, OM, CP, NDF, and in-vitro organic matter disappearance (IVOMD). No three or two-way interactions were observed for amount of residue OM (kg/ha; $P \geq 0.61$), but amount of residue differed by plant part and time collected ($P \leq 0.02$). Of residue remaining before grazing, stems make up the greatest proportion (42.1%) followed by leaves (33.8%), cobs (14.1%), and husks (9.9%). Little removal of stems (2% of original amount) was observed. Cobs and leaves were moderately removed from the light stocking rate (41.1% and 35.0%, respectively) and heavy stocking rate (26.8% and 20.0%, respectively) compared to control (17.9% and 0%, respectively). Proportionally, most husks were removed from the heavy stocking rate treatment (87.9%), moderately for light stocking rate treatment (54.3%), and least for control treatment (32.3%).Leaf residue (5.6 to 6.1%%) had greater CP compared to husks (3.5 to

4.6%), cobs (3.8 to 4.9%), and stems (3.0 to 3.6%) prior to grazing. Cob (87.2 to 88.0%) and husk (86.8 to 91.6%) residue had greater NDF content compared to leaf (78.4 to 82.0%) and stem (80.2 to 84.9%). In vitro OM digestibility of the residue numerically decreased over grazing time for all plant parts among all treatments except for husk residue from the CON treatment and leaf residue from the LG treatment ($P < 0.01$). Undegradable intake protein digestibility ranged from 6.37% to 40.7%. Cattle grazing corn residue removed primarily husk, leaf, and to a lesser extent, cobs. Husk and leaf had greater IVOMD and CP than cob or stem. Cob and husk residue had greater NDF content compared to leaf and stem residue. The low UIP digestibility of corn residue, combined with low CP values, suggest cattle grazing corn residues need to be supplemented with a protein source to meet requirements. Cattle on all treatments lost BW. Cattle on the HG treatment lost more BW compared to the LG treatment ($P = 0.05$). Mature cows lost more BW compared to heifers ($P = 0.05$)

Introduction

The most expensive component of raising beef cattle is winter feed sources (Reid and Klopfenstein, 1983). Utilization of corn residue to extend the grazing season is an economically viable option for wintering cattle (Wilson et al., 2004). Grazing corn residue presents a unique situation because all the forage available for consumption is present at the beginning of grazing. Cattle will select the highest quality plant parts first, consuming husk and leaf material before cobs and stems (Vetter et al., 1970; Petriz et al., 1975; Klopfenstein et al., 1987). Wilson et al. (2004) reported husk (3.6% CP and 67% IVDMD) and leaf (7.8% CP and 47% IVDMD) were more palatable than stem (4.5% CP

and 45% IVDMD) and cob (2.2% CP and 35% IVDMD). Fernandez-Rivera and Klopfenstein (1989a) observed that 65 to 72% of DM utilized was represented by leaf and husk. Variation in quality of residue can be attributed to plant part, genetics, maturity, and plant growing conditions (Acock, 1978; White et al., 1981; Erickson, 1982; Klopfenstein et al., 1987; Rasby, 2008).

Demand for corn grain increases supply of corn residue but weather and demand by cattle producers for grazing may reduce availability. Some producers may then increase stocking rates, which limits the amount of highly digestible forage available to each animal; therefore, digestible residue decreases at an increasing rate. The decreasing quality of forage available for consumption also leads to decreased animal performance (Fernandez-Rivera and Klopfenstein, 1989a; Cline et al., 2010).

The objectives of this study were to 1) evaluate animal performance by measuring BW and body condition score (BCS) change and 2) compare changes in nutrient quality of residue at two different levels of residue removal by increasing the stocking rate of cattle.

Materials and Methods

Fifteen non-lactating crossbred beef cows (567 ± 90 kg) in the third trimester of pregnancy and 63 first calf, crossbred, beef heifers (399 ± 37 kg) also in the third trimester of pregnancy, were assigned randomly to treatment paddocks. Paddocks were assigned randomly to one of four treatments with two replications per treatment.

Treatments included no removal (CON), light grazing (LG), heavy grazing (HG), and baling (BALE). The grazing treatments were designed to provide stocking rates of

2.5 and 4.9 animal unit months per acre (AUM/ha) for the light and heavy grazing paddocks respectively. Treatments were applied to eight 6.6 ha paddocks on a 53 ha center pivot irrigated field of corn residue for 55 days from December to February.

Animals were weighed and assessed for BCS prior to trial initiation and after grazing. Cattle were supplemented with a 28% CP distillers grain cube at a rate of 0.45 kg/cow daily. Supplement was formulated to provide176 mg/kg of Rumensin.

Residue samples were collected prior to grazing at 10 locations within each paddock using a 1/2 m^2 quadrat. Ten samples were collected after grazing from the LG and HG paddocks as well as three samples from the CON and BALE paddocks. After collection, samples were sorted by plant part (leaf, stem, husk, cob, and grain) and composited into one sample of each part per paddock and per sampling date. Crude protein was measured using a combustion N analyzer (Leco FP-528, St. Joseph, MI). Neutral detergent fiber analysis was conducted according to Van Soest (1991). In vitro OM digestibility was determined using the Tilley and Terry method (1963) with the addition of 1 g/L of urea to the buffer solution (Weis, 1994). Samples were incubated in a water bath at 39˚C and swirled every 12 hours. After incubation, samples were filtered, dried for 24 hours in a 100° C forced air oven, and burned in an ash oven for 6 hours at 700º C to determine the DM and OM content of residue for the calculation of IVOMD. Neutral detergent fiber and IVOMD analysis were conducted on an OM basis to correct for soil contamination of samples. All IVOMD runs included 5 feed standards with known in vivo OM digestibility. The IVOMD of these standards was then regressed on their known digestibilities to develop regression equations for comparison of experimental samples between runs. The method was developed by Geisert et al. (2007).

Undegradable intake protein (UIP) and total tract indigestible protein as a percent of DM and OM, UIP digestibility, and intestinal disappearance of UIP were determined using the mobile nylon bag technique. Two ruminally fistulated and two duodenally fistulated steers were used to incubate 5 x 10cm Dacron bags (Ankom Inc., Fairport, NY) that had a pore size of 50 µm. Thirty-two husk, leaf, stem, and cob samples from the LG and HG treatments prior to grazing and from the CON treatment prior to and after grazing were used. These samples were selected to be representative of the forage quality at trial initiation and end. Samples were ground through a 2mm screen and heat sealed into the bags. All bags contained 1.6 g of sample. The bags were placed into a mesh bag containing a 100 g weight then placed into the ventral rumen at different time points corresponding to IVOMD. Lower quality samples were incubated longer to ensure adequate fermentation time. Incubation times were based on calculation of rate of passage with the following equation: $K_p = 0.07 * IVDMD (\%) – 0.20$ (Klopfenstein, et al., 2001), followed by determination of 75% total mean retention time (TMRT) with the following equation: $((1/k_p) + 10) * 0.75$. Bags were inserted at three time points depending on sample. Husks were incubated for 28hr, leaves for 33hr, stems and cobs for 39hr. After ruminal incubation, bags were rinsed in a washing machine for 5 cycles. Each cycle consisted of a 1 minute agitation followed by a 2 minute rinse. Following washing, half the bags were frozen, thawed, and refluxed in NDF solution to determine ruminal degradable intake protein (DIP) and UIP. The remaining bags were soaked for 3 hours in HCl and pepsin solution to simulate abomasal digestion and frozen prior to duodenal insertion. Bags were thawed and inserted into the duodenum at a rate of 1 bag every 5 minutes with a maximum of 12 bags per steer per day. Bags were collected in

the feces the following day. To correct for microbial contamination, bags collected in the feces were immediately frozen until all bags were collected. Bags were then hand washed and refluxed in NDF solution, dried in a 60°C forced air oven for 48 hours, air equilibrated for 3 hours, and reweighed. Residue was then analyzed for N in a combustion analyzer (Leco FP-528, St. Joseph, MI) for calculation of protein fractions and UIP digestibility.

Nutrient quality data were analyzed as a completely randomized design with treatment group as the experimental unit and paddock as random. Model effects included treatment, time, plant part, and all possible interactions. Results were considered significant when $P \leq 0.05$. Mobile bag data were analyzed as a completely randomized design. Model effects included time, plant part, and time by plant part interactions. Simple effects were considered significant when $P \leq 0.05$. Main effects were considered significant when $P \leq 0.1$.

Results and Discussion

Proportions of residue available before and after grazing are summarized in Table 1. No differences were observed in the proportions of plant parts available for grazing across treatments ($P = 0.81$; Table 2). Previous reports indicate cattle remove less than 1/3 of the organic matter available from the field and baling removes approximately 80% (Vetter et al., 1970; Ayers, 1973; Prewitt, 2007). Cattle on the LG treatment removed 24% (1657 kg OM/ha) of the available residue while cattle on the HG treatment removed 17% (1194 kg OM/ha). Of the residue removed by grazing, leaf and husk material were consumed in the greatest amount. The LG treatment removed 1,179 kg OM/ha of leaf

and husk material (71%) while the HG treatment removed 1061 kg OM/ha (88%). Cobs and stems were consumed to a lesser extent. Baling removed 6.0 metric tons OM/ha (83%).

Nutrient quality of corn residue is summarized in Tables 3 and 4. In general, leaf material had greater CP (4.8 to 6.4%) compared to husks (3.3 to 6.1%), cobs (3.0 to 4.9%), and stem (2.3 to 3.6%). The range of protein variability can be partially attributed to the variability of the field. Low spots allowed for moisture accumulation and likely higher protein content of plant parts from those areas. Protein content of the plant parts did not differ between treatments prior to or after grazing with the exception of stem and cob material post-grazing ($P > 0.05$). Previous research has found similar CP values for corn residue (Perry, 1973; Fernandez-Rivera and Klopfenstein, 1989a; Rasby, 2008). Some CP values were numerically greater at the end of grazing compared to before grazing. The increase could be attributed to the variability of the field or microbe activity during decomposition. Although the protein values observed in this trial are similar to previous research, these values are not high enough to maintain a gestating beef cow without supplementation.

Differences in NDF content between individual plant parts were observed ($P < 0.01$). Fiber content of individual plant parts was not different across treatments ($P > 0.05$; Tables 3 and 4). Fiber content tended to increase over time likely due to the consumption of the cell solubles.

Digestibility for husk residue was greatest (55.5 to 58.7%), intermediate for leaf (54.6 to 53.7%), and least for stem (48.9 to 50.7%) and cob residue (47.8 to 49.1%) at trial initiation. Digestibility values decreased at the conclusion of the trial (52.7% vs.

51.7%). Digestibilities of leaf and cob material in this trial were greater than values observed in previous research (Wilson et al., 2004). Past research showed greater digestibility for husk (66 to 68%) and stem (51 to 62%) material (Lamm and Ward, 1981; Rasby, 2008).

Protein characteristics of corn residue are reported in Table 5. An interaction between plant part and time was observed for UIP (%DM; $P = 0.05$), total tract indigestible protein (TTIDP, %DM; $P < 0.01$), and UIP digestibility ($P = 0.06$). Numerically, ruminal UIP (%DM) was similar for all plant parts prior to and after grazing, except for husk residue. Over grazing time, husk material decreased 12.7% in UIP content. Numerically, total tract indigestible protein (%DM) in cob and stem material was similar over grazing time. However, TTIDP in leaf and husk material increased over grazing time (0.97 to 1.10% and 0.77 to 1.08% for leaf and husk respectively). Overall, cobs appeared to have the greatest UIP digestibility (40.42%). Numerically, leaf and stem UIP digestibility did not change over grazing time (23.08 and 21.39% respectively). However, UIP digestibility of husk residue numerically decreased from 25.47 to 6.37%. Intestinal disappearance of UIP (%DM) was different between plant parts ($P < 0.01$), but did not differ with grazing time ($P = 0.20$). Cobs had the greatest DUIP at 0.92%. Leaf and stem disappearance were similar (0.31 and 0.25% respectively). Numerically, husk residue had the least DUIP at 0.17%.

Previous research on the UIP content and digestibility of corn residue is non-existent. Undegradable intake protein is absorbed across the wall of the small intestine and serves as a protein source for the animal itself along with bacterial CP. The digestibility of UIP plays a major role is how much of the diet UIP is actually available

for the animal. The Beef NRC model (1996) uses a constant UIP digestibility of 80%. The Dairy NRC (2001) recognizes the variability of UIP digestibility and now uses values ranging from 50 to 100%. Previous research shows that as forages become senescent, the content and digestibility of the UIP decreases (Benton et al., 2006). When corn is harvested the plant material is mature and will no longer change, therefore, undegradable intake protein of corn residue would not be expected to change over time. A significant decrease in UIP digestibility with time was not observed for any plant material except husks in this trial. From trial initiation to end, husk material decreased in UIP digestibility from 25.5% to 6.4%. Over grazing time, husk residue numerically increased in CP content for the CON treatment and was similar for LG and HG treatments. The 41% increase in TTIDP from 0.77 to 1.08% may explain the decrease in UIP digestibility. Cattle consume residual corn grain first, followed by husk and leaf material. It is likely that most of the husk residue was consumed before the UIP digestibility reached 6.4%. Cattle consuming residue with such a low UIP digestibility will need to be supplemented with a UIP protein source.

In retrospect, treatment groups were stocked at 3.4 and 6.9 AUM/ha for the LG and HG treatments, respectively. Cattle lost BW on both the LG (-5 kg) and HG (-31 kg; Table 6) treatments (P = 0.05). Cows (-31kg) lost more body weight compared to heifers (-5 kg; P = 0.05). Body condition score increased for cattle on the LG treatment, and decreased for cattle on the HG treatment ($P < 0.01$). Body condition scores were not different between cows and heifers (P = 0.71). Body condition scores are measured in whole numbers, 1 through 9, so although an interaction was observed between treatment

and age of the animal (P = 0.02) the difference is less than ½ BCS. Cattle lost weight on both treatments; however, large BCS changes did not occur.

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Table 1. Proportions of corn residue before and after grazing for all treatments[1].

	Plant Part					
	Grain	Husk	Leaf	Stem	Cob	Total
Control						
Amount Available, kg/ha	518	1300	4558	5599	1855	13830
Proportion Available, %	3.7	9.4	33.0	40.5	13.4	
Amount Removed, kg/ha	498	234	3	138	200	575
Amount Remaining, kg/ha	20	881	4552	5352	1499	12304
Proportion Removed, %	74.7	32.3	-1.31	4.0	17.9	
Light Grazing (3.4 AUM/ha)						
Amount Available, kg/ha	555	1215	4248	4913	1833	12764
Proportion Available, %	4.3	9.5	33.3	38.5	14.4	
Amount Removed, kg/ha	524	362	818	66	412	1657
Amount Remaining, kg/ha	91	570	2788	4796	1098	9343
Proportion Removed, %	94.1	54.3	35.0	3.8	41.1	
Heavy Grazing (6.9 AUM/ha)						
Amount Available, kg/ha	902	1227	3942	5353	1636	13060
Proportion Available, %	6.9	9.4	30.1	41.0	12.5	
Amount Removed, kg/ha	897	603	458	--	262	1194
Amount Remaining, kg/ha	5	150	3125	5583	1169	10032
Proportion Removed, %	99.3	87.9	20.0	-3.4	26.8	
BALE						
Amount Available, kg/ha	894	1223	4404	5463	1858	13842
Proportion Available, %	6.5	8.5	31.8	39.5	13.4	
Amount Removed, kg/ha	893	659	2239	2435	681	6015
Amount Remaining, kg/ha	2	23	408	1118	643	
Proportion Removed, %	99.8	96.5	91.1	80.2	68.8	2194

[1] *P*-values associated with proportions are available in Table 2.

Table 2. P-values associated with proportions and amounts of corn residue removed from all treatments.

	Proportion Available		Proportion Removed	
Effect	SE	P-value	SE	P-value
Treatment	0	1.00	41.86	< 0.01
Plant part	309.39	< 0.01	17.52	< 0.01
Treatment*part	0.56	0.81	3.5	0.02

Table 3. Nutrient quality of husk and leaf residue for all treatments before and after grazing.

Item	Control	Light Grazing	Heavy Grazing	Baled	SE	P-value
Husk						
Pre-grazing						
OM, %	97.7	97.1	97.7	96.8	.40	0.38
DM, kg/ha	745.8	700.2	703.4	708.5	105.17	0.99
OM, kg/ha	728.3	280.8	687.4	685.3	102.68	0.99
CP, %	4.1	3.5	3.6	4.3	0.19	0.10
NDF(OM), %	91.6	86.8	86.9	87.0	1.29	0.14
IVOMD, %	57.1	58.7	58.0	55.5	2.40	0.80
Post-grazing						
OM, %	95.9	97.2	95.1	--	1.44	0.63
DM, kg/ha	515.1[b]	327.4[ab]	88.0[a]	--	73.11	0.06
OM, kg/ha	494.0[b]	319.2[ab]	84.1[a]	--	71.98	0.06
CP, %	4.7	3.3	6.1	--	0.65	0.12
NDF(OM), %	86.5	88.9	81.4	--	2.20	0.19
IVOMD, %	58.6	57.7	57.5	--	1.00	0.74
Leaf						
Pre-grazing						
OM, %	87.1	85.6	85.0	87.3	1.62	0.72
DM, kg/ha	2939.6	2778.7	2614.2	2828.3	331.88	0.91
OM, kg/ha	2554.3	2380.4	2209.4	2468.0	252.10	0.80
CP, %	5.7	5.6	6.0	6.1	0.51	0.88
NDF(OM), %	81.7	82.0	79.1	78.4	1.55	0.38
IVOMD, %	54.1	54.6	54.5	53.7	0.58	0.70
Post-grazing						
OM, %	87.9	88.4	89.0	84.7	2.20	0.57
DM, kg/ha	2903.1[c]	1773.8[b]	1966.4[b]	277.5[a]	219.21	< 0.01
OM, kg/ha	2551.2[c]	1562.7[b]	1751.5[b]	228.6[a]	184.26	< 0.01
CP, %	5.4	4.8	4.8	6.4	0.38	0.12
NDF(OM), %	80.5	83.6	81.4	70.5	6.50	0.55
IVOMD, %	53.4[c]	54.6[c]	51.0[b]	47.9[a]	0.49	0.01

[abc] Means within a row with different superscripts differ.

Table 4. Nutrient quality of stem and cob residue for all treatments before and after grazing.

Item	Control	Light Grazing	Heavy Grazing	Baled	SE	P-value
Stem						
Pre-grazing						
OM, %	94.7	94.1	95.1	94.6	0.57	0.75
DM, kg/ha	3311.9	2872.9	3156.3	3234.2	363.12	0.84
OM, kg/ha	3137.5	2753.4	3000.0	3061.7	371.85	0.89
CP, %	3.3	3.0	3.2	3.6	0.32	0.69
NDF(OM), %	84.9	81.8	80.9	80.2	1.79	0.38
IVOMD, %	48.9	50.7	49.6	49.1	1.09	0.68
Post-grazing						
OM, %	96.0	95.9	95.9	93.1	0.85	0.18
DM, kg/ha	3124.3[b]	2799.2[b]	3261.5[b]	668.0[a]	534.10	0.07
OM, kg/ha	2999.3[a]	2687.8[a]	3128.9[a]	626.4[a]	520.10	0.08
CP, %	3.2[b]	2.3[a]	2.8[ab]	3.6[b]	0.20	0.05
NDF(OM), %	85.0	86.5	82.9	83.1	2.02	0.59
IVOMD, %	47.6	49.1	47.8	44.5	1.33	0.23
Cob						
Pre-grazing						
OM, %	97.3	97.6	96.6	96.8	0.87	0.84
DM, kg/ha	1710.7	1051.8	947.8	1078.4	430.31	0.62
OM, kg/ha	1661.6	1027.4	917.1	1041.5	415.10	0.62
CP, %	3.8	4.4	4.9	4.0	0.56	0.53
NDF(OM), %	88.0	87.3	87.2	87.8	1.60	0.98
IVOMD, %	48.6	48.9	49.1	47.8	0.89	0.77
Post-grazing						
OM, %	90.1	88.6	79.0	88.4	3.18	0.20
DM, kg/ha	933.8	694.0	836.0	413.9	167.68	0.28
OM, kg/ha	940.1	615.6	655.3	360.2	139.39	0.26
CP, %	3.9[b]	3.2[a]	3.0[a]	3.4[a]	0.10	0.01
NDF(OM), %	86.1	86.4	89.8	92.4	2.50	0.43
IVOMD, %	48.3	48.4	45.9	45.3	0.99	0.23

[abc] Means within a row with different superscripts differ.

Table 5. Protein characteristics of corn residue before and after grazing.

	CP, %DM	UIP[1], %DM	UIP, %CP	TTIDP[2], %DM	TTIDP[3], %CP	Digestibility of UIP[4], %CP	DUIP[5], %DM
Before Grazing							
Husk	3.75	1.03	27.44	0.77	20.37	25.47	0.26
Leaf	5.75	1.32	22.80	0.98	17.10	25.25	0.33
Stem	3.18	1.15	36.23	0.91	28.96	19.36	0.22
Cob	4.34	2.34	55.38	1.39	32.41	40.13	0.94
After Grazing							
Husk	4.71	1.15	26.51	1.08	24.30	6.37	0.07
Leaf	5.02	1.39	25.75	1.10	20.37	20.92	0.29
Stem	2.78	1.16	36.13	0.90	27.80	23.10	0.26
Cob	3.39	2.23	56.67	1.32	33.61	40.71	0.91
Time							
SE	0.12	0.02	0.76	0.02	0.64	2	0.03
P-value	0.10	0.33	0.31	< 0.01	0.06	0.13	0.20
Plant Part							
SE	0.16	0.03	1.11	0.03	0.93	2.93	0.04
P-value	< 0.01	< 0.01	< 0.01	<0.01	< 0.01	< 0.01	< 0.01
Interaction							
SE	0.4	0.04	1.51	0.04	1.27	4	0.05
P-value	< 0.01	0.05	0.53	<0.01	0.21	0.06	0.27

[1] Undegradable intake protein (UIP, %DM) = (NDIN at 75% total mean retention time * 6.25) /sample DM
[2] Total tract indigestible protein (TTIDP, %DM) = (fecal NDIN * 6.25) / sample DM
[3] Total tract indigestible protein (TTIDP, %CP) = (fecal NDIN * 6.25) / (sample DM * %CP)
[4] Digestibility of UIP = 1-(TTIDP/UIP)
[5] Intestinal disappearance of UIP (DUIP, %DM) = (UIP – TTIDP)

Table 6. Cattle performance grazing corn residue.

	LG	HG	SE	P-value	Cows	Heifers	SE	P-value
BW change, kg	-5	-31	6	0.05	-31	-5	6	0.05
BCS change	0.10	-0.17	0.04	0.01	-0.02	-0.04	0.04	0.71

Effect of Corn Hybrid on Amount and Quality of Residue Available for Grazing

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Abstract

Twelve commercially available corn hybrids were selected from test plots at two locations (Paxton and Scottsbluff, NE) for determination of residue quantity and quality. Ten plants per hybrid were selected as a representative sample, cut at ground level, and sorted into husk, leaf, stem, cob, and grain fractions. Plant density was measured by counting the number of plants present in a 4.6 m length of row. Husk, leaf, stem, and cob samples were composited into 5 samples per hybrid and analyzed for DM, OM, CP, NDF (DM and OM), and in vitro DM and OM digestibility. Corn grain yield among hybrids at Paxton were not different (13,240 kg DM/ha; P= 0.23). Differences were observed between hybrids in amount of husk, leaf, stem, and cob. Total OM content of all plant parts ranged from 86.0 to 99.2%. Crude protein was greatest in leaf material (6.0 to 7.7%), intermediate for husks (3.8 to 6.1%), and least for stems (2.7 to 5.1%) and cobs (2.2 to 3.7%; $P < 0.01$). Cobs (88.2 to 92.3%) tended to have the greatest NDF (OM) content compared to husk (80.0 to 84.9%), leaf (79.1 to 81.2%), and stem (72.0 to 84.7%). Greater digestibility was observed for husk and leaf material (58 and 52% respectively) compared to stem and cob material (49 and 48% respectively; $P < 0.01$). Organic matter digestibility of husk, leaf, and stem residue differed between hybrids ($P < 0.01$). Nutrient quality of residues in this trial is consistent with past research.

Introduction

The most expensive component of raising beef cattle is winter feed sources (Reid and Klopfenstein, 1983). Utilization of corn residue to extend the grazing season is an economically viable option for wintering cattle (Wilson et al., 2004). Grazing corn residue presents a unique situation because all the forage available for consumption is present at the beginning of grazing. Cattle will select the highest quality plant parts first, consuming husk and leaf material before cobs and stems (Vetter et al., 1970; Petriz et al., 1975; Klopfenstein et al., 1987). Wilson et al. (2004) reported husk (3.6% CP and 67% IVDMD) and leaf (7.8% CP and 47% IVDMD) were more palatable than stem (4.5% CP and 45% IVDMD) and cob (2.2% CP and 35% IVDMD). Fernandez-Rivera and Klopfenstein (1989a) observed that 65 to 72% of DM utilized was represented by leaf and husk. Variation in quality of residue can be attributed to plant part, genetics, maturity, and plant growing conditions (Acock, 1978; White et al., 1981; Erickson, 1982; Klopfenstein et al., 1987; Rasby, 2008).

Wilson et al. (2004) estimate that 0.29 kg of husk and leaf material is produced per kg of corn grain yield. However, this relationship varies among hybrids. Therefore, relative amount of plant parts, as well as their quality, could affect performance by grazing animals. The objectives of this research were to determine 1) whether differences exist among hybrids in the amount of residue available for grazing independent of corn grain yield and 2) whether residue from different corn hybrids differ in quality.

Materials and Methods

Hybrids representing a wide range of production traits were selected from test plots near Paxton and Scottsbluff, NE. The following hybrids were evaluated at Paxton: Pioneer P0541XR (hybrid 8), P1173HR (hybrid 38), P1395XR (hybrid 46), Dekalb 59-35 (hybrid 21), 61-04 (hybrid 35), NK N68B-GT (hybrid 29), N74C-3000GT (hybrid 48), Croplan Genetic 5757 VT3 (hybrid 10), Golden Harvest 8211 3000GT (hybrid 5), and Midwest Genetics 76482R (hybrid 25). Plots received center pivot irrigation and had a silt loam soil type. Dekalb 42-91(hybrid 1) and Mycogen 2R416 (hybrid 2) were produced at Scottsbluff.

The plot contained four 400 m rows per hybrid and rows were 76.2 cm apart. Plants were selected randomly for each hybrid by spacing samples about 30 meters apart then arbitrarily selecting the nearest plant. The plant 10 plants away from the arbitrarily selected plant was collected by cutting it at ground level. Collecting the plant 10 plants from the arbitrarily selected plant eliminated any bias in the selection of plants for collection. Plant density was measured by counting the number of plants present in a 4.6 m length of row.

Each plant was sorted into leaf (including leaf sheath), husk, stem, cob, and corn grain. Plant parts were dried in a forced air oven at 60º C then burned in an ash oven at 700º C for 6 hours to determine DM yield per plant and OM content. Plant density was calculated only for hybrids produced at Paxton. Yield was then expressed for each hybrid on a kg/ha basis using the following equation: average plant yield (kg)*plant density (# plants present in a 0.762 X 4.572 m area)/0.000348 ha. Plant part samples from all hybrids were composited into five samples per hybrid and analyzed for NDF, CP, and in-vitro organic matter disappearance (IVOMD). Neutral detergent fiber

analysis was conducted according to Van Soest (1991). Crude protein was measured using a combustion N analyzer (Leco FP-528, St. Joseph, MI). In vitro OM digestibility was determined using the Tilley and Terry method (1963) with the addition of 1 g/L of urea to the buffer solution (Weis, 1994). Samples were incubated in a water bath at 39˚C and swirled every 12 hours. After incubation, samples were filtered, dried for 24 hours in a 100° C forced air oven, and burned in an ash oven for 6 hours at 700º C to determine the DM and OM content of residue for the calculation of IVOMD. All IVOMD runs included 5 feed standards with known in vivo OM digestibility. The IVOMD of these standards was then regressed on their known digestibilities to develop regression equations for comparison of experimental samples between runs. The method was developed by Geisert et al. (2007).

Data were analyzed as a completely randomized design using the mixed procedures of SAS (SAS Inst., Inc., Cary, N.C.). Model effects included hybrid and part. Differences were considered significant when $P < 0.05$. Grain yield and plant density was not recorded for hybrids produced at Scottsbluff. Therefore, they are not included in those analyses. All twelve hybrids were evaluated for nutrient quality.

Results and Discussion

Corn grain yield among hybrids (15,754 kg/ha at 15.5% moisture; 13,240 ± 145 kg/ha, DM basis $P = 0.23$) at Paxton were not different. Differences were present between hybrids in amount of stems, leaves, husks, and cobs (Table 1). Total residue production (sum of stems, leaves, husks and cobs) was different among hybrids. However, differences also existed in the ratio of corn grain to total residue production

and corn grain to leaf and husk, indicating potential differences in plant efficiency. Wilson, et al. (2004) reported an average of 7.3 kg leaf and husk produced per 25.4 kg grain yield for corn producing 2,698 to 11,486 kg/ha. However, a relationship among hybrids was not observed in this trial (P = 0.87, R^2 = 0.004; Figure 3). Leaf and husk produced per 25.4 kg grain in the current study ranged from 6 to 9 kg. Husk and leaf weight (DM kg/ha) were correlated (P = 0.03, R^2 = 0.47; Figure 4); weight of husk material increased as weight of leaf material increased.

Nutrient quality of individual plant parts is summarized in Table 2. Nutrient quality of all hybrids is summarized in Table 3. In general, cobs had greater OM content, husks and stems were intermediate, and leaves contained the least. Total organic matter content of all plant parts ranged from 86.0 to 99.2%. Organic matter for individual plant parts tended to be numerically similar across hybrids but was significantly different (P < 0.01). Cobs contained approximately 96% OM, followed by husk (96%) stem (95%), and leaf (88%). Ash is primarily composed of soil and minerals such as potassium, phosphates, calcium, magnesium, manganese, zinc, and iron. Leaves are the primary residue part consumed by grazing cattle and their high ash content may be an important factor in regards to energy consumption and protein supplementation. The nutrient content of the leaf would be diluted by approximately 12% ash. The increased ash content of leaves compared to husk, stem, and cob, may be explained in part by the pH of the soil. Weaver and Hamill (1985) reported markedly increased manganese and zinc content in leaves from corn plants grown in low pH soil.

Crude protein was greatest in leaf material (6.0 to 7.7%) intermediate for husks (3.8 to 6.1%), and the least for stems (2.7 to 5.1%) and cobs (2.2 to 3.7%). Lamm

and Ward (1981) reported greater protein content for cob (6.8%) and stem (6.6%) material compared to this trial. However, the CP values observed in this trial are consistent with other previous research regarding corn residue (Vetter, 1973b; Klopfenstein et al., 1987; Fernendez-Rivera and Klopfenstein, 1989a; Rasby et al., 2008). Protein content was significantly different across hybrids for all plant parts ($P < 0.01$).

Neutral detergent fiber analysis was conducted on both a DM and OM basis. Organic matter analysis was conducted to correct for possible soil contamination of the corn residue. Among the plant parts, cobs tended to have the greatest amount of NDF on an OM basis (88.2 to 92.3%) compared to husk (80.0 to 84.9%), leaf (79.1 to 81.2%), and stem (72.0 to 84.7%). These values are supported by previous research (Klopfenstein et al., 1987; Fernandez-Rivera and Klopfenstein, 1989b). Fiber values observed in this trial are higher than those observed by Lamm and Ward (1981) who reported values for cobs at 71.5%, leaf plus husk at 68.4%, and stems at 61.5%. Fiber content of husk and stem material differed among hybrids ($P < 0.01$).

Husk material had greater DM digestibility (48.9 to 56.3%) compared to leaf (43.1 to 49.8%), stem (41.0 to 49.6%), and cob (38.9 to 46.8%). Husk and leaf material had greater digestibility than stems and cobs. In vitro digestibility was also conducted on both a DM and OM basis to account for any soil contamination within the sample. There was variation in OM digestibility among hybrids for the husk, leaf, and stem residue ($P <$ 0.01 Total residue digestibility among hybrids ranged from 48.1 to 57.5% ($P < 0.01$; Table 3). Digestibility of leaf or husk material was not highly correlated with leaf or husk residue weight ($P = 0.45$, $R^2 = 0.07$ for leaf and $P = 0.23$, $R^2 = 0.17$ for husk; Figures 1, 2). Residue digestibility observed in this trial is consistent with previous

research (Fernandez-Rivera and Klopfenstein, 1989b; Klopfenstein, 1987; Perry, 1973). Digestibility of plant parts observed in this trial is lower than those observed by McDonnell (1982) who reported values ranging from 64-70% for husks, 55-58% for leaves, 51-61% for cobs, and 49-58% for stems.

Improving crop residues for livestock consumption has largely been focused on chemical treatment to improve digestibility (Klopfenstein, 1981) or proper supplementation (Ward, 1973). However, because of natural variation in quality among crop residues, there is opportunity to capitalize on this variation through harvesting systems and/or hybrid selection (Bartle and Klopfenstein, 1988). As a plant matures, digestibility declines due to an increase in cellulose and lignin and a decrease in cell solubles. Higher quality residues may be obtained when plants are harvested at less mature stages. Steers fed stalklage from high moisture grain harvest had 0.2 kg/day greater ADG and were 19% more efficient compared to steers fed stalklage from dry grain harvest (Berger et al., 1979). This performance difference is explained in part by the increase in NDF and ADF from early to late harvest. Voluntary intake was improved in cattle when corn residue was harvested at higher grain moisture content (25%) compared to mature residue (15%; Johnson et al., 1984-85). In a trial conducted by Bartle et al. (1984), hybrids (n = 30) differed in the rate of stalk and cob IVDMD decline. Other research shows the decline in stover IVDMD ranging from 1.5 to 2.0 percentage unit/week (Leask and Daynard, 1973; Berger et al., 1979; McDonnell, 1983).

Nutritional value of corn residue may be influenced through hybrid selection. Leask and Daynard (1973) reported corn residue IVDMD ranging from 42 to 63% among 22 hybrids in Ontario, Canada. Residue use as a livestock feed source is secondary to

grain production. Improvements in residue quality therefore, cannot be made at the expense of grain yield. Bartle et al. (1984) and McDonnell (1982) reported correlations of less than 0.1 for the relationship between residue digestibility and corn grain yield. In the current trial, grain yield among the hybrids produced at Paxton were not significantly different and IVOMD ranged from 50-53%. Literature reviewed by Bartle and Klopfenstein (1988) demonstrated that it is possible to achieve a 10 percentage unit improvement in IVDMD with selection of hybrid cultivars and harvest maturity. The possibility for such improvement was not observed in this trial.

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Table 1. Composition of corn residue components of 12 corn hybrids grown in western Nebraska (DM basis)[3].

Hybrid[1]	Grain[2], kg/ha	Stem, kg/ha	Husk, kg/ha	Leaf, kg/ha	Cob, kg/ha	Total[4], kg/ha	Leaf+Husk, kg/bu
5	16,131	4,944[cde]	906[abc]	2,859[a]	1,553[b]	10,263[a]	5.9
8	15,754	4,508[bcd]	1,113[c]	3,556[b]	1,825[cd]	11,002[abc]	7.5
10	15,629	4,367[bc]	928[bc]	3,157[ab]	1,463[ab]	9,915[a]	6.6
21	16,696	4,423[bc]	909[abc]	3,512[b]	1,565[b]	10,408[ab]	6.7
25	15,943	4,214[ab]	989[bc]	3,269[ab]	1,649[bc]	10,121[a]	6.8
29	15,001	3,722[a]	1,103[bc]	3,374[ab]	1,555[b]	9,753[a]	7.6
35	15,441	5,067[de]	1,131[c]	3,725[b]	1,908[d]	11,830[bc]	8.0
38	15,503	5,289[e]	879[ab]	3,352[ab]	1,583[bc]	11,102[abc]	6.9
46	13,432	6,035[f]	968[bc]	3,648[b]	1,454[ab]	12,085[c]	8.7
48	14,499	5,071[de]	684[a]	2,918[a]	1,259[a]	9,931[a]	6.3
SE	690	223	82	206	89	535	
P-value	0.23	< 0.01	0.01	0.05	< 0.01	0.02	

[1] Where 1 = Dekalb 42-19, 2 = Mycogen 2R416, 5 = Golden Harvest 8211 3000GT, 8 = Pioneer P0541XR, 10 = Croplan Genetics 5757 VT3, 21 = Dekalb 59-35, 25 = Midwest Genetics 76482R, 29 = NK N68B-GT, 35 = Dekalb 61-04, 38 = Pioneer P1173HR, 46 = Pioneer P1395XR, 48 = NK N74C-3000GT.
[2] 15.5% moisture.
[3] Measurements are calculated from whole plants collected prior to harvest.
[4] Total = Stem, Husk, Leaf, and Cob residue
[abc] Means within a column with different superscripts differ (P < 0.05)

Table 2. Nutrient quality of husk, leaf, stem, and cob residue from 12 corn hybrids grown in western Nebraska.

	Plant Part					
Item	**Husk**	**Leaf**	**Stem**	**Cob**	**SE**	**P-value**
OM, %	96.4[c]	88.6[a]	95.5[b]	98.7[d]	0.13	< 0.01
CP, %	4.4[c]	6.9[d]	3.9[b]	2.9[a]	0.10	< 0.01
NDF (DM), %	81.5[c]	75.8[a]	77.7[b]	90.4[d]	0.35	< 0.01
NDF (OM), %	82.7[b]	80.5[a]	80.4[a]	90.1[c]	0.36	< 0.01
IVDMD, %	52.2[d]	45.7[c]	43.6[b]	42.1[a]	0.40	< 0.01
IVOMD, %	57.5[c]	52.3[b]	48.7[a]	48.1[a]	0.47	< 0.01

[abc] Means within a row with different superscripts differ.

Table 3. Nutrient quality of stem and cob residue for all treatments before and after grazing.

Item	1	2	5	8	10	21	25	29	35	38	46	48	SE	P-value
Husk														
OM, %	96.7^{cde}	96.9^{de}	96.3^{abc}	96.3^{abc}	96.9^{e}	96.4^{abcd}	96.5^{bcde}	96.3^{abc}	96.5^{bcde}	95.9^{a}	96.1^{ab}	96.5^{bcde}	0.18	0.01
CP, %	6.1^{d}	3.9^{a}	3.6^{a}	4.4^{abc}	5.1^{bcd}	4.4^{abc}	3.8^{a}	4.2^{abc}	3.8^{a}	4.1^{ab}	5.4^{cd}	4.3^{abc}	0.40	< 0.01
NDF (DM), %	79.7^{ab}	83.2^{d}	79.6^{a}	81.5^{bcd}	82.3^{cd}	82.6^{d}	81.0^{bcd}	82.7^{d}	83.5^{d}	81.4^{bcd}	80.0^{abc}	81.7^{bcd}	0.87	< 0.01
NDF (OM), %	80.5^{ab}	83.9^{d}	80.0^{a}	82.8^{bcd}	83.1^{cd}	83.8^{cd}	82.5^{abcd}	84.0^{d}	84.8^{d}	83.2^{cd}	81.4^{abc}	82.9^{bcd}	0.86	0.01
IVDMD, %	55.5^{f}	56.3^{f}	55.3^{ef}	51.4^{bcd}	50.5^{abc}	50.5^{abc}	48.9^{a}	50.1^{ab}	50.3^{ab}	51.7^{bcd}	52.6^{cd}	53.3^{de}	0.77	< 0.01
IVOMD, %	60.4^{de}	61.0^{e}	60.5^{de}	56.8^{abc}	55.9^{ab}	56.1^{ab}	54.5^{a}	55.6^{ab}	55.9^{ab}	57.2^{bc}	57.9^{bc}	58.5^{cd}	0.81	< 0.01
Leaf														
OM, %	88.0^{abc}	89.6^{cd}	86.0^{a}	88.1^{bc}	88.5^{bcd}	88.3^{bcd}	89.5^{cd}	89.5^{cd}	87.4^{ab}	90.3^{d}	89.9^{cd}	88.3^{bcd}	0.70	0.01
CP, %	6.9^{bc}	6.6^{ab}	6.8^{bc}	7.0^{bc}	6.8^{bc}	6.9^{bc}	6.9^{bc}	7.3^{bcd}	6.9^{bc}	7.5^{cd}	7.7^{d}	6.0^{a}	0.25	< 0.01
NDF (DM), %	76.0	76.1	74.7	76.3	75.6	75.9	75.4	76.6	75.1	76.5	76.3	75.2	0.69	0.69
NDF (OM), %	80.8	79.1	81.1	81.2	80.3	80.9	80.0	81.0	80.2	80.2	80.2	80.7	0.85	0.91
IVDMD, %	49.8^{c}	50.4^{c}	44.8^{ab}	45.6^{b}	45.5^{b}	44.0^{ab}	44.4^{ab}	45.4^{b}	43.1^{a}	45.4^{b}	44.4^{ab}	45.2^{b}	0.64	< 0.01
IVOMD, %	56.4^{b}	57.3^{b}	51.5^{a}	52.1^{a}	52.1^{a}	50.7^{a}	50.8^{a}	52.0^{a}	49.9^{a}	51.8^{a}	50.9^{a}	51.9^{a}	1.11	< 0.01
Stem														
OM, %	95.5^{bcd}	95.2^{abc}	95.8^{de}	95.7^{cde}	95.6^{bcde}	94.6^{a}	95.0^{ab}	95.6^{bcde}	95.2^{bc}	96.2^{e}	95.6^{bcde}	95.7^{cde}	0.22	< 0.01
CP, %	5.1^{f}	2.7^{a}	4.2^{de}	3.6^{bcd}	3.7^{bcde}	4.0^{de}	4.1^{de}	3.8^{bcde}	4.3^{e}	3.4^{bc}	3.3^{b}	4.0^{cde}	0.21	<0.01
NDF (DM), %	69.3^{a}	78.4^{ef}	75.7^{bc}	80.2^{fg}	82.0^{g}	78.2^{def}	81.1^{g}	81.4^{g}	75.8^{cd}	76.8^{cde}	73.2^{b}	80.0^{fg}	0.87	< 0.01
NDF (OM), %	72.0^{a}	81.7^{efg}	77.8^{bc}	82.7^{fgh}	84.7^{h}	81.3^{def}	84.4^{h}	84.3^{gh}	78.8^{cd}	79.2^{cde}	76.0^{b}	82.6^{fgh}	0.94	< 0.01
IVDMD, %	49.6^{c}	48.5^{c}	43.0^{ab}	42.9^{ab}	41.2^{a}	42.9^{ab}	41.0^{a}	41.4^{a}	41.2^{a}	42.7^{ab}	45.6^{b}	43.8^{ab}	1.03	< 0.01
IVOMD, %	54.5^{c}	53.2^{bc}	48.3^{a}	47.8^{a}	46.4^{a}	47.9^{a}	46.0^{a}	46.7^{a}	45.9^{a}	47.9^{a}	50.4^{abc}	49.0^{ab}	1.68	0.01
Cob														
OM, %	99.2^{d}	98.7^{bc}	98.6^{bc}	99.0^{cd}	98.7^{bc}	98.6^{bc}	98.5^{ab}	99.0^{cd}	98.7^{bc}	99.0^{cd}	98.7^{bc}	98.2^{a}	0.14	< 0.01
CP, %	2.7^{ab}	2.7^{b}	2.7^{b}	2.2^{a}	3.0^{bc}	2.8^{bc}	2.7^{b}	3.2^{cd}	2.8^{bc}	2.9^{bc}	3.7^{d}	3.2^{cd}	0.18	< 0.01
NDF (DM), %	91.3	91.5	89.1	92.7	91.8	91.2	89.8	90.3	89.7	89.3	89.9	88.0	0.98	0.06
NDF (OM), %	90.7	91.4	88.8	92.3	91.4	91.0	89.7	90.1	89.6	89.1	89.7	88.2	0.92	0.10
IVDMD, %	40.4^{ab}	45.1^{de}	41.1^{abc}	42.2^{abcd}	40.7^{ab}	40.8^{ab}	40.8^{ab}	38.9^{a}	40.7^{ab}	44.7^{cde}	42.9^{bcd}	46.8^{e}	1.28	< 0.01
IVOMD, %	46.4	50.8	47.1	48.2	46.6	46.9	47.0	45.2	46.8	50.8	49.1	52.6	1.77	0.14

^{abc} Means within a row with different superscripts differ.

Figure 1. Organic matter digestibility of leaf material in relation to leaf weight.

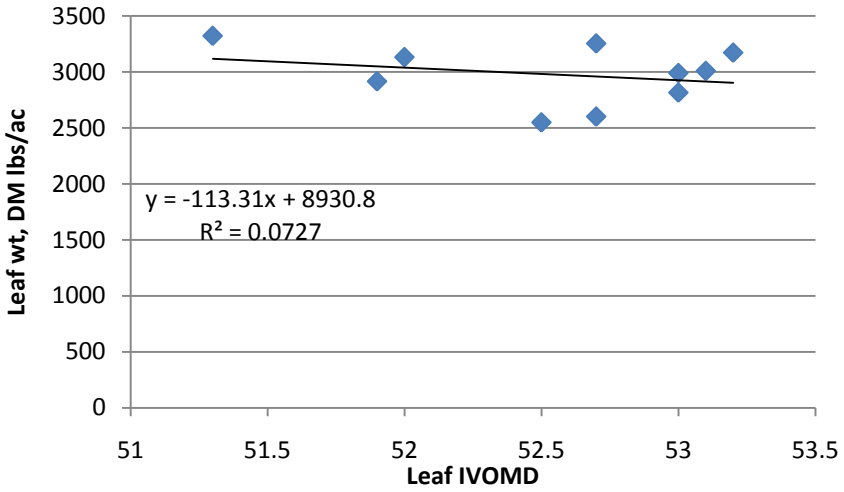

Figure 2. Organic matter digestibility of husk material in relation to husk weight.

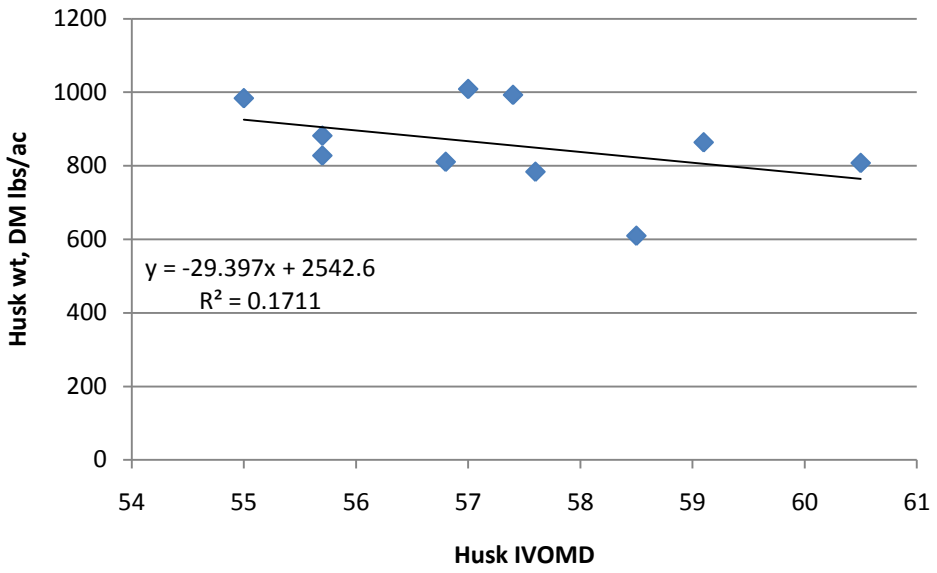

Figure 3. Leaf and husk material weight in relation to grain yield.

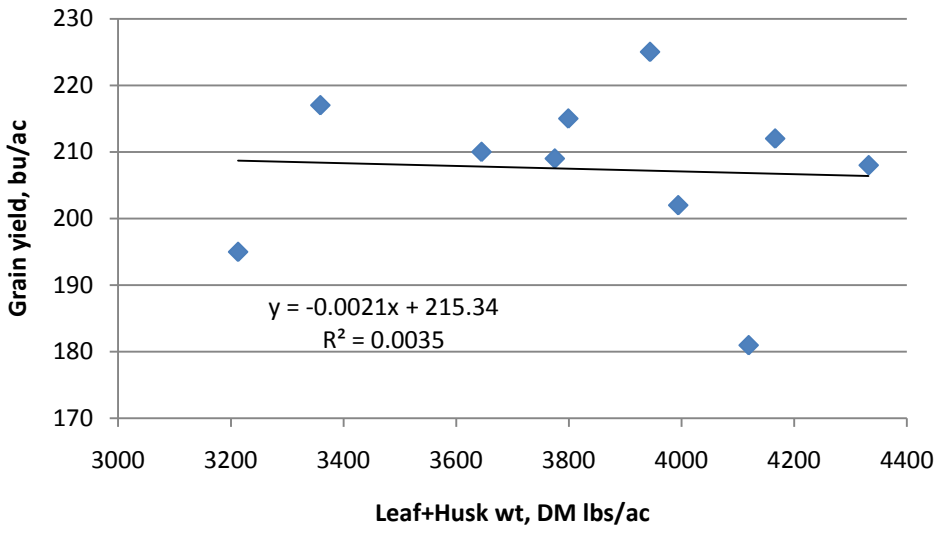
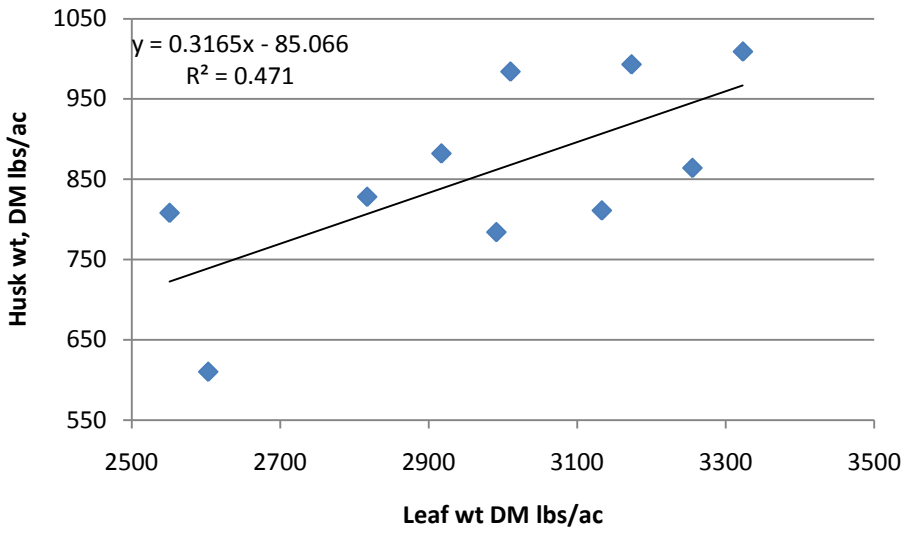
Figure 4. Relationship between leaf and husk weight.