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Corn Residue Grazing as a Component of Semi-Confined Cow-Calf Production and the Effects of Post-weaning Management on Feedlot Performance

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by

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Grazing corn residue can be a valuable alternative to harvested winter feed in a cow-calf production enterprise. The objectives of the first study were to: 1) determine the sample size needed to accurately estimate yield of corn grain and residue and 2) evaluate changes in residue quality throughout the fall/winter and spring-grazing seasons. Results suggest that 6-10 plants serve as a representative sample for grain yield while 7-10 plants are needed for a representative sample of residue yield. In vitro OM digestibility was greatest at the beginning of the fall and spring grazing seasons and declined over time ($P < 0.01$). In vitro OM digestibility of available residue declined 21% over the fall-grazing season and 51% throughout the spring-grazing season. A second study evaluated the effects of 2 winter cow-calf production systems on cow-calf performance at 2 locations. Cows wintered on cornstalks at ENREC lost BW and had a 0.46 unit decrease in BCS, while cows in the dry-lot gained BW and had a 0.24 unit increase in BCS ($P < 0.01$). At PREC, BCS increased by 0.03 units for cows wintered in the dry-lot and decreased by 0.26 units for cows wintered on cornstalks ($P = 0.04$). At

both locations, calves wintered in the dry-lot had greater ADG and BW per d of age compared to calves wintered on cornstalks ($P \leq 0.03$). A partial budget suggests that lower winter production inputs may be significant enough to compensate for reduced performance of calves when cow-calf pairs are wintered on cornstalks. A third experiment evaluated the effects of winter cow-calf production system and post-weaning management on finishing performance and carcass characteristics of calves sourced from experiment two. Calves that had previously been winter grazed on cornstalks had lighter initial BW entering the finishing phase than calves wintered in the dry-lot ($P < 0.01$). Calves directly adapted to a finishing diet following weaning had greater finishing ADG ($P < 0.01$) and improved G:F ($P < 0.01$). Calves that were fed a growing diet prior to the finishing phase produced 35 kg greater final BW ($P < 0.01$) and 23 kg greater carcass weight ($P < 0.01$). Directly finishing calves resulted in greater net profit compared to growing calves prior to the finishing phase ($P < 0.01$) as the extra carcass weight did not offset the cost of the additional 49 days in the feedlot.

DEDICATION

“Inquire of God, please, that we may know whether the journey on which we are setting out will succeed.” And the priest said to them, “Go in peace. The journey on which you go is under the eye of the Lord.”

Judges 18:5-6

The heart of man plans his way, but the Lord establishes his steps.

Proverbs 16:9

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Introduction

Greater animal protein demand is anticipated to result from rapid population growth in developing countries and changing socio-demographics, such as increasing per capita incomes (Henchion et. al., 2017). Industry infrastructure and the viability of beef as a staple protein source will rely on sustainable beef cow-calf production systems in order to meet increasing protein demand while production is constrained by limited resources. Beef cow-calf production has traditionally relied heavily on range or pasture land as a forage resource. However, the amount of pasture and rangeland has declined in recent years. Furthermore, temporal and regional drought conditions can exacerbate the availability of forage resources required for traditional cow-calf production. A combination of factors has resulted in increased land prices, which has further challenged the potential for expansion within the cow-calf industry.

A primary factor recently influencing the availability of traditional forage resources has been a shift in hectares from grassland to corn production with a majority of the conversion occurring in the Midwest and Northern Great Plains regions. With more land in corn production, a greater supply of distillers grains and corn residue has resulted in these areas. These by-products of corn grain production represent valuable feed resources for beef cow-calf production. Incorporating these feed resources into an intensively managed beef cowherd may be an alternative to traditional cow-calf production when economically feasible. Available for fall and winter grazing, corn residue has typically been considered an economical feed resource in ruminant diets. Integrating fall and winter corn residue grazing into a semi-confined cow-calf production

system with a summer-calving cowherd may reduce production costs. However, limited data are available regarding the performance of cow-calf pairs grazing corn residue, as well as the economics of semi-confined cow-calf production. Furthermore, post-weaning management of calves produced in such a system warrants evaluation. The objectives of this research were to:

1. Evaluate the nutritive value of corn residue as well as the sample size required for accurate analysis.
2. Evaluate the effects of wintering system on cow-calf performance. Additionally, a partial budget was conducted to evaluate the economics associated with each wintering system.
3. Evaluate post-weaning management of calves produced from either a confined or semi-confined cow-calf production system. Economics of each post-weaning management were also evaluated.

Industry Overview

Although the beef cowherd is distributed throughout the United States, inventory is concentrated in Texas (4.46 million), Oklahoma (2.10 million), Missouri (2.05 million), Nebraska (1.92 million), Kansas (1.57 million), and Kentucky (1.02 million). As of January 1, 2017, the national beef cowherd tallied to 31.2 million head, exceeding the 2016 inventory by 3%. In addition, 6.4 million (up 1.2% from 2016) beef heifers were retained for breeding purposes (USDA, 2017a), indicating a phase of cowherd expansion.

A cattle cycle is defined as “a period of time in which the number of beef cattle in the nation is alternately expanded and reduced for several consecutive years in response to perceived changes in profitability of beef production” (USDA, 2016a). The most

recent completed cycle occurred from 2004 to 2014, which was characterized with 3 years of expansion followed by 7 years of liquidation. The most dramatic drop in cattle and calf inventory occurred in 2011 to 2012 when widespread drought throughout the U.S., especially in the Southern Plains, forced herd liquidation. In 2015, the U.S. cattle inventory began a new cattle cycle with the cattle industry launching a stage of expansion due to more favorable weather conditions and consequently greater forage availability across many regions. However, an overall contraction in cattle and calves inventory has occurred since its peak in 1975 with 132 million head (USDA, 2016a). Although beef cow inventory and commercial cattle slaughter have trended down since 1990, beef production has increased due to increased dressed weights of harvested cattle (USDA, 2016b).

Competition for land, specifically from crop production, has challenged cow-calf production on traditional forage resources. Cow-calf producers have experienced less availability for grassland and increased prices for pasture and native range, which has significantly increased input cost for the enterprise. Furthermore, the capital requirement for the purchase of grassland needed to support expansion has increased substantially in recent years.

Forage Availability

Land Conversion

Within the last decade, the agriculture industry incurred a period of high corn and soybean prices that resulted in a period of rapid conversion of grassland to cropland. Wright and Wimberly (2013) analyzed grassland conversion in the Western Corn Belt from 2006 to 2011 utilizing satellite imagery that mapped agricultural land cover. Those

researchers observed increased rates of grass-to-corn/soy conversion, specifically in North Dakota, South Dakota, Nebraska, Minnesota, and Iowa. Grassland conversion was concentrated in the eastern regions of North Dakota and South Dakota as corn and soybean cropping expanded westward. Nebraska also experienced western expansion of the grass-to-corn/soy conversions. Overall, the Western Corn Belt experienced a net decline of 530,000 ha of grass-dominated land cover with annual conversion rates averaging between 1 and 5.4%. South Dakota and Iowa experienced the greatest net decline in grass-dominated land cover with 182,513 and 152,161 ha, respectively, being transformed (Wright and Wimberly, 2013). Across South Dakota, the cropland to rangeland ratio ranged from 3.0 to 3.6 during 2000 to 2009. In a period of cropland upsurge (2010 to 2014) that ratio ranged from 4.1 to 4.7 (Janssen et al., 2015).

Pasture Demand

With increased competition for declining pastureland, rental rates and land values have increased over the last decade. In 2006, tillable and non-tillable grazing land averaged \$464 and \$352, respectively, per acre across Nebraska (Johnson et al., 2006). Nebraska grassland increased by 26-36% from 2010 to 2015, setting records for land value with price per acre at \$1515 (tillable land) and \$1005 (non-tillable land) (Jansen and Wilson, 2015). Likewise, Nebraska pasture rental rates have increased over the same time period. By 2012, pasture rental rates increased by approximately 40% on average compared to 2006 (MacDonald et al., 2014). In 2015, monthly cow-calf pair rates ranged from \$40.90 to \$65.55 (Jansen and Wilson, 2015). Beginning in 2016, value of grazing land slightly receded with a 1% (tillable land) and 3% (non-tillable land) decline with reported cash rental rates ranging from \$36.15 to \$63.80 per cow-calf pair (Jansen and

Wilson, 2016).

A similar trend has followed in South Dakota. In 2015, South Dakota had the highest reported AUM rates (range of \$41 to \$50) within the past 25 years (Janssen et al., 2015). By 2015, rangeland and pasture values more than doubled from 2010 and increased by six-fold from values in 2000 (Janssen et al., 2015). In ten of the past thirteen years, values have increased by more than 10% annually. The year 2016 was one of those exceptions with an average rangeland value per-acre increase of 2.9% and a 6.4% decrease in land values for tame pasture (Davis and Sand, 2016).

Forage Production

O'Brien (2016) reported that U.S. total area harvested for all hay production has had an overall decline with approximately 216,067 less ha harvested each year over the 2000–2016 period. Since 2010, the declining rate has slowed to 136,820 less ha harvested annually. In 2016, USDA estimated 21.7 million ha in hay production, which is 5% below 2015 (USDA, NASS). Declining area in hay production is specifically evident in Nebraska and Iowa. In 2016, Nebraska used 991,480 ha for hay production compared to 1.1 million ha used in 2006. Furthermore, Iowa had 368,264 ha in hay production in 2016 compared to 594,888 ha in 2006 (USDA, NASS). Within the last decade, the U.S. has also experienced an increase in corn production and area harvested for corn. In 2016, acres harvested for corn were estimated at 37.6 million ha, which is approximately 6.3 million more ha than 2006. Additionally, corn grain production in 2006 totaled over 10.5 billion bushels. In 2016, corn grain production exceeded 15 billion bushels (USDA, 2017).

The last decade has resulted in reduced traditional forage resources; however, the increase in corn grain production has provided additional corn residue. An increase of 5 billion bushels in corn production would increase supply of corn residue by over 100 billion kg, assuming a harvest index of 0.55 (Gallagher and Baumes, 2012). Although the cow-calf industry has been challenged by limited traditional forage resources, opportunity may exist with greater availability of corn residue as a forage resource.

Ethanol By-products

The amount of corn processed into ethanol has grown substantially over the last two decades. Between 1985 and 2000, the amount of corn used to produce ethanol increased by approximately 6% annually. The next decade resulted in an annual growth rate of 24%. More recently, that growth has slowed to 1% annually (Zulauf, 2016). In 2016, two hundred operating ethanol biorefineries produced a record 15.25 billion gallons of fuel and approximately 42 million tons of by-product. Approximately 90% of the grain ethanol is produced from dry mills, with the remaining 10% produced during the wet milling process (RFA, 2017).

During the dry-milling process, starch within the corn kernel is fermented to ethanol, and the remaining nutrients are recovered in distillers grains. Approximately two-thirds of corn is starch. Therefore, nutrients in distillers grains are concentrated three-fold relative to the nutritive profile of corn (Erickson et al., 2010). Ethanol by-products can be differentiated by moisture content and composition. By-products of dry-milling corn include wet distillers grains plus solubles (WDGS), modified distillers grains plus solubles (MDGS), dried distillers grains plus solubles (DDGS), and condensed

distillers solubles (CDS). The nutritive profile of distillers grains has made it an effective source of protein and energy in ruminant diets (Klopfenstein et al., 2008).

Ethanol plants are primarily localized in the Midwest near major corn production. Nebraska is home to twenty-five ethanol plants distributed throughout the state. The ethanol plants have a combined production capacity over 2 billion gallons, making Nebraska the second largest ethanol producing state. Along with ethanol production, the plants also produce over six million tons of distillers grains by-product annually (NE Ethanol Board, 2017).

Confined Cow-calf Systems

A confined cow-calf production system is an alternative management system to traditional pasture beef production. It consists of a period of confinement in which the cowherd is fed in a dry-lot situation at some phase of the production cycle (Lardy et al., 2017). It has historically been perceived that confined feeding of beef cows is not economically competitive with traditional range or pasture grazing. Therefore, confined feeding has typically been used as a management strategy when year-round grazing is not practical, during the winter months when forage quality declines, or as drought management. However, management of cows and calves in confinement during months of traditional pasture grazing has been less common until recent years (Gunn et al., 2014).

It has been suggested that managing in a confined setting offers many opportunities, including close observation of the herd, easier breeding management (synchronization, artificial insemination, increased cow exposure per bull), low weaning stress, greater beef produced per unit of land, and time for pasture recovery. Furthermore,

producers may have greater flexibility to develop a cow-calf enterprise, regardless of availability of pasture. However, confinement also poses many disadvantages, including greater demand for labor and equipment, quicker depreciation on facilities and equipment, increased risk for spread of contagious diseases, and requirement for harvested feed (Lardy et al., 2017).

Research has been focused on the efficiency of confined cow-calf production in which multiple production factors have been evaluated. A primary area of research has been directed toward nutrition of confined beef cows and calves and the efficacy of various commodities fed in such a system.

Nutritional Considerations

Adequate nutrition must be provided to maintain a cow in a normal production cycle with a 365- day calving interval. Nutrient composition of feed ingredients must be known in order to balance a ration that meets the cow's requirements based on her milk production, body condition, age, and size (NASEM, 2016). Although a variety of commodities can be used to balance a beef cow ration, ingredient inclusion will depend on availability, cost, and nutrient composition of the commodity. Early research (Wyatt et al., 1977) on feeding confined beef cow-calf pairs relied on forage-based diets. In areas with low availability, harvested forages may be expensive. Many nutritional programs have evaluated a non-traditional approach of limit-feeding gestating and lactating beef cows in confinement. The principle to a limit-fed nutritional program is to meet all the nutrient requirements of the cow while restricting dry matter intake. Therefore, dependence on harvested forages is reduced (Jenkins and Rasby, 2014).

Limit-fed nutritional programs for beef cows have been based on a variety of feedstuffs. Loerch (1996) investigated limit-feeding a corn-based diet as an alternative to ad-libitum hay to gestating beef cows. Researchers observed that cows fed ad-libitum hay had approximately twice the intake as cows that were limit-fed a corn-based diet. However, BW change during the feeding period was not affected by feeding system. Furthermore, no detrimental effects on subsequent cow reproductive performance were observed (Loerch, 1996). In a similar study, Schoonmaker et al. (2003) reported that maintaining a cow in early to mid-gestation with ad-libitum hay cost approximately twice that of limit-feeding a corn-based diet. Limit-feeding processed corn to cow-calf pairs has also been shown to result in similar cow-calf performance compared to the performance of pairs fed ad libitum hay (Tjardes et al., 1998).

Regions with access to crop residues and by-product feeds may benefit from limit-feeding low-quality forages and energy-dense by-product feeds to confined beef cows. Across 3 experiments, research has evaluated limit-feeding various blends of cornstalks or wheat straw with distillers grains or sugar beet pulp at less than 2% BW (DM) to gestating beef cows (Jenkins et al., 2015). In experiment 1, a blend of WDGS:wheat straw (30:70 ratio, DM basis) was fed at 8.3 kg DM compared to feeding 9.1 kg of alfalfa hay. Researchers reported that final BW, BCS, and calf BW were not affected by dietary treatments. In experiment 2, a blend of WDGS:beet pulp:wheat straw (20:20:60 ratio, DM basis) fed at 8.5 kg was compared to feeding 8.5 kg of a WDGS:wheat straw blend (30:70, DM basis) or 7.8 kg of alfalfa hay to gestating beef cows. Cows fed alfalfa hay gained less BW and had lower BCS compared to cows fed either the WDGS:wheat straw or WDGS:beet pulp:wheat straw blend. The 3rd experiment

evaluated greater concentration of sugar beet pulp in a WDGS:beet pulp:wheat straw blend (20:45:35 ratio, DM basis) compared to the 20:20:60 blend of WDGS:beet pulp:wheat straw. Researchers observed no difference in cow performance or calf BW. Those researchers suggested that gestating cows could be maintained by limit-feeding crop residues and by-products as an alternative to forage intake as long as diets are balanced to meet cow requirements (Jenkins et al., 2015).

Energy efficiency of confined cows and cow-calf pairs

Trubenbach et al. (2015) evaluated the effects of dietary energy concentration and intake level on energy metabolism. Gestating cows were fed a high energy (2.45 Mcal ME/kg) or low energy (1.94 Mcal ME/kg) ration at either 80% or 120% of NRC recommendations. Restricting intake increased organic matter digestibility across both diets by 4.5% (Trubenbach et al., 2014). A regression analysis of the data indicated that cows fed the high energy diet had a 23.5% reduction in daily NEm requirements (Trubenbach et al., 2014). Researchers concluded that when the high energy diet is fed, the combination of increased energy density and reduced maintenance requirement of the cow resulted in a definitive reduction in cost per cow for purchased calories when compared to the low energy diet (Trubenbach et al., 2014).

In addition to energy efficiency of cows in a confined system, research has evaluated the effects of calf age at weaning (91 d of age compared to 203 d of age) on cow and calf performance and feed utilization by cow-calf pairs. Warner et al. (2015) reported that calf ADG per unit of total feed energy intake of cow-calf pairs in a conventional (203 d) weaning system was greater than or equal to cow-calf pairs in an

early (91 d) weaning system. Researchers suggested that early weaning may have minimal effects on reducing feed energy requirements (Warner et al., 2015).

Management

An important consideration for management of cows and calves in confinement is adequate bunk space and access to a water source. It is generally recommended that a cow and calf in confinement require a minimum of 0.61 m and 0.3 m, respectively, of bunk space (Jenkins and Rasby, 2014). Calves will begin to consume feed at an early age while in confinement with the dam. Calves less than 90 d of age will consume around 0.37% BW DM, whereas older calves (200-300 days of age) will consume approximately 1.5% BW DM (Jenkins and Rasby, 2014). Limit-feeding often results in cows aggressively consuming feed in the bunk, potentially decreasing the opportunity for calves to consume feed. Consequently, creep feeding or early-weaning has been advised (Jenkins and Rasby, 2014; Lardy et al., 2017). Furthermore, nursing calves will drink from a water source at a young age so it is important that water is adequately accessible to both cows and calves in confinement (Jenkins and Rasby, 2014).

Economics

In an economic analysis, profitability was modeled for a year-round confined cow-calf production system located in the Midwest (Warner et al., 2015). Production parameters were measured on a summer-calving cowherd managed in a feedlot year-round. Calves, weighing approximately 204 kg, were weaned and marketed at 7 months of age. A common diet consisting of 60% distillers and 40% crop residue (DM basis) was fed in varying amounts to non-lactating cows and cow-calf pairs. Researchers reported that feed expenses reflected at least 50% of total costs. Because calf prices largely

influenced gross revenue and distillers grains was the primary component of feed cost, distillers price (as a proportion of corn) was manipulated relative to varying calf prices. Researchers suggested that a year-round confined cow-calf system may obtain positive returns if calf prices are above \$2.36 per 0.45 kg and corn is priced at \$3.50 per bu or less (Warner et al., 2015).

In another recent analysis of confined cow-calf systems, researchers projected profitability under varying calf prices (range of \$2.20 to \$3.50 per 0.45 kg) for 250 kg weaned calves (Close, 2015). Returns were estimated to be -\$22 to \$693 per cow in a system that purchased young replacements that would produce a total of 7 calves on average. When researchers directly compared a confined beef cow-calf system to a pasture system, data indicated that total net cost was approximately \$22 greater per pair in a confined system, resulting in a \$0.23 greater cost to produce 0.45 kg of weaned calf (Anderson et al., 2013).

Lalman et al. (2014) investigated the economics of a partially-confined cow-calf system. Researchers reported data from 1 year of a multi-year study comparing a partial-intensive cow-calf production system (incorporating early-summer and fall grazing of native range with restricted winter grazing of small grains and restricted summer grazing of annuals) to an extensive production system using only native range. The annual costs for a cow-calf pair in the intensive system was estimated to be approximately \$95 greater than a pair in the extensive system. However, calves in the intensive system produced 30 more kg at weaning than calves in the extensive system. Researchers concluded that increased production costs offset the value of increased weaning weights of calves in the intensive system. It was noted that cows in the intensive system gained an additional 50

kg of BW and 0.7 units of body condition score over that of cows in the extensive system. Researchers suggested that the improved performance of cows in the intensive system may be of little economical value (Lalman et al., 2014).

In a recent economic analysis, Warner et al. (2015) predicted profitability through weaning of conventional and alternative cow-calf systems across Nebraska. Conventional systems consisted of summer pasture grazing and winter cornstalk grazing. Alternative systems were either a total confinement of cows or partial confinement of cows with winter cornstalk grazing. Conventional cow-calf systems appeared to be more economical compared to alternative systems at assumed base prices used in the study. Researchers concluded that an alternative system of summer confinement with fall/winter cornstalk grazing may be more economical than conventional systems as pasture prices increase (Warner et al., 2015).

While assumptions made in these data can vary largely, an important factor affecting profitability of a system is time of weaning and concomitantly weaning weight. Stockton et al. (2007) indicated that calving season influences time of marketing. Furthermore, Griffin et al. (2012) reported that cattle prices based on size can vary by season. Typical spring-calving cowherds produce a calf ready for market in the fall which has been noted as a time of seasonally weaker prices (Feuz and Burgener, 2005). Shifting the marketing window to periods of stronger market prices could impact returns for a cow-calf enterprise.

Grazing Corn Residue

Grazing corn residue can play a significant role in beef production systems as it allows the grazing season to be extended throughout the winter without requiring

additional acres of pasture. Additionally, it can serve as an economical alternative to high winter inputs from feeding harvested forages or concentrate diets to cows (Klopfenstein, 1987). Although generally considered a low-quality forage, grazing residue can fit multiple beef production systems through the use of different supplementation strategies.

Components of Corn Residue

The corn plant consists of six primary components: husk, leaf, leaf sheath, stem, cob, and grain. Following grain harvest, residue is available as a forage resource in cattle diets. Residual corn grain, resulting from adverse weather conditions, different harvest methods, ear drop, etc., can also be available for consumption in which the nutritive value of corn residue increases.

McGee et al. (2012) observed the proportion of total forage residue DM to be 7.5, 18.7, 12.6, 45.4, 14.7, and 1.1 % for husk, leaf, leaf sheath, stem, cob, and shank, respectively. Pordesimo et al. (2004) found similar results in which forage residue fractions were reported as 12.9, 21.0, 50.9, and 15.2% for husk, leaf, stem, and cob, respectively. When corn plants were collected at multiple time points, Jones et al. (2015) found that the distribution of corn residue fractions remained relatively constant after the plant reached physiological maturity. Researchers concluded that, at typical time of grain harvest, any loss in residue DM was attributed to environmental effects.

Selective Grazing

Grazing corn residue in the field provides the most economical utilization of the feed (Klopfenstein et al., 1987). An important aspect of grazing corn residue is that the highest quality and availability of residue exists on the first day. This is partly due to cattle selectively grazing the more digestible/palatable corn residue fractions first, which

leads to a redistribution of the residue components over time. Fernandez-Rivera and Klopfenstein (1989) noted that the residue consumed by grazing calves was 65 to 72% leaf and husk. Lamm and Ward (1981) investigated changes in proportion of corn residue fractions prior to cows grazing in the fall and after grazing in late winter. Corn residue DM from fall samples prior to grazing consisted of 11.2% grain, 9.1% cobs, 40.7% stalks, and 39.0% husks/leaves. Following 86 days of grazing, residue DM was composed of 1.4, 13.1, 54.8, and 30.6% of the DM for grain, cobs, stalks, and husks/leaves, respectively. Those researchers concluded that over the 86 d grazing period, the residue components were selectively consumed in the following order: grain, husks/leaves, cobs, and stalks. This is supported by findings of Fernandez-Rivera and Klopfenstein (1989) who reported that the starch content of esophageal samples collected at various points during a grazing period declined as grazing continued. Gutierrez-Ornelas and Klopfenstein (1991) observed that grain, husks, and leaf blades disappeared to the greatest extent during the grazing season. Throughout a grazing period, recognizing the dynamics of corn residue fractions becomes important as nutrient provisions of the residue are changing.

Nutritive Value

Corn residue is generally considered a low-quality forage; however, the individual plant parts vary in nutritive value. McGee et al. (2013) observed a range of 34 to 61.2% for the digestibility of individual plant parts. Values for IVDMD were reported as 61.2, 49.2, 44.9, 41.3, 40.8, 37.2, 34.0% for the husk, shank, leaf blade, cob, leaf sheath, top 1/3 of the stem, and bottom 2/3 of the stem, respectively. The proportion of NDF in each plant part was reported as leaf sheath (90.6%), leaf blade (90.1%), bottom 2/3 of the stem

(79.8%), husk (79.3%), top 1/3 of the stem (79.1%), shank (76.1%), and cob (73.1%). Researchers found that CP was highest in the leaf blade (8.7%), followed by shank (7.6%), leaf sheath (6.9%), top 1/3 of the stem (4.7%), bottom 2/3 of the stem (3.9%), cob (3.9%) and lastly husk (3.3%). Relative values for CP of plant parts are in agreement with the findings of Fernandez-Rivera and Klopfenstein (1989) in which researchers reported that leaf blade had the greatest CP content and husk and cob have the least. However, McGee et al. (2013) observed greater absolute CP values for leaf blade and cob compared to Fernandez-Rivera and Klopfenstein (1989). McGee et al. (2013) noted that the stem consisted of similar quality measures throughout the plant. However, digestibility of the leaf sheath was considerably lower than the leaf blade for digestibility, NDF, and CP content, suggesting that the leaf sheath should be analyzed as a separate component from the leaf blade.

Due to the variation in nutrient composition across the corn residue components, diet quality is highly dependent on the type of plant parts available for consumption. Fernandez-Rivera and Klopfenstein (1989b) reported that in vitro dry matter disappearance decreased 0.6 percentage units per day of grazing. Researchers attributed the decline in IVDMD to the decreasing proportion of grain in the diet and digestibility of the roughage consumed.

Corn Residue Yield

Estimating corn residue yield in a field is important when determining stocking rate. Producers can estimate the amount of corn residue remaining in a field based on the corn grain yield following harvest. Wilson et al. (2004) described the relationship between bushels of grain and leaf/husk yield as [(bu/acre corn yield × 38.2) + 429] × 0.39

for every lb. of leaf/husk produced in an acre. Other research has quantified leaf/husk residue at 7.2 to 7.6 kg of leaf/husk residue (DM) per 25.5 kg of corn grain harvested (Fernandez-Rivera et al., 1989; McGee et al., 2013).

The harvest index, defined as the proportion of grain in total above ground dry biomass, also provides a means of estimating corn residue in a field following harvest. Generally ranging from 0.45 to 0.55, the harvest index is relatively constant across fields (Gallagher and Baumes, 2012). An estimate of corn residue remaining in the field after grain harvest can be made by multiplying the dry weight grain by the harvest index. Given a harvest index of 0.55, each 1 kg of corn grain yields approximately 0.8 kg of aboveground residue (Watson et al., 2015).

Effects of Weathering

Because all forage is exposed to external elements beginning on day one, extensive losses in DM and nutrients of corn residue can occur. Lamm and Ward (1981) investigated the changes in plant part composition and amount of forage remaining on a corn residue field following a wintering period. When harvested prior to grazing in the fall, residue components averaged 8.8% (% of OM) for CP and 72.0% for IVOMD. Residue collected from ungrazed exclosures in late winter indicated that CP and IVOMD had decreased to 8.2% (% of OM) and 59.2%, respectively. More specifically, a 38.0% decline in IVOMD was observed in husks/leaf material. Samples collected from the ungrazed exclosures in March also revealed that grain and husks/leaves were affected the greatest with an approximate 50% reduction in DM over the wintering period. Guterrez-Orneles and Klopfenstein (1991) found that weather conditions reduced the amount of leaf blade by 42% during a 30 d period prior to the winter grazing period. Residue

fractions with the greatest nutritive value may be more prone to DM losses as a result of weathering.

These data reiterate the concept that performance of grazing animals may depend on annual variation in residue availability and weather conditions. As selective grazing, trampling, and environmental losses occur, quality of the residue will decline. To exploit the highest quality and availability of residue, cattle should be turned out to graze soon after harvest.

Forage Intake by Cow-calf Pair

Determining forage intake of a cow-calf pair is important when considering stocking rate in any grazing system. Meyer et al. (2009) evaluated forage intake of beef animals in different physiological states, including nursing cow-calf pairs. Cattle were offered hay (IVDMD = 52.2%; CP = 11.2%) harvested from sub-irrigated meadows. Cow and calf were considered as one unit, with calves averaging 42 days and 73 kg at the beginning of the study. Researchers observed calves consuming hay; however, forage was not deliberately partitioned between the cow and calf. Researchers reported that cow-calf pairs consumed 2.5% BW (DM basis) of forage. When adequate forage is available calves compensate for reduced milk intake by increasing forage consumption (Boggs et al., 1980; Ansotegui et al., 1991). Loy et al. (2002) noted that by 219 days of age, nursing calves will consume 1.87% BW in OM. Accounting for increasing intake of growing calves that are grazing corn residue is important, especially during longer grazing seasons.

Supplementing Distillers Grains to Cattle Grazing Corn Residue

Distillers grains can be complimentary to a forage-based diet. Distillers grains are low in starch content due to a majority of the starch being removed during ethanol production. Rapid fermentation of starch found in grain-based supplements can reduce ruminal pH and decrease forage digestibility and intake (Chase and Hibberd, 1987). Because DGS supplementation supplies energy without an abundance of starch, negative effects of starch on fiber digestion are avoided. Summer and Trenkle (1998) observed greater NDF digestibility (58.2%) of corn stover-based diets with DDGS inclusion; whereas DRC inclusion tended to decrease NDF digestibility (42.8%) of the corn stover-based diets. The nutrient concentration of distillers grains also makes it an attractive supplement to low quality forage. Distillers grains are high in protein (30%), which is largely ruminally undegradable protein (NASEM, 2016). Furthermore, Ahern et al. (2016) reported that distillers grains have a high energy value relative to corn supplementation in forage-based diets. Researchers found no difference in energy value between WDGS and DDGS. Based on cattle performance data, the energy value of WDGS in high forage diets was 136% relative to DRC when fed at 30% of diet DM. If DRC has a TDN value of 83% in forage based diets (Loy et al., 2003), then WDGS supplementation in a forage based diet would have a TDN value of approximately 113% (Ahern et al., 2016).

Corn reside alone may not provide adequate nutrients for growing cattle. Tibbitts et al. (2016) noted that calves (initial BW = 234 kg) grazing corn residue with no supplement lost 0.08 kg of BW per day. Research has demonstrated that supplementing DGS to growing calves grazing corn residue increased ADG (Gustad et al., 2006; Jones et al., 2014; Tibbitts et al., 2016). Gustad et al. (2006) supplemented DDGS at 0.29, 0.49,

0.69, 0.88, 1.08, or 1.27% BW to weanling calves (BW = 232 kg) grazing corn residue. A quadratic increase in ADG was observed for calves supplemented with increasing levels of DDGS. Jones et al. (2014) also reported a quadratic response in ADG of calves (BW = 197 kg) grazing corn residue with increasing levels (0.3, 0.7, or 1.1% of BW) of DDGS or modified distillers grains plus solubles (MDGS). The quadratic increase in ADG was attributed to refusals of supplement observed for calves supplemented at higher levels (Gustad et al., 2006; Jones et al., 2014). However, Jones et al. (2015) observed no refusals and reported that calves (235 kg) grazing corn residue with DGS supplementation (0.3, 0.5, 0.7, 0.9, or 1.1% BW) responded with a linear increase in ADG with increasing supplementation level. In a pooled analysis combining data from 3 experiments in which 300 steer calves were observed, Welchons and MacDonald (2017) determined a prediction equation ($ADG = 0.55 + 1.93x – 0.60x^2$) to estimate gain of calves supplemented with DGS at varying levels of % BW while grazing corn residue.

Research has indicated that mature, non-lactating beef cows can be maintained on corn residue with minimal supplementation (Wilson et. al., 2004; Warner et al., 2011). However, data are limited on a lactating cow and her calf grazing corn residue. Griffin et al. (2010) evaluated the effects of calving date and wintering system on cow-calf performance. Calving dates were March, June, and August. Varying levels of a DDGS-based supplement were fed at different times for each wintering system based on calving date. Researchers observed a reduction in cow BW and BCS for cows wintered on cornstalks and an ADG of 0.83 kg per day for their nursing calves. When evaluating the effects of calving date on cow-calf performance, June-calving cows lost 45 kg BW and 1 unit of BCS from the time of pre-breeding to weaning (April). Researchers observed that

June-born calves had daily gains of 0.73 kg and weighed 253 kg at weaning in April, regardless of wintering treatment.

Relationship Among Nutrition and Reproduction in Beef Females

Profitability of a cow-calf enterprise is heavily driven by reproductive efficiency. Where reproductive traits tend to be lowly heritable, environment can largely influence reproduction (Funston, 2006). Because the livestock producer can control inputs, nutrition is the most practical environmental cue (Dunn and Moss, 1992). Recognizing the impact nutrition can have on reproduction is important as reproduction has low biological priority when nutrients are partitioned (Short and Adams, 1988). The relationship between nutrition before and after calving and subsequent reproductive performance of beef females has been extensively reviewed (Hess et al., 2005).

Pre-partum Nutrition

Low energy feed levels during the pre-partum phase have been shown to reduce body condition score at calving, extend the post-partum interval, and reduce subsequent pregnancy rates when compared to high energy intake (Bellows and Short, 1978). Corah et al. (1975) found that feeding 65% or 50% of NRC (1970) recommended energy levels to heifers or cows, respectively, did not impact postpartum interval. However, researchers noted that the lack of response from energy intake may have been due to adequate BCS observed in females at the initiation of the pre-partum treatment period.

Research has implied that BCS at calving is the single most important factor affecting subsequent reproductive performance in cows (Richards et al., 1986; Selk et al., 1988; Wettemann et al., 2003). Houghton et al. (1990) demonstrated the importance of BCS at calving on return to estrus in lactating beef cows. Cows that calved in thin

condition (BCS < 3) had a postpartum anestrous interval of 28 to 58 d longer than moderate condition (BCS 5 to 6) or fleshy (BCS 7 to 9) cows. Furthermore, pregnancy rates were greater in cows that had moderate condition at breeding compared to under or over conditioned cows. Researchers concluded that cows should be managed accordingly post-partum to achieve moderate condition before the breeding season. Rebreeding in primiparous cows may be more sensitive to BCS at parturition due to the combined nutrient demands for continued growth and lactation (Spitzer et al., 1995).

Although BCS at parturition is a primary determinant for the length of post-partum interval and pregnancy rate, nutrient intake before calving may compound subsequent reproductive performance. Dunn and Kaltenbach (1980) observed that a greater percentage of cows in thin and moderate condition at calving had shorter postpartum intervals when they gained weight during the pre-partum phase compared to those that lost weight. Selk et al. (1988) evaluated pre-partum BW changes on reproductive performance of range beef cows. Treatments throughout gestation included: maintain BW, lose 5% BW and then maintain BW, lose 10% BW, or lose 5% BW and then regain 5% BW prior to calving. Selk et al. (1988) observed greater pregnancy rates in cows that were fed to maintain BW throughout gestation compared to cows that were fed to fluctuate in BW. Researchers concluded that pre-partum BW changes, as well as pre-partum nutrient intake in which BCS is altered, impact subsequent pregnancy rates of beef cows.

Postpartum Nutrition

Houghton et al. (1990) evaluated different pre- and post-calving energy levels designed to force cows to maintain or lose BW during gestation and to gain or lose BW

during lactation. Researchers observed an interaction of pre-partum and postpartum energy intake on the duration of the postpartum interval and the percentage of cows expressing estrus within 60 days post-calving. Interestingly, cows that received a pre-partum low energy diet followed by a postpartum high energy diet had the shortest postpartum interval. Furthermore, the same energy combination increased the percentage of cows displaying estrus by 60 days postpartum compared to cows fed low energy diets both during the pre-partum and postpartum phases. However, no interaction occurred between pre- and postpartum energy intake to influence pregnancy rate.

Researchers have demonstrated that the response to post-partum nutrition may depend on body condition at parturition. Richards et al. (1986) evaluated the effects of postpartum nutritional management on subsequent reproductive performance. Cows were maintained pre-partum to have a BCS of 4 to 7 at calving. Following calving, cows were fed to either gain 0.68 kg/d, lose 0.45 kg/d, or maintain BW throughout the post-partum period. Researchers reported that reproductive performance of beef cows calving in a BCS of $\geq$ 5 was not improved by greater nutrition post-partum. If cows were in moderate BCS at calving, postpartum weight loss did not significantly reduce subsequent pregnancy rates. Cows that calved in a BCS of $\leq$ 4 and then were maintained or gained BW post-partum had improved reproductive performance compared to cows that continued to lose weight. However, researchers noted that BCS at calving had the greatest influence on early return to estrus and pregnancy rate.

Spitzer et al. (1995) fed primiparous cows to achieve BCS of 4, 5, or 6 at calving. Following parturition, cows were fed to gain either 0.45 kg/d or 0.90 kg/d. Researchers observed that the percentage of BCS 6 cows in estrus during the first 20 days post-partum

increased from 40 to 85% when fed to gain 0.90 kg/d. In comparison, the percentage of BCS 4 cows in estrus increased from 33 to 50% when fed to the higher rate of gain during the first 20 days post-partum. Researchers also found that increasing post-partum BW gain resulted in greater subsequent pregnancy rates compared to moderate gains in primiparous cows, regardless of BCS at calving (Spitzer et al., 1995). Likewise, Ciccioli et al. (2003) observed that primiparous cows fed to gain 0.90 kg/d after calving had a shorter postpartum interval compared to cows fed to gain 0.45 kg/d. Researchers noted that thin cows or primiparous cows generally respond with improved reproductive performance when post-partum nutrient intake is increased (Ciccioli et al., 2003).

Although additive effects may be observed from other variables, data strongly suggest that BCS at calving is the greatest factor influencing post-partum reproductive performance (Wettemann et al., 2003). Lalman et al. (1997) demonstrated the challenge of reducing postpartum interval by improving postpartum energy balance of beef heifers in poor body condition. Managing BCS prior to calving may be the most practical and effective method of ensuring adequate reproductive performance.

Calf Age at Weaning

Traditional age of calves at weaning is 7 to 8 months (USDA, 1997). However, certain production systems consist of relatively long grazing seasons and potentially a longer calf nursing period. Corn residue is generally available for grazing from mid-October to early-April. Conventional weaning time falls in the middle of the corn residue grazing season for cowherds with summer or fall calving seasons. Weaning at the traditional time could increase costs to the system due to hauling expenses. Furthermore, research has demonstrated that growing calves can successfully be backgrounded on corn

residue with supplementation. Producers grazing cow-calf pairs on corn residue could wean calves later than the traditional weaning age and obtain higher weaning weights. However, extended nursing periods may affect long-term production, particularly reproduction, of a cowherd. Therefore, research on cow and calf performance is warranted for later weaning dates.

Story et al. (2000) evaluated the effects of calf age (150, 210, 270 d of age) at weaning on cow and calf performance for a spring-calving cowherd. Cows were managed to attain a minimum BCS of 5 before calving. Following each weaning time point, weaned calves were received into the feedlot and adapted to a concentrate finishing diet. Researchers reported that cows from which calves had been early weaned had greater BW and BCS; however, pregnancy rates were not different between cows with different weaning dates. Later weaned calves had greater initial BW and ADG during the feedlot phase compared to early weaned and normal weaned calves.

Pate et al. (1985) investigated long-term production of Brangus cows with calves weaned at 8.5 or 10.5 months of age. Cows were grazed year-round and were weighed at each weaning date and at the beginning and end of the breeding season. Calves were weighed at each weaning date. Researchers observed that cows nursing calves for an extended 2 months gained 15 kg less weight than dry cows; however, annual BW change was not different. Researchers indicated that the cows that weaned 10.5 month old calves compensated during other periods of the year for the lower weight gain observed between the two weaning dates. Conception rate and calving rate were not different between treatments. Researchers noted that cows in both treatments were in adequate body condition year round. Calves that were weaned at 10.5 months gained 37.2 kg during the

additional 2 months of nursing, which resulted in 31.9 kg more BW at weaning compared to calves weaned at 8.5 months. Interestingly, rate of gain of calves weaned at 10.5 months declined by about 20% compared to the previous 8.5 months. Researchers attributed the reduced performance to decreasing milk production of the cow and/or declining quality of forage (58 vs. 53% TDN) being grazed.

Hudson et al. (2010) evaluated weaning date on performance of Angus cow-calf pairs grazing native range in a fall calving system. Weaning dates were normal weaning in mid-April (210 d of age) and late weaning in mid-July (300 d of age). Following weaning in mid-April, normal weaned calves were re-located to a separate native grass pasture. Nursing cows gained less weight compared to dry cows from mid-April to mid-July. In contrast to the findings of Pate et al. (1985), normally weaned cows maintained this BW advantage all the way to the calving season. Additionally, researchers did not find any adverse effects on reproductive performance of mature cows weaned at either date. During the interval between weaning dates, ADG was greater (1.12 kg/d) for later weaned calves compared to ADG (0.92 kg/d) of normal weaned calves, resulting in greater BW for later weaned calves in mid-July. Warner et. al. (2015) found that the ADG of early weaned calves fed wet, high-energy diets with distillers grains was comparable to calves that were not weaned. Those researchers suggested that feed energy requirements are not reduced by early weaning.

Weaning calves at a later age offers a cow-calf enterprise the opportunity to utilize available resources and market heavier calves as long as subsequent cow reproductive performance remains satisfactory. The length of an extended nursing period would depend on BCS of the cow as condition score largely influences subsequent

reproductive performance. Another option that may yield similar results is to background calves after weaning and prior to marketing.

Post-weaning Management

Griffin et al. (2007) described two primary types of beef production systems: intensive and extensive. In an intensive system, calves are placed in the feedlot following weaning and are fed a concentrate finishing diet until time of harvest. In an extensive system, calves are grown for a period of time, typically through forage-based rations, before being finished for harvest. Initial size and BW are two primary determinants of which class of production best fits the calf as overweight (Vieselmeyer, 1993) or underweight (Turgeon, 1984) cattle can be costly in beef production.

The type of system utilized influences subsequent finishing performance and carcass characteristics of cattle. Griffin et al. (2007) compared the performance and economics of a long-yearling system to that of a calf-fed system. Calves were purchased in the fall and sorted into a calf-fed system (intensive) or long-yearling system (extensive) based on BW. Calves in the calf-fed system were placed in the feedlot and fed a finishing diet until harvest. Calves in the long-yearling system grazed corn residue followed by summer grazing before being finished in the feedlot. At feedlot entry, long-yearlings weighed 143 kg more than calf-feds. Dry matter intake during the finishing phase was greater for the long-yearlings; however, total DM consumed was greater for the calf-feds. Although calf-feds were 18.7% more efficient, long-yearlings finished with greater ADG and 38 kg more final BW. As for carcass characteristics, long-yearlings had 24 kg more carcass weight. Although quality grade was not different between systems, calf-feds had 0.15 cm greater fat thickness. The long-yearling system also resulted in

decreased DOF compared to the calf-fed system. Griffin et al. (2007) concluded that cattle in the long-yearling system produced greater final BW, which resulted in greater profitability when compared to cattle in the calf-fed system largely due to the use of inexpensive forages to grow the cattle prior to entry into the feedlot. Lancaster et al. (2014) conducted a meta-analysis of effects of calf-fed verse yearling production systems on finishing performance and carcass characteristics from compiled data across 10 different experiments. Researchers concluded that yearlings finish with greater ADG (1.71 kg/d) and DMI (11.52 kg) with less efficiency (0.157) compared to the ADG (1.52 kg/d), DMI (8.49 kg), and feed efficiency (0.178) of calf-feds with similar yield and quality grade.

Post-weaning management can vary depending on available resources. A variety of production systems exist to grow weaned calves prior to the finishing phase. Growing systems may include grazing wheat pasture common to the southern plains or grazing corn residue which is more typical in the Midwest. Confined feeding in which by-products are fed may also serve to grow calves prior to the finishing phase. Warner et al. (2015) evaluated two different methods of growing cattle in the feedlot before being fed a concentrate finishing diet. Post-weaning management treatments were fast-track or slow-track. Calves in the fast-track system were targeted for a high ($\geq$ 1.36 kg) ADG during an 85 day growing period before being adapted to a concentrate finishing diet in May. In the slow track system, calves were grown for 85 days with moderate (0.68 kg) ADG, which was achieved by limit-feeding the same diet as the fast-track calves. Slow track calves then grazed smooth bromegrass in the summer followed by feedlot finishing in the fall. Growing and finishing diets were common between treatments. Warner et al. (2015)

reported that calves in the slow-track treatment had greater DMI, ADG, final BW, HCW, and marbling compared to fast-track calves during the finishing phase. Improved feed efficiency observed in slow-track cattle during the finishing phase was attributed to restricted feed intake throughout the growing phase. Warner et al. (2015) noted that 12th rib fat was similar between treatments, indicating that comparable endpoints were met. When analyzing economics, profitability was greater for fast-track cattle as opposed to slow-track cattle regardless of marketing basis (live, dressed, or grid). Warner et al. (2015) suggested that the greater weight produced from cattle in the slow-track system was not enough to overcome increased feed/grazing expenses and decreased fed cattle prices realized during market seasonality. Warner et al. (2015) also noted that fast-track cattle were not true calf-feds as they were winter-grazed on corn residue before the finishing phase in the feedlot. In contrast, the age of slow-track cattle was comparable to the age of short-yearlings (14-15 mo) at the start of the finishing phase.

Conclusion

Intensification, or increasing beef output per unit acre, is a logical objective as the beef industry faces increasing pressure on the availability of land resources. Reduced input cost and increased efficiency of confined production systems will influence profitability of confined production systems. Where corn residue and distillers grains are likely to remain valuable feed resource in heavy corn production regions, confined or partial-confined cow-calf production systems seemingly compliment these regions. Different management strategies within confined production systems merit further evaluation.

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CHAPTER II

Representative sample size for corn grain and residue yield estimates and an evaluation of residue quality throughout the grazing season

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ABSTRACT

Corn residue is a valuable resource for fall and winter grazing. To efficiently use corn residue for grazing purposes, reliable estimates of grain and residue yield are important. Furthermore, residue quality can change over time due to selective grazing and weathering. The objectives of this study were to: 1) determine the sample size needed to accurately estimate yield of corn grain and residue and 2) evaluate changes in residue quality throughout the fall/winter and spring-grazing seasons. Prior to grain harvest, 10 consecutive corn plants were hand harvested from 12 plots for a total of 120 plant samples. Each of the 120 corn plants was separated into grain, leaf blade, leaf sheath, and husk. Amount of DM was determined for each plant component. To determine representative sample size needed, the standard error of mean for grain and corn residue yield was calculated for each replication. The analysis was repeated 10 times using 1 corn plant, 2 corn plants, etc. until all 10 plants were included in the analysis. Following grain harvest, diet samples from ruminally fistulated steers grazing corn residue were collected at the beginning and end of each grazing season to determine changes in residue quality for fall/winter and spring-grazing seasons. Diet samples were analyzed for in vitro OM digestibility and digestible OM (DOM). Results suggest that 6-10 plants serve as a representative sample for grain yield while 7-10 plants are needed for a representative sample of residue yield. In vitro OM digestibility was greatest at the beginning of both grazing seasons and declined over time ($P < 0.01$). Slight weathering resulted in lower DOM of corn residue available at the beginning of spring-grazing compared to the beginning of fall grazing ($P = 0.04$). In vitro OM digestibility of available residue declined 21% over the fall-grazing season and 51% throughout the spring-grazing season.

As the availability of nutrients declines over time, adjustments in feeding management or rotational grazing may be necessary to meet energy requirements of grazing cattle.

Key Words: cornstalk, grazing, sample

INTRODUCTION

With the conversion of much grassland to cropland, supply of traditional forage resources has decreased. However, an increase in acres planted for corn production has resulted in greater availability of corn residue, which can be a valuable feed resource for grazing situations. It is important to the cattle industry to make efficient use of this corn residue. Extensive sampling of corn residue has occurred and been previously reported (McGee et al., 2012; Row et al., 2016). Previous research was done utilizing 10 corn plants as an experimental unit, assuming 10 plants was a representative sampling size. In addition, corn residue quality can vary over time due to selective grazing of higher quality plant parts (husk and leaves) and weathering. Characterizing a cornstalk field for nutrient quality throughout a grazing period is important because adjustments in feeding management or rotational grazing may be necessary to meet the nutrient requirements of animals grazing the field. The direct objectives of this study were to 1) determine corn plant sample size required to accurately estimate grain and residue yield and 2) evaluate diet quality of a cornstalk field throughout fall/winter and spring grazing periods. Secondary objectives were to 1) evaluate the effects of grazing treatment and crop rotation on subsequent corn residue yield and quality and 2) re-evaluate energy values of corn residue components.

MATERIALS AND METHODS

An irrigated cornfield located at the Eastern Nebraska Research and Extension Center (ENREC) was utilized in a study conducted over two years. Crop-rotation differed between year one and two of the study. In year one, the field was divided in half with the east side producing corn and the west side producing soybeans (Figure 1). In year two,

the crop-rotation applied to the field was altered by changing the division of the field. Consequently, the north side of the field produced corn whereas the south side produced soybeans (Figure 2). Therefore, corn plant samples collected in year one were under a corn-soybean rotation. In year two, half of the corn plant samples were collected from plots under a corn-corn rotation with the other half collected from plots in a corn-soybean rotation. In addition, three grazing treatments (fall-grazed, spring-grazed, and non-grazed) with four replications (plots) of each treatment were applied to the field annually. Each year, cattle grazed the fall-grazed plots from November to February and the spring-grazed plots from March to mid-April.

Year 1

In year one, ten consecutive whole corn plants harvested above the anchor root were collected from each plot (3 grazing treatments × 4 replications = 12 plots) just prior to grain harvest. Plant samples (n = 120) were separated into individual plant components (grain, husk, leaf blade, and leaf sheath), dried in a forced air oven at at 60°C for 48 hours, and weighed to determine DM content (AOAC, 1965, Method 935.29). The amount of DM from each plant part was calculated as a percentage of grain yield. Plant parts were ground through a 1-mm screen using a Wiley Mill (Thomas Scientific, Swedesboro, NJ) and composited by replication. Composite samples were then analyzed for *in vitro* organic matter digestibility (IVOMD) in two runs using the Tilley and Terry method (1963) modified by the inclusion of 1 g urea/ml of buffer (Wiess, 1994). A set of forage (grass and corn residue) standards with established in vivo values were included in each run to develop regression equations that allowed for the comparison between runs (Geisert et al., 2007). Triplicate samples from each plant fraction and standard were

weighed into 100 ml *in vitro* tubes. Rumen fluid was collected from two donor steers fed a 30% concentrate diet. McDougall's buffer was mixed with rumen fluid to form inoculum, which was added to each tube. *In vitro* tubes were then incubated in a 39ºC water bath for 48 hours and swirled every 12 hours. Following 48 hours of incubation, fermentation was ceased by adding 5 mL of 20% hydrochloric acid and 3 mL of 5% pepsin to each tube. Tubes remained in the water bath for an additional 24 hours and then frozen immediately following removal. Contents from each tube were filtered through Whatman 541 filter paper, rinsed with distilled water, and dried in a 100ºC oven for 12 hours to determine DM. Filters were then placed in a muffle furnace at 600ºC for 6 h to determine ash and OM (AOAC, 1999; method 4.1.10). Digestible organic matter (DOM) was calculated by multiplying the IVOMD and percent OM of the original residue sample.

Year 2

Corn plant samples were collected using the same procedures as in year 1. Plant samples (n = 120) were then composited by plot and separated into grain, husk, leaf, and sheath. Plant components were measured for DM and analyzed for IVOMD and DOM using the procedures as previously described for year 1. Following grain harvest of the cornfield, cow-calf pairs grazed the fall-grazed (approximately November to February) and the spring (March) plots at a stocking rate of 1.4 and 0.5 acres per cow-calf pair, respectively. To determine changes in forage quality throughout each grazing period, diet samples were collected from 6 ruminally fistulated steers at the initiation and completion of each grazing season. Fistulated steers were managed on a separate cornstalk field to ensure adequate grazing experience. Prior to sampling, rumen contents were removed

from each steer. Steers were then transported to the cornstalk field and assigned randomly to plot with 3 steers per plot. After approximately 30 minutes of grazing, freshly consumed feed was collected from each steer's rumen and placed in a cooler for later analysis. Former rumen contents were returned to the rumen of the respective steer and steers were turned out to their original cornstalk field. Diet samples were subsampled, freeze dried (Virtis Freezemobile 25ES, SP Scientific, Warminster, PA), ground through a 1-mm screen using a Wiley Mill, and then analyzed for IVOMD and DOM using the same procedures as in year 1. In addition, a starch analysis (Megazyme Total Starch Assay, Megazyme International Ireland Ltd., Ireland) was conducted on diet samples to determine the percentage of grain within diet samples.

For analysis of sample size, corn plot was the experimental unit. The standard error of mean (SEM) for grain and corn residue yield was analyzed for each replication. The analysis was repeated 10 times using 1 corn plant, 2 corn plants, etc. until all 10 plants from 1 plot were averaged together. Data (corn plant part and corn residue diet samples) were analyzed as a randomized complete block design using the MIXED procedure of SAS (SAS Institute., Cary, NC). In year one, the model for corn plant analysis included grazing treatment as a fixed effect. In year two, the model included grazing treatment, crop rotation, and plant part as fixed effects. The statistical analysis on diet samples included grazing season (fall or spring), time (beginning and end of grazing season), and the interaction as fixed effects.

RESULTS AND DISCUSSION

Year 1

Amount of grain per plant and the amount of residue (as a percentage of grain) in year one are presented in Table 1. Grain yield was not affected by grazing treatment (P = 0.53). Interestingly, a grazing treatment effect (P = 0.01) was observed for husk yield with the spring-grazed plots yielding greater husk in comparison to fall-grazed and non-grazed plots which were not different from each other (P = 0.58). Leaf and sheath components of the corn plant were not affected by grazing treatment ($P \geq 0.28$). The relative amount measured for each plant fraction is consistent with McGee et al. (2012). Those researchers reported that the corn plant (excluding grain) was composed of 18.7% leaf blade, 12.6% leaf sheath, and 7.5% husk. Similarly, Fernandez-Rivera and Klopfenstein (1989) quantified corn plant fractions and reported that husk and leaf composed 45.5% of the plant.

The change in the SEM of grain yield as additional plants were added to the analysis is illustrated in Figure 3. The analysis is the same as reported in Table 1. Results suggest that 6 to 10 plants are needed to obtain sufficient statistical power when measuring grain yield. Likewise, the SEM observed for residue (leaf, sheath, and husk) yield was reduced at the inclusion of the 7^{th} plant (Figure 4) and remained constant through the 10^{th} plant. Cornelissen et al. (2003) measured the coefficient of variation for a range of field plants from several datasets and suggested that a minimum of 5 plants (preferred sample size of 10 plants) are needed when measuring leaf dry matter content.

Year 2

No effect of grazing treatment ($P \geq 0.22$; Table 2.) or crop-rotation ($P \geq 0.82$; data not presented) was observed for residue yield in year two. A significant difference was observed between plant components with yield being greatest for leaf, followed by

sheath, and least for husk ($P < 0.01$; Table 3). Gutierrez-Ornelas and Klopfenstein (1991) observed that cattle grazing corn residue selectively consume the husk and leaf and very little of the stem and cob. In the current study, the average amount of leaf blade, leaf sheath, and husk was 31.8 % of grain yield. This equates to 8.1 kg of highly digestible residue DM produced per 25.5 kg (bu) of corn grain at 15.5% moisture. Previous research has suggested that 7 to 8 kg of leaf and husk are produced per 25.5 kg (bu) of corn grain (Fernandez-Rivera and Klopfenstein, 1989; McGee et al., 2012).

No significant difference was observed for corn residue IVOMD or DOM between plots that were either in a corn-soybean rotation or corn-corn rotation ($P \geq 0.95$; Table 4). Previous grazing treatment also did not affect IVOMD or DOM of corn residue harvested ($P \geq 0.97$; data not presented). Corn residue samples averaged 44.2% IVOMD and 40.7% DOM. A significant difference in IVOMD and DOM was observed between plant parts ($P < 0.01$; Table 5). Both IVOMD and DOM were greatest for the husk, intermediate for leaf blade, and least for leaf sheath. Relative digestibility values from the current study are consistent with previous research (McGee et al., 2012; Jones., 2017). However, current DOM values for the leaf sheath and leaf blade fractions are slightly lower than observations by Jones et al. (2017) who reported DOM values of 41.0 and 37.5% for leaf and sheath, respectively.

A treatment by time interaction was observed for IVOMD of the corn residue diet samples ($P < 0.01$; Table 6) with the greatest digestibility observed at the beginning of the fall and spring-grazing seasons, intermediate at the end of the fall grazing, and least for the end of the spring-grazing season. A treatment by time interaction was also observed for DOM of corn residue ($P = 0.04$). The beginning of the fall grazing season

provided the greatest DOM compared to all other time points within both grazing seasons. The beginning of spring-grazing had greater DOM than the end of fall-grazing. Digestible OM was least at the end of spring-grazing compared to all other grazing time points. From initiation of grazing to the end of the grazing season, IVOMD declined 21% while DOM declined 32% for the fall-grazed treatment. However, the greatest decline over time was observed for spring-grazing with IVOMD and DOM declining by 51 and 52%, respectively.

Starch in the diet samples ranged from 0.04% to 6.44% (average of 1.6%) at the beginning of both grazing seasons. The broad range in starch content indicates significant variability in grazing selection among steers. Given that corn is approximately two-thirds starch (NASEM, 2016), 2.4 % (range of 0.06 to 9.6%) of the steer's diet contained corn at the start of the grazing season.

The greater IVOMD of the corn residue diet samples observed at the beginning of both grazing seasons would suggest that cattle are selectively eating the husk and grain within the field. The difference in DOM observed between the beginning and end of both grazing seasons is evidence that as the availability of husk and grain decreases, cattle begin to consume the leaves. Leaves are lower in IVOMD than husks and even lower in DOM due to greater ash content (approximately 15% ash). In addition, the lower DOM observed at the beginning of the spring-grazing compared to the beginning of the fall-grazing would indicate that weathering may be responsible for a portion of DOM reduction. This is further supported by the difference observed between IVOMD and DOM at the beginning of the fall-grazing and spring-grazing season. Weathering (wind

loss, soil contamination and/or decay) may exacerbate reductions in DOM between grazing seasons.

IMPLICATIONS

Results suggest that 6 to 10 plants are required for a representative sample when measuring grain yield, while 7 to 10 plants may need to accurately estimate yield of leaf, sheath, and husk residue. The energy content that a corn residue field provides to grazing cattle is greatest at the beginning of the fall-grazing season. However, as cattle selectively consume the higher digestible plant parts and weathering deteriorates the corn residue, the field provides less and less energy to the cattle. Characterizing a field for its nutrient profile is important during the grazing season. As the availability of nutrients declines over time, adjusting feeding management or utilizing rotational grazing may be necessary to continue to meet energy requirements of the grazing cattle.

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Figure 1. Year 1 (2014) diagram of corn field and treatment layout

Soybeans	Corn	
	Fall-Grazed	277 Rows
	Spring-Grazed	36 Rows
	Non-grazed	32 Rows
	Spring-Grazed	36 Rows
	Fall-grazed	100 Rows

Irrigation Access Road

N

	Fall-Grazed	164 Rows
	Spring-Grazed	36 Rows
	Non-grazed	32 Rows
	Spring-Grazed	36 Rows
	Fall-Grazed	166 Rows

Figure 2. Year 2 (2015) diagram of corn field and treatment layout

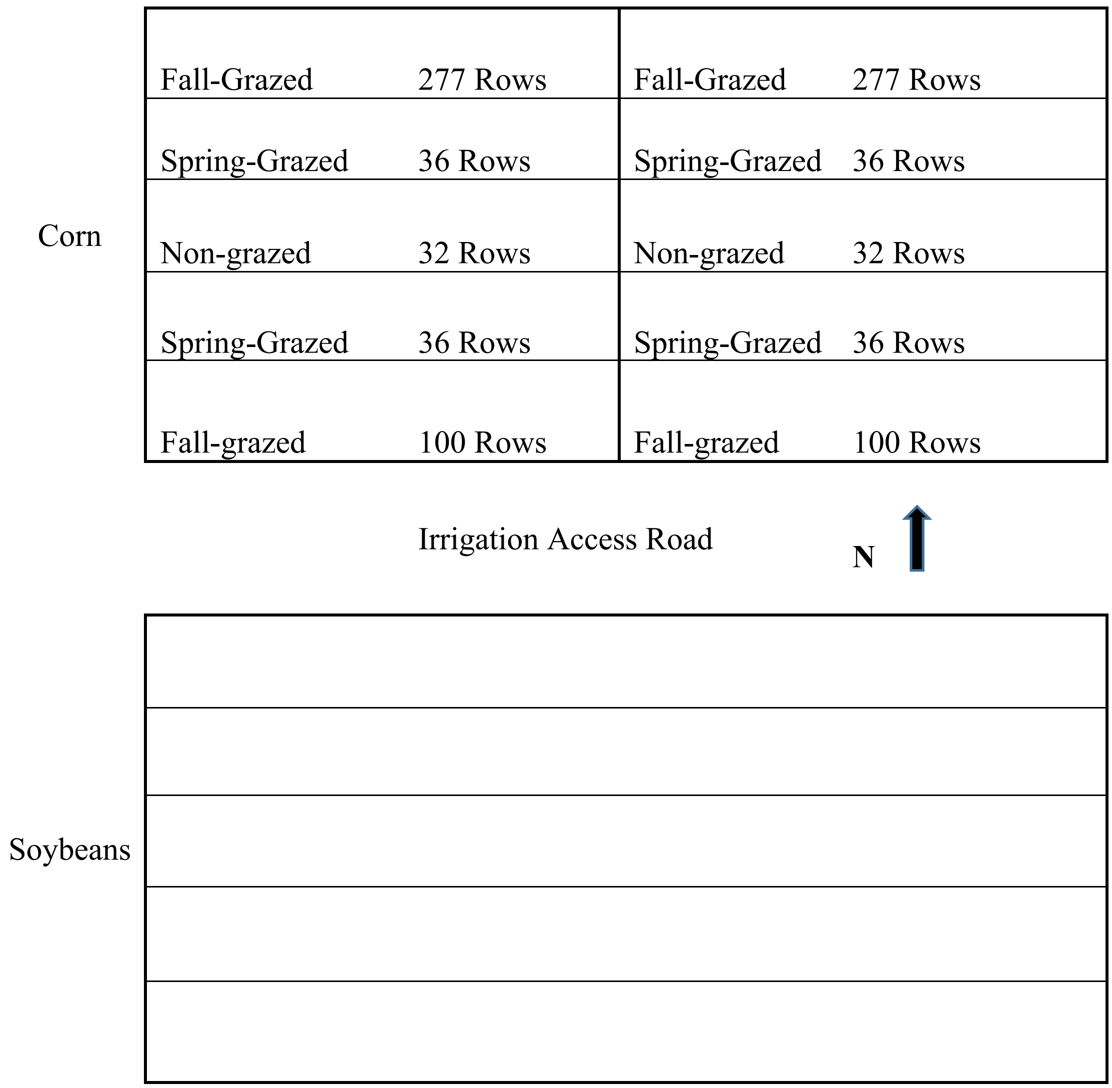

Table 1. Yield of corn grain and residue per plant in year 1

	Grazing Treatment[1]				
Yield[2]	Fall Grazed	Spring Grazed	Non-grazed	SEM	*P*-value
Grain, g	206.89	203.19	199.31	4.84	0.53
Husk, % of grain	5.65[b]	6.02[a]	5.56[b]	0.11	0.01
Leaf, % of grain	11.52	10.95	11.44	0.28	0.28
Sheath, % of grain	6.21	6.31	6.29	0.14	0.87

[1]Samples were collected from a field in corn-soybean rotation. Treatments were due to timing of cattle grazing residue 2 years prior to these samples being collected. Ten plants were collected from each plot (3 treatments x 4 replications = 12 plots).
[2]Measured by collecting individual corn plants
[a,b] Means within a row without a common superscript differ ($P < 0.05$).

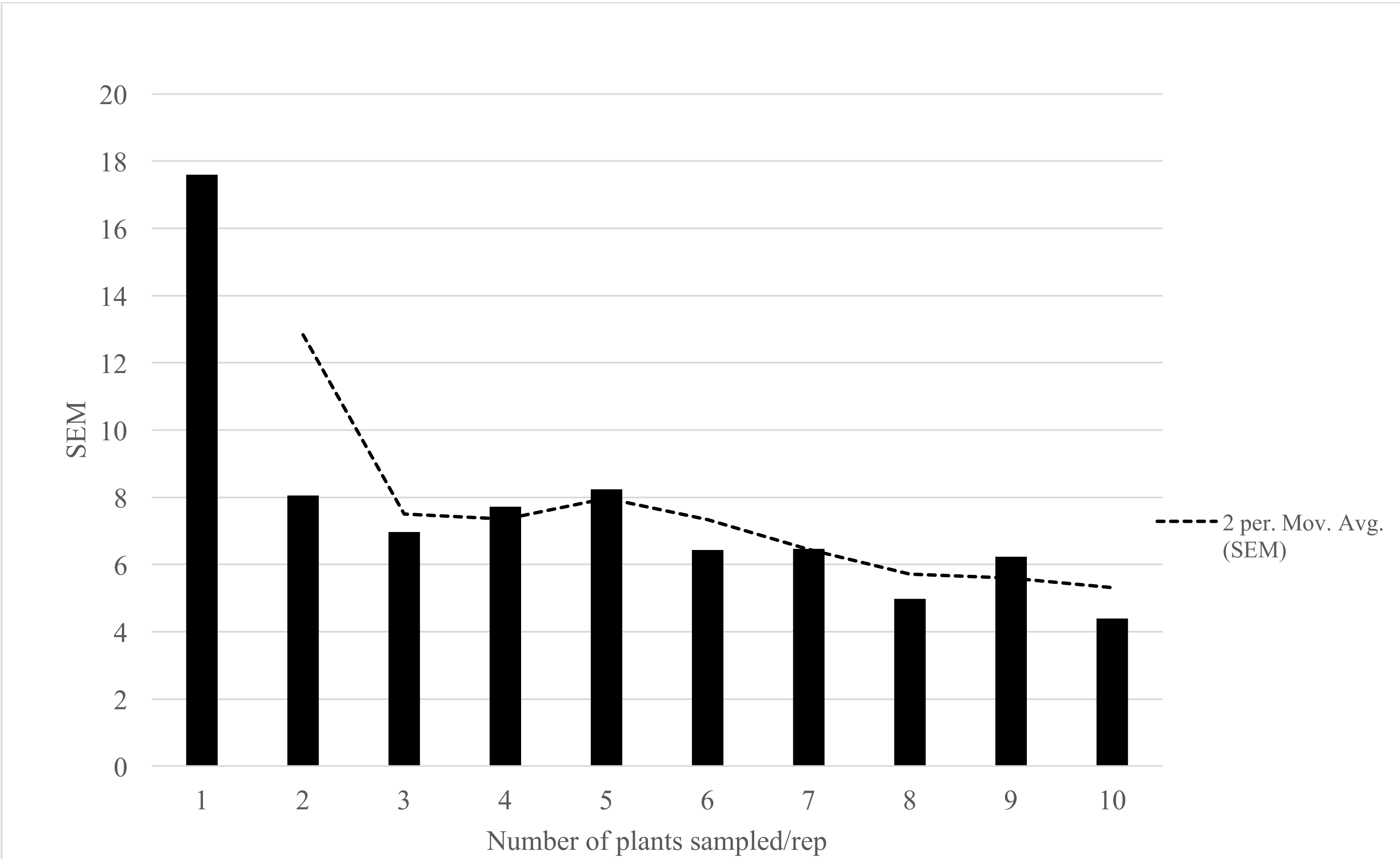

Figure 3. Standard error of the mean for grain yield (g) as the number of plants sampled per replication increased from 1 to 10

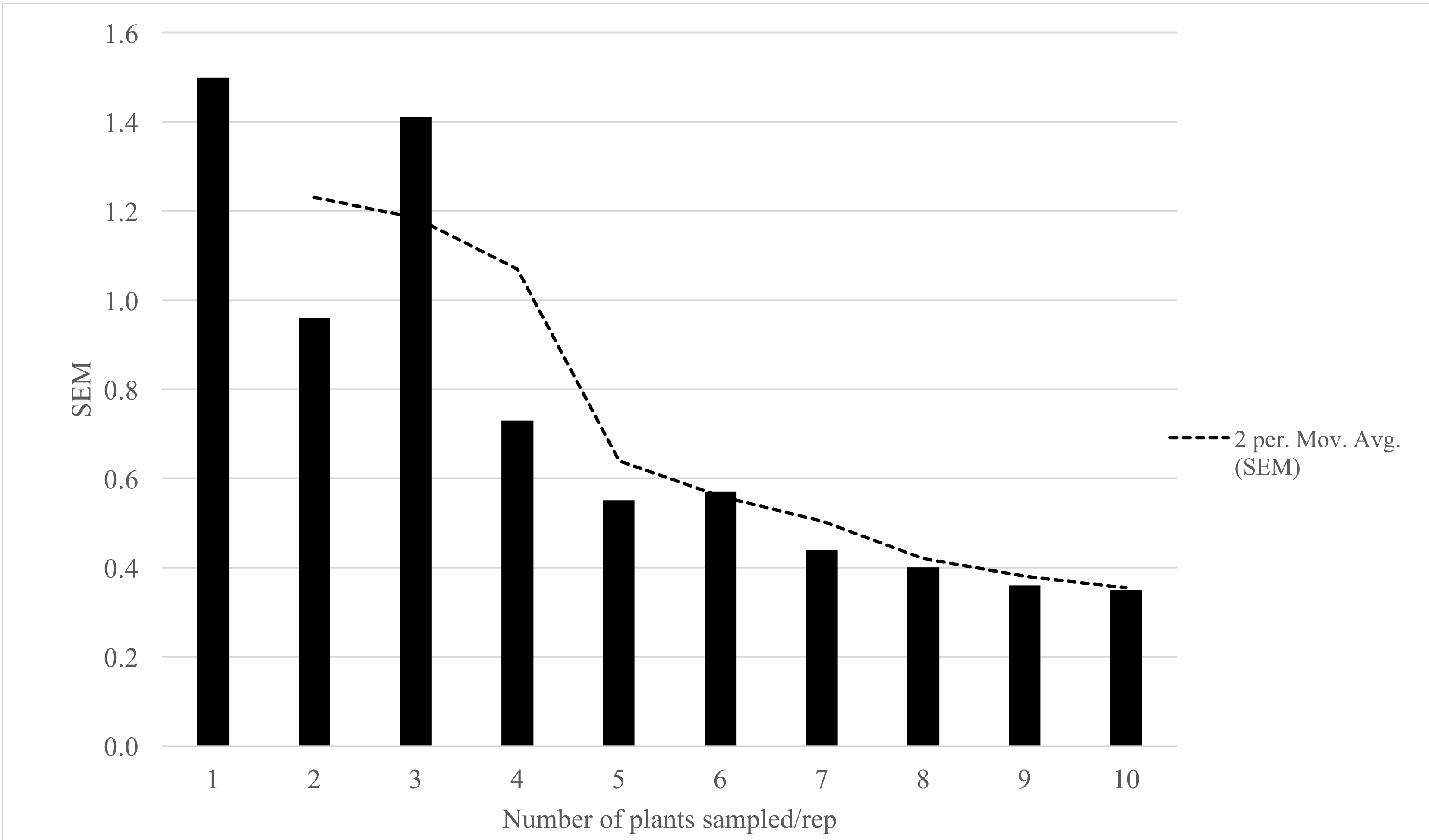

Figure 4. Standard error of the mean for residue (leaf + sheath + husk) yield, expressed as a % of grain yield, as the number of plants sampled per replication increased from 1 to 10.

Table 2. Yield of corn residue (% of corn grain yield) in year 2

	Grazing Treatment[1]				
Yield[2]	Fall grazed	Spring grazed	Non-grazed	SEM	*P*- value
Husk	5.8	6.1	5.3	0.32	0.22
Leaf	17.6	18.2	16.9	1.04	0.68
Sheath	8.6	8.7	8.2	0.49	0.77

[1]Treatments were due to timing of cattle grazing residue either 1 or 2 years prior to these samples being collected. Ten corn plants were collected from each plot (3 treatments x 4 replications = 12 plots).
[2]Measured by clipping individual corn plants and compositing by plot

Table 3. Yield of residue (% of corn grain yield) measured by clipping individual corn plants in year 2

	Husk	Leaf Blade	Leaf Sheath	SEM	*P*-value
Yield	5.74 ^{c}	17.6^{a}	8.49^{b}	0.6	< 0.01

^{abc}Means within a row with unique superscripts differ ($P < 0.05$)

Table 4. *In vitro* organic matter digestibility (IVOMD) and digestible organic matter (DOM) of corn plant samples by crop-rotation[3] (Yr 2)

	Crop-rotation			
Item	C-SB[1]	C-C[2]	SEM	*P*-value
IVOMD, %	44.3	44.0	3.0	0.96
DOM[4], %	40.8	40.5	3.2	0.95

[1]Area that was in a corn-soybean rotation
[2]Area that was in a corn-corn rotation
[3]Samples were from hand clipped whole corn plants
[4]Digestible organic matter (as a % of dry matter); calculated as OM content (%) × IVOMD (%)

Table 5. *In vitro* organic matter digestibility (IVOMD) and digestible organic matter (DOM) of corn plant parts[1] (Yr 2)

Item	Husk	Leaf Blade	Leaf Sheath	SEM	*P*-value
IVOMD, %	60.0 [a]	39.7[b]	32.7[c]	0.6	<0.01
DOM[2], %	58.1[a]	33.7[b]	30.2[c]	0.6	<0.01

[1] Samples were from hand clipped whole corn plants divided into individual plant parts
[2]Digestible organic matter (as a % of dry matter); calculated as OM content (%) × IVOMD (%)
[abc]Means within a row with unique superscripts differ ($P < 0.05$)

Table 6. *In vitro* organic matter digestibility (IVOMD) and digestible organic matter (DOM) of corn residue diet samples by treatment and time[1] (Yr 2)

	Fall		Spring			P-value[2]		
Item	Beginning	End	Beginning	End	SEM	Trt	Time	Int.
IVOMD, %	62.1 [a]	48.9 [b]	58.6 [a]	29.0 [c]	3.0	<0.01	<0.01	<0.01
DOM[3], %	58.5 [a]	40.0 [c]	53.5 [b]	25.7 [d]	2.9	<0.01	<0.01	0.04

[1]Treatments are due to timing of grazing (fall or spring) and timing of sample collection (at the beginning or end of grazing). Diet samples were obtained from fistulated steers.
[2]Trt= fixed effect of treatment; Time= fixed effect of time; Int. = treatment × time interaction
[3] Digestible organic matter (as a % of DM); calculated as OM content (%) × IVOMD (%); adjusted for ash content of saliva
[abcd]Means within a row with unique superscripts differ ($P < 0.05$)

CHAPTER III

Effects of winter cow-calf production system on cow-calf performance

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ABSTRACT

Limited traditional forage resources have prompted interest for alternative cow-calf production systems. A study evaluated the effects of 2 winter cow-calf production systems on cow-calf performance in a summer-calving, intensively managed cowherd. The study was conducted over 3 years in eastern Nebraska (ENREC) and 2 years in western Nebraska (PREC). Lactating, crossbred beef cows (n=127 at ENREC; n=56 at PREC) with summer-born calves were utilized in the study. In year 1, cow-calf pairs within location were blocked by cow BW (4 blocks at ENREC; 2 blocks at PREC), stratified by calf age, and assigned randomly within strata to 1 of 2 winter cow-calf production treatments with 4 (ENREC) or 2 (PREC) replications per treatment. Treatments were 1) dry-lot feeding (DL) or 2) cornstalk grazing with supplementation (CS). Treatments were maintained on cows following assignment in year 1. The trial was initiated at the beginning of cornstalk grazing (mid-November) within each location. Dry-lot pairs within location were limit-fed a crop residue and distillers-based diet formulated to meet energy requirements of a lactating cow in early gestation. A dried distillers grain-based pellet was supplemented to pairs wintered on cornstalks at a rate of 2.4 kg DM/pair daily. The trial was completed when winter cornstalk grazing ended (mid-April), which coincided with weaning. Cow-calf pairs grazed on average 151 and 139 d at ENREC and PREC, respectively. Dry-lot cow-calf pairs were limit-fed 12.3 kg/d DM (ENREC) or 11.9 kg/d (PREC) throughout the trial. At ENREC, a significant different was observed between treatments for cow BW and BCS change ($P < 0.01$). Cows wintered on cornstalks at ENREC lost BW and had a 0.46 unit decrease in BCS, while cows in the dry-lot gained BW and had a 0.24 unit increase in BCS. At PREC, a significant

difference was observed between treatments for BCS change (*P* = 0.04). Body condition score increased by 0.03 units for cows wintered in the dry-lot and decreased by 0.26 units for cows wintered on cornstalks. At both locations, calves wintered in the dry-lot had greater ADG and BW per d of age compared to CS calves ($P \leq 0.03$). A partial budget suggests that lower winter production inputs may be significant enough to compensate for reduced performance of calves when cow-calf pairs are wintered on cornstalks.

Key Words: cornstalk, grazing, cow-calf

INTRODUCTION

Reduced land availability for grazing and forage production and subsequently greater production costs have encouraged many cow-calf producers to seek alternative production systems. Research has shown that intensive management of cows can be utilized as an alternative system to traditional pasture cow-calf production (Warner et al., 2015a). Areas that are challenged by limited traditional forage resources commonly have greater grain crop production, resulting in greater availability of corn residue for fall/winter grazing with by-product supplementation. A simulated economic analysis of an alternative production system suggests that using corn residue grazing as a component of a semi-confined cow-calf production system could reduce production costs and provide a competitive alternative to traditional pasture cow-calf production (Warner et al., 2015b). Research has indicated that non-lactating, gestating spring-calving cows maintain BW and BCS while grazing corn residue (Warner et al., 2011). However, minimal research is available on the performance of cow-calf pairs grazing corn residue. Therefore, the objective of the current study was to evaluate the effects of winter corn residue grazing in a semi-confined cow-calf production system on cow and calf performance.

MATERIALS AND METHODS

All experimental facilities and management procedures were approved by the University of Nebraska-Lincoln Institutional Animal Care and Use Committee. A study was conducted over three years at the Eastern Nebraska Research and Extension Center (ENREC) near Mead, Nebraska and two years at the Panhandle Research and Extension Center (PREC) at Scottsbluff, Nebraska. Lactating, composite (Red Angus × Red Poll ×

Tarentaise × South Devon × Devon) beef cows (n=127 at ENREC; n=56 at PREC) with summer-born calves were used in a randomized complete block design with two treatments. In year one, cow-calf pairs within location were blocked by cow BW (4 blocks at ENREC; 2 blocks at PREC), stratified by calf age, and assigned randomly within strata to one of two winter cow-calf production treatments with four (ENREC) or two (PREC) replications (pens or paddocks) per treatment per year. Treatments were 1) dry-lot feeding (DL) or 2) cornstalk grazing (CS). In the subsequent years, cows within location were assigned to the same treatment as assigned in year one. To maintain herd size, cows culled between years were replaced with pregnant, multiparous cows sourced from the same supplier and herd of the original cows.

Prior to trial initiation, cows within location were managed in a common feedlot pen and limit-fed a distillers grain and crop residue-based diet from mid-April to mid-November each year. Approximately one month prior to calving, cows were vaccinated against *bovine rotavirus, bovine coronavirus, escherichia coli, and clostridium perfringens type C* (ScourGuard 4KC, Zoetis, Florham Park, NJ).

Cows calved in a feedlot pen during the summer with mean calving dates of July 14 (ENREC) and July 15 (PREC). Following parturition, calf birth date, weight, and sex were recorded and bull calves were band castrated. At approximately 30 d of age, calves were vaccinated for the prevention of blackleg caused by *Clostridium chauvoei*, malignant edema caused by *Clostridium septicum*, black disease caused by *Clostridium novyi*, gas-gangrene caused by *Clostridium sordellii*, enterotoxemia and enteritis caused by *Clostridium perfringens* (types B, C, and D), and disease caused by *Histophilus somni* (Ultrabac 7, Zoetis) and were vaccinated against IBR, BVD (types 1 & 2), PI3, BRSV,

and *Mannheimia haemolytica type A1* (Bovi-Shield Gold One Shot, Zoetis). All calves were revaccinated at 70 d of age with Bovi-Shield Gold One Shot and Ultrabac 7. At approximately 210 d of age, all calves were revaccinated against IBR, BVD (types 1 & 2), PI3, and BRSV (Bovi-Shield Gold 5, Zoetis).

The trial was initiated at the beginning of cornstalk grazing on approximately November 11 and November 22 for ENREC and PREC, respectively (Yr 1: Nov 6 at ENREC; Yr 2: Nov 11 at ENREC and Dec 4 at PREC; Yr 3: Nov 15 at ENREC and Nov 11 at PREC).

Cow-calf pairs assigned to the DL treatment remained in dry-lot pens. Dry-lot pairs within location were limit-fed a diet (Table 1) formulated to meet energy requirements for a lactating cow in early gestation. Feed was delivered as a TMR once daily in concrete fence-line feed bunks (0.9 m linear space per cow-calf pair). Dry matter offered increased by 0.45 kg monthly throughout the study to account for increasing intake of the growing calves. In years one and two, the amount of DM offered ranged from 11.6 kg to 13.4 kg/d. During years one and two, cows fed in the dry-lot were gaining BW and BCS and were not at maintenance. To correct for the BW and BCS gain, the amount of DM offered to cows in the dry-lot was reduced to a range of 11.1 to 12.9 kg/d during year three.

Within location, cow-calf pairs assigned to the CS treatment were hauled to a harvested irrigated corn field. Stocking rate for cow-calf pairs grazing corn residue was calculated using estimated daily residue intake (range of 12.7 to 14.5 kg DM/d) for the cow-calf pair (Meyer et. al., 2012 throughout the grazing period and assuming 3.6 kg (DM) of husk and leaf residue were available for consumption per 25.5 kg of corn grain

yield (Watson et al., 2015). The amount of supplement needed to meet the energy requirements of a cow-calf pair grazing corn residue was calculated using estimated residue intake of a pair (Meyer et. al., 2012) and estimated digestibility values of corn residue throughout the grazing period (Wilson et. al., 2004). Cow-calf pairs grazing corn residue were supplemented daily in bunks (0.9 m of linear space per pair) with dried distillers grain based-cubes (Table 2) at a rate of approximately 2.4 kg (range of 1.7 kg to 3.2 kg) DM per pair daily. The amount supplemented was initially targeted to provide an equivalent energy intake to that of the dry-lot pairs. However, in year three, supplementation to cows on cornstalks was held constant while the DM offered to cows in the dry-lot was reduced. If snow cover prevented grazing, additional supplemental feed was fed to grazing pairs. In year 2, approximately 77 kg (DM) of ammoniated cornstalks were fed per pair at ENREC.

The trial was completed when winter cornstalk grazing ended on approximately April 10 and April 9 for ENREC and PREC, respectively (Yr 1: April 13 at ENREC; Yr 2: April 12 at ENREC and April 14 at PREC; Yr 3: April 8 at ENREC and April 4 at PREC). The completion of the cornstalk grazing period coincided with weaning of all calves. Cow BW and calf BW were recorded over two consecutive days at trial initiation and completion to determine changes in BW from November to April. A trained technician at each location evaluated body condition score (Wagner et al., 1988; 1 = emaciated; 9 = obese) of cows at trial initiation and completion. Prior to being weighed at trial initiation, all cow-calf pairs were limit-fed a common diet for a minimum of 5 consecutive days to reduce weight variation due to gastrointestinal tract fill (Watson et

al., 2013). At trial completion, cows and calves were separated and again limit-fed a common diet for a minimum of 5 days before being weighed.

Cows were exposed to Simmental × Angus bulls (1 bull: 10 cows) beginning approximately Sept 25 each year and September 26 with a 73 and 74-day breeding season at ENREC and PREC, respectively. Cows received pre-breeding vaccinations for the protection against infectious bovine rhinotracheitis (IBR), bovine viral diarrhea (BVD) (types 1 and 2), parainfluenza3 (PI3), and bovine respiratory syncytial virus (BRSV; Bovi-Shield Gold FP5 VL5 HB, Zoetis) and (Ultrabac 7; Zoetis). All bulls were examined for breeding soundness and approved by a licensed veterinarian prior to the breeding season. Approximately 135 days after bull removal, blood samples were collected and tested for the presence of Pregnancy-Specific Protein B to determine cow pregnancy status (BioPRYN; BioTracking, Inc., Moscow, ID).

In vitro analysis of corn residue collected from each location was conducted to determine residue quality. Within location, ten consecutive whole corn plant samples harvested above the anchor root were collected from six sampling sites just prior to grain harvest. Plant samples were separated into individual plant components (husk, leaf blade, and leaf sheath). Plant components were then composited within replication and ground through a 1mm screen using a Wiley Mill (Thomas Scientific, Swedesboro, NJ). Composite samples were then analyzed for *in vitro* organic matter digestibility (IVOMD) in two runs using the Tilley and Terry method (1963) modified by the inclusion of 1 g urea/ml of buffer (Wiess, 1994). A set of forage (grass and corn residue) standards with established in vivo values were included in each run to develop regression equations that allowed for the comparison between runs (Geisert et al., 2007). Triplicate samples from

each plant fraction and standard were weighed into 100 ml *in vitro* tubes. Rumen fluid was collected from two donor steers fed a 30% concentrate diet. McDougall's buffer was mixed with rumen fluid to form inoculum, which was added to each tube. *In vitro* tubes were then incubated in a 39ºC water bath for 48 hours and swirled every 12 hours. Following 48 hours of incubation, fermentation was ceased by adding 5 mL of 20% hydrochloric acid and 3 mL of 5% pepsin to each tube. Tubes remained in the water bath for an additional 24 hours and then frozen immediately following removal. Contents from each tube were filtered through Whatman 541 filter paper, rinsed with distilled water, and dried in a 100ºC oven for 12 hours to determine DM. Filters were then placed in a muffle furnace at 600ºC for 6 h to determine ash and OM (AOAC, 1999; method 4.1.10). Digestible organic matter (DOM) was calculated by multiplying the IVOMD and percent OM of the original residue sample.

Statistical Analysis

Data from the 2 locations (ENREC and PREC) were analyzed separately using the MIXED procedures of SAS (SAS Institute., Cary, NC). Performance data were analyzed as a randomized complete block design. The model included pen or paddock as the experimental unit, cow-calf production system as the fixed effect, and block and year as random effects. Because the proportion of steer and heifer calves varied across replications, proportion of steers was included in the model as a covariate for all calf performance variables. For corn residue data, plant part was included as a fixed effect in the model. Significance was declared at $P \leq 0.05$.

Economic Analysis

A partial budget was conducted retrospectively to economically compare wintering systems for cow-calf pairs within location. Economic assumptions were applied to each treatment with respect to days spent in each treatment. Treatment differences in expenses and income were entered into a partial budget Microsoft® Excel (Microsoft®, Redmond, WA) spreadsheet (Tigner, 2015) for both ENREC and PREC.

Cash corn prices were collected from Johanns (2017) to determine a 10-year (2007-2016) average corn price of \$4.59/bu. The cost of distillers grains was calculated as 100% the value of corn on a DM basis. For the diet fed to DL cow-calf pairs, base price for baled crop residue was \$50 per 907 kg. An additional \$15 per 907 kg was charged to crop residue to account for grinding cost. Total diet cost was calculated on a DM basis for all feeds. Daily feed cost was calculated by multiplying diet cost by DM intake for DL cow-calf pairs within location. Feedlot yardage was modified from Jensen and Mark (2010) and set at \$0.50 per pair per day with regard to increased maintenance from a nursing calf.

A freight expense for delivery of dry distillers grain to PREC was charged at \$2.80 per loaded km (381 km). For CS cow-calf pairs, daily supplementation cost was calculated as the price of distillers grain multiplied by supplementation rate (2.4 kg per pair). Due to differences in regional availability of corn residue, leased acres for corn residue grazing were priced at \$12/0.41 ha and \$17/0.41 ha for ENREC and PREC, respectively, which corresponded to \$0.20 (ENREC) and \$0.30 (PREC) per pair daily. Grazing yardage expenses associated with animal care, fencing, and supplementing was charged at \$0.20 per cow-calf pair per day. At ENREC, cows that had been wintered on cornstalks were fed an additional 1.6 kg of feed for 75 days post-weaning in order to

compensate for BW and body condition losses incurred throughout the winter grazing period. Therefore, an additional feed cost was charged to CS cows at ENREC. The cost of additional feed was determined by multiplying the total amount fed over 75 days by the diet cost. Calf prices were collected from Shulz (2017) to determine 10-year average prices received for weaned calves. To account for the lighter weaning weight of CS calves observed at both locations, a price slide of \$17.23/45 kg was used to determine the price received for weaned calves. The price slide was based on a regression of a 10-year average price of steer and heifer calves weighing 226-272 kg and a 10-year average price of steer and heifer calves weighing 272-318 kg.

RESULTS AND DISCUSSION

Cow-calf pairs grazed corn residue at ENREC for approximately 151 days (Nov 11 to April 10). At PREC, the grazing period was approximately 139 days (Nov 22 to April 9). Dry-lot cow-calf pairs consumed 12.3 kg DM/d (ENREC) or 11.9 kg DM/d (PREC) on average throughout the trial.

Cow performance is presented in Table 3. Initial cow BW and BCS were similar between treatments at both locations ($P \geq 0.50$). Cows that were managed in the dry-lot at ENREC had greater ending BW and BCS compared to cows grazing cornstalks ($P < 0.01$). Cows wintered on cornstalks at ENREC lost BW (33 kg) and had a 0.46 unit decrease in BCS, while cows in the dry-lot gained BW (40 kg) and had a 0.24 unit increase in BCS. At PREC, a significant difference was observed between treatments for cow BCS change ($P = 0.04$). Body condition score increased by 0.03 units for cows wintered in the dry-lot and decreased by 0.26 units for cows wintered on cornstalks. No

significant differences ($P \geq 0.41$) were observed between treatments for any other cow performance variables at PREC.

Overall, pregnancies were 90% of cows exposed, but the number of cows is too small to make a treatment comparison. Reproduction data required that cows had a treatment applied prior to the breeding season; therefore, treatment effect on pregnancy rate could only be measured for years two and three at ENREC and year two at PREC. There were 61 cows (CS= 33; DL= 28) and 19 (CS=10; DL= 9) cows total from ENREC and PREC, respectively, that met these criteria. At ENREC, pregnancy rates were 98 and 83% for CS and DL cows, respectively. Pregnancy rates at PREC were 88 and 89% for CS and DL cows, respectively.

The performance of the cows grazing cornstalks is in agreement with Griffin et. al. (2012) who reported that lactating, June-calving cows winter grazed on corn residue and fed a dried distillers grain-based supplement (0.45 kg per cow daily; 28% CP; pro-rated for delivery 3 d per wk) lost BW and BCS. In the present study, the loss in BCS for cows wintered on cornstalks implies that the amount of energy provided was less than anticipated. An overestimation of the quality and/or residue intake may explain the reduced performance of cows grazing cornstalks.

The increase in BCS and BW observed in cows managed in the dry-lot over the winter indicates that DL cows were over-fed and not at maintenance. It is possible that cows become metabolically adapted during restricted intake and, therefore, have reduced energy requirements (Boardman et al., 2016). Furthermore, limit-feeding confined cows may influence diet digestibility. Trubenbach et al. (2014) observed a 4.5 percentage unit increase in apparent OM digestibility when cows were restricted to 80% of energy

maintenance requirements. Warner et al. (2011) reported that nonpregnant, nonlactating cows limit-fed (1.3% of BW) a diet consisting of 41% WDGS and 59% corn residue tended to have greater ADG compared to cows with ad libitum intake of a mixture of bromegrass hay, corn residue, and alfalfa haylage. These data suggest that the energy provided to cows in limit-fed systems may be under estimated.

Performance of calves is presented in Table 4. Calves at PREC were approximately 10 days older than calves at ENREC at the onset of the cornstalk grazing period. Similar cow-calf production effects were observed at both locations. Initial calf BW was not significantly different between treatments ($P \geq 0.08$). Calves wintered in the dry-lot had greater ending BW and BW change compared to calves grazing cornstalks ($P \leq 0.04$). Likewise, calves wintered in the dry-lot had greater ADG and BW per d of age compared to calves grazed on cornstalks ($P \leq 0.03$). These observations are in agreement with Griffin et al. (2012) who reported similar weaning weights and ADG for June calves grazed on cornstalks and weaned in April.

Numerically, the cows grazing cornstalks at PREC gained 9 kg while the cows at ENREC lost 33 kg. Calves at PREC gained 0.7 kg per day while those at ENREC gained 0.6 kg per day. In vitro analysis of the corn residue from each location was conducted to determine if residue quality was related to the apparent differences in performance of the pairs grazing cornstalks. *In vitro* OM digestibility and DOM of corn residue from ENREC and PREC are presented in Table 5 and Table 6, respectively. Assuming cattle consume residue (husk, leaf, and sheath) in the same proportion as it is produced on the plant (18% husk, 55% leaf, and 27% sheath; Gardine et al., 2017), DOM of consumed residue in the current study was 42.6 % and 55.7 % at ENREC and PREC, respectively.

The 13.1 % unit difference in DOM of corn residue observed between locations may explain variation in cow-calf performance.

A partial budget of incorporating winter cornstalk grazing into a semi-confined cow-calf production system indicated that grazing cow-pairs on corn residue was a more profitable system compared to year-round confinement. A partial budget utilizing data from ENREC (Table 7) suggested that winter grazing cow-calf pairs on corn residue resulted in a greater net profit of $97 per pair compared to feeding cow-calf pairs in the dry-lot over the winter. At ENREC, grazing cornstalks saved the system $200 per pair (additional cost - reduced cost). Because the calves wintered on cornstalks at ENREC were 49 kg lighter at weaning compared to calves wintered in the dry-lot, income was decreased by $103 per calf. A partial budget for PREC (Table 8) indicated that grazing pairs on cornstalks over the winter resulted in $79 greater net profit per pair compared to cow-calf pairs fed in the dry-lot. By grazing cow-calf pairs on cornstalks at PREC, $162 (additional cost – reduced cost) were saved compared to feeding in the dry-lot. The 37 kg lighter weaning weight of calves wintered on cornstalks compared to calves fed in the dry-lot resulted in $83 less income per calf. Overall, the decrease in production cost more than offset reduced performance of calves wintered on cornstalks at both locations.

IMPLICATIONS

Cow-calf pairs grazing corn residue in the winter may have similar or reduced performance compared to pairs fed a complete diet throughout the winter in the dry-lot. Although calf ADG appears to be greater for calves wintered in the dry-lot, gain in BW and BCS of cows fed in the dry-lot may be of little economical value. Lower winter

production inputs may be significant enough to compensate for reduced performance of calves when cow-calf pairs are wintered on cornstalks.

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Table 1. Diets fed to cow-calf pairs from November to April by location and year[1]

Ingredient, % diet DM	Year 1 ENREC[2]	Year 2 ENREC[2]	Year 2 PREC[3]	Year 3 ENREC[2]	Year 3 PREC[3]
Modified distillers grains plus solubles[4]	55	55	--	55	--
Wet distillers grains plus solubles[4]	--	--	58	--	58
Cornstalks[5]	--	40	--	--	--
Wheat straw[5]	40	--	40	40	40
Supplement[6]	5	5	2	5	2
Calculated Composition					
DM, %	62.4	59.9	47.0	62.4	47.0
CP, %	19.3	19.3	18.8	19.3	18.8
TDN, %	79.1	79.1	81.0	79.1	81.0

[1]Dry matter offered (range of 11.1 kg to 13.4 kg/d) increased monthly throughout the study
[2]ENREC = Eastern Nebraska Research and Extension Center near Mead, NE
[3]PREC = Panhandle Research and Extension Center near Scottsbluff, NE
[4]Formulated using 108% TDN value
[5]Formulated using 43% TDN value
[6]Supplement included limestone, trace minerals, and vitamins A,D,E premix

Table 2. Supplement fed to cow-calf pairs grazing cornstalks[1]

Ingredient, % diet DM	
Dried distillers grains plus solubles	93.28
Limestone	6.23
Pelleting binder (urea formaldehyde polymer and calcium sulfate)	0.21
Vitamins A,D,E	0.11
Trace mineral[1]	0.17

[1]Supplemented on average at a rate of 2.4 kg (range of 1.7 kg to 3.2 kg) DM/pair daily
[2]Trace mineral: 0.4389% Cu, 3.1818% Mn, 2.1511% Zn, 0.0067% Co, 0.0152% I, 94.2064% limestone carrier

Table 3. Performance of cows by cow-calf production system

	ENREC[1]				PREC[2]			
Item	CS[3]	DL[4]	SEM	*P*-value	CS[3]	DL[4]	SEM	*P*-value
Cow BW, kg								
Initial[5]	553	556	27	0.86	604	590	60	0.59
Ending[6]	520	596	22	<0.01	613	617	44	0.86
Cow BW Change, kg	-33	40	9	<0.01	9	27	17	0.42
Cow BCS[7]								
Initial[5]	5.49	5.58	0.31	0.62	6.09	5.92	0.71	0.50
Ending[6]	5.03	5.82	0.18	<0.01	5.83	5.95	0.70	0.41
Cow BCS change[4]	-0.46	0.24	0.20	<0.01	-0.26	0.03	0.08	0.04

[1]ENREC = 3 yr of data from the Eastern Nebraska Research and Extension Center near Mead, NE
[2]PREC = 2 yr of data from the Panhandle Research and Extension Center near Scottsbluff, NE
[3]CS= pairs wintered on cornstalks
[4]DL= pairs wintered in dry-lot
[5]Initial date= November 11 at ENREC and November 22 at PREC
[6]Ending date= April 10 at ENREC and April 9 at PREC
[7]BCS on a 1 (emaciated) to 9 (obese) scale (Wagner et al., 1988)

Table 4. Performance of calves by cow-calf production system[1]

Item	ENREC[1] CS[3]	ENREC[1] DL[4]	SEM	*P*-value	PREC[2] CS[3]	PREC[2] DL[4]	SEM	*P*-value
Initial age, d[5]	121	118	4	0.43	131	129	17	0.62
Calf BW, kg								
Initial[6]	150	142	4	0.08	144	144	13	0.97
Ending[7]	240	289	5	<0.01	233	270	15	<0.01
Calf BW change	90	148	4	<0.01	96	127	11	0.04
Calf ADG, kg	0.60	0.98	0.03	<0.01	0.70	0.93	0.06	0.03
BW•d^{-1} age^{-1}, kg[8]	0.88	1.08	0.03	<0.01	0.89	1.03	0.06	0.02

[1]ENREC = 3 yr of data from the Eastern Nebraska Research and Extension Center near Mead, NE
[2]PREC = 2 yr of data from the Panhandle Research and Extension Center near Scottsbluff, NE
[3]CS= pairs wintered on cornstalks
[4]DL= pairs wintered in dry-lot
[5]Initial age= age at initiation of cornstalk grazing period
[6]Initial date= November 11 at ENREC and November 22 at PREC
[7]Ending date= April 10 at ENREC and April 9 at PREC
[8]Weight per d of age at collecting weights following weaning

Table 5. *In vitro* organic matter digestibility (IVOMD) and digestible organic matter (DOM) of corn plant components collected prior to grain harvest at ENREC[1]

	Plant component[2]				
Item	Husk	Leaf Blade	Leaf Sheath	SEM	P-value
IVOMD, %	63.9[a]	45.8[b]	36.2[c]	1.3	<0.01
DOM[3], %	61.4[a]	40.9[b]	33.4[c]	1.3	<0.01

[1]Eastern Nebraska Research and Extension Center

[2]Samples were from hand clipped whole corn plants divided into individual plant parts

[3]Digestible organic matter (as a % of dry matter); calculated as OM content (%) × IVOMD (%)

[abc]Means within a row with unique superscripts differ ($P < 0.05$)

Table 6. *In vitro* organic matter digestibility (IVOMD) and digestible organic matter (DOM) of corn plant components collected prior to grain harvest at PREC[1]

	Plant component[2]				
Item	Husk	Leaf Blade	Leaf Sheath	SEM	P-value
IVOMD, %	70.1[a]	62.6[b]	59.0[c]	2.1	<0.01
DOM[3], %	67.0[a]	53.2[b]	53.1[b]	1.9	<0.01

[1]Panhandle Research and Extension Center

[2]Samples were from hand clipped whole corn plants divided into individual plant parts

[3]Digestible organic matter (as a % of dry matter); calculated as OM content (%) × IVOMD (%)

[abc]Means within a row with unique superscripts differ ($P < 0.05$)

Table 7. Partial budget analysis of grazing cow-calf pairs on corn residue at ENREC[1,2]

Additional Revenue	Amount	Reduced Revenue	Amount
		Lighter CS calf weaned[6]	$103
Reduced Cost		**Additional Cost**	
No total mixed diet fed ($145/907 kg)[3,4]	$298	Cornstalk rent[7]	$31
No feedlot yardage[5]	$76	Supplement[3]	$78
		Grazing yardage[8]	$45
		Post-weaning feed for CS cow[9]	$20
Total additional revenue and reduced cost	$374	Total reduced revenue and additional cost	$277
Net change in profit	$97		

[1]Eastern Nebraska Research and Extension Center near Mead, NE

[2]Partial budget evaluated changes in cost and revenue due to grazing cow-calf pairs on cornstalks throughout the winter as opposed to feeding in the dry-lot.

[3]Distillers grains priced at 100% the value of corn at $4.59 per bu (Johanns, 2017).

[4]Base crop residue priced at $50/907 kg plus an additional $15/907 kg for grinding.

[5]Feedlot yardage charged at $0.50 per pair per d

[6]The difference in calf value at weaning between treatments. Calf price determined through a regression of 10-yr average prices for calves weighing between 226-272 kg and 272-318 kg (Shulz, 2017).

[7]Rent was charged at $12/0.41 ha ($0.20 per pair per day)

[8]Grazing yardage charged at $0.20 per pair per day

[9]Cost to feed an additional 1.6 kg (DM) of feed for 75 days post-weaning to compensate for BW and BCS losses incurred throughout the winter grazing period.

Table 8. Partial budget analysis of grazing cow-calf pairs on corn residue at PREC[1,2]

Additional Revenue	Amount	Reduced Revenue	Amount
		Lighter CS calf weaned[6]	$83
Reduced Cost		**Additional Cost**	
No total mixed diet fed[3,4]	$264	Cornstalk rent[7]	$41
No feedlot yardage[5]	$70	Supplement[8]	$89
		Grazing yardage[9]	$42
Total additional revenue and reduced cost	$334	Total reduced revenue and additional cost	$255
Net change in profit	$79		

[1]Panhandle Research and Extension Center near Scottsbluff, NE

[2]Partial budget evaluated changes in cost and revenue due to grazing cow-calf pairs on cornstalks throughout the winter as opposed to feeding in the dry-lot.

[3]Distillers grains priced at 100% the value of corn at $4.59 per bu (Johanns, 2017).

[4]Base crop residue priced at $50/907 kg plus an additional $15/907 kg for grinding.

[5]Feedlot yardage charged at $0.50 per pair per d

[6]The difference in calf value at weaning between treatments. Calf price determined through a regression of 10-yr average prices for calves weighing between 226-272 kg and 272-318 kg (Shulz, 2017).

[7]Rent was charged at $17/0.41 ha ($0.30 per pair per day)

[8]A freight expense for delivery of dry distillers grain to PREC was charged at $2.80 per km ($4.50 per loaded mile).

[9]Grazing yardage charged at $0.20 per pair per day

CHAPTER IV

Effects of cow-calf production system and post-weaning management on growing and finishing performance and carcass characteristics

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ABSTRACT

Research has indicated that cornstalk grazing can be integrated into a semi-confined cow-calf production system. Furthermore, post-weaning management can affect finishing performance and carcass characteristics of beef cattle. The objective of the current study was to evaluate the effects of cow-calf production system and post-weaning management on finishing performance and carcass characteristics of calves produced from an intensively managed cowherd. The study was conducted over 3 years. Cows with summer-born calves at side were subject to 1 of 2 treatments: dry-lot feeding or cornstalk grazing with supplementation. From November to mid-April, cow-calf pairs assigned to the dry-lot treatment were fed a distillers and crop residue-based diet, and pairs assigned to cornstalk grazing were supplemented with distillers-based cubes. Following the cornstalk grazing period, all calves were weaned and received into the feedlot for post-weaning management. Summer-born steer (n = 114) and heifer (n = 95) calves (BW 264 ± 42 kg) were allocated by previous cow-calf production system, stratified by initial BW, and assigned randomly to 1 of 2 post-weaning treatments with 2 replications per treatment per year. The treatment design was a 2 × 2 factorial arrangement. Treatment factors included: 1) cow-calf production system: dry-lot feeding (DLOT) or cornstalk grazing (STALK) and 2) post-weaning management: finishing (FINISH) or grow-finishing (GROW). In the FINISH treatment, calves were directly adapted to a finishing diet following weaning. Calves in the GROW treatment were placed on a growing diet (30% Sweet Bran, 35% distillers grains, and 35% wheat straw) for 76 days before being adapted to the common finishing diet. Calves from STALK had lighter initial BW entering the finishing phase than calves from DLOT ($P < 0.01$). However, there were no

effects of cow-calf production system on final BW or carcass weight ($P \geq 0.15$). Calves in the FINISH treatment had greater ADG ($P < 0.01$) and improved G:F ($P < 0.01$). GROW calves produced 35 kg greater final BW ($P < 0.01$) and 23 kg greater carcass weight ($P < 0.01$). An economic analysis indicated that directly finishing calves resulted in greater net profit compared to growing calves prior to the finishing phase ($P < 0.01$) as the extra carcass weight did not offset the cost of the additional 49 days in the feedlot.

Keywords: cornstalk grazing, post-weaning, feedlot

INTRODUCTION

When traditional forage resources are limited, alternative beef production systems may be necessary. Research has demonstrated that year-round confinement of the cowherd can be used as an alternative to traditional pasture cow-calf production (Warner et. al., 2015). However, total confinement can be an expensive system. Areas challenged by limited grassland tend to favor grain crop production. Consequently, a greater supply of corn residue is available for grazing. Research has demonstrated that production costs can be reduced by using corn residue grazing as a component of a semi-confined cow-calf production system (Gardine, 2018). However, data are limited on subsequent feedlot performance of calves produced from a confined cow-calf production system.

In addition to alternative cow-calf production systems, different post-weaning management strategies may be implemented. Two common post-weaning systems are calf-fed and yearling systems. Calf-fed systems refer to calves that are directly adapted to a finishing diet following weaning, whereas a yearling system consists of a period of growth prior to the finishing phase. Calves are commonly grown in an extensive system using grazed forages or crop residue. An alternative growing program consists of backgrounding calves in pens in which harvested forages are fed. The type of post-weaning management utilized can affect finishing performance and carcass characteristics. Research has indicated that calf-feds have improved feed efficiency, but yearlings gain faster and finish with greater BW (Griffin et al., 2007). The objective of the current study was to evaluate cow-calf production system and post-weaning management on finishing performance and carcass characteristics of steer and heifer calves produced from an intensively managed cowherd.

MATERIALS AND METHODS

All experimental facilities and management procedures were approved by the University of Nebraska-Lincoln Institutional Animal Care and Use Committee. Summer-born steer (n = 114) and heifer (n = 95) calves (BW 264 $\pm$ 42 kg) were utilized in a study conducted over three years at the Eastern Nebraska Research and Extension Center (ENREC) feedlot. Calves were sourced from two cowherds maintained at either ENREC (124 calves) or the Panhandle Research and Extension Center (PREC; 85 calves).

Cow-calf Production System

Within each location, cowherds were maintained in confinement from approximately April to November during which the calving season occurred. In November, cow-calf pairs were assigned randomly to one of two winter cow-calf production treatments: 1) dry-lot feeding (DLOT) or 2) corn residue grazing with supplementation (STALK). Cow-calf pairs assigned to the DLOT treatment were limit-fed a distillers and crop residue-based diet formulated to meet energy requirements of a lactating cow in early gestation. The amount of DM offered increased monthly to account for increasing intake of the growing calf. Cow-calf pairs assigned to the STALK treatment were hauled to irrigated cornstalk fields and supplemented with approximately 2.4 kg (range of 1.7 kg to 3.2 kg) of a distillers-based cube daily. Calves from both cow-calf production systems were weaned in April and received into the ENREC feedlot for post-weaning treatments.

Post-weaning Management

Once received into the feedlot, calves were allocated by previous location and winter cow-calf production treatment, stratified by initial BW, and assigned randomly

within strata to one of two post-weaning treatments. The study was completely randomized with a 2 × 2 factorial treatment design. Factors were 1) cow-calf production system and 2) post-weaning management. Cow-calf production treatments included winter dry-lot feeding (DLOT) or corn residue grazing (STALK). Post-weaning management treatments were a finish (FINISH) or a grow-finish (GROW) treatment. Calves in the FINISH treatment were directly adapted to a concentrate finishing diet (Table 1) following weaning. In the GROW treatment, calves were fed a growing diet (Table 1) for approximately 76 days before being adapted to the same finishing diet as calves in the FINISH treatment.

At initial processing in year 1, calves in both treatments were vaccinated against infectious bovine rhinotracheitis (IBR), bovine viral diarrhea (types 1 & 2) (BVD), parainfluenza 3 (PI3), and bovine respiratory syncytial virus (BRSV) (Bovi-Shield Gold 5, Zoetis, Florham Park, NJ), poured with an insecticide (Standguard, Elanco Animal Health, Greenfield, IN), and implanted on day 1 with 200 mg trenbolone acetate and 40 mg estradiol (steers; Revalor XS, Merck Animal Health, Summit, NJ) or 80 mg trenbolone acetate and 8mg estradiol (heifers; Revalor-IH, Merck Animal Health). Heifers were re-implanted with 200 mg trenbolone acetate and 20 mg estradiol (Revalor 200, Merck Animal Health) approximately 100 days prior to harvest date. Calves in the FINISH treatment began the finishing phase April 21 and were harvested Nov. 4 (197 days on feed). A grower diet was fed to calves in the GROW treatment for 79 days. The GROW calves were then adapted to the common finishing diet (Table 1) and harvested on Jan 6 (181 days on feed).

In years 2 and 3, all calves were vaccinated against IBR, BVD (types 1 & 2), PI3, and BRSV (Titanium 5, Elanco Animal Health), poured with an insecticide (StandGuard, Elanco Animal Health), and implanted with 80 mg trenbolone acetate and 16 mg estradiol (steers; Component TE-IS, Elanco Animal Health) or 80 mg trenbolone acetate and 8 mg estradiol (heifers; Component TE-IH, Elanco Animal Health) at initial processing. All calves were then re-implanted with component TE-200 approximately 100 days before harvest. In year 2, calves in the FINISH treatment entered the finishing phase April 27 and were harvested Nov 2 (189 days on feed). The GROW calves were fed the grower diet for 73 days before adaptation to the common finishing diet. The GROW calves were harvested Dec 28 (166 days on feed). In year 3, FINISH calves began the finishing phase on April 21 and were harvested on November 7 (201 days on feed). Calves in the GROW treatment were fed the grower for 77 days prior to adaptation to the finishing diet. GROW calves were then harvested on December 20 (160 days on feed).

Ractopamine hydrochloride (Optaflexx; Elanco Animal Health) was included (300 mg/head daily) in the common finishing diet for the last 28 days on feed for all cattle every year. Weights were collected over two consecutive days at trial initiation. Prior to collecting weights, calves were limit-fed a common diet for a minimum of five days to minimize gastrointestinal weight variation (Watson et al., 2013). For calves in the GROW treatment, ending BW for the growing phase was used as initial BW for the finishing phase. In year 1, a 4% shrink was applied to calves in the GROW treatment upon completion of the growing phase due to calves not being limit-fed prior to collecting weights on 2 consecutive days. In years 2 and 3, GROW calves were limit-fed between phases prior to collecting weights on 2 consecutive days. To obtain a common

physiological endpoint between treatments, ultrasonography was used to detect 12th rib fat thickness on GROW cattle approximately 40 days prior to projected harvest date each year. The ultrasound scans were then used to predict harvest date by targeting backfat thickness to FINISH cattle.

All cattle were harvested at Greater Omaha Packing Co. (Omaha, NE). On the day of harvest, hot carcass weight (HCW) and liver abscess scores were recorded. Following a 48-hour chill, 12th rib fat thickness, marbling score, and LM area were recorded. Final BW, ADG, and G:F were calculated on a carcass-adjusted basis using a common dressing percentage of 63%. Yield grade was calculated using the following equation: $2.5 + (6.35 \times 12^{th}$ rib fat depth, cm$) - (2.06 \times$ LM area, cm$^2) + (0.2 \times$ KPH, %$) + (0.0017 \times$ HCW, kg$)$ (USDA, 2016).

Economic Analysis

A 10-year (2007 – 2016) analysis was used to economically compare post-weaning management systems. The analysis covered economics from the time of weaning through harvest. Days spent in each phase and performance data from the current study were used to determine costs, revenue, and net profit on a dressed pricing basis.

For initial purchase price, calf prices were collected from Shulz (2017) to determine 10-year average prices for the purchase of weaned calves (Table 2). To account for differences in weaning weights between cow-calf production systems, a price slide of $17.23/45 kg was used. The price slide was based on a regression of a 10-year average price of steer and heifer calves weighing 226-272 kg and a 10-year average price of steer and heifer calves weighing 272-318 kg. When calculating feed costs, all costs

were calculated on a DM basis. Cash corn prices were collected from Johanns (2017) to determine a 10-year average corn price of $4.59/bu. The costs of distillers grains and Sweet Bran were calculated as 100% of the value of corn (DM basis). Base price for grass hay/wheat straw was $50 per 907 kg. An additional $15 per 907 kg was charged to grass hay/wheat straw to account for grinding cost. Supplement was priced at $200 per 907 kg. Interest rates for agricultural operating loans were collected from the Federal Reserve Bank of Kansas City. A 10-year average interest rate of 6.2% was applied to the total cost associated with each phase and half of the initial animal cost. Feedlot yardage was held constant at $0.45 per head per day for both treatments. Similarly, all cattle were charged $15 per head for health and processing fees. A 10-year average live cattle price as reported by Shulz (2017) was adjusted to a 63% dressing percentage to determine selling price ($1.83/0.45 kg) on a dressed basis.

Total revenue was calculated by multiplying dressed selling price by HCW. Total costs included initial purchase cost with interest plus costs associated with the growing and/or finishing phase. Net profitability was then determined by subtracting total costs from total revenue. Cost of gain (COG) in each phase was calculated by dividing cost associated with each phase (not including purchase price of the animal) by the BW gained during the phase.

Data were analyzed using the mixed procedure of SAS (SAS Institute, Inc., Cary, N.C.) as a completely randomized design. Experimental unit was pen with cow-calf production system, post-weaning management, and the cow-calf × post-weaning interaction included in the model as fixed effects. Location and year were included as

random effects. Because the proportion of steers and heifers varied within pen, proportion of steers within each pen was included as a covariate for all variables.

RESULTS AND DISCUSSION

Growing Phase

Performance of GROW cattle during the growing phase is presented in Table 3. Initial BW was lighter for calves that had previously been wintered on cornstalks compared to calves wintered in the dry-lot ($P = 0.02$). However, STALK calves had greater ADG ($P = 0.03$) and tended to have greater DMI ($P = 0.09$) and improved feed efficiency ($P = 0.07$) compared to DLOT calves.

Finishing Phase

No significant cow-calf production by post-weaning management interactions were observed for any finishing performance variables tested ($P \geq 0.15$; Table 3). Cattle that were previously wintered on cornstalks had lighter initial BW entering the finishing phase than cattle that had been wintered in the dry-lot ($P < 0.01$). However, STALK cattle appeared to have a compensatory response characterized by greater ($P \leq 0.02$) ADG and G:F and a tendency ($P = 0.08$) for greater DMI during finishing compared to DLOT cattle. Previous research has also reported that cattle have increased DMI (Mader et al., 1989; Sainz et al., 1995) and compensatory gain (Carstens et al., 1991; Neel et al. 2007; Sainz et al., 1995) following a period of growth restriction.

When evaluating the effects of post-weaning management on finishing performance, GROW cattle had greater initial BW, final BW, and DMI compared to FINISH cattle ($P < 0.01$). However, cattle in the FINISH treatment had increased ADG and subsequently improved G:F compared to GROW cattle ($P < 0.01$).

Although results from the current study are generally consistent with previous data evaluating calf-feds and yearlings, the age of calves used in the current study varied from typical calf-feds and yearlings. The GROW and FINISH cattle were nearly 9 months old at the onset of post-weaning treatments. Consequently, FINISH cattle were older than typical calf-feds at feedlot placement. However, GROW cattle were similar to short-yearlings regarding age (12 mo) upon entering the finishing phase. Previous data suggest that calf-feds have lower DMI, similar ADG, and improved feed efficiency compared to short-yearlings (Adams et al., 2010). Although the responses observed for DMI and G:F of the FINISH and GROW cattle are similar to that of calf-feds and yearlings, daily gain during finishing was greater for FINISH cattle compared to GROW cattle. The relatively fast rate of gain during the 76-day growing period may have influenced subsequent finishing daily gain of GROW cattle. Lancaster et al. (2014) observed that stocker-phase ADG was inversely related to finishing ADG and G:F, indicating that greater rate of gain during the stocker phase is followed by slower rate of gain and worsened feed efficiency during the finishing phase.

Initial finishing BW may also affect ADG during finishing. Initial finishing BW of GROW cattle was nearly 100 kg heavier than initial BW of FINISH cattle. Similar to the responses observed in the current study, Reinhardt et al. (2009) observed that finishing ADG declined as initial finishing BW increased. In contrast, other researchers have reported that BW at the onset of finishing is positively related to finishing ADG (Reuter and Beck, 2013). Furthermore, Reuter and Beck (2013) reported that initial finishing BW is a more powerful predictor than stocker ADG when predicting finishing performance.

Carcass Characteristics

A significant post-weaning management effect was observed for HCW with cattle in the GROW treatment producing 23 kg greater carcass weight than FINISH cattle ($P < 0.01$; Table 3). Twelfth rib fat thickness tended to be greater for GROW cattle relative to FINISH cattle ($P = 0.06$). A significant post-weaning management by cow-calf production interaction was observed for marbling ($P = 0.04$). Cattle in the GROW-STALK treatment had greater marbling compared to cattle in the GROW-DLOT, FINISH-DLOT, or FINISH-STALK treatments which were not different from each other. A post-weaning management effect was also observed for calculated yield grade with GROW cattle having greater yield grade than FINISH cattle ($P = 0.04$).

The increase in carcass weight of GROW cattle is in agreement with Adams et al. (2010) who observed a 37 kg increase in HCW for short-yearlings compared to calf-feds. In that study, short-yearlings and calf-feds were harvested at similar back fat thickness. Klopfenstein et al. (2000) illustrated the importance of comparing cattle at equal fat endpoints, especially when cattle are fed in different feeding programs. Bruns et. al. (2004) reported that increased DOF resulted in increased HCW, fat thickness, and marbling. Because equal back fat was not obtained between treatments in the current study, it is difficult to determine if the difference in performance between the two post-weaning systems was due to treatment or from feeding the GROW cattle to the point in which 12^{th} rib fat thickness was increased. Because GROW cattle were harvested at greater fat thickness, it is interesting that marbling of GROW-DLOT cattle did not increase to the same degree as marbling of GROW-STALK cattle.

Economic Analysis

No significant cow-calf production by post-weaning management interactions were observed for any economic variables tested ($P \geq 0.57$; Table 4). Due to differences in initial BW, initial purchase cost during the growing phase was greater if calves had previously been wintered in the dry-lot compared to calves wintered on cornstalks ($P = 0.04$; Table 4). Although no significant difference between treatments was observed for growing cost ($P = 0.26$), growing COG tended ($P = 0.10$) to be lower for STALK calves as a result of greater daily gain during the growing phase.

Likewise, initial purchase cost and COG during the finishing phase was greater for DLOT calves compared to STALK calves ($P = 0.01$; Table 4). When evaluating the main effects of post-weaning management on finishing variables, finishing cost was greater ($P < 0.01$) for FINISH cattle compared to GROW cattle largely due to FINISH cattle having 27 more DOF during the finishing phase. Conversely, finishing COG was less ($P < 0.01$) for FINISH cattle compared to GROW cattle due to FINISH cattle having improved feed efficiency during finishing.

For the economics of total system (weaning through harvest), STALK cattle had less overall COG ($P = 0.01$; Table 4), which was a reflection of the improved feed efficiency observed for STALK cattle relative to DLOT cattle. Although similar revenue ($P = 0.46$) was generated between treatments, STALK cattle produced \$37 greater net profit than DLOT cattle ($P = 0.01$) as a result of reduced initial purchase cost of STALK cattle. Because of increased HCW, GROW cattle generated \$86 greater total revenue in relation to revenue received from FINISH cattle. However, FINISH cattle had decreased total cost and COG, which subsequently resulted in \$35 greater net profit compared to GROW cattle ($P \leq 0.01$). In the current analysis, the growing diet was 83% the cost of

the finishing diet ($156/907 kg ÷ $188/907 kg). In order for net profitability to be equal between the GROW and FINISH treatments, the cost of the growing diet would need to be 58% ($108 per 907 kg) of the cost of the finishing diet.

Partial budget of complete production system

When investigating systems, it is meaningful to evaluate economics of a complete production system from cow-calf production through harvest. A partial budget (Gardine, 2018) indicated that winter grazing nursing calves on cornstalks compared to feeding in the dry-lot resulted in greater net profit per weaned calf. The cow-calf production partial budget was expanded to include data from post-weaning treatments presented here. Calves produced in the STALK cow-calf production system finished with numerically less HCW at harvest and, therefore, averaged $10.13 less revenue compared to DLOT cattle. In addition, STALK cattle consumed more feed during post-weaning management, which resulted in an average of $11.26 greater feedlot cost compared to DLOT cattle. A partial budget of a complete production system of calves produced at ENREC is presented in Table 5. When the difference in post-weaning cost and revenue are factored in, a partial budget indicated that using winter corn residue grazing during cow-calf production at ENREC resulted in a greater profit of $179 per calf compared to wintering cow-calf pairs in the dry-lot. Likewise, a partial budget of a complete production system of STALK calves produced at PREC resulted in $141 greater net profit than DLOT calves (Table 6).

IMPLICATIONS

Subsequent finishing performance of cattle that were previously wintered alongside their dams on either cornstalks or in the drylot indicates that calves wintered on

cornstalks consistently responded with compensatory growth during the feedlot growing and finishing phases. Cattle wintered on cornstalks weighed less at the onset of post-weaning treatments compared to cattle that had been wintered in the drylot. However, HCW was similar between treatments. Net profitability realized during the feedlot finishing phase was, therefore, dependent on compensatory growth of cattle previously wintered on cornstalks. Furthermore, net profitability of calves wintered on cornstalks appears to increase when ownership is retained through harvest.

Utilizing a relatively rapid growing phase (76 d) on cattle prior to the finishing phase produced greater HCW and generated more revenue compared to cattle directly adapted to a finishing diet following weaning. However, improved feed efficiency and greater daily gain of cattle directly adapted to the finishing diet resulted in greater net profit relative to cattle fed a grower diet prior to being finished.

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Table 1. Diet composition of growing and finishing diets[1]

	Growing Diet		
Ingredient, %	Year 1	Year 2	Year 3
Sweet Bran[2]	30	30	30
Wheat Straw	31	31	31
MDGS[3]	35	-	-
WDGS[4]	-	35	35
Supplement[5,6]	4	4	4
	Finishing Diet		
Ingredient, %	Year 1	Year 2	Year 3
HMC	50	51	51
Sweet Bran[2]	30	30	30
Wheat Straw	5	-	-
Grass Hay	-	5	5
MDGS[2]	10	10	-
WDGS[3]	-	-	10
Supplement[5,7]	5	4	4

[1]All values presented on a DM basis
[2]Sweet Bran wet corn gluten feed (Cargill Corn Milling, Blair, NE)
[3]Modified distillers grains plus solubles
[4]Wet distillers grains plus solubles
[5]Supplement includes limestone, trace minerals, and vitamin A,D,E premix
[6]Formulated for 200 mg/animal of Rumensin daily (Elanco Animal Health, Greenfield, IN)
[7]Formulated for 330 mg/animal of Rumensin and 90 mg/animal of Tylan daily (Elanco Animal Health, Greenfield, IN)

Table 2. Economic assumptions applied to post-weaning management systems

	Treatments	
Item	FINISH[1]	GROW[2]
Growing phase		
Yardage, \$/hd daily	-	0.45
Health, \$/hd	-	15.00
Diet cost, \$/907 kg	-	156.49
Interest, %	-	6.2
Finishing phase		
Yardage, \$/hd daily	0.45	0.45
Health, \$/hd	15.00	15.00
Diet cost, \$/907 kg	188.15	188.15
Interest, %	6.2	6.2
Cattle Prices		
Feeder calf price[3], \$/0.45 kg	1.53	1.53
Feeder calf price[4], \$/0.45 kg	1.36	1.36
Selling price dressed basis[5], \$/0.45 kg	1.83	1.83
Interest, %	6.2	6.2

[1]FINISH = calves directly adapted to finishing diet following weaning

[2]GROW = calves fed grower ration for 76 d diet prior to finishing phase

[3]10-yr average calf price for steers and heifers weighing 226-273 kg

[4]10-yr average calf price for steers and heifers weighing 272-318 kg

[5]10-yr average live cattle price adjusted to a 63% dressing percentage for calculation of selling price on a dressed basis

Table 3. Effects of post-weaning management & cow-calf production system on finishing performance and carcass characteristics

	FINISH[1]		GROW[2]			*P*-value		
	DLOT[3]	STALK[4]	DLOT[3]	STALK[4]	SEM	Post-weaning	Cow-calf	Int.[5]
Growing performance								
DOF			76	76				
Initial BW, kg	-	-	283	250	8	-	0.02	-
Ending BW, kg	-	-	376	355	8	-	0.11	-
DMI, kg/d	-	-	7.9	8.3	0.5	-	0.09	-
ADG, kg	-	-	1.22	1.37	0.1	-	0.03	-
G:F	-	-	0.155	0.167	0.019	-	0.07	-
Finishing performance								
DOF	196	196	169	169				
Initial BW, kg	279	251	377	356	10	<0.01	<0.01	0.62
Final BW[6], kg	594	589	631	621	15	<0.01	0.15	0.65
DMI, kg/d	9.4	9.6	9.9	10.3	0.4	<0.01	0.08	0.60
ADG, kg	1.61	1.73	1.48	1.58	0.05	<0.01	<0.01	0.80
G:F	0.172	0.180	0.150	0.152	0.004	<0.01	0.02	0.15
Carcass characteristics								
HCW, kg	374	371	399	391	10	<0.01	0.15	0.64
LM area, cm^2	87.7	89.0	89.7	88.4	1.9	0.66	0.92	0.15
12^{th} rib fat, cm	1.4	1.32	1.52	1.52	0.1	0.06	0.65	0.65
Marbling[7]	424[a]	422[a]	438[a]	491[b]	15	<0.01	0.05	0.04
Calc. Yield Grade	3.3	3.1	3.4	3.4	0.2	0.04	0.44	0.33

[1]FINISH = calves directly adapted to finishing diet following weaning
[2]GROW = calves fed grower ration for 76 d diet prior to finishing phase
[3]DLOT = winter dry-lot feeding of cow-calf pair prior to weaning
[4]STALK = winter corn residue grazing of cow-calf pair prior to weaning
[5]Test for cow-calf production by post-weaning management interaction
[6]Calculated on a carcass-adjusted basis using a common dressing % (63%)
[7]Marbling score: 400 = Small, 500 = Modest, etc.

Table 4. Economic analysis of cattle by post-weaning management and cow-calf production system

	Treatments					*P*-value		
	FINISH[1]		GROW[2]					
Item[5]	DLOT[3]	STALK[4]	DLOT[3]	STALK[4]	SEM	Post-weaning	Cow-calf	Int.
Growing Phase								
Purchase Cost[7]	-	-	894.80	835.70	15.34	-	0.04	-
Growing Cost[8]	-	-	157.83	161.67	9.32	-	0.26	-
Growing COG[6,9]	-	-	0.79	0.71	0.08	-	0.10	-
Finishing Phase						-		-
Purchase Cost[7]	891.72	834.44	-	-	14.8	-	0.01	-
Finishing Cost[10]	498.63	507.59	455.20	464.58	21.63	<0.01	0.21	0.98
Finishing COG[6,11]	0.72	0.68	0.82	0.79	0.02	<0.01	0.01	0.57
Total System Cost								
Total Cost[12]	498.63	507.61	612.78	626.31	26.48	<0.01	0.25	0.81
Total COG[6,13]	0.72	0.68	0.80	0.76	0.02	<0.01	0.01	0.95
Total Revenue[14]	1502.56	1488.62	1585.23	1578.92	36.89	<0.01	0.46	0.78
Net Profit[15]	97.19	132.03	59.58	99.04	20.71	0.01	0.01	0.86

[1]FINISH = calves directly adapted to finishing diet following weaning
[2]GROW = calves fed grower ration for 76 d diet prior to finishing phase
[3]DLOT = winter dry-lot feeding of cow-calf pair prior to weaning
[4]STALK = winter corn residue grazing of cow-calf pair prior to weaning
[5]Variables presented as $ per animal
[6]Variable presented as $ per 0.45 kg
[7]Calculated by multiplying BW by 10-yr average steer and heifer price in 45.4 kg weight groups
[8]Total diet, yardage, health, and interest cost during the growing phase
[9]Growing cost / BW gained during growing phase
[10]Total diet, yardage, health, and interest cost during the finishing phase
[11]Finishing cost / BW gained during the finishing phase
[12]Total of finishing or growing-finishing cost
[13]Total cost / BW gained during the finishing or growing-finishing phase
[14]Calculated by multiplying HCW times dressed selling price
[15]Total revenue - total costs

Table 5. Complete production system: partial budget analysis of grazing cow-calf pairs on corn residue at ENREC ($/cow)[1,2]

Additional Revenue	Amount	Reduced Revenue	Amount
		Less revenue received at finishing[5]	$10
Reduced Cost		**Additional Cost**	
No total mixed diet fed[3,4]	$298	Cornstalk rent[3,7]	$31
No feedlot yardage[3,6]	$76	Supplement[3,5]	$78
		Grazing yardage[3,8]	$45
		Post-weaning feed for CS cow[3,9]	$20
		Feedlot (growing/finishing) cost[5,10]	$11
Total additional revenue and reduced cost	$374	Total reduced revenue and additional cost	$195
Net change in profit	$179		

[1]Eastern Nebraska Research and Extension Center near Mead, NE
[2]Partial budget evaluated changes in cost and revenue throughout a complete production system (cow-calf production to harvest) due to grazing cow-calf pairs on cornstalks throughout the winter as opposed to feeding in the dry-lot during the cow-calf production phase
[3]Cow-calf production phase
[4]Distillers grains priced at 100% the value of corn at $4.59 per bu (Johanns, 2017). Base crop residue priced at $50/907 kg plus an additional $15/907 kg for grinding.
[5]Post-weaning phase
[6]Feedlot yardage charged at $0.50 per pair per d
[7]Rent was charged at $12/0.41 ha ($0.20 per pair per day)
[8]Grazing yardage charged at $0.20 per pair per day
[9]Cost to feed an additional 1.6 kg (DM) of feed for 75 days post-weaning to compensate for BW and BCS losses incurred throughout the winter grazing period.
[10]Difference in total post-weaning cost (growing/finishing feedlot cost)

Table 6. Complete production system: partial budget analysis of grazing cow-calf pairs on corn residue at PREC ($/cow)[1,2]

Additional Revenue	Amount	Reduced Revenue	Amount
		Less revenue received at finishing[6]	$10
Reduced Cost		**Additional Cost**	
No total mixed diet fed[3,4]	$264	Cornstalk rent[3,7]	$41
No feedlot yardage[3,5]	$70	Supplement[3,8]	$89
		Grazing yardage[3,9]	$42
		Feedlot (growing/finishing) cost[6,10]	$11
Total additional revenue and reduced cost	$334	Total reduced revenue and additional cost	$193
Net change in profit	$141		

[1]Panhandle Research and Extension Center near Scottsbluff, NE
[2]Partial budget evaluated changes in cost and revenue throughout a complete production system (cow-calf production to harvest) due to grazing cow-calf pairs on cornstalks throughout the winter as opposed to feeding in the dry-lot during the cow-calf production phase
[3]Cow-calf production phase
[4]Distillers grains priced at 100% the value of corn at $4.59 per bu (Johanns, 2017). Base crop residue priced at $50/907 kg plus an additional $15/907 kg for grinding.
[5]Feedlot yardage charged at $0.50 per pair per d
[6]Post-weaning phase
[7]Rent was charged at $17/0.41 ha ($0.30 per pair per day)
[8]A freight expense for delivery of dry distillers grain to PREC was charged at $2.80 per km
[9]Grazing yardage charged at $0.20 per pair per day
[10]Difference in total post-weaning cost (growing/finishing feedlot cost)