CHANGES IN CORN RESIDUE QUALITY THROUGHOUT THE GRAZING PERIOD AND EFFECT OF SUPPLEMENTATION OF CALVES GRAZING CORN RESIDUE

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CHANGES IN CORN RESIDUE QUALITY THROUGHOUT THE GRAZING PERIOD AND EFFECT OF SUPPLEMENTATION OF CALVES GRAZING CORN RESIDUE

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 Animal Science

Major: Animal Science

Under the Supervision of Professor

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Lincoln, Nebraska

December 2014
Changes in Corn Residue Quality Throughout the Grazing Period and Effect of Supplementation of Calves Grazing Corn Residue

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University of Nebraska, 2014

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Corn residue is an abundant feed source in Nebraska that can be utilized as an alternative winter feed. Calves were backgrounded on corn residue in order to determine gain and estimate forage intake when supplemented with distillers grains (DGS). Calves grazing the non-irrigated field gained more (1.03 kg/calf daily) when compared to those grazing the irrigated field (0.90 kg/calf daily; $P < 0.01$). In year 1, a quadratic effect for intake of DGS was present ($P < 0.01$) while year 2 observed a linear effect for increasing level of DGS ($P < 0.01$). The nutritional quality of corn residue was evaluated over time in order to determine changes in blade/sheath, cob, husk/shank and stem. Minimal changes in DM of the forage components occurred was grain reached 15.5% moisture. Digestibility of the blade/sheath declined linearly over time ($P < 0.01$) while the husk remained constant ($P = 0.40$). Cob digestibility decreased quadratically ($P < 0.01$) throughout the sampling period with few changes once grain reached 15.5% moisture. Differences observed in the digestibility of the blade/sheath were attributed to the effects of weathering. A third set of trials was conducted to evaluate the effects of by-product supplementation of calves grazing irrigated corn residue and supplemented with DGS or continuous access to lick tubs. The DGS treatment gained more (0.62 kg/calf daily) than the lick tub treatment.
(0.38 kg/calf daily; \( P < 0.01 \)). Calves offered DGS consumed more supplement as a percentage of BW (0.52%) when compared with calves offered lick tubs (0.36%; \( P < 0.01 \)) on a DM basis. Calves supplemented with DGS had a higher supplement efficiency (46.3% to 42.9%, DM basis) although no differences were present between treatments (\( P = 0.49 \)). When analyzed on an OM basis, however, calves offered lick tubs had a numerically higher supplement efficiency (50.4%) in comparison to calves supplemented with DGS at 48.1% (\( P = 0.64 \)). The greater supplement efficiency for the lick tubs on an OM basis was attributed to the higher mineral content of the lick tubs.
DEDICATION

“One thing I ask of the Lord,
this is what I seek:
that I may dwell in the house of the Lord
all the days of my life,
to gaze upon the beauty of the Lord,
and seek Him in his temple.”

---Psalm 27:4
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Chapter I. Review of Literature

Introduction
Over the past several decades there has been a decrease in pasture available for grazing and haying due to commercialization or land being planted to a crop that will increase an operation’s profitability. With less land available, harvested forage prices have increased and producers have looked for feed alternatives during the winter months. Spring-born calves, which are typically weaned in the fall and fed harvested forages throughout the winter, can graze crop residues as an alternative feed source. All of the corn residue remains in the field after grain harvest and can act to extend the grazing season without adding additional pasture acreage or costs to producers.

Residue is grazed by ruminants or baled and fed in a confinement situation. The amount of residue removed is dependent on the method utilized by producers. Lamm and Ward (1981) found baling the residue removed 50 to 60% of what was left in the field following grain harvest, including parts of the stem that cattle do not typically consume. Grazing, on the other hand, has only been shown to remove 20 to 25% of residue in the field (Klopfenstein et al., 1987; Clanton, 1989; Rasby et al., 2006). Even though less residue is removed through grazing, grazing is considered a more economical means of residue removal when compared with baling residue. Selection by cattle allows for the consumption of the most energy-rich and palatable components first.

Allowing cattle to graze residue has also been shown to decrease moisture retention and increase nutrient recycling by the soil (Swan et al., 1987; Dam et al., 2005; Johnson et al., 2010).
In 2013, approximately 9.95 million acres were planted to corn in Nebraska (USDA NASS, 2014), making residue an abundant resource within the state. Grazing residues allows producers to extend the grazing season and take advantage of a forage-based production system which reduces annual feed and operational costs.

**Maturation of the Corn Plant**

Van Soest (1964) classified forages as containing both fiber and soluble components, with both fractions contributing to the nutritive value of the feed. The cellular contents consist of carbohydrates, lipids, proteins and pectins, while the cell wall is composed of cellulose, hemicellulose and lignin. The soluble fraction is almost completely digestible and not subject to lignification, while partial digestibility occurs to the fibrous part and is dependent on the amount of lignin (Van Soest, 1965). Lignin is a complex polymer that, in its naturally-occurring form, cannot be broken down by the microbial community in the rumen. As the plant matures the amount of lignin in the cell wall increases and is associated with a decrease in dry matter digestibility (Johnson et al., 1962; Allinson and Osbourn, 1970; Van Soest, 1964). Jung and Vogel (1986) found that digestibility of grass samples collected at varying maturities showed a negative curvilinear relationship between lignin and digestibility of the forage. This is supported by previous research (Ford et al., 1979; Akin et al., 1983) showing a reduction in digestibility as the cell wall concentration increases in the maturing forage.

Similar to other forages, maturation of the corn plant changes the composition of the chemical constituents and is dependent on hybrid, location, temperature and moisture. In all cases, the vegetative stage begins when the seedling emerges and ends when the plant tassels (Hanway, 1963; Nevens et al., 1954). Once tasselling occurs, vegetative growth
ceases and ear formation is the primary process to occur. Johnson et al. (1966) recorded changes in soluble carbohydrate of the stem and blade, finding an increase in concentration prior to tasselling. After tasselling and fertilization, however, soluble concentrations sharply declined to pre-tasselling levels, supporting the concept of little vegetative growth occurring once ear formation begins and the translocation of soluble carbohydrate shifts to the ear. After fertilization, kernels develop to physiological maturity, or blacklayer, at approximately 60 days after silking. Highest yields are observed at this time although a decline in total digestibility occurs as the plant advances in maturity (Perry and Compton, 1977; Leask and Daynard, 1973).

The corn plant is composed of several distinct components that vary in physical and chemical characteristics. The major components are grain, blade, husk, cob and stalk with the smaller and less obvious components being the shank and sheath. As the plant advances in maturity after tasselling, an increased rate of DM accumulation is observed. Johnson et al. (1966) found the distribution of DM changed from tasselling to grain harvest. Similarly, Nevens et al. (1954) observed an increase in total DM of the stalk, blade and ear as the plant matured with changes in DM composition at 14 to 36%, 19 to 79%, and 10 to 62%, respectively. Perry and Compton (1977) found similar increases in DM accumulation, estimating that 84% was due to the plant advancing in maturity. Grain accounts for approximately half the dry matter weight of the whole corn plant at maturity (Weaver et al., 1978; Shinners and Binversie, 2007). Pordesimo et al. (2004) further supported the data by showing that the DM content of the corn plant when harvested at 30% moisture was 45.9% grain, 27.5% stalk, 11.4% blade, 8.2% cob and 7.0% husk.
Weaver et al. (1978) found that whole plant DM of corn plants harvested at 2-wk intervals from September 9, 1975 to December 9, 1975 increased over time until plant DM reached 35%. Dry matter content of the plant remained relatively constant throughout the remainder of the trial. An inverse relationship was observed between stem and grain on a DM basis, and attributed to the translocation of carbohydrates from the stem to ear after tasselling. Percent CP content declined over the first three sampling dates (7 to 6%) with little change after the mid-October sampling for the remainder of the trial, suggesting that losses occurring after maturity are due to DM loss. Total plant IVDMD was 89% at the first sampling date and decreased to 83% by the mid-October sampling where it remained relatively constant as the plant reached more advanced stages of maturity. The reduction in digestibility was not primarily due to increased concentration of lignin as in other forages; instead, decreases in digestibility were attributed to an increase in neutral detergent fiber (NDF) due to the loss of soluble carbohydrate to the ear. Berger et al. (1979) also observed an increase in the concentration of NDF and concomitant decrease in IVDMD over time for harvested stalks.

An inverse relationship has been observed between DM and CP of each plant part (Perry and Compton, 1977). Data collected from the two consecutive years showed higher CP amounts for year 1 in comparison to year 2, with higher values for year 1 attributed to the hot, dry growing season. Blade CP (year 1: 18.5%; year 2: 12.5%) was greater than stalk (year 1: 7.0%; year 2: 3.5%) at approximately 9 days after ear formation began. A decline in blade CP was evident during both years and occurred until harvest (approximately 58 days after initial ear formation) to approximately 7.5%. A decrease in CP of stalk to 4%
was only evident during year 1, most likely due to the low CP value of year 2 at time of ear formation. The CP of the ear (year 1: 17%; year 2: 14%) declined the first 30 days after ear formation to approximately 8.5% for both years with no significant changes occurring the last 30 days prior to harvest. A 50% decline in total CP was evident as the plant matured. A decrease in IVDMD occurred for both blade and stalk at each sampling time, with the greater decline in the stalk attributed to the translocation of non-structural carbohydrates to the ear.

**Composition of Corn Residue**

Residues are utilized once the grain has been harvested and consist of the stalk, blade, husk and cob. The amount of grain left in the field after harvest is dependent on ear drop, weather conditions and harvest procedures, and improves the nutritive value of the residue.

Perry and Olson (1975) found a relationship between grain yield and amount of residue remaining in the field. Researchers have since tried to quantify the relationship in order to better determine stocking rate. Russell (1986) found that with adequate rainfall during the growing season, the forage to grain yield relationship was 1:1 at grain harvest. Pordesimo et al. (2004) measured biomass of the corn plant over time and found a ratio of 0.8:1 more appropriate when grain was harvested at physiological maturity. Gutierrez-Ornelas and Klopfenstein (1991) conducted grazing trials during two consecutive years and found the ratio ranged between 0.6:1 and 0.8:1. The low residue to harvested grain ratio occurred during a time of drought stress which may have caused a decline in DM directed to the grain as the plant matured (Jurgens et al., 1978).
When classifying residue into individual parts, Pordesimo et al. (2004) found that following harvest of grain the field consisted of 50.9% stalk, 21.0% blade, 15.2% cob and 12.9% husk on a DM basis. Lamm and Ward (1981) collected residue prior to and after the grazing period in order to determine changes due to weathering and grazing. They found that prior to fall grazing, amounts of husk/leaf constituted 38.9% of residue weight on a DM basis, with stalks 40%, grain 11.2% and cobs 9.1%. Composition of ungrazed residue at the end of the winter period consisted of husk/leaf 35.2%, stalk 39.8%, grain 9.3% and cobs 15.6%, with changes attributed to wind loss and plant deterioration throughout the winter months.

Shinners and Binversie (2007) collected plant residue approximately 45 days prior to harvest and again at harvest over a three year period, focusing on the plant parts that remain in the field after harvest. They found an increase in DM yield over time for the whole plant during the 45 days prior to grain harvest, from 17.4% to 21.5%. Losses were attributed to weathering and senescence of the blade, husk and upper stalk.

**Animal Selectivity**
Unlike typical grazing situations, cattle grazing corn residue have all the forage available the first day they are turned out. This allows for animal selectivity of the highest quality parts to occur prior to consumption of lower quality parts. Lamm and Ward (1981) examined the relationship between corn plant components as well as changes within these parts due to weathering and grazing by mature cows in late gestation. Corn residue was collected from two exclosures at the beginning and end of the trial: an ungrazed field and a field that was grazed by cattle for 85 days. The ungrazed exclosure consisted of 11.2% grain, 35.2% husk-leaf, 9.1% cob and 39.8% stalk while the grazed contained 1.4% grain,
30.6% husk-leaf, 13.1% cob and 54.8% stalk. Cattle were able to selectively identify and consume the grain, husk and leaf, leaving the cob and stem which are of lower quality.

Similar results were observed in work done by Fernandez-Rivera and Klopfenstein (1989b) and Gutierrez-Ornelas and Klopfenstein (1991) who showed that selectivity of residue also occurs when backgrounding steers on corn residue. Fernandez-Rivera and Klopfenstein (1989b) found cattle were able to selectively identify and consume the grain, followed by husk and blade, and lastly the cob and stalk. Gutierrez-Ornelas and Klopfenstein (1991) collected extrusa samples weekly and observed that after a 2 to 3 day acclimation period, steers consumed predominately grain and husk for the first 30 days of the grazing period. Husk and leaf were the major components consumed for the remaining 30 days of the trial, with no consumption of cobs and stem. Steers selected for and consumed the most palatable residue components first.

Wright and Tjardes (2004) estimated the nutritional quality of residue prior to grazing to be 70% TDN and 8% CP. As cattle select for higher quality parts, the nutritional quality of the field is expected to decrease over time to 40% TDN and 5% CP. Due to animal selectivity, it is expected that the total dietary nutrients of the field are high at the beginning of the grazing period and decrease as cattle are forced to consume components of lower nutritive value.

Fernandez-Rivera et al. (1989) developed a model to predict animal performance of cattle grazing corn residue. The model incorporates effects of weathering and amount of residue available over time. With the highest quality plant parts available at the beginning
of the grazing period, gain and intake are expected to be greater when compared to the end of the grazing period.

**Nutritive Value of Residue**

Residue is relatively low in protein and energy due to the advanced maturity of the corn plant after harvest, variation in quality of plant parts and animal selectivity. Lamm and Ward (1981) collected field samples from an irrigated corn residue field at the beginning and ending of the backgrounding trial and samples were analyzed for CP and IVOMD. Values of the total field samples for CP and IVOMD declined during the time period from 8.8 to 8.2% and 72.0 to 59.2%, respectively. Upon analysis of each component, a decline in nutritional quality occurred for all plant parts. The CP of grain, cob, stalk and husk-leaf was 12.6, 6.8, 6.6 and 7.3% for the fall sampling period and 12.2, 5.6, 5.8 and 7.6% for the winter sampling, respectively. Calculated IVOMD of grain, cob, stalk and husk-leaf for the fall and winter sampling was 95.2, 62.2, 62.1 and 66.2% and 92.5, 37.7, 48.8 and 47.9%, respectively. The decline in quality over time was attributed to environmental effects and a loss of plant part DM.

Nutritional quality of corn residue is largely dependent on what remains in the field. Fernandez-Rivera and Klopfenstein (1989b) conducted a trial to determine the proportion of residue remaining in the field and utilization by cattle. In a trial replicated over three years, proportions of residue available prior to grazing were determined to be 45% blade/husk, 40% stem, 11% cob and 4% grain for an irrigated field in comparison to a non-irrigated field at 51% blade/husk, 33% stem, 12% cob and 4% grain, respectively.

Research conducted by McGee et al. (2012) separated the corn plant into its individual parts to determine residue amounts and IVDMD of each respective part. The sheath was
separated from the blade and the shank from the cob in order to determine if there was a
difference in digestibility and consumption by calves. The top 1/3 of stalk, bottom 2/3 of
stalk, blade, sheath, husk, shank and cob comprised 3.60, 41.83, 18.72, 12.60, 7.48, 1.09
and 14.68% of residue dry matter and had IVDMD values of 37.57, 33.85, 45.70, 38.56,
59.03, 49.75 and 34.94%, respectively. Digestibility was similar for the top and bottom
fractions of the stalk. However, a difference in digestibility was observed when the
comparison was made between the blade and sheath as well as the cob and shank. The
sheath had a lower digestibility than the blade while the shank was found to be more
digestible than all of the components except the husk. Nutritive value of residue
degrees during the grazing period because cattle are selecting for the highest quality
parts first.

**Impact of Field Type**

According to the Nebraska Corn Board, 70% of corn produced in Nebraska is in irrigated
fields (28 June 2013). Irrigation improves crop yield, leading to an increase in the
proportion of total residue dry matter available in the field (Fernandez-Rivera and
Klopfenstein, 1989a; Gutierrez-Ornelas and Klopfenstein, 1991). Non-irrigated residue
contains a higher proportion of blade and husk to stem in comparison to irrigated residue.

In a two year grazing trial, Fernandez-Rivera and Klopfenstein (1989a) evaluated the
residue utilization of calves grazing corn residue. No differences were observed in
utilization for year 1. During year 2, a higher utilization rate was found in the non-
irrigated field \((P < 0.05)\) and may be attributed to the higher quality residue components.
Blade and husk accounted for 65% of the total irrigated residue utilized during year 2 and
72% of the total non-irrigated residue. Total plant CP was lower for the irrigated field at
3.4% when compared to the non-irrigated field at 6.2% \((P < 0.05)\). These findings were supported by previous research by Harder et al. (1982) and Jurgens et al. (1978) who observed lower CP content of grain in irrigated fields. Lower CP values for irrigated fields may be due to greater competition for nitrogen associated with higher planting densities as well as a greater proportion of starch in the grain.

Gutierrez-Ornelas and Klopfenstein (1991) conducted corn residue grazing trials on irrigated and non-irrigated fields in order to determine availability and nutritive value of the residue. Prior to grazing, total residue DM for the irrigated field was 8,574 kg/ha compared to 2,809 kg/ha for the non-irrigated field. A larger percentage of residue was removed from the irrigated field (27.4%) in comparison to the non-irrigated field (18.9%) at the end of the trial. The rate of husk and blade disappearance varied for each field at 51.7% and 53.9%, respectively, removed from the irrigated field compared to 72.0% and 43.5%, respectively, from the non-irrigated field. Proportions of each respective plant part were similar to previously discussed research by Pordesimo et al. (2004) and McGee et al. (2012). The CP of grain, husk, blade, stem and cob of the irrigated field were 9.46, 4.10, 5.89, 4.77 and 2.54%, respectively, and values for the non-irrigated field were 11.39, 4.42, 5.97, 5.43 and 3.09%, respectively. Differences in CP did not occur with respect to field type in regards to husk and blade, and is attributed to drought conditions and the higher amount of CP allocated to the grain when severe dry conditions occur. Husk was the most digestible roughage proportion of corn residue. Calculated IVOMD values for the grain, husk, blade, stem and cob in the irrigated field were 95.8, 60.5, 50.8, 43.6 and 29.7%, respectively. The IVOMD values of the non-irrigated field for grain, husk, blade, stem and cob at 93.9, 71.9, 51.9, 44.4 and 52.4%, respectively. Husk from
the non-irrigated field had greater IVOMD when compared to the irrigated field. The IVOMD from both fields decreased as the grazing season progressed.

Faulkner et al. (1982) studied how the quality of the corn plant affects calf performance by feeding HMC from an irrigated or non-irrigated field in order to evaluate differing levels of IVDMD. The non-irrigated field had an IVDMD of 7.6 percentage units higher than the irrigated field. This resulted in 0.09 kg greater daily gain and consumption of 0.30 kg less feed per kg of gain for cattle offered ensiled residue from the non-irrigated field. The decrease in quality between field types was further supported by Guyer et al. (1983). A reduction in feeding value was observed when irrigation was utilized, even in years when there was no difference in IVDMD values between field types. Increasing the quality of the plants improved calf performance, with irrigation playing a major role.

**Utilization of Residue**

The most economical use of corn residue is to allow animals to graze the material in the field as opposed to harvesting the residue (Klopfenstein et al., 1987). Grazing residue, however, does not maximize removal from the field, with only 20 to 30% removed during winter grazing (White, 1973; Fernandez-Rivera and Klopfenstein, 1989b). These estimates include losses due to consumption, weathering and trampling.

Unlike typical grazing situations, residue is at its highest quality and availability on day one. Continuous grazing trials have shown a 20 to 30% removal of corn residue by calves and cows, with this management practice not considered an effective means of removing the residue (Fernandez-Rivera and Klopfenstein, 1989b; Lamm and Ward, 1981). In a typical continuous grazing system, a linear decline in diet quality occurs over time (Fernandez-Rivera and Klopfenstein, 1989c; Russell et al., 1993). This is due to cattle
selecting for the most palatable parts of available residue and does not encourage consumption of the least desirable parts. Utilizing a continuous grazing system also increases trampling of the residue as cattle search the field for downed ears prior to consuming husk and blade.

An alternative strategy to improve the utilization of residue is through a strip grazing system where cattle are frequently rotated through more than one pasture based on forage availability. This may increase utilization of residue by reducing trampling and encouraging cattle to eat more of the less palatable parts at the end of the rotation period. A rotational grazing plan allows cattle to have access to high quality parts at the beginning of the rotation but diet quality will decline faster due to the smaller grazing area. Overall diet quality for the grazing season would be expected to decline at a slower rate, better meeting cow nutrient requirements with minimal supplementation.

Russell et al. (1993) attempted to improve utilization of residue and animal performance by assessing continuous and strip grazing systems stocked at a rate of 0.41 ha/cow. Diet samples collected from cows in the strip grazing system had a 5.5% increase in IVOMD when compared to the continuously stocked system for all three years of the treatment. Although strip grazing improves the efficiency of residue utilization, overall cow BW losses were greater (-0.12 kg/d) when compared to cows in a continuously stocked system (-0.06 kg/d). Weather was deemed the major factor in accounting for cow BW changes in the strip grazing system. In years with great amounts of winter precipitation, the cow’s access to the highest quality parts of residue was reduced during periods of heavy snow or ice, thereby reducing diet quality. Cow BW gains during years of low precipitation were similar to those of a continuously stocked system, allowing cattle
access to the highest quality parts of residue and improving diet quality. Grazing management systems differ in the amount of residue utilized.

**Effects of Weathering**
Weathering and environmental losses may have a large impact on what is available for cattle to consume. Extensive losses due to wind or precipitation will affect the amount and digestibility of each plant part.

Gutierrez-Ornelas and Klopfenstein (1991) conducted two early- and two late-season residue grazing trials on irrigated and non-irrigated fields. Field samples were collected prior to grazing and at periodic intervals throughout each of the four trials. They found that weather conditions affected the DM proportion of blade to a greater degree than other plant parts, with a loss of 364 kg/ha of blade occurring in the 30 days prior to grazing late-season corn residue. This is most likely due to a loss of DM and a portion of the blade taken up by wind. No differences between grazing and weathering were observed during the grazing period. Therefore, researchers concluded that the disappearance of blade was due to weathering rather than grazing.

Perry et al. (1973) collected corn residue samples at six selected sites in Nebraska. They found that years of high moisture reduced the nutritional quality of residue when it is left in the field after harvest. Plant parts containing less than 60 to 70% DM often resulted in heating and spoilage of the residue component in the field, resulting in a reduction of the nutritional quality of the plant parts.

Russell et al. (1993) grazed cows in midgestation on corn residue for 56 days over three consecutive years to determine the effects of grazing allowance and system on residue
removal and animal performance. An exclusion cage was used to collect samples prior to and after grazing. Observations showed a 48.3% increase in ash and 55% decrease in IVOMD from pre- to post-grazing due to weathering. Plant parts of the highest nutritive quality may be the most susceptible to losses in DM from weathering due to wind and the environment. Therefore, to optimize animal performance, cattle should be turned out as soon as possible in order to capitalize on available residue.

**Stocking Rate**

Stocking rate will have a large impact on cattle performance when grazing corn residue due to the uniqueness of the forage. Unlike typical grazing situations, all of the forage is available from day one and declines in quality over time due to selection of the most nutritious components. Numerous trials have been conducted to determine appropriate stocking rates for weaned calves grazing corn residue.

In a trial conducted over three consecutive years, Russell et al. (1993) grazed cows in midgestation on corn residue at varying stocking rates and management systems for 56 days. In a continuously stocked system, cows were stocked at 0.41, 0.82 and 1.64 ha/cow or at 0.41 ha/cow in a strip-stocking system in years 2 and 3. Weight gain for cows in the continuously stocked system at 0.41, 0.82 and 1.64 ha/cow were -0.06, -0.01 and 0.41 kg/day, respectively. The body weight changes of cows grazing continuously stocked and strip-stocked fields at 0.41 ha/cow were 0.15 and 0.30 kg/day during year 2 and -0.33 and -0.53 kg/day in year 3, respectively. As the number of grazing days increased, researchers found that IVOMD declined over the time period for all stocking rates but were greater for the heavier stocking rates. This is supported by previously cited research conducted by Fernandez-Rivera and Klopfenstein (1989a) who showed a decrease in field quality
throughout the grazing period. Furthermore, Russell et al. (1993) found that as stocking rate increased, the amount of organic matter removed from the field increased. Cows stocked at 0.41 ha/cow removed 3,362 kg/ha DM in comparison to 2,095 kg/ha DM for cattle stocked at 1.64 ha/cow. The amount of residue removed plays a role in diet quality because the most palatable and nutritious parts are selected for first by cattle. Fields with heavier stocking rates have a smaller grazing allowance per animal and force cattle to consume lower quality parts, thereby reducing the quality of the diet.

Irlbeck et al. (1991) focused on how an increase in stocking rate affected utilization of residue and found that decreasing stocking pressure caused an increase in animal performance. This finding is supported by earlier work from Fernandez-Rivera et al. (1989b) who found a linear decrease in CP as stocking rate increased. This was attributed to the fact that at lower stocking rates, cattle were allotted a larger grazing allowance which resulted in the more digestible components being available for a longer period of time.

Fernandez-Rivera et al. (1989a) evaluated stocking rate of yearlings grazing corn residue and found a higher stocking rate increased the amount of husk and blade removed from the field. In an irrigated field stocked at 2.47 steer/ha cattle removed 624 kg/ha while those in a field stocked at 4.69 steer/ha removed 867 kg/ha. Cattle grazing non-irrigated residue removed 689 kg/ha of blade and husk when stocked at a rate of 2.47 steer/ha. Amount of residue remaining in the non-irrigated field after grazing was 437 kg/ha of blade and husk which is similar to the amount of residue that remained in an irrigated field stocked at 4.69 steer/ha. Daily gain of calves on irrigated and non-irrigated corn residue stocked at 2.47 steer/ha was 0.43 and 0.70 kg/day for the first 28 days of grazing
and 0.42 and 0.56 kg/day for the 54 day grazing period, respectively. Gain of calves on a non-irrigated field stocked at 1.54 steer/ha gained 0.79 kg/day during the first 28 days of grazing and 0.61 kg/day for the 54 day grazing period, respectively. Less corn residue is available in a non-irrigated field, particularly blade and husk, so the stocking rate needs to be adjusted accordingly to ensure animal performance is not hindered. Researchers concluded that since a lower amount of residue is available in a non-irrigated field compared to an irrigated field, stocking rates should be based on grain yield and irrigation method as opposed to the number of hectares available for grazing.

**Quantity of Residue**
Approximately 40 to 50% of total plant DM is available after grain harvest as residue with the most palatable portions being the blade, blade sheath and husk (Johnson et al., 1966). A direct correlation has been shown between the amount of grain harvested and residue (leaf and husk) left in the field, with 7.3 kg of blade and husk for every bushel of grain harvested (Fernandez-Rivera et al., 1989). Part of the residue is unavailable for grazing due to effects of weathering or trampling and the losses are generally estimated to be 50% of the residue available immediately following grain harvest. Multiplying the amount of grain produced, in bushels, by 3.13 calculates the amount of residue available in the field (Terry Klopfenstein, personal communication). The estimated residue amount can then be used for determining a stocking rate where cattle will primarily consume the most nutritious parts and not be forced to consume the stem and cob.

**Voluntary Forage Intake**
Voluntary forage intake is typically the most critical factor in understanding animal performance. Grazing cattle or those fed forage-based diets are limited by reticulo-rumen
capacity and passage rate (Conrad, 1966). This implies that rumen fill as well as rates of digestion and passage regulate the feed intake of grazing cattle.

Voluntary DMI of forages may be limited by restricted flow of digesta through the gastrointestinal tract. Allen (1996) concluded that the fill capacity of the rumen is related to the weight and volume of digesta, which causes distension and affects the rate of flow. Cattle on high forage diets were limited primarily by distension of the reticulo-rumen, with a linear decrease in DMI occurring with increasing amounts of gut fill. The NDF in forages is fermented and passed at a slower rate than other non-fibrous constituents, creating a greater fill effect over time compared with other dietary components. Other factors have been shown to affect fill, including particle size, chewing frequency, indigestible NDF fraction and characteristics of reticular contractions.

**Supplementation of Grazing Cattle**
The ruminant’s unique digestive system allows for microbial fermentation of forages in the rumen, producing microbial proteins and volatile fatty acids (VFAs). Proteins are utilized by the microbes for growth and development while the VFAs act as a by-product and are diffused across the rumen wall and used as an energy source by the animal.

During times of low forage quality or when animal nutrient requirements are high, supplementation may be needed in order for the animal to maintain or increase BW. Calves have high nutrient requirements due to their fast growth rate (NRC, 2000). Therefore, a nutrient deficiency at this time may inhibit calf gain.

Grings et al. (1994) evaluated protein supplementation of fall- and spring-born cattle in order to determine animal response over two years. Steers were supplemented with crude protein to meet NRC requirements while grazing native range in late summer and early
fall. During both years, gain was higher for calves that received supplementation compared to calves that were not offered a protein supplement. Younger calves showed a more consistent response to protein supplementation.

Bodine and Purvis (2003) evaluated animal performance of yearling steers grazing dormant native tallgrass prairie and receiving four different types of supplementation. The supplements were corn plus soybean meal, corn plus soybean hulls, soybean meal or a cottonseed hull-based control. Calves receiving corn plus soybean meal supplementation experienced higher gain when compared to cottonseed hull-based control calves. This supported previous work by DelCurto et al. (1990) who showed how increasing the level of protein in a low quality forage diet increased the intake and utilization of the forage. Improved gain and utilization of the forage is attributed to adequate ruminal degradable protein available to the microbial community for the breakdown of starch.

Calves grazing corn residue, a low quality forage, are also shown to benefit from protein supplementation. In trials conducted by Fernandez-Rivera and Klopfenstein (1989b), calves grazing corn residue received differing levels of protein supplementation. During trial 1, CP was supplemented at 0.229 kg DM/steer/day. In trial 2, CP was supplemented at 0.454 kg DM/steer/day. Gain was positively correlated with protein content of the diet and not with the available corn grain, suggesting CP was limited in the diet.

Alfalfa is a common feed source fed to grazing cows during the winter season and is typically considered a high protein source. Gutierrez-Ornelas and Klopfenstein (1994) evaluated the role of alfalfa and escape protein supplementation on the performance of
calves grazing corn residue. Daily gain of steers was not affected by alfalfa type or level of supplementation. Researchers found that extrusa samples collected at the end of the grazing period were lower in escape protein (EP) when compared with samples from earlier in the grazing period. This was attributed to animal selectivity of the residue, with cattle consuming the more nutritious parts first.

**Distillers Grains as a Supplementation Source**

Cereal grains have been traditionally fed as an energy source. However, the addition of starch to a forage-based diet interferes with fiber fermenting microbes and causes a depression in fiber digestion. The negative associative effect occurs due to the increased passage rate in the rumen with starch present.

Alternative supplementation strategies have become available in recent years due to the availability of corn milling by-products within Nebraska. In 2013, Nebraska ranked second in ethanol production capacity, with 23 plants producing 1.96 billion gallons of ethanol (Nebraska Department of Agriculture, 2014). Distillers grains, a by-product of the ethanol industry, has provided producers with a high protein and energy supplementation alternative to cereal grains.

Distillers grains are formed as a by-product of the dry milling process. The basic process converts starch in corn grain to alcohol by yeast fermentation (Stock et al., 1999). After distillation, the whole stillage is centrifuged to remove the larger feed particles from the liquid fraction. The particles are then sold as wet distillers grains or dried to form either modified or dried distillers grains. The other fraction is known as thin stillage and is used to form condensed distillers solubles. Solubles are marketed as slurry or added back to
the distillers grains forming distillers grains plus solubles (DGS). A variety of products are marketed, leading to variations in nutrient composition (Spiehs et al., 2002).

Despite variations between products and plants, the nutrient composition of DGS is approximately three times the nutrients of the cereal grains used. The concentration of nutrients allows DGS to fit well in a forage-based diet. The nutrient composition is approximately 30.5% CP, with 63% of the CP available as RUP (Paz et al., 2013). Due to the low forage quality of corn residue, dried DGS acts as both an energy and protein source for calves grazing residue.

**Supplementation with Distillers Grains**
One advantage of supplementation with DGS over grain is that most of the starch has been removed and the highly digestible fiber in DGS may have less negative associative effects on fiber digestion. Summer and Trenkle (1998) evaluated the effects of supplementation on a high or low quality forage diet. Forage was replaced at 50% of DM by DRC or dried DGS. Feeding dried DGS with the low quality forage increased NDF digestibility whereas DRC tended to decrease NDF digestibility. Feeding a high quality forage and supplementing with dried DGS increased NDF digestibility when compared with supplementation of DRC. However, the response to supplementation when cattle were fed a high quality forage was lower than when a low quality forage diet was consumed.

Loy et al. (2007) compared the effects of dry-rolled corn (DRC) and dried DGS, fed daily or on alternate days, with heifers fed low quality hay. Heifers receiving supplementation had lower hay intakes, regardless of supplementation type. Hay intake was lower for heifers fed on alternate days and those receiving dried DGS showed less variation in
intake than heifers supplemented with DRC. Heifers receiving no supplementation had a higher rate and extent of digestion when compared with supplemented heifers, with the DRC treatment having the lowest rate of digestion.

Watson et al. (2012) conducted a five-year trial to evaluate management strategies for different methods of backgrounding calves on smooth bromegrass. Treatments included fertilized pastures, nonfertilized pastures with no supplement, nonfertilized pastures with supplement offered and control pastures where fertilization and supplementation were not applied. Researchers found that supplementing cattle with dried DGS increases animal performance and reduces forage consumption. Therefore, supplementation can be utilized as a means of extending the grazing season as well as improving animal performance.

Dried DGS has predominately been fed as a protein supplement in high forage diets. When protein supplements were fed less frequently (Huston et al., 1999; Bohnert et al., 2002), grazing cattle responded similarly to the more frequently supplemented treatment. Similarly, Loy et al. (2008) evaluated the differences in supplementation frequency of dried DGS in a high forage diet. Reducing supplementation frequency from daily to three times per week resulted in similar gains. Calves receiving sufficient ruminal degradable protein are able to rely on nitrogen recycling in order to meet microbial needs. Stalker et al. (2009) further supported previous research when they evaluated the frequency of DGS supplementation on the forage digestibility and performance of calves. The researchers also found, however, that a higher supplementation frequency resulted in improved animal performance when DGS was fed above 15% of the diet.
**Distillers Grains Supplementation of Calves on Corn Residue**

Supplementation with DGS may be appropriate during times of low forage quality or quantity. Winter backgrounding situations often warrant supplementation due to the low quality of crop residues or dormant winter range. Research evaluating the effects of DGS for calves grazing corn residue is limited. Gustad et al. (2005) supplemented dried DGS to calves on irrigated corn residue in order to determine the gain response from increasing levels of supplementation. Supplementation was offered at 0.2, 0.4, 0.6, 0.8, 1.0 or 1.2% BW daily through the Calan system. Gain increased quadratically with increasing supplementation from 0.4 to 0.8 kg/steer/day for the winter grazing period. Researchers found the optimal level of supplementation to be 1.1% BW in order to minimize feed refusals and maximize gain. The increase in inclusion level was supported by Ahern et al. (2011) who found that gain improved with increasing level of DGS in a forage-based diet.

Feedlot research has shown the energy value of DGS is dependent on the level of moisture, with wet DGS having a higher energy value when compared with modified or dried DGS (Ham et al., 1994). The same has not held true for grazing cattle or those fed forage-based diets. Nuttelman et al. (2008) evaluated wet and dried DGS as a supplementation source for growing cattle. Ending BW and ADG were similar between cattle supplemented with wet DGS compared to those supplemented with dried DGS. Similar results were found for Ahern et al. (2011) who evaluated the energy value of wet and dried DGS in high forage diets for growing cattle. Type of DGS did not affect ADG in forage-based growing diets ($P = 0.81$). This may be attributed to the drying process having little effect on protein in DGS (Ham et al., 1994).
**Supplementation with Lick Tubs**

Block (or lick tub) supplementation has been gaining in popularity due to the convenience of feeding and ease of storage. Minimal research is available evaluating effects on gain when supplementing with lick tubs. In a 3-year grazing trial using crossbred wethers, Mulholland et al. (1976) evaluated the effects of feeding a urea block supplement or no supplement while grazing oat stubble. No differences were observed throughout the grazing trial between treatments. This was attributed to above average rainfall each year which allowed for new forage growth and selection by the wethers.

Coombe and Mulholland (1983) evaluated intake response to sheep supplemented with a self-fed liquid or block molasses-urea supplement while grazing oat stubble. Average supplement intake as a percentage of the targeted supplement intake was 41% for blocks and 76% for liquid supplementation. Targeted intake of the block supplement was not reached during the 10-week experimental period, whereas the targeted liquid consumption was reached by week 5. The percentage of wethers that did not consume block supplementation was 2.5% compared to 22.5% of those offered liquid supplementation. Even though the targeted block supplementation was not reached, a lower percentage of wethers did not consume supplementation when compared to those offered liquid supplementation. Garossino et al. (2003) found that mean DM intake did not differ between liquid and block supplementation for cows on dormant range. However, there was a larger deviation in intake for cows supplemented with the block compared to liquid supplement \( (P < 0.05) \). Cows offered liquid supplement visited the feeder more often \( (P < 0.05) \), consumed supplement at a faster rate \( (P < 0.05) \) and spent
less time at the feeder ($P < 0.05$). Differences in intake may be due to the structure of the supplements, with results showing the liquid supplement having a higher ease of intake.

**Summary of Research**
The present data suggest there are minimal changes that occur in the DM composition and quality of corn residue after harvest of the grain. However, limited research has been conducted on whole corn plants to determine changes in nutritional quality of the forage components after grain harvest. Based on previous findings, it is believed that the residue will decrease in quality during the winter grazing season due to environmental effects and trampling in the field.

Corn residue is a readily-available winter feed source that is low in CP and energy to meet the needs of calves. The nutrient quality of residue decreases over time due to cattle selecting for the most palatable parts of the plant first. Quality of the residue is also determined in how the field was irrigated, with a non-irrigated field yielding residue higher in nutritive quality. Limited research has been performed with calves on corn residue in evaluating type and level of supplementation in order to achieve optimal gain with minimum feed refusals.

The objective of these trials was to examine the nutritional changes in corn residue over time as well as the impact of supplementation level and type on the performance of calves grazing corn residue.
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Chapter II. Effect of Distillers Grains on Average Daily Gain of Cattle Grazing Corn Residue

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1 This work is a contribution of the University of Nebraska Agricultural Research Division, supported in part by funding through the Hatch Act.
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ABSTRACT
There is significant potential for grazing corn residues due to the acres of corn planted annually. Grazing residues increases the length of the grazing season, allowing producers to feed less harvested feeds thereby reducing annual feed costs. The objective of these trials was to compare the effects of distillers grains (DGS) at differing levels of supplementation for calves grazing irrigated or non-irrigated corn residue. Experiment 1 backgrounded one hundred twenty crossbred steers on corn residue from November to the end of December 2012 at the University of Nebraska- Lincoln Agricultural Research and Development Center (UNL ARDC) near Mead, Neb. Treatments were arranged in a 2 x 2 x 3 factorial design, with two types of DGS (modified or dried), two types of corn residue (irrigated or non-irrigated) and three levels of inclusion (0.3%, 0.7% or 1.1% of BW). Exp. 2 utilized sixty steers backgrounded at UNL ARDC on irrigated corn residue and supplemented with dried DGS at 0.3, 0.5, 0.7, 0.9 and 1.1% of BW. Steers were assigned randomly to treatment for both experiments and received supplementation daily through the Calan System. Diet samples were collected throughout both trials and were analyzed for IVOMD. Gain improved quadratically in Exp. 1 for calves supplemented at 0.3, 0.7 and 1.1% of body weight with gains of 0.80, 1.04 and 1.08 kg daily ($P < 0.01$). Steers grazing non-irrigated residue gained (1.03 kg/day) more ($P < 0.01$) in comparison to steers grazing irrigated residue (0.90 kg/day). Gain improved linearly in Exp. 2 for calves supplemented dried DGS, respectively. Forage intake was estimated in Exp. 2 by utilizing titanium dioxide as a fecal marker and showed a 0.90 kg decline in corn residue intake for every 1% of BW increase in DGS supplementation. For both experiments, diet quality remained relatively constant throughout the grazing period. Calves receiving
higher levels of DGS supplementation as a percentage of BW had greater gains compared to those supplemented at low levels while grazing corn residue.

**KEYWORDS**: backgrounding, corn residue, forage intake, grazing

**INTRODUCTION**
There is significant potential for grazing corn residues in the state of Nebraska due to the amount of corn planted annually. Grazing residues increases the length of the grazing season, allowing producers to feed less harvested feeds thereby reducing annual feed costs.

Corn residue is different from typical grazing situations in that all of the forage is available immediately following grain harvest. This allows for the selection and consumption of the most palatable components first. Due to selective grazing by cattle, dietary CP and escape protein may not be constant throughout the grazing period (Lamm and Ward, 1981).

Residues, however, are lower in crude protein and energy than what is required to meet the needs of calves due to their rapid growth and development (NRC, 2000). Fernandez-Rivera and Klopfenstein (1989a) observed a growth response of calves grazing residue with or without protein supplementation and suggest CP may be a limiting factor in the animal’s diet.

Distillers grains plus solubles (DGS) are approximately 30.5% CP, with 63% of the CP available as RUP (Paz et al., 2013). Once protein needs of the calf are met, the excess protein is utilized by the animal as an energy source (MacDonald et al., 2007). Providing
protein supplementation in the form of RUP allows producers to optimize winter gain of calves on corn residue (Gutierrez-Ornelas, 1991).

Research in finishing cattle has shown improvements in gain for wet DGS when compared to diets containing modified or dried DGS (Klopfenstein et al., 2007). However, a difference has not been observed between types of DGS in calves consuming a high forage diet (Nuttelman et al., 2008; Ahern et al., 2012). A quadratic response on gain has been shown for calves receiving dried DGS at increasing levels and grazing irrigated corn residue, with optimal supplementation being at 1.1% of body weight (Gustad et al., 2006).

Stocking rates are traditionally based on available forage and not the quality of the forage. Non-irrigated corn residue fields have a higher nutritional value, although a lower quantity of total residue, compared to irrigated fields (Fernandez-Rivera and Klopfenstein, 1989a; Gutierrez-Ornelas, 1991). The improvement in quality observed for non-irrigated fields should result in an increase in gain for the calves. The objective of these trials was to compare two types of DGS at varying levels of supplementation in order to determine gain and forage intake of calves grazing irrigated or non-irrigated corn residue field.

**MATERIALS AND METHODS**

All procedures and facilities utilized were approved by the University of Nebraska-Lincoln Institutional Animal Care and Use Committee.

*Experiment 1*
One hundred twenty crossbred steers (237 kg ± 11.20) were backgrounded on corn residue from November 1, 2012 to December 22, 2012 at the University of Nebraska-Lincoln Agricultural Research and Development Center (ARDC) near Mead, Neb. The trial was terminated earlier than the 70 day grazing period due to substantial ice and snowfall. Treatments were arranged in a 2 x 3 x 2 factorial design, with two types of DGS, three levels of inclusion and two different types of corn residue fields in order to evaluate the effects of gain when supplementing dried or modified DGS to calves grazing an irrigated or non-irrigated corn residue field. Each type of DGS was fed at an inclusion level of 0.3, 0.7 or 1.1% of BW and amounts were adjusted every 21 days after 3-day weights were recorded.

Calves were received into pens and processed within 24 hours of arrival at the ARDC feedlot in the fall of 2012. Calves were tagged with an electronic identification tag, metal clip tag and panel tag, and were vaccinated according to university protocol. Initial processing included vaccination with a modified live viral vaccine (Bovi-Shield Gold 5, Zoetis Animal Health, Madison, NJ), *Haemophilus somnus* bacterin (Somubac, Zoetis Animal Health) and an injectable dewormer (Dectomax Injectable, Zoetis Animal Health). Calves were fed a 1:1 blend of alfalfa hay and Sweet Bran (Cargill, Blair, Neb.) during the receiving period. Approximately 27 days later calves were revaccinated with a modified live viral vaccine, *Haemophilus somnus* bacterin and pinkeye vaccine (Piliguard Pinkeye + 7, Merck Animal Health, DeSoto, KS). Calves were implanted with Ralgro (Merck Animal Health) on day 1 of the trial.

At the end of the receiving period, calves were trained to the Calan system for 30 days (American Calan Inc., Northwood, NH) and fed the same diet as during receiving. Once
trained to the Calan bunks, calves were limit fed at 2% of BW on a 25% grass hay, 25% alfalfa hay and 50% Sweet Bran diet for five days prior to the initiation of the trial. Three day weights were taken on day -1, 0 and 1 (Stock et al., 1983) in order to reduce variation in gut fill (Watson, et al., 2013). Cattle were stratified by BW and assigned randomly to treatment based on day -1 and day 0 weights.

At the conclusion of the trial, calves were limit fed for five days a diet of 25% grass hay, 25% alfalfa hay and 50% Sweet Bran at 2% of BW. Three day weights were collected the last three days of the limit feeding period.

The Calan system was used to monitor the amount of supplement each calf consumed daily while grazing corn residue. Calves were gathered each morning at sunrise, penned up for supplement consumption for approximately 2 hours and then turned out to graze the remainder of the day.

Daily supplementation included a premix in order to meet the steer’s calcium requirements. The premix was mixed in a 23 kg batch mixer (#2-100DA, Leland Detroit Mfg Co., Detroit, MI) and stored in a 200L barrel at ARDC. Each batch contained dried DGS, salt, Rumensin (Elanco Animal Health, Indianapolis, IN) and limestone and was fed at 18, 11, 1 and 60 g/calf daily, respectively. The premix was weighed out and top-dressed on the supplement.

Stocking rate was calculated based on yield of the field at harvest and research by Fernandez-Rivera and Klopfenstein (1989b) quantifying the amount of residue consumed per acre. The yield of corn grain (kg/hectare), estimated forage availability (12.5 kg/bu available due to trampling, weathering and leaving adequate ground cover), grazing
efficiency factor (100% for non-irrigated, 85% for irrigated) and number of acres were multiplied together to estimate the total available forage for each field. Total available forage was then divided by estimated DMI (4.5 kg/calf daily) of all calves allotted to graze each respective field in order to get days of available grazing. Using this calculation, the 13 hectare irrigated field was fenced to allow 66 steers to graze for 70 days based on a yield of 13,375 kg of grain/hectare. The non-irrigated field totaled 17 hectares and had a yield of 6,250 kg of grain/hectare, allowing sixty steers to graze seventy days. Due to the limited number of Calan gates, only 60 calves could graze the irrigated field and have supplement consumption monitored. Six ruminally canulated calves also grazed the irrigated field and were utilized for diet sampling although they were not monitored for supplement consumption. The trial was terminated after 52 d of grazing due to substantial ice and snow.

The canulated steers received dried DGS at 0.7% of BW in a feed bunk next to the Individual Feeding Barn. Diet samples were collected four times throughout the trial by emptying the rumen of solid and liquid particulate matter. Prior to turn out, steers were assigned randomly to graze either the irrigated or non-irrigated field (three per field type). Once steers had a chance to graze for thirty minutes they were brought back in and the grazed forage was collected from the rumen, sealed in a 33 cm x 46 cm Reloc Zipit reclosable bag (4 mil, Consolidated Plastics, Stow, OH) and stored on ice for later analysis of in-vitro organic matter disappearance (IVOMD). The original rumen contents prior to diet sampling were replaced in the rumen of the respective steer prior to turning them out with the herd.
Diet samples were subsampled in the Ruminant Nutrition Laboratory and placed in fecal containers labeled with steer number and sampling date. The samples were freeze dried (Virtis Freezemobile 25ES) and then ground through the Wiley Mill (1mm; Thomas Scientific, Swedesboro, NJ) before analyzed for IVOMD using the Tilley and Terry method (1963) which was modified by adding 1 g urea/mL buffer (Weiss, 1994). Diet samples were weighed out in triplicate into 100 mL in vitro tubes and rumen fluid was collected from two canulated steers fed a diet of 70% grass hay and 30% concentrate, and housed in the digestion area of the Animal Science building. Hay and corn residue standards with known in vivo values were included in order to develop regression equations that would allow for the comparison of values between runs (Geisert, 2007). Samples were placed into a 39°C water bath for 48 h and swirled every 12 h to facilitate contraction and mixing of rumen contents. Hydrochloric acid and pepsin were added to each tube after the 48 h fermentation period, and tubes were kept in the water bath for an additional 24 h prior to being removed and frozen. Tubes were filtered using Whatman 541 ashless filters and dried in a 100°C oven for 12 h to determine a DM weight. The filtered samples were then placed in a muffle furnace at 600°C for 6 h in order to determine ash and OM content.

Two loads of modified DGS (ADM, Columbus, NE) and one load of dried DGS were delivered throughout the experimental period and analyzed for nutrient analysis (Table 1). Samples were composited by load and dried in a forced-air oven at 60°C for 48 hours to determine DM (AOAC, 1999 method 4.1.03) according to Buckner (2011). Feed samples were then ground through a 1-mm screen of the Wiley mill prior to further analysis. Samples were also analyzed for ash and OM by placing crucibles in a muffle
furnace for 6 hours at 600°C, NDF according to Van Soest et al. (1991), CP by the use of a combustion-type N analyzer (Leco FP 528 Nitrogen Analyzer, St. Joseph, MO) sulfur (TruSpec Sulfur Add-On Module, Leco Corporation, St. Joseph, MO) and ether extract by performing a biphasic lipid extraction procedure as described by Bremer (2010).

Feed refusals were collected each week and analyzed for DM. Refusals for each individual animal were subtracted from the total amount of supplement offered to calculate actual supplement intake as a percentage of BW.

Data were analyzed using the GLIMMIX model of SAS (SAS Inst., Inc, Cary, N.C.). A multifactorial comparison was utilized in order to compare the different levels of the three variables. Some calves did not consume all of their supplement so covariate regression analysis was used to evaluate linear and quadratic effects of DGS level (Littell et al., 2002). The model includes field, DGS type, linear and quadratic terms for supplement intake, field x DGS type, field x supplement intake, DGS type x supplement intake and field x DGS type x supplement intake. No two-way or three-way interactions were present ($P > 0.05$), so the interaction terms were removed from the model and only the main effects were included. Calves were not blocked and the experimental unit consisted of each individual steer. Type of DGS and field were included in the model statement. Diet samples were evaluated using covariate regression for linear and quadratic terms in order to compare contrasts between the sampling periods based on the type of field.

*Experiment 2*
Sixty crossbred steers (234 kg ± 8.18) were backgrounded on corn residue from November 6, 2013 to January 31, 2014 at ARDC. Treatments were designed to evaluate the effects of gain for calves grazing corn residue while receiving dried DGS supplementation and to estimate the amount of forage consumed. Dried DGS was supplemented at 0.3, 0.5, 0.7, 0.9 or 1.1% of BW.

Calves were received into pens and processed within 24 hours of arrival at the ARDC feedlot in the fall of 2013. Calves were tagged with an electronic identification tag, metal clip tag and panel tag, and were vaccinated according to university protocol.

Initial processing was similar to year 1 and included vaccination with a modified live viral vaccine (Bovi-Shield Gold 5, Zoetis Animal Health, Madison, NJ), *Haemophilus somnus* bacterin (Somubac, Zoetis Animal Health) and an injectable dewormer (Dectomax Injectable, Zoetis Animal Health). Calves were fed a 1:1 blend of alfalfa and Sweet Bran during the receiving period. Approximately 27 days later calves were revaccinated with a modified live viral vaccine, *Haemophilus somnus* bacterin and pinkeye vaccine (Piliguard Pinkeye + 7, Merck Animal Health, DeSoto, KS). Calves were implanted with Ralgro (Merck Animal Health) on day 1 of the trial.

At the end of the receiving period, calves were trained to the Calan system for 30 days and fed the same diet as during receiving. Once trained to the Calan bunks, calves were limit fed at 2% of BW on a 25% grass hay, 25% alfalfa hay and 50% Sweet Bran diet for five days prior to the initiation of the trial. Three day weights were collected on day -1, 0 and 1. Cattle were stratified by BW and assigned randomly to treatment based on day -1 and day 0 weights.
Calves were gathered from the field at 1600 daily and brought in over night to offer supplementation through the Calan gates. Steers were turned out by 0700 to graze residue. All calves received monensin at 200 mg/steer and limestone at 60 g/steer daily as part of supplementation.

Stocking rate was determined using the same equation as Exp. 1. The 13 hectare irrigated field was fenced to allow 66 steers to graze for 90 days based on a yield of 16,250 kg of grain/hectare. Sixty Calan gates were utilized for the monitoring of supplement consumption and six ruminally canulated steers grazed the field although they were not monitored for supplement consumption.

The ruminally canulated calves received dried DGS at 0.7% of BW in a feed bunk next to the Individual Feeding Barn. Diet samples were collected three times throughout the trial by evacuating the rumen of solid and liquid particulate matter similar to Exp. 1. Once steers grazed for thirty minutes they were brought back in and the grazed forage was collected from the rumen, sealed in a 33 cm x 46 cm Reloc Zipit reclosable bag and stored on ice for later analysis of IVOMD. The original rumen contents prior to diet sampling were replaced in the rumen of the respective steer prior to turning them out with the herd.

Total grazed contents were frozen and subsequently freeze dried. Samples were ground through a 1 mm screen prior to analysis. Diet IVOMD was determined by incubating each sample for 48 hours in a solution of MacDougall’s buffer and rumen fluid. Samples were then filtered, dried and ashed to obtain DM and OM amounts for the IVOMD calculation, similar to Exp. 1.
Fecal samples were collected at periodic intervals throughout the trial in order to estimate forage intake. Titanium dioxide was utilized as a marker and fed at 10 g/calf daily (Titgemeyer et al., 2001) beginning five days prior to and throughout the fecal collection period. Three kg of the marker were added to 34.10 kg of condensed distillers solubles (Green Plains LLC, Central City, Neb.) for each collection period and mixed in a 22.7 kg batch mixer. The mixture was stored in plastic containers for transport to the Individual Feeding Barn. The mixture was stored in a heated room to prevent freezing and mixed prior to feeding. Calves received 100mL of the mixture on top of their dried DGS supplementation and premix.

Three fecal collection periods were three days in length and consisted of a grab sample once calves were in the chute. Samples were placed in a labeled Whirl-Pak bag and stored on ice prior to returning to the Ruminant Nutrition Laboratory. Feces were freeze dried and ground through a Wiley Mill (1mm screen). Fecal samples were weighed out in duplicate and analyzed utilizing the wet ash procedure developed by Myers et. al (2004) for analysis of titanium dioxide. Forage intake was calculated as 1 minus the proportion of undigested material divided by what was digested in the diet.

Three loads of dried DGS were delivered throughout the experimental period and analyzed for nutrient analysis. Samples were composited by load and dried in a forced-air oven at 60°C for 48 hours to determine DM according to Buchner (2011). Feed samples were then ground through a 1-mm screen of the Wiley mill prior to further analysis. Samples were also analyzed for ash and OM, NDF, CP, sulfur and ether extract, similar to Exp. 1.
Bunks were slick each morning. Therefore, no feed refusals were collected during this trial.

Data were analyzed used the GLIMMIX model of SAS. Covariate regression analysis was used to determine linear and quadratic effects of DGS supplementation, as well as change in IVOMD across sampling dates. Calves were not blocked and the experimental unit consisted of each individual steer. Level of DGS was included in the model statement.

RESULTS

Experiment 1

No interactions were present among treatments with $P > 0.05$. Differences were not found in initial BW since calves were assigned randomly to treatment and stratified based on initial weight.

Ending BW did not differ based on the type of corn residue field even though calves grazing the non-irrigated field gained more and had a greater ending BW (Table 1). Differences were observed between field type for calf gain (Table 2). Calves grazing the non-irrigated field gained 1.03 kg/day compared to 0.90 kg/day for calves on the irrigated field. Differences in ending BW were not present for type of DGS, with calves supplemented with dried DGS weighing 285 kg and those supplemented with modified at 287 kg. As level of DGS supplementation increased, a linear improvement in ending BW was observed. Calves supplemented at 0.3, 0.7 and 1.1% of BW weighed 278, 288 and 293 kg, respectively, at the end of the trial. A quadratic increase in gain occurred with increasing level of supplementation for calves grazing irrigated and non-irrigated corn.
residue. Calves supplemented at 0.3, 0.7 and 1.1% of body weight gained an average of 0.80, 1.04 and 1.08 kg/day, respectively.

Differences in field type were not present ($P = 0.90$) for diet samples collected throughout the sampling period (Table 3). No differences were present for IVOMD of diet samples over time although there was a tendency for a linear decline of diet samples from the non-irrigated field.

**Experiment 2**

No feed refusals were observed for steers supplemented at any level throughout the duration of the trial.

Ending BW increased linearly with increasing level of dried DGS supplementation for calves grazing irrigated corn residue (Table 3). The average ending BW of calves supplemented at 0.3, 0.5, 0.7, 0.9 and 1.1% of BW were 270, 286, 305, 313 and 329 kg, respectively. Correspondingly, a linear increase in gain occurred with increasing level of dried DGS supplementation. Calves supplemented at 0.3, 0.5, 0.7, 0.9 and 1.1% of BW gained an average of 0.35, 0.65, 0.78, 0.89 and 1.00 kg/calf daily.

No difference in IVOMD of diet samples was present over time with samples remaining relatively constant ($P > 0.25$; Table 4).

Forage intake tended to decline linearly with increasing DGS supplementation ($P = 0.07$; Figure 1). Results showed that calves were expected to consume 0.90 kg less corn residue each day for every 1% of BW increase in supplementation.
DISCUSSION
Corn residue is low in protein and energy to meet the needs of calves due to their rapid growth and development. Both trials observed a positive correlation between supplementation level and gain. As the level of supplementation offered increased as a percentage of BW, the daily gain of the calf improved. Gustad et al. (2005) observed a quadratic increase in gain with increasing levels of dried DGS supplementation to calves grazing irrigated corn residue. The response in gain to supplementation of DGS is further supported by Grings et al. (1994), Nuttelman et al. (2008) and Ahern et al. (2011) who supplemented calves on a high forage diet with DGS.

Finishing trials have observed the energy value of DGS to be dependent on the level of moisture, with wet DGS having a higher energy value when compared with modified or dried DGS (Ham et al., 1994; Bremer, 2010). However, differences in ending BW and ADG have not been present for cattle fed forage-based diets and supplemented with different types of DGS (Ahern et al., 2011; Nuttelman et al., 2008). This trial is supported by previous forage-based research and may show the drying process to have little effect on the protein in DGS.

A difference in ending BW for supplementation level was found in Exp. 2 but not for Exp. 1. This may have been due to the early termination of Exp. 1 caused by substantial ice and snow fall. Unlike typical grazing situations, cattle grazing corn residue have all the forage available the first day of grazing and no new growth of the corn plant is expected to occur throughout the winter grazing period. This allows for the selectivity and consumption of the highest quality parts to occur and a decline in field quality throughout the grazing period (Gutierrez-Ornelas and Klopfenstein, 1991; Fernandez-
Rivera and Klopfenstein, 1989). The shorter grazing season in Exp. 1 may not have limited calf consumption of husk and leaf remaining in the field and allowed calves to select for and consume the highest quality parts until early termination of the trial. Diet samples collected during both years, however, do not reflect the decline in IVOMD expected throughout the grazing season. This is most likely attributed to corn residue fields stocked to where calves would have sufficient blade and husk throughout the grazing season.

Experiment 1 utilized a non-irrigated field in addition to the irrigated field that was not available in Exp. 2 due to the corn-soybean rotation. Results for gain were similar to previous work conducted by Fernandez-Rivera and Klopfenstein (1989) who observed calves grazing an irrigated field gained less than those on a non-irrigated field even though initial availability of grain, husk and leaf were higher on an irrigated field than a non-irrigated field. The higher gain was attributed to the higher CP content of the non-irrigated field suggesting that calves grazing the irrigated field may have been limited in amount of protein available, resulting in lower calf gains. The higher gains of calves grazing non-irrigated residue were evident in Exp. 1 although not supported by the diet samples collected. This may be due to sampling error or the ruminally cannulated steers being unaware of where the most palatable parts were in the non-irrigated field since they grazed the irrigated field on a daily basis.

While a difference in gain was present based on type of field, diet samples collected throughout the trial did not portray variations based on field type or over time. Fernandez-Rivera and Klopfenstein (1989a) collected diet samples and observed calves grazing a non-irrigated field selected material with a higher CP content when compared
to calves grazing an irrigated field. A linear decline in CP content of the diet samples occurred throughout the grazing period with a slower decline in CP for the non-irrigated field. In the present trial, stocking rates were lower, resulting in a higher quantity of grain and husk available for a longer period of time and a slower decline in the quality of the diet samples.

Research estimating forage intake of calves grazing corn residue and supplemented with DGS is not available. However, Watson et al. (2012) evaluated forage intake of steers supplemented dried DGS while grazing brome grass and observed a 0.79 kg decline in forage intake with every 1 kg of supplementation. This can be applied to the present trial in that a decline in forage intake occurred with increasing supplementation of DGS.

**IMPLICATIONS**
Supplementing at a higher level of DGS as a percentage of BW resulted in greater calf gain when grazing corn residue. Therefore, if optimal gain during the winter period is the goal, then supplementation at high levels is key in order to maximize growth.
LITERATURE CITED


Table 1. Effect of Irrigation, type of distillers grains plus solubles (DGS) and level of DGS intake on average daily gain of calves grazing corn residue

<table>
<thead>
<tr>
<th>Item</th>
<th>Type of field</th>
<th>Type of DGS</th>
<th>Level of DGS intake&lt;sup&gt;1,2&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>irrigated</td>
<td>non-irrigated</td>
<td>SEM</td>
</tr>
<tr>
<td>Initial BW, kg</td>
<td>238</td>
<td>236</td>
<td>2.90</td>
</tr>
<tr>
<td>Ending BW, kg</td>
<td>283</td>
<td>289</td>
<td>3.07</td>
</tr>
<tr>
<td>ADG</td>
<td>0.90</td>
<td>1.03</td>
<td>0.02</td>
</tr>
</tbody>
</table>

<sup>1</sup> Intake adjusted to account for feed refusals during each feeding period

<sup>2</sup> Values expressed as a percentage of body weight
Table 2. Effect of time on field type of *In-vitro* Organic Matter Disappearance for Experiment 1\(^1,3\)

<table>
<thead>
<tr>
<th>Sampling dates</th>
<th>11/6/2012</th>
<th>11/20/2012</th>
<th>12/4/2012</th>
<th>12/18/2012</th>
<th>SEM(^2)</th>
<th>Linear</th>
<th>Quadratic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irrigated</td>
<td>55.50</td>
<td>61.70</td>
<td>57.70</td>
<td>53.70</td>
<td>0.05</td>
<td>0.47</td>
<td>0.21</td>
</tr>
<tr>
<td>Non-Irrigated</td>
<td>62.00</td>
<td>56.70</td>
<td>57.30</td>
<td>51.00</td>
<td>0.05</td>
<td>0.09</td>
<td>0.90</td>
</tr>
</tbody>
</table>

\(^1\) All values reported as a percentage.
\(^2\) Standard error of the least-squared mean
\(^3\) Interaction not significant (*P* = 0.46)
Table 3. Effect of varying levels of dried distillers grains (DGS) on animal performance

<table>
<thead>
<tr>
<th>Item</th>
<th>0.3</th>
<th>0.5</th>
<th>0.7</th>
<th>0.9</th>
<th>1.1</th>
<th>S.E.</th>
<th>F-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial BW, kg</td>
<td>238</td>
<td>227</td>
<td>234</td>
<td>232</td>
<td>237</td>
<td>4.79</td>
<td>0.40</td>
</tr>
<tr>
<td>Final BW&lt;sup&gt;2&lt;/sup&gt;, kg</td>
<td>270</td>
<td>286</td>
<td>305</td>
<td>313</td>
<td>329</td>
<td>6.27</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>ADG&lt;sup&gt;2&lt;/sup&gt;, kg</td>
<td>0.35</td>
<td>0.65</td>
<td>0.78</td>
<td>0.89</td>
<td>1.00</td>
<td>0.08</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>

<sup>1</sup> Values expressed as a percentage of body weight.

<sup>2</sup> Linear effect of level of DGS supplementation $P < 0.01$
Table 4. Effect of in vitro organic matter disappearance over time for Experiment 2

<table>
<thead>
<tr>
<th></th>
<th>11/22/2013</th>
<th>12/13/2013</th>
<th>1/17/2014</th>
<th>SEM$^1$</th>
<th>Linear</th>
<th>Quadratic</th>
</tr>
</thead>
<tbody>
<tr>
<td>IVOMD, %</td>
<td>62.4</td>
<td>61.9</td>
<td>64.8</td>
<td>2.05</td>
<td>0.25</td>
<td>0.82</td>
</tr>
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</table>

$^1$ Standard error of the least-squared mean
Figure 1. Effect on forage intake with increasing levels of dried distillers grains (DGS) supplementation

Forage Intake, kg

Level of Dried Distillers Grains Supplementation

\[ y = -0.90x + 5.41 \]

linear \( P = 0.07 \)

SEM = 0.49
Chapter III. Evaluation of changes in nutritional quality of corn residue throughout grazing period

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1 This work is a contribution of the University of Nebraska Agricultural Research Division, supported in part by fund through the Hatch Act.

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ABSTRACT
Residues of corn (*Zea mays*) have successfully been utilized as an economical roughage and energy source for ruminants. Two experiments were conducted utilizing standing corn plants for two hybrids (102 and 119 d maturity) in order to determine the change in nutritive value of the forage components over time. Experiment 1 was planted May 27th and Exp. 2 was planted April 27th. Corn plants were harvested at periodic intervals from September 2012 to December 2012 in order to determine changes in quality and proportion of corn residue as the plant dried and was exposed to effects of weathering. Plants were separated into stem, blade and sheath, husk and shank, cob and grain. Samples were analyzed for DM, NDF and true digestibility. Estimates of true digestibility were derived from NDF content and *in situ* estimations of NDF digestibility assuming 100% digestibility from the soluble fraction. Hybrid did not influence the proportion of plant components (*P* > 0.40) for Exp. 1. Percentage of DM in each plant part increased until the November sampling date for both hybrids and planting dates and then remained relatively constant (*P* < 0.01). Grain, as a percentage of the total plant DM, tended to increase to approximately 60% where it then remained relatively constant for both planting dates and hybrids (*P* < 0.15). Proportions of stem, blade/sheath, husk/shank and cob made up smaller components of total plant DM as it matured with the largest relative reduction occurring in the blade/sheath and stem. A linear increase over time for NDF content was observed for both hybrids in Exp. 1 of all plant parts except stem (*P* < 0.01). No differences were found in the NDF content for Exp. 2 (*P* = 0.40). Hybrid had an impact on the true digestibility (*P* < 0.01) primarily because the 119 d hybrid was less mature at the early sampling dates. In both experiments, digestibility of husk/shank remained constant (*P* > 0.40) whereas cob decreased (*P* < 0.10). While corn hybrid and
planting date affect the quality of residue, plant component appears to be the largest contributor in determining the quality of residue available for grazing.

**KEYWORDS:** corn residue, forage quality, plant components

**INTRODUCTION**
Corn (*Zea mays*) has successfully been utilized as an economical roughage and energy source for ruminants. The grain has the highest energy value and constitutes approximately 50% of total plant DM (Pordesimo et al., 2004). After grain harvest, however, the forage components of the corn plant are the majority of what is left in the field. Residue proportions are estimated to be 43% stem, 44% husk/blade, 9% cob and 4% grain for an irrigated field (Fernandez-Rivera and Klopfenstein, 1989). Residue acts as an alternative winter feed source and is more economical when grazed by cattle compared to baling the residue (Klopfenstein et al., 1987).

Overall, the quality of residue is relatively low in protein and energy due to the advanced stage of maturity after harvest, variation among plant parts and animal selectivity. As cattle selectively graze the most palatable components first, the quality of the field declines over time as the least desirable parts are left in the field. Fernandez-Rivera and Klopfenstein (1989) found that cattle select for and consume the grain first followed by the husk, blade and if forced to graze that low, the cob and stem. McGee et al. (2012) analyzed the forage components of the corn plant and found husk to be the highest quality forage component while stem was of the lowest quality. This is supported by previous research conducted by Lamm and Ward (1981) and Russell (1986). Few trials have been conducted to measure how the forage components are affected after grain harvest. Based on previous forage research (Van Soest, 1964; Jung and Vogel, 1986), the
forage components are believed to decrease in quality as the plant matures with the change in quality largely dependent on advanced maturity and the effects of weathering. However, Weaver et al. (1978) found that the nutritional quality of corn stover remained relatively constant after grain harvest. The objective of this trial was to determine the nutritional quality of corn residue components over time.

MATERIALS AND METHODS
Two experiments were conducted in 2012 at the University of Nebraska- Lincoln Agricultural Research and Development Center near Mead, Neb. utilizing standing corn plants. Experiment 1 was planted May 27\textsuperscript{th} and Exp. 2 was planted April 27\textsuperscript{th}. Corn plants were harvested at periodic intervals from August 2012 to December 2012. Both experiments contained two hybrids, a 102d (DKC52-59) and 119d (DKC69-40) maturity of DeKalb brand BT3 corn seed (Monsanto Co., St. Louis, MO), and the same inputs were applied throughout the field.

Standing corn plants were harvested from irrigated demonstration plots (Figure 2). The field was approximately 43 meters long and 23 meters wide, with Exp. 1 on the north end of the field and Exp. 2 on the south end. The center of the plot (approximately 19 meters) consisted of a different planting date and was not utilized in this trial. Each hybrid was planted to 8 rows and the field was irrigated with a center pivot as needed. Corn plants in Exp. 1 were harvested at two week intervals August through October and then four week intervals through December while Exp. 2 was harvested at four week intervals from October through December. Samples from the outside row of each planting date were avoided in order to maintain a more uniform sample and reduce field bias in the analysis.
as described by Anderson et al. (2007). Corn was not harvested for grain; instead, the plant remained standing in the field for the duration of the collection period.

Hybrids within each experiment were divided into quadrats and a sample from each quadrat was collected at sampling time for a total of four replications (n = 4). Bypass loppers (model # 7080) were used to cut plants for each rep, beginning at the southwest corner of the field and moving counterclockwise through each respective planting date. Replications consisted of five competitive plants, or five plants in a row that were representative of the field.

The ears and blade/sheath were removed in the field and placed in labeled 24” x 24” white block reclosable bags (4 mil, Uline, Hudson, WI) for transport back to the Ruminant Nutrition Laboratory in order to reduce the loss of leaves and ears during transport. The stems were weighed at the field, sent through a chipper shredder (model # D11334 AC, Troy Built, MTD Products, Valley City, OH) and placed in labeled 13” x 18” Reloc Zipit reclosable bags (4 mil, Consolidated Plastics, Stow, OH). The ear was further separated at the laboratory into husk/shank, cob, and grain and placed into labeled 13” x 18” airtight bags. Prior to placement in the labeled bag, cob samples were chopped using the Ohio Mill (Silver Manufacturing Co., Salem, OH) and blade/sheath and husk/shank were cut with bypass loppers in order to reduce particle size for equal drying and more accurate determination of DM. Field weights of the plant parts were recorded and all samples were dried in duplicate in a 60⁰C forced-air oven for 48 hours. A portion of each sample collected from August through October was also freeze dried (Virtis Freezemobile 25ES). These samples were not expected to have reached physiological maturity and freeze drying removed moisture while avoiding soluble volatilization from
the plant component. Nutrient analysis was conducted on the freeze dried sample and DM weight was estimated from the portion that was dried in the forced-air oven. After DM was obtained, each sample was ground through a 2-mm screen in the Wiley mill and placed in labeled Whirl-Pak bags (B01297, Nasco, Kellogg, ID).

Blacklayer data was not collected from the field. Instead, blacklayer was calculated with an equation using planting date, hybrid and weather pattern data to estimate maturity relative to the time of sampling (High Plains Regional Climate Center, 2014).

Plant parts for each sampling date were analyzed for neutral detergent fiber (NDF) digestibility using 5 cm x 10 cm Ankom in situ bags (R510) with a 50 µm pore size (Ankom Technology Corp., Macedon, NY). Quadruplicate 1.25 g samples were weighed into each in situ bag and the bags were sealed twice with an Ankom heat sealer (Ankom Technology Corp. Macedon, NY). The bags were assigned randomly to two ruminally canulated steers utilized for in situ (2 bags/steer). The steers were fed a forage-based diet (70% grass hay, 30% concentrate) at approximately 1400 daily. In situ bags were then randomly grouped into sets of forty and placed in a mesh bag. Eight mesh bags were placed in a steer during each 28 hour incubation period. After incubation, bags were washed in a washing machine using a 1 min agitation and 2 min spin cycle, and repeated 5 times (Haugen et al., 2006). The bags were refluxed in NDF solution (Ankom Technology Corp., Macedon, NY). In situ bags were then dried in a forced-air oven at 100°C for 12 hours and weighed back for DM.

True digestibility of stem, blade/sheath, husk/shank and cob were calculated in order to determine the amount that is fermented by the microbial community during retention time
in the rumen. Digestibility of NDF was determined by comparing the amount of NDF prior to ruminal incubation to the amount remaining after the incubation period. Plant solubles were considered 100% digestible and were calculated by subtracting the percentage of NDF from 100%. Therefore, true digestibility is the sum of the solubles and digestible NDF.

Kilogram of plant fraction for every 25.5 kilograms of grain yield over time was calculated utilizing the proportion of the plant part on a DM basis relative to grain yield.

Data were analyzed using the MIXED procedure of SAS (SAS Inc., Cary, NC). Repeated measures were used to determine how plant parts changed over time in regards to NDF content, NDF digestibility and true digestibility. The experimental unit consisted of the five competitive plants within each replication (n = 4) for each exp. All model statements included hybrid and plant component within each exp. as a fixed effect. The interaction was not significant at $P > 0.10$ so the main effects are presented. The best fit for covariate structure of DM proportion, NDF content, NDF digestibility and true digestibility occurred with the Toeplitz model based on its lowest AICC values. In analyzing for kg of plant fraction for every 25.5 kg of grain yield, the best fit for Exp. 1 was the Toeplitz model while the best fit for Exp. 2 was first-order auto regressive. A covariate regression was developed to determine linear and quadratic responses to quality of plant parts over time (Littell et al., 2002).

RESULTS

Experiment 1
No interaction occurred between hybrid and plant component \( (P > 0.05) \). Therefore, the main effects of time within plant component are presented.

There was a quadratic change in the proportion of residue DM over time for stem, blade/sheath and husk/shank, with few changes in DM proportion occurring once grain was estimated to reach 15.5% moisture \( (P < 0.01; \text{Table 5}) \). No differences were present in the proportion of cob throughout the sampling period \( (P = 0.80) \).

By sampling to more advanced stages of maturity, a quadratic increase in NDF content was evident over time for blade/sheath, husk/shank and cob \( (P < 0.01; \text{Table 6}) \). The NDF content of these plant parts remained relatively constant after grain harvest at 15.5% moisture. A linear decrease in the NDF content of stem occurred throughout the sampling period, from 70.6% to 64.3% \( (P = 0.01) \).

A quadratic decrease in NDF digestibility occurred over time for cob, with the majority of the decline occurring prior to normal grain harvest and then remaining relatively constant for the remainder of the sampling period \( (P < 0.01; \text{Table 7}) \). No differences were found over time for the other plant parts \( (P > 0.05) \). The NDF digestibility of the blade/sheath, husk/shank and stem remained relatively constant for each sampling point, with the blade/sheath at 30%, husk/shank at 40% and stem less than 10%.

True digestibility of cob decreased quadratically over time and remained relatively constant once grain reached 15.5% moisture \( (\text{Table 8}) \). A linear decrease in true digestibility occurred for blade/sheath \( (P < 0.01) \) while a linear increase in true digestibility of the stem \( (P = 0.01) \) occurred over time. True digestibility of the husk/shank remained relatively constant throughout the sampling period \( (P = 0.40) \).
The amount of residue produced per 25.5 kg of grain yield differed by plant component (Table 9). At typical harvest time, stem made up the greatest proportion per 25.5 kg of grain yield (8.0 kg), followed by blade/sheath (6.3 kg), cob (2.6 kg) and husk/shank (1.6 kg). A quadratic decrease occurred for blade/sheath and cob ($P < 0.01$), with the majority of the change occurring prior to estimated blacklayer. A linear decrease per 25.5 kg grain yield was present for stem ($P < 0.01$). No differences were present for husk/shank which remained relatively constant throughout the sampling period ($P = 0.90$).

**Experiment 2**

A quadratic increase in the proportion of residue DM was evident over time for both cob and husk/shank while a quadratic decrease occurred for the stem ($P < 0.01$; Table 10). No differences were found in the proportion of residue DM over time for blade/sheath ($P = 0.90$).

An interaction between hybrids was found for NDF content so results were separated. A linear increase in NDF content of husk/shank for the 102d hybrid occurred over time ($P < 0.01$; Table 11). No differences in NDF content of the 102d hybrid were found for the stem, blade/sheath and cob. The NDF content of stem and husk/shank in the 119d hybrid showed a linear decrease over time ($P < 0.01$; Table 12). No differences were observed for blade/sheath and cob of the 119d hybrid.

A linear decline was found for NDF digestibility of cob ($P = 0.04$; Table 13) with no differences observed in the blade/sheath, husk/shank and stem ($P > 0.05$). True digestibility of the husk increased linearly ($P = 0.04$; Table 14). No differences were observed in the blade/sheath, cob and stem ($P > 0.05$) over time.
The amount of residue produced per 25.5 kg of grain yield differed by plant component (Table 15). Stem made up the greatest proportion per 25.5 kg of grain yield (15.6 kg) followed by blade/sheath (7.3 kg), cob (6.2 kg) and husk/shank (3.9 kg). Differences were not found over time although numerical changes were present for each of the plant parts.

**DISCUSSION**

Experiment 2 was sampled approximately 50 days after estimated blacklayer formation and had fewer sampling time points when compared to Exp. 1 which was sampled prior to and after blacklayer formation. Samples from Exp. 2 were more mature at the start of sampling which may have contributed to the different responses between the experiments.

Similar to Exp. 1, Weaver et al. (1978) sampled standing corn plants and found minimal changes in plant part DM after the time of grain harvest. Perry and Compton (1977) also harvested standing corn plants and found that 84% of the increase in DM accumulation of plant parts that occurred during the sampling period was due to the plant having reached physiological maturity. Any additional changes in DM that occurred after the plant reached physiological maturity were attributed to the effects of weathering. Differences seen for Exp. 2 in regards to changes in proportion of DM over time may be due to the short sampling time frame and more mature corn plants when sampling began. A sampling schedule for Exp. 2 that began prior to normal grain harvest and extended into the winter grazing period may have minimized the differences seen after the plant reached physiological maturity and showed results similar to Exp. 1.
The NDF of most of the plant parts for both experiments increased until the plants were physiologically mature and then remained relatively constant throughout the remainder of sampling times. Van Soest (1967) showed the amount of NDF increased with advancing grass maturity with relatively little change in NDF once the grass reached physiological maturity.

Increasing amounts of NDF were shown to have a negative effect on digestibility of the forage and have been correlated with a decrease in solubles of the plant part (Weaver et al., 1978; Berger et al., 1979). Stem had a linear decline in NDF content for both experiments and husk/shank for Exp. 2, indicating that these plant parts increased in solubles over time. This is not supported by previous research since solubles are metabolized by the plant as it matures and it is unlikely that the concentration of solubles in these parts increased over time. It is unclear what displaced NDF in the stem as it remained standing in the field.

As the plant reaches physiological maturity, true digestibility is expected to decline due to the increase in fiber content and reduction in amount of solubles. For both experiments, true digestibility remained relatively constant once the plant reached physiological maturity. This supports the observation by Perry and Compton (1977) of any changes in the composition of the corn plant after physiological maturity being due to weathering. Research is not typically conducted after grain harvest, however, so limited research exists showing how the true digestibility of the plant part is affected by the environment. Weaver et al. (1978) found the digestibility of the corn plant components to decline when a weather event such as frost, snow or sleet occurred. The fall of 2012 was mild and no major weather events occurred during the sampling times which is consistent
with the relative consistency in digestibility seen for both experiments. The stem increased in true digestibility due to the decline of NDF content and suggests cell solubles are increasing in the stem. As previously stated, it is unclear what displaced NDF in the stem and it seems unlikely that the true digestibility of the stem increased over time based on previous research by Van Soest (1967).

The true digestibility of husk/shank was greatest among the forage components followed by blade/sheath. McGee et al. (2012) separated corn plants into their respective parts when grain was 15.5% moisture and found husk to be the most digestible part followed by the blade. A decline in the digestibility of blade/sheath was present for Exp. 1 although it remained higher in digestibility than the cob and stem. The decline after the plant reached physiological maturity may mean the blade/sheath is more affected by wind and other weather events than the other plant components. The husk/shank remained relatively consistent in digestibility regardless of the advanced stage of maturity. This may denote the husk/shank having less of an effect from weathering than other plant components. Weaver et al. (1978) also found minimal changes in digestibility of the husk after the plant reached physiological maturity. Digestibility of the forage components is expected to decline due to the increase in size of the cell wall as the plant advances to physiological maturity (Van Soest, 1964; Johnson et al., 1962). For Exp. 2, the sampling of corn plants later than typical grain harvest may have contributed to the lack of differences present for true digestibility and the relatively constant values.

The largest proportion of residue per 25.5 kg of grain yield for both experiments was the stem while the smallest component was the husk/shank. This was supported with previous research conducted by McGee et al. (2012) who found the stem to make up the
largest proportion of residue per 25.5 kg of grain yield while husk made up the smallest proportion. Few changes occurred in the proportion of residue once grain reached 15.5% moisture. Therefore, any reduction in amount of residue per 25.5 kg of grain yield after normal grain harvest can be attributed to environmental effects. Cattle select for and consume the husk/shank and blade/sheath prior to consuming the other plant components. However, half of the forage available is lost to trampling and other losses (Gutierrez-Ornelas and Klopfenstein, 1991). Estimating the amount of residue available in the field will avoid overgrazing and allow cattle to consume the more palatable fractions.

**IMPLICATIONS**
Plant part is the major contributor to the quality of residue. The husk/shank makes up one of the smaller components of residue on a DM basis and is the most digestible forage component. Stem, on the other hand, makes up the largest forage component and has a low digestibility. Digestibility and proportion of the husk/shank remained relatively constant after the time of typical grain harvest.
LITERATURE CITED


High Plains Regional Climate Center Online Data Services. Retrieved 2 February 2014 from http://www.hprcc.unl.edu/


**Figure 2. Diagram of demonstration plot**

<table>
<thead>
<tr>
<th>Date</th>
<th>Rows</th>
</tr>
</thead>
<tbody>
<tr>
<td>May 119d</td>
<td>8</td>
</tr>
<tr>
<td>May 102d</td>
<td>8</td>
</tr>
<tr>
<td>Not used for trial</td>
<td></td>
</tr>
<tr>
<td>April 119d</td>
<td>8</td>
</tr>
<tr>
<td>April 102d</td>
<td>8</td>
</tr>
</tbody>
</table>
Table 5. Dry matter proportion of residue components over time for Experiment 1\(^1\)

<table>
<thead>
<tr>
<th></th>
<th>days from blacklayer(^2)</th>
<th>P-value</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th>S.E.</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-18</td>
<td>-4</td>
<td>10</td>
<td>38</td>
<td>52</td>
<td>66</td>
<td>81</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>blade &amp; sheath(^3,4)</td>
<td>38.5</td>
<td>19.0</td>
<td>34.2</td>
<td>9.6</td>
<td>23.9</td>
<td>22.0</td>
<td>24.7</td>
<td>1.27</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>cob(^3,4)</td>
<td>13.9</td>
<td>17.2</td>
<td>14.5</td>
<td>16.7</td>
<td>17.8</td>
<td>15.8</td>
<td>18.7</td>
<td>1.27</td>
<td>0.80</td>
<td>1.0</td>
</tr>
<tr>
<td>husk &amp; shank(^3,4)</td>
<td>7.5</td>
<td>10.3</td>
<td>8.4</td>
<td>22.7</td>
<td>9.1</td>
<td>7.9</td>
<td>11.7</td>
<td>1.27</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>stem(^3,4)</td>
<td>40.2</td>
<td>53.5</td>
<td>42.9</td>
<td>51.0</td>
<td>49.2</td>
<td>54.3</td>
<td>45.0</td>
<td>1.27</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>

\(^1\) Values reported as a percent
\(^2\) Blacklayer was calculated using planting date, hybrid and weather pattern data from High Plains Regional Climate Center.
\(^3\) Main effect of time and hybrid not significant \(P > 0.05\)
\(^4\) Quadratic effect of dry matter proportion \(P < 0.01\)
Table 6. Total neutral detergent fiber content of plant parts in Experiment 1

<table>
<thead>
<tr>
<th></th>
<th>blade &amp; sheath&lt;sup&gt;3,4&lt;/sup&gt;</th>
<th>cob&lt;sup&gt;3,4&lt;/sup&gt;</th>
<th>husk &amp; shank&lt;sup&gt;3,4&lt;/sup&gt;</th>
<th>stem&lt;sup&gt;3&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>days from blacklayer&lt;sup&gt;2&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-18</td>
<td>-4</td>
<td>10</td>
<td>38</td>
</tr>
<tr>
<td>blade &amp; sheath&lt;sup&gt;3,4&lt;/sup&gt;</td>
<td>61.1</td>
<td>63.3</td>
<td>65.3</td>
<td>71.3</td>
</tr>
<tr>
<td>cob&lt;sup&gt;3,4&lt;/sup&gt;</td>
<td>69.2</td>
<td>78.6</td>
<td>83.1</td>
<td>80.7</td>
</tr>
<tr>
<td>husk &amp; shank&lt;sup&gt;3,4&lt;/sup&gt;</td>
<td>74.0</td>
<td>79.1</td>
<td>78.1</td>
<td>83.1</td>
</tr>
<tr>
<td>stem&lt;sup&gt;3&lt;/sup&gt;</td>
<td>70.6</td>
<td>68.7</td>
<td>65.6</td>
<td>72.1</td>
</tr>
</tbody>
</table>

<sup>1</sup> Values reported as a percent
<sup>2</sup> Blacklayer was calculated using planting date, hybrid and weather pattern data from High Plains Regional Climate Center.
<sup>3</sup> Main effect of time and hybrid not significant \( P > 0.05 \)
<sup>4</sup> Linear effect of dry matter proportion \( P < 0.01 \)
<table>
<thead>
<tr>
<th>Part</th>
<th>Days from blacklayer</th>
<th>P-value</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-18</td>
<td>-4</td>
<td>10</td>
</tr>
<tr>
<td>blade &amp; sheath³</td>
<td>29.5</td>
<td>30.8</td>
<td>31.8</td>
</tr>
<tr>
<td>cob³</td>
<td>30.7</td>
<td>26.5</td>
<td>25.2</td>
</tr>
<tr>
<td>husk &amp; shank³</td>
<td>36.0</td>
<td>40.2</td>
<td>38.9</td>
</tr>
<tr>
<td>stem³</td>
<td>6.5</td>
<td>4.0</td>
<td>4.3</td>
</tr>
</tbody>
</table>

¹ Values reported as a percent
² Blacklayer was calculated using planting date, hybrid and weather pattern data from High Plains Regional Climate Center.
³ Main effect of time and hybrid not significant $P > 0.05$
Table 8. True digestibility of plant parts in Experiment 1

<table>
<thead>
<tr>
<th></th>
<th>days from blacklayer</th>
<th>P-value</th>
<th></th>
<th></th>
<th></th>
<th>S.E.</th>
<th>L</th>
<th>Q</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-18</td>
<td>-4</td>
<td>10</td>
<td>38</td>
<td>52</td>
<td>66</td>
<td>81</td>
<td></td>
</tr>
<tr>
<td>blade &amp; sheath³</td>
<td>58.1</td>
<td>56.3</td>
<td>55.5</td>
<td>52.3</td>
<td>51.8</td>
<td>49.5</td>
<td>50.4</td>
<td>1.20</td>
</tr>
<tr>
<td>cob³</td>
<td>51.9</td>
<td>42.3</td>
<td>37.8</td>
<td>38.1</td>
<td>35.9</td>
<td>39.8</td>
<td>37.7</td>
<td>1.20</td>
</tr>
<tr>
<td>husk &amp; shank³</td>
<td>53.4</td>
<td>52.7</td>
<td>52.3</td>
<td>50.8</td>
<td>55.1</td>
<td>52.1</td>
<td>55.7</td>
<td>1.20</td>
</tr>
<tr>
<td>stem³</td>
<td>33.8</td>
<td>34.1</td>
<td>37.2</td>
<td>32.8</td>
<td>42.6</td>
<td>45.3</td>
<td>38.3</td>
<td>1.20</td>
</tr>
</tbody>
</table>

1 Values reported as a percent
2 Blacklayer was calculated using planting date, hybrid and weather pattern data from High Plains Regional Climate Center.
3 Main effect of time and hybrid not significant $P > 0.05$
4 True digestibility calculated as the sum of the solubles and digestible NDF.
Table 9. Kilograms of plant fraction per 25.5 kilograms of grain yield over time for Experiment 1

<table>
<thead>
<tr>
<th></th>
<th>days from blacklayer$^2$</th>
<th></th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-18</td>
<td>-4</td>
<td>10</td>
</tr>
<tr>
<td>blade &amp; sheath$^3$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>cob$^3$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>husk &amp; shank$^3$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>stem$^3$</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$^1$ Values reported in kilograms
$^2$ Blacklayer was calculated using planting date, hybrid and weather pattern data from High Plains Regional Climate Center.
$^3$ Main effect of time and hybrid not significant $P > 0.05$
Table 10. Proportion of residue dry matter over time for Experiment 2\(^1\)

<table>
<thead>
<tr>
<th></th>
<th>days from blacklayer(^2)</th>
<th></th>
<th></th>
<th></th>
<th>(P)-value</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>51</td>
<td>93</td>
<td>108</td>
<td>S.E.</td>
<td>L</td>
<td>Q</td>
<td></td>
</tr>
<tr>
<td>blade &amp; sheath(^3)</td>
<td>23.9</td>
<td>22.4</td>
<td>20.5</td>
<td>1.26</td>
<td>0.9</td>
<td>0.9</td>
<td></td>
</tr>
<tr>
<td>cob(^3)</td>
<td>16.1</td>
<td>20.7</td>
<td>20.5</td>
<td>1.26</td>
<td>(&lt;0.01)</td>
<td>(&lt;0.01)</td>
<td></td>
</tr>
<tr>
<td>husk &amp; shank(^3)</td>
<td>9.5</td>
<td>13</td>
<td>13.3</td>
<td>1.26</td>
<td>(&lt;0.01)</td>
<td>(&lt;0.01)</td>
<td></td>
</tr>
<tr>
<td>stem(^3)</td>
<td>50.6</td>
<td>43.9</td>
<td>45.7</td>
<td>1.26</td>
<td>(&lt;0.01)</td>
<td>(&lt;0.01)</td>
<td></td>
</tr>
</tbody>
</table>

\(^1\) Values reported as a percent

\(^2\) Blacklayer was calculated using planting date, hybrid and weather pattern data from High Plains Regional Climate Center.

\(^3\) Main effect of time and hybrid not significant \(P > 0.05\)
Table 11. Total neutral detergent fiber content of plant parts for 102d hybrid in Experiment 2

<table>
<thead>
<tr>
<th>Plant Part</th>
<th>51</th>
<th>93</th>
<th>108</th>
<th>S.E.</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blade &amp; Sheath</td>
<td>69.2</td>
<td>66.7</td>
<td>69.1</td>
<td>1.51</td>
<td>0.6</td>
</tr>
<tr>
<td>Cob</td>
<td>83.9</td>
<td>77.3</td>
<td>79.6</td>
<td>1.51</td>
<td>0.2</td>
</tr>
<tr>
<td>Husk &amp; Shank</td>
<td>75.2</td>
<td>70.4</td>
<td>72.8</td>
<td>1.51</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Stem</td>
<td>57.2</td>
<td>56.4</td>
<td>60.1</td>
<td>1.51</td>
<td>0.9</td>
</tr>
</tbody>
</table>

1 Values reported as a percent
2 Blacklayer was calculated using planting date, hybrid and weather pattern data from High Plains Regional Climate Center.
Table 12. Total neutral detergent fiber content of plant parts for 119d hybrid in Experiment 2

<table>
<thead>
<tr>
<th>Plant Part</th>
<th>51</th>
<th>93</th>
<th>108</th>
<th>S.E.</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>blade &amp; sheath</td>
<td>71.4</td>
<td>68.6</td>
<td>71.9</td>
<td>1.51</td>
<td>0.30</td>
</tr>
<tr>
<td>cob</td>
<td>85.4</td>
<td>84.4</td>
<td>79.7</td>
<td>1.51</td>
<td>0.10</td>
</tr>
<tr>
<td>husk &amp; shank</td>
<td>80.3</td>
<td>74.4</td>
<td>76.2</td>
<td>1.51</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>stem</td>
<td>59.0</td>
<td>49.5</td>
<td>49.8</td>
<td>1.51</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>

1 Values reported as a percent
2 Blacklayer was calculated using planting date, hybrid and weather pattern data from High Plains Regional Climate Center.
Table 13. Total neutral detergent fiber digestibility of plant parts for Experiment 2

<table>
<thead>
<tr>
<th></th>
<th>days from blacklayer</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>51</td>
<td>93</td>
</tr>
<tr>
<td>blade &amp; sheath</td>
<td>18.5</td>
<td>21.4</td>
</tr>
<tr>
<td>cob</td>
<td>20.5</td>
<td>15.9</td>
</tr>
<tr>
<td>husk &amp; shank</td>
<td>30.3</td>
<td>34.9</td>
</tr>
<tr>
<td>stem</td>
<td>0</td>
<td>1.6</td>
</tr>
</tbody>
</table>

1 Values reported as a percent
2 Blacklayer was calculated using planting date, hybrid and weather pattern data from High Plains Regional Climate Center.
3 Main effect of time and hybrid not significant $P > 0.05$
Table 14. True digestibility of plant parts for Experiment 2\textsuperscript{1}

<table>
<thead>
<tr>
<th></th>
<th>days from blacklayer\textsuperscript{2}</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>51</td>
<td>93</td>
</tr>
<tr>
<td>blade &amp; sheath</td>
<td>43.0</td>
<td>46.8</td>
</tr>
<tr>
<td>cob</td>
<td>32.7</td>
<td>31.9</td>
</tr>
<tr>
<td>husk &amp; shank\textsuperscript{3}</td>
<td>46.0</td>
<td>52.9</td>
</tr>
<tr>
<td>stem</td>
<td>41.9</td>
<td>47.9</td>
</tr>
</tbody>
</table>

\textsuperscript{1} Values reported as a percent

\textsuperscript{2} Blacklayer was calculated using planting date, hybrid and weather pattern data from High Plains Regional Climate Center.

\textsuperscript{3} No effect $P = 0.40$
Table 15. Kilograms of plant fraction per 25.5 kilograms of grain yield over time for Experiment 2

<table>
<thead>
<tr>
<th></th>
<th>days from blacklayer</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>51</td>
<td>93</td>
</tr>
<tr>
<td>blade &amp; sheath³</td>
<td>8.5</td>
<td>6.9</td>
</tr>
<tr>
<td>cob³</td>
<td>5.7</td>
<td>6.3</td>
</tr>
<tr>
<td>husk &amp; shank³</td>
<td>3.4</td>
<td>4.0</td>
</tr>
<tr>
<td>stem³</td>
<td>18.3</td>
<td>13.5</td>
</tr>
</tbody>
</table>

¹ Values reported in kilograms
² Blacklayer was calculated using planting date, hybrid and weather pattern data from High Plains Regional Climate Center.
³ Hybrid did not influence proportion of plant parts
Chapter IV. Comparison of Commercial Lick Tubs to Distillers Grains Supplementation for Calves Grazing Corn Residue


Department of Animal Science, University of Nebraska-Lincoln 68583; *Department of Agricultural Economics, University of Nebraska-Lincoln 68583

1 This work is a contribution of the University of Nebraska Agricultural Research Division, supported in part by fund through the Hatch Act.

2 Corresponding author: C220 Animal Science Building; Phone: 402-472-6780; Fax: 402-472-6362; Email: jmacdonald2@unl.edu
ABSTRACT
Corn residue is a forage source low in energy and crude protein to meet the needs of growing calves. Providing supplementation increases average daily gain of calves grazing corn residue. The objective of this trial was to compare the use of a commercially available lick tub to daily by-product supplementation of calves grazing corn residue.

One hundred twenty five crossbred steers (240 kg ± 2.65) were backgrounded on irrigated corn residue for a 70 d grazing period at the University of Nebraska- Lincoln Agricultural Research and Development Center near Mead, Neb. The trial was replicated over two consecutive years. Each year, an irrigated corn residue field was divided into eight paddocks, with four replications receiving dried distillers grains (DGS) and four having continuous access to lick tubs (n = 8). Calves on the DGS treatment received supplementation in a bunk at 1.34 kg/steer per day. Stocking rate was calculated based on grain yield of the field at harvest multiplied by an estimated 12.5 kg forage consumed/bu, 85% grazing efficiency factor and number of hectares available for grazing. Data was analyzed using Proc Glimmix with year included as a random effect. Gain of steers receiving dried DGS was 0.62 kg/steer per day in comparison to 0.38 kg/steer per day for steers on the lick tub treatment (P < 0.01). Average supplement intake for cattle on the lick tub treatment was 0.76 kg/day on an OM basis compared to 1.28 kg/day for steers receiving dried DGS (P < 0.01). Since forage intake was not measured, supplement efficiency was used to compare the change in gain to intake by dividing ADG by supplement intake. Supplement efficiency for the lick tubs and dried DGS treatments were 43 and 46% on a DM basis (P < 0.01) compared to 50% and 48% on an OM basis, respectively (P = 0.64). Lick tubs are a convenient method for providing supplementation
to calves and on an OM basis, offer similar supplement efficiency when compared with daily by-product supplementation.

**KEYWORDS:** corn residue, grazing, stocker cattle, supplementation

**INTRODUCTION**
Corn residue is an abundant forage source within the state of Nebraska, with approximately 9.95 million acres planted to corn in 2013 (USDA NASS, 2014). After grain is harvested, corn residue is utilized by producers to extend the grazing season and take advantage of a forage-based production system.

Residue, however, is low in energy and crude protein to meet the needs of calves (Fernandez-Rivera and Klopfenstein, 1989). Providing protein supplementation to calves grazing corn residue optimizes gain of the calves and improves intake of low-quality forages. Dried DGS have a high protein (30.5% CP; Paz et al., 2013) and energy content (95% TDN; NRC, 2000) and have been shown to maintain or improve gain of cattle grazing corn residue (Gustad et al., 2005). Various methods of supplementation exist although dried distillers grains plus solubles (DGS) are among the most common.

Other forms of supplementation are available as lick tubs and may result in similar performance while improving convenience for producers. Mulholland et al. (1976) observed no differences in animal performance for wethers grazing oat stubble and offered urea block supplementation versus a non-supplemented control group. Average daily gain and wool production were correlated with above average rainfall which allowed sufficient regrowth of forage and selection by the wethers. Performance of cattle supplemented with the lick tubs relative to a common supplementation strategy is
unknown. The objective of this trial was to compare the use of commercial lick tubs to daily by-product supplementation of dried DGS for calves grazing corn residue.

MATERIALS AND METHODS
One hundred twenty five crossbred steers (240 kg ± 2.65) were backgrounded on irrigated corn residue for a 70 day grazing period at the University of Nebraska- Lincoln Agricultural Research and Development Center (ARDC) near Mead, Neb. The trial was replicated over two consecutive years. Each year, an irrigated corn residue field was divided into eight paddocks, with four replications receiving dried distillers grains plus solubles (DGS) and four having continuous access to lick tubs.

Calves were received in the fall and processed within 24 hours of arrival at the ARDC feedlot. Calves were tagged with an electronic identification tag, metal clip tag and panel tag, and were vaccinated according to university protocol.

Initial processing for both years included vaccination with a modified live viral vaccine (Bovi-Shield Gold 5, Zoetis Animal Health, Madison, NJ), *Haemophilus somnus* bacterin (Somubac, Zoetis Animal Health) and an injectable dewormer (Dectomax Injectable, Zoetis Animal Health). In both years, cattle were fed a 1:1 blend of alfalfa hay and Sweet Bran (Cargill, Blair, NE) during the receiving period. Cattle were revaccinated approximately 27 days later with a modified live viral vaccine, *Haemophilus somnus* bacterin and pinkeye vaccine (Piliguard Pinkeye + 7, Merck Animal Health, DeSoto, KS). Steers were implanted with Ralgro (Merck Animal Health) on day 1 of the trial, prior to being turned out to graze.
The dried DGS treatment received supplementation in a bunk at 1.34 kg/steer daily on a DM basis. Lick tubs were replaced in each paddock when less than 10% remained and the plastic tray was removed once the supplement was consumed. Each lick tub was weighed prior to placement in the field and upon removal and was corrected for DM to determine the amount of supplement consumed.

The commercial lick tubs (Sweet Pro, Walhalla, ND) utilized for this trial were designed to provide mineral to cattle and contained yeast and enzymes from the proprietary fermentation process, making them higher in protein and fat when compared with a molasses-based block. A pressing technique is used to give the product its characteristic hardness and assists in controlling intake. The company offers different types of lick tubs depending on the stage of growth of the animal. Prior to initiation of the trial, calves were offered starter blocks for 5 days due to their light weight and to acclimate them to the lick tubs. The starter blocks were lower in DM and easier for the calves to learn how to consume supplement from a lick tub. At the start of the trial, calves were offered Kalf Kandy which was classified as having moderate hardness and was fed until pen intake was approximately 1.14 kg per day for a 3 day period. Sweet Pro 16, a block typically reserved for long yearlings, was then fed in place of the Kalf Kandy tubs to assist in controlling intake for the remainder of the trial.

Cattle were limit fed at 2% of BW for 5 days prior to the initiation of the trial (Stock et al., 1983; Watson et al., 2013). The diet consisted of a 1:1 blend of alfalfa and grass hay fed at 2% of BW, and calves had unlimited access to the starter lick tubs. Three day weights were taken on day -1, 0 and 1 in order to reduce variation due to gut fill. Cattle were assigned to each paddock based on day -1 and day 0 weights. Paddock was then
assigned randomly to treatment. At the conclusion of the trial, steers were limit fed a diet of 50% Sweet Bran, 25% alfalfa hay and 25% grass hay at 2% of BW for 5 days with three-day weights collected at the end of the limit feeding period.

Stocking rate was calculated based on grain yield of the field at harvest and previous research quantifying the amount of residue consumed per acre. The yield (kg/hectare), estimated forage availability (12.5 kg/bu available due to trampling, weathering and leaving adequate ground cover), grazing efficiency factor (85% for irrigated) and number of hectares were multiplied together to estimate the total available forage for each field. Total available forage was then divided by estimated DMI (4.5 kg/steer daily) of all steers allotted to graze each respective paddock in order to calculate days of available grazing. Using this calculation, the 24.3 hectare irrigated field would allow 125 steers to graze for 70 days based on a yield of 7,719 kg of grain/hectare. The field was then divided into eight paddocks to allow four replications of each treatment.

Two loads of DGS were delivered throughout the experimental period and each load was analyzed for nutrient analysis (Table 1). Samples of lick tubs were collected two times during the trial and were composited by collection period. Tubs not consumed at the end of the trial were weighed to account for refusals and sampled to account for changes in DM. Samples were dried in a forced-air oven at 60⁰C for 48 hours to determine DM (AOAC, 1999 method 4.1.03) according to Buckner (2011). Ash and OM were determined by placing samples in a muffle furnace for 6 hours at 600⁰C. Feed samples were then ground through a 1-mm screen of a Wiley mill (Thomas Scientific, Swedesboro, NJ) in order to analyze for CP (AOAC, 1999 method 990.03) using a
combustion-type N analyzer (Leco FP 528 Nitrogen Analyzer, St. Joseph, MO) and macro-mineral content as outlined by Campbell and Plank (1991).

Forage intake was not estimated during this trial. In order to compare the change in gain to the amount of supplement intake, supplement efficiency was estimated. This allows for the difference between supplement types to be accounted for and was adapted from research conducted by Horn et al. (1995). Supplement efficiency was calculated by dividing gain by supplement intake.

*Economic Analysis*

Economic analysis was applied to performance values and days of grazing from year 1 and year 2.

Initial purchase price was calculated as a 5-year average from the first week of November in 2009, 2010, 2011, 2012 and 2013 for 227-245 kg large-framed, number 1 steers. Feeder cattle weighted average sale data were collected from the archives at USDA Agricultural Marketing Service (AMS) at the Huss-Platte Valley location (WH_LS750). The price of distillers grains was calculated at three different corn prices ($0.13/kg, $0.18/kg and $0.23/kg) and priced at 120% the value of corn. The lick tub was priced at $80 per tub and was not adjusted with the price of corn. Selling price was calculated as a 5-year average for the last week of January in 2010, 2011, 2012, 2013 and 2014 for large-framed, number 1 steers from the archives at USDA AMS for the Huss-Platte Valley location. Ending weights varied by treatment and year.

Irrigated corn residue was charged at $37.07 per hectare and approximately 0.20 hectare was allotted per steer for the grazing period. Yardage was set at $0.30/steer when feed
was delivered daily and $0.15/steer on days when feed was not delivered. Dried DGS was supplemented daily while the lick tub was replaced approximately every 4 days.

Net return was calculated as total revenue (selling price of the calf) minus total costs (initial price of the calf, total price of supplement, price of grazing residue and yardage costs). Cost of gain was calculated as total costs divided by the gain of the calf. Total feed costs were calculated as the price of supplement plus the price of grazing residue.

Data were analyzed using PROC GLIMMIX procedures of SAS (SAS Inc., Cary, NC). Analysis of variance for the two-way mixed model was utilized in order to compare the two treatments across years. Year was set as a random effect in order to look at the population of steers as a whole as opposed to by individual year. Treatment was included in the model statement as a fixed effect. Experimental unit was each paddock (n = 8).

RESULTS AND DISCUSSION
Both types of lick tubs (76% for Kalf Kandy and 62% for Sweet Pro 16) contained lower amounts of OM compared to dried DGS (95%; Table 16). Differences were observed when values were expressed on a DM and OM basis due to the high mineral content of the tub.

Average daily gain of steers supplemented with dried DGS was greater (0.62 kg) than those with access to lick tubs (0.38 kg; Table 17). A meta-analysis by Griffin et al. (2012) compared pasture grazing trials and found that supplementation with DGS increased the ending BW and ADG for cattle offered DGS supplementation when compared to a control group that did not receive DGS supplementation. Nuttelman et al. (2010) fed cow/calf pairs a low-quality forage diet with or without supplementation of DGS and
found the treatment offered DGS supplementation experienced higher calf and cow gains when compared to those in the control group that were stocked at the same rate.

On a DM basis, steers receiving dried DGS consumed 1.34 kg DM per day compared to 0.92 kg DM for steers offered lick tubs ($P < 0.01$). Previous research is not available comparing a commercial lick tub to dried DGS so a comparison cannot be made. Garossino et al. (2003) compared molasses-based liquid and block supplements offered free choice to grazing cattle and found variability in consumption for the block on a daily basis. This is similar to previous research (Elliot, 1970; Lobato and Pearce, 1980) and has been attributed to a lower palatability and ease of consumption of block supplementation. Lower consumption of the block in this trial may also be related to consumption issues due to the hard consistency of the tubs.

On a DM basis, supplement efficiency for the DGS treatment was 46% compared to 43% for cattle on the lick tub treatment. Jenkins et al. (2009) evaluated supplement efficiency of the non-supplemented group of cattle grazing native range relative to those receiving incremental levels of DGS supplementation and found efficiency decreased as level of supplementation increased. This reflects a diminished gain response as the quality of the diet is increased. No data is available evaluating supplement efficiency of cattle consuming lick tubs for a comparison to be made.

Due to the high mineral content of the tub, analysis was also performed on an OM basis. Results were similar for gain but varied in analyses for variables based on supplementation (Table 17). Calves consumed 1.28 kg per steer daily on the DGS treatment compared with 0.76 kg per steer daily for those with free choice access to the
lick tub. Supplement efficiency was not different on an OM basis for the dried DGS (48%) and lick tub treatments (50%). When expressed on an OM basis, the supplement efficiency of DGS and the lick tub appear to be similar. The energy content of the lick tub may be the same as DGS although the greater mineral content of the lick tub may dilute its energetic effects.

_Economic Analysis_

Yardage was equally charged across all scenarios at $20.25 for the DGS treatment versus $12.66 for the tub treatment. Grazing cost was also equally charged across treatments at $7.11 for cattle consuming DGS and $7.22 for those offered lick tubs.

In scenario 1, corn was priced at $0.13 per kg of corn grain and a difference exists between treatments for price of supplementation with the price of dried DGS at $32.99 per steer compared to $55.89 per steer for the lick tub (Table 18). There are differences in net return when comparing dried DGS to the lick tubs at $102.82 and $38.09, respectively. The cost of gain was greater for the lick tub treatment at $3.54 compared with $1.69 for dried DGS. Total feed costs were higher for calves on the lick tub treatment at $63.10 in comparison to those supplemented with dried DGS at $35.14.

In scenario 2, the price of corn was set at $0.18 per kg of corn grain (Table 18). A difference in supplementation was not present for this scenario with the price of supplementing with dried DGS at $40.54 versus the lick tub at $55.89. Differences were found for net return, with the dried DGS treatment at $95.27 and the lick tub at $38.09, respectively. The cost of gain was higher for the lick tub treatment at $3.54 compared
with dried DGS at $1.90. Total feed cost was lower for those supplemented with dried DGS at $47.66 compared with $63.10 for the lick tub treatment.

In the third scenario, corn was priced at $0.23 per kg of corn grain (Table 18). Differences were not found in price when supplementing dried DGS ($54.55) compared to the lick tubs ($55.89). Differences were found in net return with dried DGS treatment at $81.26 and the lick tub at $38.09, respectively. The cost of gain was higher for the lick tub treatment at $3.54 compared with $2.29 for the dried DGS treatment. In this scenario, differences were no longer present for total feed costs, with dried DGS at $61.67 and the lick tub at $63.10, respectively.

The only variable changing in each of the scenarios was the cost of corn grain. Price of DGS, set at 120% the value of corn, increased with increasing corn price and caused an increase in feed cost and total steer cost. Increased steer cost caused a decline in net return, although it is not equivalent to the net return of the lick tub. Even when the price of corn is $0.23/kg of corn grain, the steer cost of the DGS treatment is numerically greater than with the lick tub treatment. However, the DGS treatment was still more profitable than the lick tub treatment due to the greater amount of gain and higher revenue of the calves supplemented with DGS.

An economic analysis of lick tubs was not available for analysis. However, a comparison can be made between supplementation with DGS compared with a non-supplemented group. Rolfe et al. (2012) and Morris et al. (2005) observed a favorable economic response of cattle consuming low-quality forage and receiving DGS supplementation when compared to a control group that was not supplemented. Morris et al. (2006) found
supplementation to be profitable in a yearling production system due to the increased BW sold at the end of the grazing season and reduced forage cost. Similarly, Watson et al. (2010) observed a higher profit and lower cost of gain for cattle supplemented with DGS, which agrees closely with data from this trial.

**IMPLICATIONS**
The high mineral content of the tub appears to dilute the energy available from OM, resulting in lower gain for cattle on the lick tub treatment. In all economic scenarios, it appears to be more profitable to supplement with dried DGS when compared with the lick tubs due to the lower cost of gain and higher net return. Supplementation costs increased for the DGS treatment as the price of corn relative to DGS increased. This corresponds with a higher cost of gain and lower net return for the DGS treatment when corn was more expensive. Despite a high corn priced scenario, calves on the DGS treatment had a lower cost of gain and higher net return when compared to those supplemented with the lick tubs.

The lick tubs are, however, a more convenient method of supplementation since they are replaced in the field approximately every 4 days. This reduces the cost of daily feeding as well as the use and type of equipment needed for feeding.
LITERATURE CITED


Table 16. Analyzed nutrient composition of supplementation types

<table>
<thead>
<tr>
<th>Nutrient, % of DM</th>
<th>Mean</th>
<th>S.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dried DGS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DM</td>
<td>90.00</td>
<td>0.03</td>
</tr>
<tr>
<td>OM</td>
<td>95.00</td>
<td>0.01</td>
</tr>
<tr>
<td>Ca</td>
<td>0.20</td>
<td>0.28</td>
</tr>
<tr>
<td>P</td>
<td>1.00</td>
<td>0.01</td>
</tr>
<tr>
<td>K</td>
<td>1.51</td>
<td>0.00</td>
</tr>
<tr>
<td>Mg</td>
<td>0.56</td>
<td>0.19</td>
</tr>
<tr>
<td>CP</td>
<td>29.39</td>
<td>0.03</td>
</tr>
<tr>
<td>Kalf Kandy^1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DM</td>
<td>76.90</td>
<td>0.34</td>
</tr>
<tr>
<td>OM</td>
<td>76.00</td>
<td>0.01</td>
</tr>
<tr>
<td>Ca</td>
<td>2.09</td>
<td>0.06</td>
</tr>
<tr>
<td>P</td>
<td>1.45</td>
<td>0.02</td>
</tr>
<tr>
<td>K</td>
<td>1.31</td>
<td>0.03</td>
</tr>
<tr>
<td>Mg</td>
<td>3.62</td>
<td>0.10</td>
</tr>
<tr>
<td>CP</td>
<td>23.70</td>
<td>0.17</td>
</tr>
<tr>
<td>Sweet Pro 16^2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DM</td>
<td>89.00</td>
<td>0.40</td>
</tr>
<tr>
<td>OM</td>
<td>62.00</td>
<td>0.02</td>
</tr>
<tr>
<td>Ca</td>
<td>2.95</td>
<td>0.18</td>
</tr>
<tr>
<td>P</td>
<td>2.08</td>
<td>0.16</td>
</tr>
<tr>
<td>K</td>
<td>1.08</td>
<td>0.27</td>
</tr>
<tr>
<td>Mg</td>
<td>3.72</td>
<td>0.19</td>
</tr>
<tr>
<td>CP</td>
<td>26.76</td>
<td>0.16</td>
</tr>
</tbody>
</table>

^1 Kalf Kandy is intended for starting 450-650 lb calves grazing pasture.

^2 Sweet Pro 16 is intended for stocker cattle, heifers and brood cows.
Table 17. Comparison of dried distillers grains (DGS) and lick tub supplementation for calves grazing corn residue on a dry and organic matter basis

<table>
<thead>
<tr>
<th></th>
<th>Dried DGS</th>
<th>Lick Tub</th>
<th>S.E.</th>
<th>F-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial BW, kg</td>
<td>240</td>
<td>240</td>
<td>2.65</td>
<td>0.62</td>
</tr>
<tr>
<td>Ending BW, kg</td>
<td>276</td>
<td>263</td>
<td>4.18</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>ADG, kg/d</td>
<td>0.62</td>
<td>0.38</td>
<td>0.03</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>DM</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supp. Intake, kg/h/d</td>
<td>1.34</td>
<td>0.92</td>
<td>0.10</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Supp. Intake, % BW</td>
<td>0.52</td>
<td>0.36</td>
<td>0.03</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Supp. Efficiency, %</td>
<td>46.3</td>
<td>42.9</td>
<td>2.05</td>
<td>0.49</td>
</tr>
<tr>
<td>OM</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supp. Intake, kg/h/d</td>
<td>1.28</td>
<td>0.76</td>
<td>0.04</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Supp. Intake, % BW</td>
<td>0.50</td>
<td>0.30</td>
<td>0.01</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Supp. Efficiency, %</td>
<td>48.1</td>
<td>50.4</td>
<td>1.52</td>
<td>0.64</td>
</tr>
</tbody>
</table>

1 Dried DGS was provided at 1.34 kg/steer daily.
2 Ad-libitum access to lick tubs.
3 Calculated based on a 3-day mean.
4 Calculated as total gain x number of grazing days
5 Calculated as total supplement consumed per paddock x number of steers x number of grazing days
6 Total supplement consumed per animal x average body weight
7 Calculated as total gain x total supplement intake
Table 18. Economics of feeding distillers grains at 120% the value of corn when compared to a commercial lick tub\(^1\)

<table>
<thead>
<tr>
<th>Item</th>
<th>$0.13/kg corn grain(^2)</th>
<th>$0.18/kg corn grain(^2)</th>
<th>$0.23/kg corn grain(^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dried DGS</td>
<td>Lick Tub</td>
<td>S.E.</td>
</tr>
<tr>
<td>$/steer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>steer cost(^3)</td>
<td>792.74</td>
<td>793.68</td>
<td>7.86</td>
</tr>
<tr>
<td>supplement cost(^4,5)</td>
<td>32.99</td>
<td>55.89</td>
<td>5.12</td>
</tr>
<tr>
<td>yardage cost(^6)</td>
<td>20.25</td>
<td>12.66</td>
<td>2.57</td>
</tr>
<tr>
<td>grazing cost(^7)</td>
<td>7.11</td>
<td>7.22</td>
<td>0.18</td>
</tr>
<tr>
<td>total feed cost(^8)</td>
<td>40.10</td>
<td>63.10</td>
<td>7.12</td>
</tr>
<tr>
<td>total steer cost(^9)</td>
<td>853.10</td>
<td>869.43</td>
<td>7.24</td>
</tr>
<tr>
<td>revenue(^10)</td>
<td>955.91</td>
<td>907.52</td>
<td>34.91</td>
</tr>
<tr>
<td>net return(^11)</td>
<td>102.82</td>
<td>38.09</td>
<td>28.72</td>
</tr>
<tr>
<td>$/kg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>cost of gain(^12)</td>
<td>1.69</td>
<td>3.54</td>
<td>0.33</td>
</tr>
</tbody>
</table>

1 Reported on a DM basis.
2 Calculated as $ per bushel x number of pounds in a kilogram x number of pounds in a bushel-1
3 Calculated as 5-year average from USDA AMS, Huss-Platte Valley (WH_LS750) sale barn.
4 Dried DGS set at 120% price of corn.
5 Lick tub priced at $80 per tub did not change with the price of corn.
6 Calculated as $0.30 per steer daily when feed was delivered and $0.15 per steer daily on non-delivery days.
7 Corn residue charged at $37.07 per hectare with 0.20 hectare allotted per steer.
8 Calculated as price of supplement + price of grazing residue.
9 Calculated as steer cost + supplement cost + yardage.
10 Selling price of the calf, calculated as 5-year average from Huss-Platte Valley (WH_LS750) sale barn.
11 Calculated as total revenue minus total costs (steer cost, price of supplement, grazing cost and yardage cost).
12 Calculated as total steer cost x kg of calf gain\(^1\)