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Intake, Digestibility, Insitu Disappearance and Ruminal Fermentation of Bermuda Grass Hay by Lactating Beef Cows Offered Corn or Hominy Feed as Supplements

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INTAKE, DIGESTIBILITY, INSITU DISAPPEARANCE AND RUMINAL FERMENTATION OF BERMUDAGRASS HAY BY LACTATING BEEF COWS OFFERED CORN OR HOMINY FEED AS SUPPLEMENTS

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ABSTRACT

Hominy feed, a co-product of dry corn milling, has been evaluated to a limited extent in feedlot and dairy rations, but has not been evaluated as a supplemental energy source for lactating beef cows. The objective of this study was to determine the effect of level of hominy feed supplementation on intake, digestibility, in situ DM disappearance, and ruminal fermentation characteristics of medium quality bermudagrass hay. Five ruminally cannulated lactating beef cows (BW = 596 kg, SE = 13.9) were used in an experiment with a 5 × 5 Latin square design. Treatments were low hominy (**LH**; 0.25% of BW), medium hominy (**MH**; 0.50% of BW), low corn (**LC**; 0.25% of BW), medium corn (**MC**; 0.50% of BW) and no supplement (**CONT**). The cows were housed individually. Supplements were offered at 0800 daily. Hay was offered to maintain 10% refusal and orts were collected daily. Fresh water was offered for ad libitum consumption. A mineral supplement was offered daily. Titanium dioxide was used as an external marker. Fecal samples were collected twice daily to estimate fecal output. Five consecutive 16–d periods were used, with 10 d for adaptation. Forage ruminal DM disappearance was measured using Dacron bags. Ruminal fluid was sampled on d 14 of each period to measure pH and for analysis of concentrations of volatile fatty acids (**VFA)** and rumen ammonia-N. Hay dry matter intake (**DMI**) was not affected ($P = 0.35$) by supplement. Total DMI (kg/d and % of BW) were greater ($P < 0.05$) for MC and MH compared with the other treatments. Dry matter digestibility did not differ ($P = 0.37$) among treatments but MC and MH had greater ($P < 0.05$) digestible DMI compared with CONT and LC. Hay fraction B (potentially degradable DM) was greater ($P < 0.05$) for LH and MC compared with MH. Mean ruminal pH tended ($P = 0.07$) to be greater for LC and CONT compared with LH. Ruminal ammonia-N and total VFA concentrations were not affected ($P \geq 0.77$) by supplements. Hominy

feed and corn were similar as supplemental feedstuffs for lactating beef cows offered bermudagrass hay.

This thesis is approved for recommendation
to the Graduate Council.

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DEDICATION

This thesis is dedicated to my late father, Martin Matalanyane Madzonga. He valued education very much and his quest for education was infectious. He always wanted his children to acquire advanced education. 'Work like a slave and live like a king' a quote he always drummed into my ears.

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CHAPTER I

INTRODUCTION

Energy is required for production of meat, milk, and fiber as well as for maintenance. Ruminant animals derive energy largely from forages. This process is achieved through ruminal microbial action which degrades the cell wall and cell contents of those forages to release energy. When the forage matures, stem:leaf ratio and lignin deposition increase thereby inhibiting energy recovery from forages. Supplementation will be required in an attempt to meet the animal's energy requirements when forage nutritive value is not sufficient to meet the animal's requirements.

The decision to provide energy and protein sources to beef cows offered low- or medium-quality forages is very critical to producers in terms of economics and animal production, particularly in the winter or the dry season and during gestation and lactation stages. With protein supplements, forage dry matter intake is often increased because of positive associative effects that occur when a N deficiency in the rumen is corrected. Starch and other non-structural carbohydrates have traditionally been good sources of energy for supplementing ruminants offered forage. However, these energy sources may present positive or negative effects on intake of low to medium-quality forages depending on the type of forage and the level of supplementation. Low levels (0.25% BW) of corn supplementation have been shown to improve intake of both low-and medium-quality forages whereas medium to high (0.50 to 0.75% of BW) levels of corn supplementation have depressed forage intake. However, total DMI or diet DMI is often increased by medium levels of corn supplementation. At greater levels of corn supplementation (0.75 to 1% of BW), both forage and total DMI are suppressed. Therefore, it has to be borne in mind that when strategies for the use of forage based diets are being

formulated, the effects of forage quality, composition and/or level of supplementation are not independent of each other; they have to be treated as interrelated.

While corn has been the predominant energy supplement used over the years, co-products of corn have increasingly been incorporated as energy supplements in forage based diets in lieu of corn. The use of corn co-products has increased as livestock feeds in recent years as a result of abundant availability from the milling, alcohol and ethanol industries, and the comparatively lower retail prices of co-products. Corn co-products are well documented as having lower starch, and higher fiber, protein, and fat content relative to corn. The fiber in the co-products is digestible, thereby providing energy to offset the low starch content in co-products. Corn co-product that are available today include corn gluten feed, corn gluten meal, corn bran, distiller's grain with solubles, and hominy feed. Of these co-products, hominy feed has received little attention and limited research has been published about its potential use as a supplemental energy source for cows offered lower-quality forages. It is hypothesized that hominy feed will improve forage utilization relative to ground corn because of lower starch and higher digestible fiber content in the hominy feed. Therefore the objective of this study was to determine the effect of hominy feed supplementation on intake, digestibility, in situ disappearance, and ruminal fermentation of bermudagrass hay in lactating beef cows.

CHAPTER II

LITERATURE REVIEW

Forage quality

Forage chemical constituents. Ruminants forage on both monocots and dicots, and the major source of energy for ruminants are in the plant cell walls. Polymers such as polysaccharides, protein and lignin are principal constituents of plant cell walls (Åman, 1991). The main polysaccharides in the primary cell walls of dicots are cellulose, xyloglucan, and pectic polysaccharides while main constituents of secondary walls are cellulose, xylans and lignin. Though the primary cell wall matrix of grasses is also made up of xyloglucan and pectic polysaccharides, the quantities are lower in comparison to dicots while the secondary cell walls are also dominated by cellulose, xylans, and lignin (Åman, 1991).

The chemical composition of forages varies greatly during the growth period. During growth and development there is an increase in the stem:leaf ratio and a secondary thickening and lignification of the cell walls. This results in increased concentrations of structural polysaccharides, which are mainly glucose residues in cellulose, xylose residues in xylans, and lignin, leading to decreased concentrations of crude protein and ash (Åman, 1991). Straw and very mature forage may contain 80to90% non-starch polysaccharides and lignin (Åman, 1991). During feed evaluation, fiber is determined as the residue after extraction of the feed with neutral detergent (neutral-detergent fiber; **NDF**), and with acid detergent (acid-detergent fiber; **ADF**; (Van Soest et al., 1991). This fiber normally is comprised of some non-polysaccharide substances like phenolic polymers (lignin) and cutin. In total, fiber is considered as cellulose, hemicellulose (xylans, mannans, glucomannans, and arabino–galactans) and pectic substances (Tamminga, 1991).

Forage physical characteristics. It is important to know how forage cell walls are organized and what they are comprised of so as to understand forage utilization by ruminant animals (Åman, 1991). Cell walls and non-starch polysaccharides are mostly arranged in complex three dimensional structures and cross-linking has negative effects on potentially digestible carbohydrates (Ralph and Helm, 1991). Stems are more prone to thickening and lignification of the epidermis cell walls as they age compared to the leaves (Wilson, 1991). In tropical grasses, epidermis cells are arranged in almost inseparable 'joints' compared to cool season grasses which have a simple and straight 'chain' form (Wilson, 1991). The mesophyll cells are mainly found in forage leaves relative to stems. The arrangement of mesophyll cells is much simpler in cool-season grasses and legumes compared to warm-season forages (Wilson, 1991).

Forage chemical and physical effects on forage degradation. The arrangement of the cells in the epidermis, as highlighted above, determines the extent to which the linkages will split when subjected to ruminal degradation. Hence tropical grasses are less degraded compared to temperate grasses and legumes (Wilson, 1991). The mesophyll cells allow easy and faster digestion of leaves, but the degradation in temperate grasses is much more rapid than in tropical grasses (Wilson, 1991). The thick cell wall that becomes lignified reduces energy recovery from the forage and hence cell wall carbohydrates become inaccessible to ruminal degradation in most cases when they are tied up in the lignin matrix (Wilson, 1991). On the other hand, digestible fiber, such as that found in mesophyll cells is accessible to ruminal degradation, and is the major source of energy for the microorganisms inhabiting the reticulo-rumen and the large intestines of the ruminant animal. Some of the microorganisms that benefit from the degradation of fiber are cellulolytic bacteria, protozoa and the fungi (Church, 1979). In addition, fiber assists in

stimulating rumen wall development in young ruminants and contractions during rumination (Tamminga, 1991; Khan et al., 2011) as well as a point of attachment for ruminal flora and fauna (Miron et al., 2001). Fiber acts as an interface for microbes and the animal: microbes digest the fiber in order for energy to be released for use by the animal.

Fiber is described as containing a completely indigestible fraction and one or more potentially digestible fractions, each of which is degraded at its own constant rate. During fiber degradation, polysaccharides are hydrolyzed and monosaccharides are converted to end-products such as volatile fatty acids (**VFA**), fermentation gases, and heat (Allen and Mertens, 1988). While fermentation gases such as methane contribute to loss of energy, VFA are recovered by the animal through ruminal absorption and contribute 50 to 80% of the total metabolizable energy consumption by the ruminant animal (Merchen and Bourquin, 1994). The extent of fiber degradation is a function of the amount of the indigestible fraction, as well as competition between rate of degradation and rate of passage out of the reticulo-rumen and the hind gut (Allen and Mertens, 1988). Indigestible fiber in grass hay increased by 12 to 20% as total fiber in grass increased from 55 to 75% (Tamminga, 1991). At this high level of fiber content in grass hay, the digestion is slowed down, passage rate of digesta is impaired, rumen fill increased and intake was reduced, possibly resulting in a negative energy balance in the animal (Allen, 1996).

Forage chemical and physical effects on forage intake. Intake is one of the parameters forage scientists and ruminant nutritionists employ to evaluate quality of the forage as well as measuring animal performance. Forage chemical and physical characteristics can either increase or decrease forage intake. Animal performance is dependent upon intake of digestible and metabolizable nutrients (Mertens, 1994). Intake per unit of metabolic body weight may decrease by 40 to 75% as cell wall constituents increase from 40 to 70%, presenting a curvilinear

relationship. In the same manner, lignin on its own may decrease intake per unit of metabolic body weight from 50 to 80% as it increases from 2 to 8% (Van Soest, 1965).

Cattle nutrient requirements

Factors affecting nutrient requirements. Nutrient requirements for the ruminant animal vary according to physiological and metabolic needs. The greatest needs occur during reproduction, lactation, and growth. For beef cows, nutrient requirements are greatest and critical during the last trimester of pregnancy and during early to mid- lactation, specifically for nutrients such as energy, protein, vitamins (A, D and E) and minerals such as Ca, P, I, Cu and Mn among others (Schingoethe et al.,1993; Forbes, 1993;Freetly et al., 2008). Grazed pastures tend to fluctuate in nutrient content throughout the year, compelling producers to employ mitigating measures with harvested forages, and energy, protein, and mineral supplements (Schingoethe et al., 1993). These measures are critical in order to prevent cows from losing body tissue from supporting the fetus or producing milk. Synthesis and catabolism of body tissues cost energy to the cow (Schingoethe et al., 1993). It is therefore important to provide additional supplementation when pasture quality is low in order to assist cows in maintaining body condition during pregnancy.

Growth and development as one of the physiological stages affecting nutrient bio-availability is considered a long term process, and some of the animal factors affecting nutrient requirements are weight and age (Schingoethe et al., 1993). Mature animals that are on maintenance diets have lower threshold for bulk limitation and energy regulation compared to rapidly growing young animals (Dinius and Baumgardt, 1970). The animal's body weight increases as it grows, hence the need to maintain the increased body size by meeting the animal`s nutrient requirements.

Effects of production stage on intake, forage degradation, and digestion kinetics.

Hormonal changes in cows and heifers may bring about certain effects on voluntary feed intake. One of those hormones is estrogen which is known to depress intake if secreted in large quantities (Muir et al., 1972; Forbes, 1993) although it can bring about some minor increases in intake if used in small doses as a growth promoter.

During the last trimester of pregnancy, growth of the fetus and increased size of the uterus may decrease the size of the abdominal cavity, thereby restricting intake of additional feed (Conrad, 1966; Forbes, 1993). At this stage, the cow may need high energy supplements to support growth of the fetus in cases where the forage energy is limiting (Freetly et al., 2008). However, supplementation with protein may enhance intake and digestibility of the poor-quality (< 5% CP) forage more than energy supplementation would (Marston and Lusby, 1995). Once the protein requirements have been met from protein supplements, any attempts to increase energy intake with supplements will be a challenge (Marston and Lusby, 1995).

Lactating ruminants have even greater nutrient requirements than during late gestation, hence the high threshold between bulk limitation by feed and energy regulation (Dinius and Baumgardt, 1970). Lactating beef cows should consume about 28% more total DM compared to when they are in the last few weeks of gestation (Marston and Lusby, 1995). Feed intake could be a determinant of milk production in dairy cows fed poorly digested feedstuffs whereas milk production could be a determinant of feed intake when highly digestible feedstuffs are offered to dairy cows (Conrad, 1966).

A lactating cow, especially if it is high yielding, will direct most of its nutrients towards milk secretion during its nutrient partitioning (Forbes, 1993), and lactating cows would tend to increase their forage intake when they are supplemented with protein compared with energy

supplements (Marston and Lusby, 1995). In this case, good quality forage would be required in order to meet the cow's nutrient requirement. Therefore, in many production situations, the negative impacts of lower forage quality on intake results in deficiencies of energy and protein to support the present production status in cows. In those instances, it becomes necessary to offer additional supplemental feedstuffs to offset these nutrient deficiencies.

Supplementation to meet energy deficiencies

Effects of grain supplementation on ruminal conditions. The importance of grain supplementation to meet energy requirements in ruminants cannot be over-emphasized. While grain as a source of energy is indispensable, various cereal grain types may have different effects on the ruminal environment. Cereal grains such as corn, barley, wheat, and oats have been studied widely as energy supplements for ruminants (Gozho and Mutsvangwa, 2008), and in the United States corn has been the most utilized cereal grain as a supplement to ruminants (Casper et al.,1999; Chen et al., 1994).

Starch from cereal grains has been found to lower ruminal pH, increase VFA concentrations, and lower ammonia concentration in the rumen when ruminants are fed grass hay. When ruminants are offered grass hay, cellulolytic and fibrolytic bacteria are the most active in plant cell wall degradation (Church, 1979). Once the starch supplement is introduced in the rumen, especially at high levels of > 40% of diet DM or 0.50 to 1% of BW (Sanson et al., 2004), there is a shift in microbial composition of the rumen from cellulolytic to amylolytic bacteria since amylolytic bacteria are responsible for breakdown of starch. This shift to fermentation of starch may lower ruminal pH to as low as 5.7 (Russel et al., 1979; Loy et al., 2007; Vuuren et al., 2010) in ruminants that are offered grass hay or grain based diets. This

condition will generally increase total VFA, reduce the acetate:propionate ratio, and decrease concentrations of ruminal ammonia–N (Cameron et al., 1991).

Effects of grain supplementation on digestion. Corn grain starch, as a non- structural carbohydrate, is highly digestible (60 to 90%) in the rumen, and only a small portion of it passes on to the intestines for post-ruminal digestion (Allen, 1997; Owens and Zinn, 2005). Total tract digestibility of corn is greater than 90% in many instances (Owens and Zinn, 2005; Gozho and Mutsvangwa, 2008). Due to its high digestibility and fermentation characteristics, starch may create an acidic environment (pH of 5.7 to 6.2) in the rumen (Russel et al., 1979; Vuuren et al., 2010), which reduces the ability of cellulolytic bacteria to degrade fiber in the forage and thereby lowers fiber digestion (Russel and Wilson, 1996; Dixon and Stockdale, 1999). The extent to which fiber digestion begins to decline as a result of starch inclusion in a forage based diet or starch supplementation to ruminants fed low-medium quality forage, depends on various interrelated factors including level and frequency of supplementation, and processing method among others. If supplemented at lower quantities, such as at 0.25% of BW, it may not present the same negative associative effects on hay DMI and NDF digestibility as when supplemented at $\geq$ 0.50% of BW (Galloway et al., 1993; Sanson et al., 2004). However, digestibility of organic matter (OM) is enhanced by starch supplementation (Chase and Hibberd, 1987; Carey et al., 1993; Galloway et al., 1993).

Processing methods for corn grain, such as grinding, creates a larger surface area and makes more starch available for amylolytic bacteria to attach to and degrade the starch (NRC, 2000). The levels of pH, ammonia-N concentration and VFA production are determined by the texture of the processed corn. Fine textured ground corn is much more exposed to microbial activity than coarse textured ground corn. This leads to high rates of fermentation causing the

pH to drop, leading to low ammonia–N while the total VFA increase, and the acetate:propionate ratio decreases (Eastridge et al., 2011).

Processing of corn may also impact fiber digestion. Dry rolled corn and ground corn have been shown to depress fiber digestion when supplemented to cattle fed low quality grass hay (Galloway et al., 1993; Loy et al., 2007). Steam flaked corn is likely to improve digestibility of NDF to a greater extent than ground corn (Cooke et al., 2009), whereas whole shelled corn may not have similar effects, mainly because the starch granules would not be exposed to the bacteria in the rumen at the same extent due to the intact protective pericarp in the shelled corn (Sanson and Clanton, 1989). While whole corn grain may have little effect on digestibility of fiber in the rumen, intestinal starch digestibility is also reduced (NRC, 2000). Therefore the grain that escapes is likely to be passed out with feces undigested (Owens and Zinn, 2005). When protein sources are offered on their own or in synchrony with starch as supplements, digestibility of fiber is often improved, contrary to when starch is offered on its own as a supplement to ruminants fed low quality forage (Casper et al., 1999; Hall and Huntington., 2008; Souza et al., 2010).

Effects of grain supplementation on forage intake. Although grain starch is a supplemental source of energy to ruminants, it has been demonstrated through various studies that starch has potential to impact negatively on hay DMI by ruminants depending on the level at which the grain is supplemented (Chase and Hibberd, 1987; Sanson and Clanton, 1989: Sanson et al., 2004). As mentioned previously, the starch from cereal grains lowers the pH of the rumen environment, which affects cellulolytic and fibrolytic bacteria adversely. This results in a low rate of fiber (cellulose and hemicellulose) degradation leading to prolonged retention in the rumen, hence low forage intake. Low forage intake translates into low productivity by the

animal because energy partitioning would have been compromised (Allen, 1997). When corn is supplemented in increasing levels, forage intake is negatively related with supplement level. The most pronounced effect is when corn supplementation is increased to > 0.50% of BW (Mulholland et al., 1976; Sanson and Clanton, 1989; Pordomingo et al, 1991; Matejovsky and Sanson, 1995). While the use of rumen degradable nitrogenous compounds with or without corn starch tend to increase forage DMI when supplemented to ruminants fed lower quality grass hay, the corn starch does the opposite when supplemented without the nitrogenous compounds (Hennessy and Williamson, 1990; Cameron et al., 1991; Souza et al., 2010).

Processing methods for corn and frequency of supplementation may affect starch available to the rumen microbes (Oba and Allen, 2003). Dry rolled corn when used in starch based supplements daily or on alternate days, tended to improve hay DMI when offered daily compared with only offered on alternate days (Loy et al., 2007). While forage DMI is inversely related to increased levels of corn supplementation, total DMI increases with increasing levels of corn supplementation (Chase and Hibberd, 1987; Jones et al., 1988; Carey et al., 1993).

Chemical differences between co-products and grain. Corn grain can be processed into different products for human consumption or for industrial purposes. Co-products that are derived during such processing include corn gluten meal, corn gluten feed, corn bran, distiller's grains with solubles, and hominy feed. These products are called co-products because they have significant value as a feed while lowering the cost of feed input in the livestock industry (Cao et al., 2009; Drewnoski et al., 2011). Chemically, co-products compete favorably with the principal food product, corn (Caton and Dhuyvetter, 1997; NRC, 2000). Co-products can be fed either as a component of a finishing diet or as supplements to ruminants on low-to medium-quality hay. In finishing diets, co-products substitute for corn proportionally (Larson et al.,

1993), therein providing energy from their fat content and digestible fiber, while at the same time minimizing the advent of acidosis (Nagaraja and Titgemeyer, 2007) since they are lower in starch compared with corn. As supplements, corn co-products can be used to supply energy and rumen-degradable protein in low- to medium-quality forages which on their own would not meet the animal's nutrient requirements.

Effects of co-product supplementation on ruminal conditions. Given their chemical composition, co-products tend to affect the ruminal environment more favorably than corn. Co-products such as corn distillers grains with solubles, corn bran, and corn gluten feed have greater concentrations of digestible fiber and CP, and lower concentrations of starch or non- structural carbohydrates than corn grain (Allen and Grant, 2000; NRC, 2000). The degradation of the fiber in the corn co-products is slower than that of starch from corn and therefore does not yield as low of pH as would corn starch. Furthermore, chewing of the fiber (Allen and Grant, 2000) tends to raise pH through increased salivation, which acts as a buffer against acidity in the rumen, and in the process raises and maintains the pH in the ranges of 6 to 6.4 (Moore et al., 2002; Gilbery et al., 2006). All of these factors combine to reduce the onset of ruminal acidosis (Boddugari et al., 2001; Gilbery et al., 2006).

Effects of co-product supplementation on forage intake. Co-products such as condensed corn distillers solubles have been used as supplements to low-quality forages and the levels of up to 15% of total intake have not affected hay DMI but increased total dry matter intake. Corn distillers solubles have also been observed to improve nutrient availability when used as a supplement for low-quality forages (Gilbery et al., 2006). This improvement in nutrient availability was attributed to the rumen degradable protein in the corn distillers solubles. Likewise, co-products such as corn gluten feed have been shown to have positive effects on total

DMI compared to hay alone when used in goat finishing or dairy cattle diets (Allen and Grant, 2000; Moore et al., 2002),but average daily gain was not affected in goat finishing diets (Moore et al., 2002).

Effects of hominy feed on animal performance. Hominy feed, which is a product of corn dry milling, is one such co-product that compares well with corn. Hominy feed is a mixture of corn bran, corn germ, and unextracted starchy portions of the corn kernel (Paliwal et al., 1981). Although hominy feed is greater in fiber content, the fiber is digestible and this attribute benefits the ruminant animal as a source of digestible energy (Caton and Dhuyvetter, 1997). Substitution of hominy feed for rolled corn at 40% of a feedlot diet increased DMI, but did not affect growth performance and feed efficiency (Larson et al., 1993). Likewise, heifers fed feedlot diets with 13.3 or 26.7% hominy substituted for dry rolled corn increased intake, but gained similarly to those fed diets with either 0 or 40% hominy feed (Larson et al., 1993).

Effects of hominy feed on digestion and intake. Hominy feed, apart from improving DMI of cattle on finishing diets, has been shown in lambs to enhance digestibility of NDF. This is most likely due to the digestible fiber in the hominy feed (Larson et al., 1993). When comparing total tract starch digestibility of hominy feed and ground corn with rolled corn, the digestibility was improved for both hominy feed and ground corn diets compared with that of rolled corn, and this was attributed to differences in particle size of the ground corn and hominy feed vs. rolled corn (Larson et al.,1993).

When young bulls were offered beseem hay and supplemented with hominy feed, the digestibility of the hay increased to 68% compared to hay alone at 57% (Paliwal et al., 1981). Digestibility of OM, NDF, and ADF determined using dual-flow continuous-culture fermenters was similar between citrus pulp and hominy feed-based diets although citrus pulp was added to

the basal diet as a source of neutral detergent-soluble fiber whereas hominy feed was added as source of neutral detergent- soluble starch (Ariza et al., 2001). Hay DMI was greatly suppressed when young bulls were offered beseem hay and supplemented with or without hominy feed at a ratio of 70 hay:30 hominy (1.13 kg/100 kg BW vs. hay alone at 1.48 kg/100 kg BW; Paliwal et al., 1981).

Effects of hominy feed on ruminal conditions. Since hominy feed contains some starch, its addition to a basal diet is likely to increase the ammonia-N in the rumen, especially when diets are iso-nitrogenous. When using dual-flow continuous-culture fermenters, a basal diet that contained hominy feed as a source of starch had greater ammonia-N concentrations compared to a diet containing citrus pulp as source of fiber, but the microbial N synthesis was greater for citrus pulp than for hominy feed (Ariza et al., 2001).

The use of hominy feed as a supplement for low- to medium-quality hay has not been reported widely. Also, the value of hominy feed as a supplemental energy source for lactating beef cows has not been reported. Therefore, we conducted this study to determine the effects of hominy feed on the utilization of bermudagrass hay by lactating beef cows.

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Chapter III

MATERIALS AND METHODS

Animal procedures

This study was conducted in accordance with an approved University of Arkansas Animal Care and Use Committee protocol # 1103.

Five multiparous, lactating, ruminally-cannulated fall-calving beef cows (BW = 596 ± 13.9 kg) were used in a study with a 5 × 5 Latin Square Design to compare 5 dietary treatments during 5 experimental periods. Cows were housed individually in 6 × 6 m pens with wood chips for bedding in an enclosed facility that allowed air circulation. Each period consisted of a 10-d dietary adaptation period followed by a 6-d sample collection period. Cows were removed from the facility and placed on a large pasture at the end of each period and offered bermudagrass hay for a minimum of 5 d for a period of exercise and rumen equilibrium. Following the first period, cows were exposed to a bull for 21 d, then returned to the facility for the initiation of period 2. Cows were weighed at the beginning and end of each period. The initial weight was used to determine the amount of supplement offered on a % BW basis and the latter weight was used to determine weight loss or gain.

Cows were offered a bermudagrass hay basal diet along with either no supplemental concentrate (**CONT**) or with supplements of hominy offered at 0.25 (**LH**) or 0.50% of BW (**MH**), or corn offered at 0.25 (**LC**) or 0.50% of BW (**MC**) on an as-fed basis. The hay and supplements were analyzed for nutritional composition (Table 1). Supplements were offered at 0800 daily after orts were removed, and corn was offered as ground corn. Cows were allowed approximately 15 to 20 minutes to consume the supplements, and there was no evidence of refused supplement.

The hay allotment for each cow was weighed into plastic bags, offered in 2 feedings at approximately 0830 and 1630, and was offered to maintain a minimum of 10% refusal. Water was supplied ad libitum and a commercial mineral supplement[1] (~ 110 g; Purina Wind and Rain All Season 4 , Purina Mills, Gray Summit, MO) was offered to each cow including the CONT cow at 0800 daily. Feces and wet bedding material were removed twice daily. Calves were allowed to nurse their dams twice daily, once after cows consumed their respective supplements, but before hay was offered, and again at approximately 1630. Calves were watched and removed as soon as they were finished nursing to prevent them from consuming hay.

Samples of hay and supplements were collected daily for 5 d beginning on d 10. Orts were collected daily for 5 d beginning on d 11. All samples were weighed and then dried at 50° C until no further weight loss was detected. Samples were composited within cow and period, then ground to pass through a 1-mm screen using a Wiley Laboratory Mill Model 4 (Thomas Scientific, Swedesboro, New Jersey). Ground samples were transferred into airtight containers and stored for later laboratory analyses.

Dry matter intake and digestion: Titanium dioxide was used as an external marker to estimate fecal output. On d 4 through d 16 of each period, cows were offered a total of 100 g/d of a supplement that contained 10% TiO_2, 80% ground corn, and 10% liquid molasses in equal feedings at 0800 and 1600. The morning marker dose was offered with the respective supplement or mineral (CONT) whereas the afternoon marker dose was offered without additional supplement. The cows readily consumed the supplement and no orts were present.

[1] Purina Wind and Rain All Season 4 Mineral contained CP not less than 5%, crude fat not less than 3%, crude fiber not more than 2%, Ca min 5%; Ca max, 5%; P min 4%; Mg min 1%; K min 3%; Zn min 2,100 ppm; Mn min 1,650 ppm; Cu min 730 ppm; Co min 75 ppm; I min 68 ppm; Se min13 ppm; Vitamin A min 176,000 IU/LB; Vitamin D min 44,000 IU/LB; Vitamin E min 220 IU/LB.

Fecal samples were collected from each cow between 0800 and 0830, and again between 1630 and 1700 for 5 d beginning on d 11. If at all possible, cows were allowed to defecate naturally and samples of the fresh feces were gathered carefully from the top of the fecal pile to avoid contamination with bedding material. Fecal samples were placed into 120 mL plastic specimen containers, then placed in a forced-air oven and dried at 50° C to constant weight. The feces were composited within cow and period and ground to pass through a 1-mm screen using a Wiley Laboratory Mill. Ground samples were put in airtight containers for later analysis of TiO_2. Fecal output was calculated by dividing the marker dose by the concentration of the marker in the feces. Digestibility of DM (DMD) was calculated using the following equation: Digestibility = [(DM intake-fecal DM output)/DM intake)]*100.

Passage rate (K_p) was estimated using total ruminal evacuation (Coblentz et al., 2002). On d 16 of each experimental period, total ruminal evacuations were carried out immediately preceding the morning feeding (0730) and at 6 h after feeding. For each session, total ruminal contents were emptied into 2 trash cans per cow, weighed, mixed thoroughly, then sampled and the contents returned into the rumen as quickly as possible. Representative samples of ruminal contents were weighed into duplicate aluminum loaf pans and dried to constant weight in a forced-air oven at 50° C.

Ruminal in situ DM disappearance. Dry matter disappearance in the rumen was determined on representative samples of hay, corn, and hominy feed using the nylon bag procedure (Vanzant et al., 1998). Hay was ground through a 2-mm screen using a Wiley Laboratory Mill. Approximately 5 g of the ground hay was weighed into 10 × 20 cm (53 ± 15 µm pore size) nylon bags (Ankom Technology, Macedon, NY) and the bags were securely tied with size 12 (4.4 × 0.16 cm) rubber bands (Alliance Rubber Company, Hot Springs, AR). Corn

and hominy were ground through a 1-mm screen using a Wiley Laboratory Mill Model 4 (Thomas Scientific). Approximately 1.25 g of each of the ground supplements were weighed into 5.5 × 12.2 cm nylon bags and the bags were securely tied with size 12 rubber bands.

On d 10 through 15 of each period, duplicate bags of hay and supplement were placed in mesh lingerie bags and inserted in reverse order under the ruminal mat in the ventral rumen. Hay samples were incubated for 124, 100, 76, 52, 24, 16, 12, 8, and 4 h. Concentrate samples were placed in the same lingerie bags with hay samples and incubated for 100, 76, 52, 36, 24, 16, 12, 8, 4, and 2 h. Concentrate bags were only inserted into the cows receiving the respective supplement. All bags were removed simultaneously on d 15 at 2100 and placed in cold tap water to rinse off particles adhering to them and to inhibit any further microbial activity.

All the bags, including representative hay and concentrate samples that were not incubated in the rumen (0 h) were rinsed 10 times in a top-loading washing machine. Each rinse consisted of a 1-minute agitation in fresh tap-water followed by a 2-minute spin cycle. After rinsing, the bags were dried in a forced-draft oven at 50° C for a minimum of 48-h. The dried sample bags were allowed to air equilibrate for a minimum of 72 h at room temperature, then weighed.

Ruminal measurements. Ruminal fluid was sampled on d 14 of each period at 0, 1, 3, 5, 7, 9, 11, and 13 h after the morning supplement feeding. Ruminal contents were collected from 4 different locations in the rumen and composited in a bucket. The composited sample was mixed, then strained through 4 layers of cotton cheese cloth into 120-mL plastic specimen containers. Ruminal pH was measured and recorded immediately using a portable pH meter (Denver AP5, Arvada, CO). One milliliter of ruminal fluid was mixed with 200 µL of 12.5% meta-phosphoric acid and frozen at -20° C for later analysis of VFA. Another 1 mL of ruminal

fluid was mixed with 400 µL of 50% (v/v) hydrochloric acid and then frozen at -20° C for later ammonia-N analysis.

Laboratory analyses

Ground samples of hay, orts, and supplements were analyzed for DM, ash, and ether extract according to AOAC (2000) procedures (934.01, 942.05, and 920.39 respectively). Crude protein was analyzed using rapid combustion (procedure # 920.03AOAC, 2000). Neutral-detergent fiber (**NDF**), acid-detergent fiber (**ADF**), and acid-detergent lignin (**ADL**) were analyzed using the ANKOM fiber analysis system (Ankom A 200, Ankom Technology, Macedon, NY) according to the procedures of Van Soest et al. (1991).

Fecal samples were analyzed for concentrations of TiO_2 using a modified procedure of (Short et al., 1996). Approximately 0.1 g of ground feces were placed in porcelain crucibles, ashed at 600° C for 13 h, and allowed to cool at room temperature. Then 10 mL of 72% sulfuric acid were added, and samples were boiled using a block digester (Type 2200, Thermolyne, Dubque, IA) in triplicate until dissolved. The sample required approximately 19 h for the TiO_2 to dissolve instead of 1 h as reported by Short et al (1996). Additional sulfuric acid was added as needed to prevent the samples from drying out. After all of the TiO_2 was dissolved, samples were diluted to a 35-mL volume using deionized water and allowed to settle overnight then analyzed for TiO_2 concentration using a using a Shimadzu UV-VIS Spectrophotometer T1201S (Shimadzu, Inc., Kyoto, Japan).

Dried ruminal samples were ground to pass through a 1-mm screen using a Wiley mill. Samples of hay, orts, supplements, and ruminal contents were analyzed for concentrations of acid-detergent insoluble ash (**ADIA**) by ashing ADF residues in a muffle furnace at 500° C for 8 h (Van Soest et al., 1991). Fractional passage rate of ADIA (K_p) was determined by dividing the

mean ADIA intake (g/h) by the mean (from the 0- and 6-h) ruminal mass of ADIA (Waldo et al., 1972). The ADIA intake on an hourly basis was determined by dividing total daily intake of ADIA by 24h for each cow.

Frozen ruminal fluid samples designated for VFA analyses were thawed overnight at room temperature, then agitated on a Vortex-Genie and centrifuged at 12,700 × g for 5 min. Volatile fatty acids were analyzed according to the procedures of Erwin et al. (1961) using automated gas chromatography (Hewlett Packard 5890 with automatic sample injector HP-7673, Avondale, PA) fitted with a Nukol^{TM} fused silica capillary column (30m × 0.25mm Ø × 0.25 µm film thickness (Supelco Inc., Bellefonte, PA), a 5m×0.25mm .Ø. fused silica intermediate polarity guard column (Supelco Inc.), and an FID detector.

The frozen ruminal fluid samples designated for ammonia-N analysis were thawed, vortexed, and centrifuged similarly to those for VFA analysis. Ammonia-N concentrations were determined using the phenol-hypochlorite procedure (Broderick and Kang, 1980) using a Shimadzu UV-VIS Spectrophotometer T1201S (Shimadzu, Inc., Kyoto, Japan).

Statistical analysis

Intake, digestibility, passage rate, and milk production data were analyzed using mixed-models procedures of SAS (SAS Institute, Inc., Cary, NC) for a 5 × 5 Latin Square design. Treatment was considered a fixed effect and period and animal were considered random effects. In the event of significant treatment effects ($P < 0.05$) or tendencies ($0.05 < P < 0.10$), means were separated using the least-significant difference test (PDIFF option) at the respective *P*-value. Ruminal pH, VFA, and ammonia-N data were analyzed using mixed-model procedures of SAS for a repeated-measures experiment. Treatment was considered a fixed effect, period and animal were considered random effects, and sampling time was considered a repeated

measurement. Effects of treatment × sampling time and cow (treatment × period) were included in the statistical model. Means from significant treatment effects were separated as mentioned above. In the event of significant treatment × sampling time interaction ($P < 0.05$), treatment means were compared within sampling time only using the least-significant difference test.

The proportion of DM remaining in the in situ bags at each incubation time were fit to the non-linear model of Mertens and Loften (1980) using PROC NLIN of SAS (SAS Institute, Inc.). The fraction that was degraded at a measurable rate (fraction B), the disappearance lag time, the rate of DM disappearance (K_d), and the undegradable fraction (fraction C) were derived directly from the model whereas the immediately-soluble fraction (fraction A) was calculated as 100 – B – C. Effective ruminal degradation was determined as $A + [B \times (K_d/(K_d + K_p))]$ (Ørskov and McDonald, 1979). Data derived from the non-linear model were analyzed using mixed-models procedures of SAS (SAS Institute, Inc.) as described previously.

Results

Dry matter intake and digestion. Data for DMI, digestibility, and ruminal fill are presented in Table 2. Hay DMI (kg/d and % of BW) did not differ ($P \geq 0.18$) across treatments. Total DMI (kg/d and % of BW) was greater ($P < 0.05$) for MC and MH compared with CONT, LC and LH. Dry matter digestibility determined by TiO_2 or ADIA was not different ($P = 0.36$ and 0.20, respectively) across treatments. However, digestible DMI (% of BW) was greater ($P < 0.05$) for cows offered MH compared with those offered CONT and LC when TiO_2 was used as an external marker. When ADIA was used as a digesta marker, digestible DMI (% of BW) was greater for cows offered MC and MH compared with those offered the other treatments. Dry matter fill, passage rate, and ruminal retention time did not differ ($P \geq 0.31$) across treatments.

Ruminal in situ DM disappearance. Hay fraction B (potentially degradable DM) was greater ($P < 0.05$) in cows offered LH and MC compared with those offered MH (Table 3), whereas hay fraction C (undegradable DM) was greater ($P < 0.05$) from cows offered MH compared with those offered MC and LH. Fraction A (immediately soluble), rate of disappearance, lag time, and effective ruminal disappearance were not affected ($P \geq 0.13$) by supplementation.

Ruminal measurements. Ruminal pH was affected ($P < 0.05$) by sampling time and tended ($P < 0.10$) to be affected by supplementation and the supplementation by time interaction (Table 4). Ruminal pH tended ($P < 0.10$) to be greater for cows offered LC compared with those offered LH, MC, and MH. Ruminal pH was greater ($P < 0.05$) in samples obtained at 0 and 1 h after feeding supplements compared with the other sampling times (Figure 1). Ruminal pH was greater ($P < 0.05$) at 3 h after feeding supplements than at the ensuing sampling times, and at 5, 9, and 11 h after feeding supplements compared with 13 h after feeding supplements.

There were no effects of supplementation ($P = 0.94$) on ruminal ammonia-N concentrations (Table 4), but there was a sampling time effect ($P < 0.05$). Ruminal ammonia concentrations were greatest ($P < 0.05$) at 1 h followed by that at 3 h after supplement feeding (Figure 2). Ruminal ammonia concentrations from these two times were greater ($P < 0.05$) compared with the remainder of the sampling times. Concentrations of total VFA were not affected ($P = 0.77$) by supplement treatments (Table 4), but varied across sampling times ($P < 0.05$). Concentrations of total VFA were greater ($P < 0.05$) at 13 h after feeding the supplements compared with immediately prior to supplement feeding, or 1, 3, or 9 h after feeding supplements (Figure 3). The sampling time × treatment interaction affected ($P < 0.05$) proportions of acetate, propionate, and the acetate:propionate ratio (Figure 4, 5, and 6, respectively). Supplementation treatments affected ($P < 0.05$) concentrations of isobutyrate and tended ($P < 0.10$) to affect proportions of isovalerate (Table 4). Concentrations of isobutyrate were greater for cows offered MC compared with those offered the other treatments, whereas concentrations of isovalerate tended to be greater for cows offered MC, LC and CONT compared with those offered LH.

Discussion

Dry matter intake and digestion. Although hay DMI was not affected by supplementation, total DMI was 13.3% greater by cows offered MC and MH compared with those offered no supplement. Cows offered LC and LH only increased their total DMI numerically by 5.5 and 3.5% respectively compared with those offered no supplement. Forage quality has to be taken into consideration whenever determining energy supplementation strategies (Sanson et al., 2004; Matejovsky and Sanson, 1995). Our findings are in agreement with those reported by others where corn and barley were used as supplements to steers offered medium-quality native meadow hay (Sanson et al., 2004), or where increasing corn up to 0.5% of BW in the supplement did not have negative impact on diet DMI by wether lambs offered medium-quality hay (Matejovsky and Sanson, 1995). Interestingly, the hay used in the previous study was a cool-season grass (Matejovsky and Sanson, 1995) whereas our hay was a warm-season grass. The hay in the current study was 10% CP and approximately 54 to 55% digestible which would likely be considered medium quality (Leng, 1990). Poor quality forage is generally accepted as below 8% CP and 55% digestible. It may be surmised from this lack of effect on hay DMI that the quality of our hay contributed sufficient limiting nutrients to the ruminal microbial population; hence the hay was consumed similarly regardless of supplementation. Digestibility of DM was not affected by supplementation, further supporting that the hay alone was not deficient in nutrients required to maintain the digestive process. However, animal energy requirements are based on intake of digestible nutrients. In this study, digestible DMI generally increased with increasing supplement levels. Particularly, digestible DMI was increased by 1.3 and 1.7 kg/d by cows offered MC and MH, respectively compared with cows offered hay without supplements. The protein concentration of our hay, the supplements, and total DMI may

have contributed to this outcome. According to Leng (1990), medium- to high-quality forage generally associates positively with starch energy supplementation compared with low-quality forage. The results of the current study are in agreement with those by Matejvosky and Sanson (1995) who also supplemented increasing levels of corn to lambs offered medium-quality (58% digestible) grass hay. However, in another study using low-quality (7.5% CP and 74% NDF) wheatgrass hay, digestible DMI (kg and % of BW) and NDF digestibility were reduced with increasing level of corn supplementation (Sanson, 1993).

Ruminal in situ DM disappearance. Overall, in situ data were somewhat consistent with digestibility data in that no differences were observed among treatments for K_d, or effective ruminal DM disappearance, as was the case for total tract digestibility and passage rate. However, cows offered LH had greater potential disappearance (fraction B) of forage DM and a lower undegradable fraction compared with those offered MH, LC, and CONT. These differences could not be readily explained by differences in DM intake or total tract digestibility. Furthermore, ruminal pH was numerically the lowest for cows offered LH, which should have provided a less-favorable ruminal environment for forage digestion. Numerically, the lowest fraction B and the greatest fraction C were from cows offered MH, which also had the greatest DMD and digestible DMI.

Fraction A (immediately soluble) and rate of DM disappearance were similar across treatments ($P = 0.18$), and to that reported by Galdámez-Cabrera et al. (2003), but lower when compared to that reported from higher-quality bermudagrass (Ogden et al., 2005) or cool-season grasses across a range in stage of maturity at harvesting (Hoffman et al., 1993). Fraction B and effective ruminal disappearance from this study are also somewhat lower than those reported previously (Galdámez-Cabrera et al., 2003; Ogden et al., 2005). These findings are most likely

due to the quality of the bermudagrass in the previous studies (11 to 20% CP and 64 to 69% NDF, Galdámez-Cabrera et al., 2003; 17% CP and 62% NDF, Ogden et al., 2005) compared with that in the present study (10% CP, 70% NDF). Although the stage of maturity for our hay was not established, the presence of seed heads in the hay led us to believe that the bermudagrass was at full inflorescence when it was harvested. Perennial cool-season grasses without grain supplementation have also shown varied B fractions ranging from 39 to 51% depending on stage of maturity (Hoffman et al., 1993), from forages with CP content ranging from 10 to 23% and NDF ranging from 49 to 63.6%.

Ruminal measurements

Ruminal pH. Ruminal pH was greater for cows offered LC compared with those offered MC, MH and LH. Our findings compare well with those reported by Sanson et al. (2004) who reported that low levels (0.25% of BW) of corn supplementation yielded pH of 6.4, as was the case in our study. The ruminal pH for wheat, corn, barley, and oats were 6.11, 6.18, 6.26, and 6.20 respectively, when compared as sources of carbohydrates in dairy cow diets (Ghozo and Mutsvangwa, 2008). In another study, supplementation with both corn and distillers grain with solubles resulted in a ruminal pH of 6.18 compared with a pH of 6.34 from hay alone (Loy et al., 2007). In the current study, ruminal pH from cows offered corn supplementation and hay were within the range of the findings of the aforementioned studies. In contrast to corn supplementation in our study, ruminal pH was lower numerically lower for cows offered LH compared with those offered MH. It is not understood how the lower level of supplement could have yielded lower pH. The suppressed pH in response to LH cannot be explained as there is no data to support or refute the current results. It could be inferred that the digestible fiber content

and residual starch in the hominy may have been fermented by both fibrolytic and amylolytic bacteria to yield low pH relative to that yielded by fermentation of corn.

Ruminal pH was greatest at sampling times of 0 and 1 h after supplement feeding (6.52 and 6.59 respectively) compared with the other time periods when averaged across treatments. Therefore, as the time progressed after feeding, pH dropped in response to feeding and rumination. It is vital that the pH be maintained above 6 throughout the day so as not to disturb the rumen ecology with acidity (Church, 1979; Russel et al., 1979; Nagaraja and Titgemeyer, 2007). The greater pH after 1 h could have been because maximum ruminal degradation of feedstuffs would not have been reached yet since the animal would still be eating and the microbes in the rumen would still be adjusting to the new substrate. This would be done by way of attachment, penetration, and subsequently degradation as observed by Miron et al. (2001) where they outlined the importance of phases of ruminal bacterial adhesion to substrate and how these phases ultimately affect substrate degradation.

Ruminal ammonia concentration. Ruminal ammonia-N concentrations were not affected by supplement but were greatest at the 1 h sampling time probably due to the immediately soluble protein in the supplement and the hay. The ammonia-N concentrations declined as sampling time increased beyond 1 h after supplement feeding. This could be attributable to the utilization of ammonia-N by the ruminal microbes as well as ammonia absorption into the blood circulatory system and transport to the liver. This decline in ammonia concentrations could also have been affected by the declining trend of the ruminal pH with increasing sampling times. Although the ammonia concentrations were low through the sampling times, the level was still within and/or above the range required (2 to 5 mg/dL) by microbes for microbial protein synthesis as described by (Satter and Slyter, 1974).

Ruminal VFA production. Total concentrations of VFA were affected by sampling time while concentrations of acetate, propionate, (as a percentage of total VFA) and the acetate:propionate ratio were affected by the treatment by sampling time interaction. A trend developed with the rise of pH at 1 h after supplement feeding, which corresponded with a rise in concentrations of ruminal ammonia-N. As pH decreased beyond 1 h after feeding, concentrations of total VFA increased and ammonia-N decreased with time. Therefore, a decrease in pH was likely the result of the accumulation of VFA whereas ammonia was not favored by the acidic environment. The acetate:propionate ratio was greatest for cows offered CONT and LC compared with those offered MC and MH at 3 h and continuing for the rest of the time periods. Cows offered CONT also had greater acetate:propionate ratios than LH, MC, and MH at 1 h after supplement feeding. This was most likely due to the acetate produced during degradation of hay in CONT and the low impact LC had on propionate production. This is in agreement with Chase and Hibberd (1987) who reported a tendency for the acetate:propionate ratio to decrease with increasing levels of corn supplementation. It is noted as well that the proportion of acetate in total VFA was greater from cows offered CONT and LC compared with those offered MC and MH at sampling times 5 through 11 h. Fermentation of the hay throughout the time periods yielded this greater proportion of acetate. In contrast to our results, Loy et al (2007) reported similar acetate:propionate ratio and acetate proportion from heifers offered hay alone or those offered hay supplemented with corn at 0.40% of BW. Also, the acetate: propionate ratio and acetate proportions were not affected when steers were offered corn and barley as supplements at 0.25 and 0.50% of BW (Sanson et al., 2004). The fact that proportions of propionate in total VFA were greater for cows offered MC and MH compared with those offered CONT and LC at 3 to 13 h after supplement feeding was expected in the current study

and was attributed to increased fermentation of the soluble carbohydrates after 3 h of feeding in the medium level supplement treatments. These results agree with those of Loy et al. (2007) who reported increased propionate production from heifers fed corn and distillers grain supplements compared to hay alone. Conversely, there was no supplement effect on propionate proportion in similar studies where they offered medium-quality meadow hay to steers and low-quality hay to beef cows respectively, and supplemented with increasing levels of corn (Sanson et al., 2004; Chase and Hibberd, 1987).

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Table 1. Chemical composition of bermudagrass hay and supplements offered to lactating, ruminally-cannulated cows (DM basis).

Item	Bermudagrass hay	Corn	Hominy feed
CP	10.3	12.3	11.3
NDF	70.7	16.0	27.5
ADF	32.4	4.3	7.0
Ash	8.0	2.5	3.0
Ether extract	1.0	4.0	7.0

Table 2. Intake, digestibility, and ruminal DM fill by lactating, ruminally-cannulated beef cows offered medium quality bermudagrass hay and supplemented with either corn or hominy.

	Treatments[a]						
Item	CONT	LC	LH	MC	MH	SEM	Effects[b]
BW change, kg	10.4	0.9	14.5	7.3	8.2	7.02	ns
DMI, kg/d							
Hay	14.3	13.9	13.5	13.6	13.5	0.74	ns
Supplement	0.0c	1.3b	1.4b	2.7a	2.7a	0.12	S
Total DMI	14.3b	15.1b	14.8b	16.2a	16.2a	0.77	S
DMI, % BW							
Hay	2.4	2.4	2.3	2.3	2.3	0.15	ns
Total	2.4c	2.6ab	2.5bc	2.7a	2.7a	0.15	S
DM digest.[c], %	54.5	51.7	55.1	56.1	58.0	2.42	ns
Digest. DMI[c], kg/d	7.84c	7.81c	8.18bc	9.06ab	9.47a	0.626	S
Digest. DMI[c], %BW	1.30c	1.35bc	1.39abc	1.51ab	1.58a	0.095	S
DM digest.[d], %	53.9	55.3	54	56.5	57.3	2.00	ns
Digest. DMI[d], kg/d	7.71c	8.39b	8.00bc	9.20a	9.30a	0.530	S
Digest. DMI[d], %BW	1.29d	1.45b	1.37c	1.53a	1.57a	0.107	S
DM fill, kg,[e]	13.6	13.1	12.8	14.4	14.2	0.65	ns
DM fill, % BW	2.3	2.3	2.2	2.4	2.4	0.14	ns
Passage rate, h^{-1}	0.037	0.039	0.040	0.035	0.036	0.0033	ns
Retention time, h	27.6	26.2	25.3	28.8	29.6	2.61	ns

Means within a row without a common letter differ ($P < 0.05$).

[a] CONT, control (no supplement); LC, low corn; LH, low hominy; MC, medium corn; MH, medium hominy.

[b] S, supplement effect ($P < 0.05$); ns, no statistical difference.

[c] Digestibility as determined using actual DMI and fecal output determined using titanium dioxide as an external marker.

[d] Digestibility as determined using actual DMI and fecal output determined using acid-detergent insoluble ash as an internal marker.

[e] DM fill represents the average of the ruminal fill measured by total ruminal evacuation immediately prior to feeding and 6 h after feeding.

Table 3. In situ DM disappearance in lactating, ruminally-cannulated beef cows offered medium quality bermudagrass hay and supplemented with different levels of corn or hominy.

	Treatments[a]						
Item[b]	CONT	LC	LH	MC	MH	SEM	Effects[c]
A fraction, %	22.0	22.0	22.9	21.7	21.9	0.16	ns
B fraction, %	47.8bc	48.4bc	50.1a	49.2ab	47.5c	1.51	S
C fraction, %	30.3ab	30.3ab	28.0c	29.1bc	30.6a	0.46	S
K_d, h^{-1}	0.034	0.032	0.028	0.030	0.032	0.0020	ns
Lag time, h	1.2	0.91	2.3	1.8	1.8	0.39	ns
ED	44.8	43.8	42.4	44.2	44.7	1.49	ns

Means within a row without a common letter differ ($P < 0.05$).

[a]CONT, control (no supplement); LC, low corn; LH, low hominy; MC, medium corn; MH, medium hominy.
[b]A, immediately soluble fraction; B, degradable fraction; C, undegraded fraction; K_d, degradation rate; ED, effective ruminal DM disappearance.
[c] S, supplement effect ($P < 0.05$); ns, no statistical difference.

Table 4. Ruminal fluid characteristics of lactating, ruminally-cannulated beef cows offered medium quality bermudagrass hay supplemented with either corn or hominy.

	Treatments[a]						
Item	CONT	LC	LH	MC	MH	SEM	EFFECTS[b]
pH	6.3ab	6.4a	6.1c	6.2bc	6.2bc	0.14	s, T, s × t
Ammonia, mg/dL	4.7	4.4	4.8	4.3	4.4	0.78	T
Total VFA, mM	106.4	99.4	107.3	108.2	105.4	5.36	T
	----------% of total VFA----------						
Acetate	70.6	69.6	68.3	67.4	67.8	0.50	S, T, S × T
Propionate	17.1	17.5	18.1	19.1	19.2	0.41	S, T, S × T
Acetate:propionate	4.2	4.0	3.8	3.5	3.6	0.11	S, T, S × T
Butyrate	10.2	10.6	11.2	11.0	10.7	0.32	T
Isobutyrate	0.65b	0.68b	0.67b	0.73a	0.69b	0.02	S, T
Valerate	0.91	0.90	0.91	0.94	0.95	0.39	T
Isovalerate	0.76a	0.77a	0.7b	0.86a	0.74ab	0.05	s, T

Means within a row without a common letter tended to differ ($P < 0.10$)

[a]CONT, control (no supplement); LC, low corn; LH, low hominy; MC, medium corn; MH, medium hominy.
[b]S and s, supplement effect ($P < 0.05$ and 0.1, respectively); T, sampling time effect; S × T and s × t, sampling time × treatment interaction ($P < 0.05$ and 0.1, respectively); ns, no supplement effect.

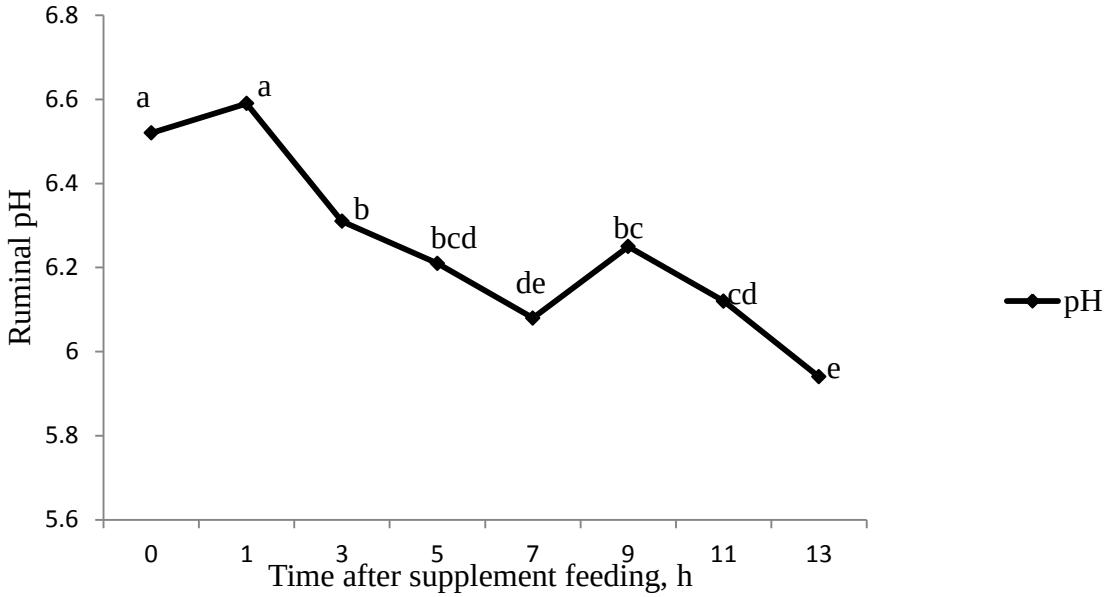

Figure 1. Ruminal pH over multiple sampling times after supplement feeding from lactating, ruminally-cannulated beef cows offered medium quality bermudagrass hay. Ruminal pH means represent those averaged across cows offered no supplement or offered different levels of either corn or hominy. [a-d]Means with different letters differ ($P < 0.05$). SE = 0.05.

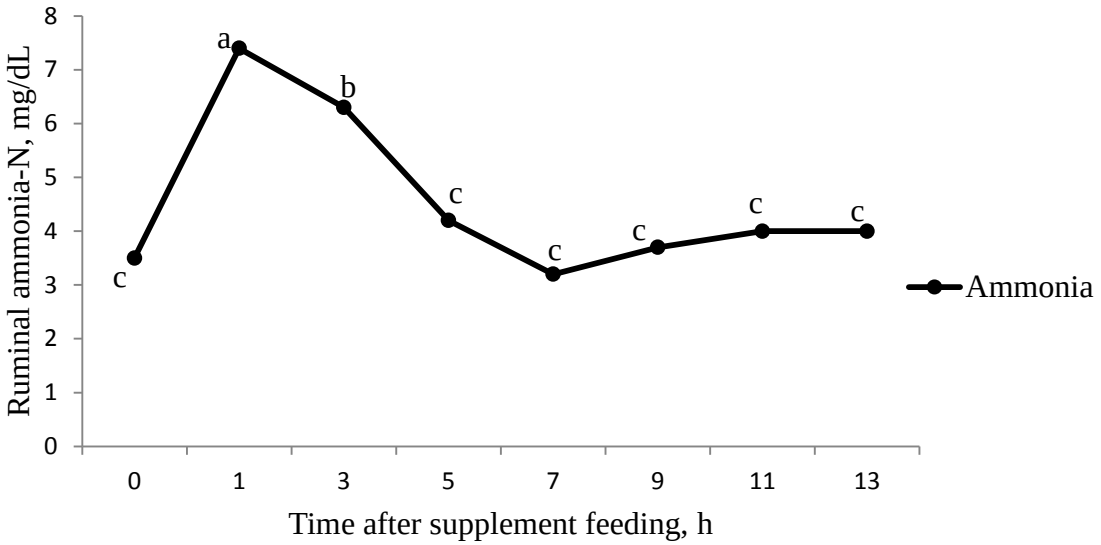

Figure 2. Ruminal ammonia-N concentrations over multiple sampling times after supplement feeding from lactating, ruminally-cannulated beef cows offered medium quality bermudagrass hay. Ruminal ammonia-N means represent those averaged across cows offered no supplement or offered different levels of either corn or hominy. [a-c] Means with different letters differ ($P < 0.05$). SE = 0.72.

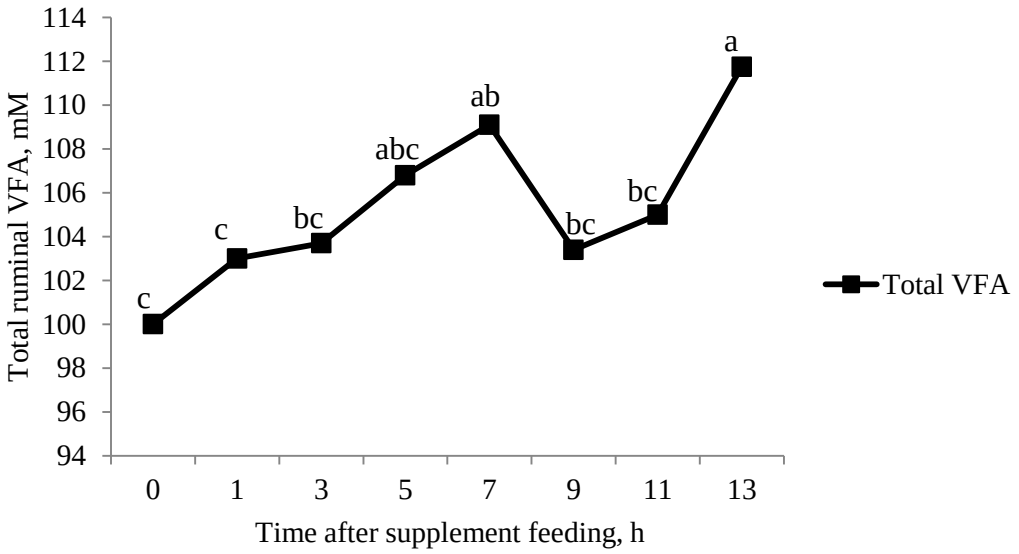

Figure 3. Total ruminal volatile fatty acids over multiple sampling times after supplement feeding from lactating, ruminally-cannulated beef cows offered medium quality bermudagrass hay. Ruminal VFA means represent those averaged across cows offered no supplement or offered different levels of either corn or hominy. [a-c] Means with different letters differ ($P < 0.05$). SE = 4.74.

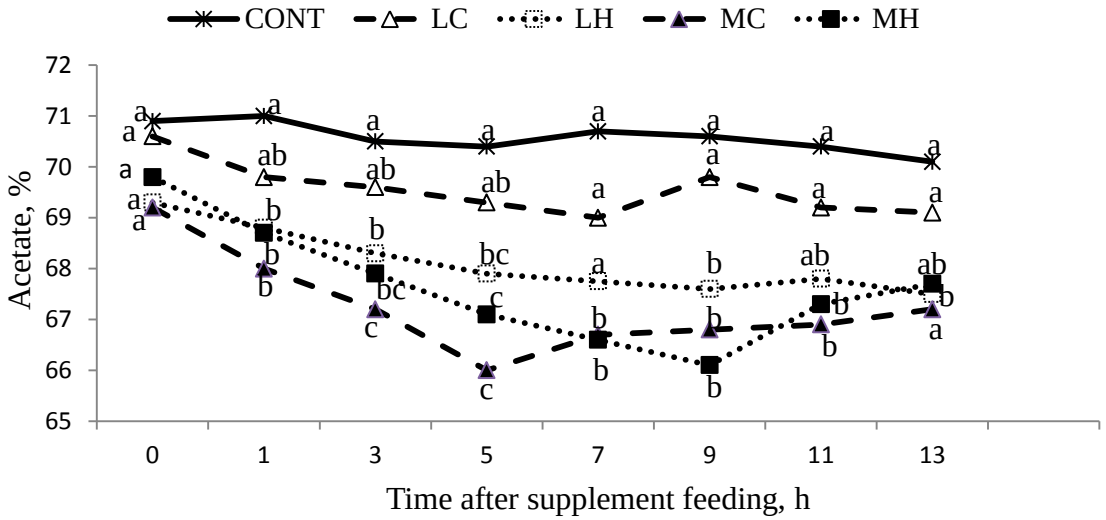

Figure 4. Ruminal % acetate in lactating, ruminally-cannulated beef cows offered medium-quality bermudagrass hay supplemented with either corn or hominy. Sampling time × treatment effect ($P < 0.05$). [a-c]Means with different letters differ within a time. SE = 0.50.

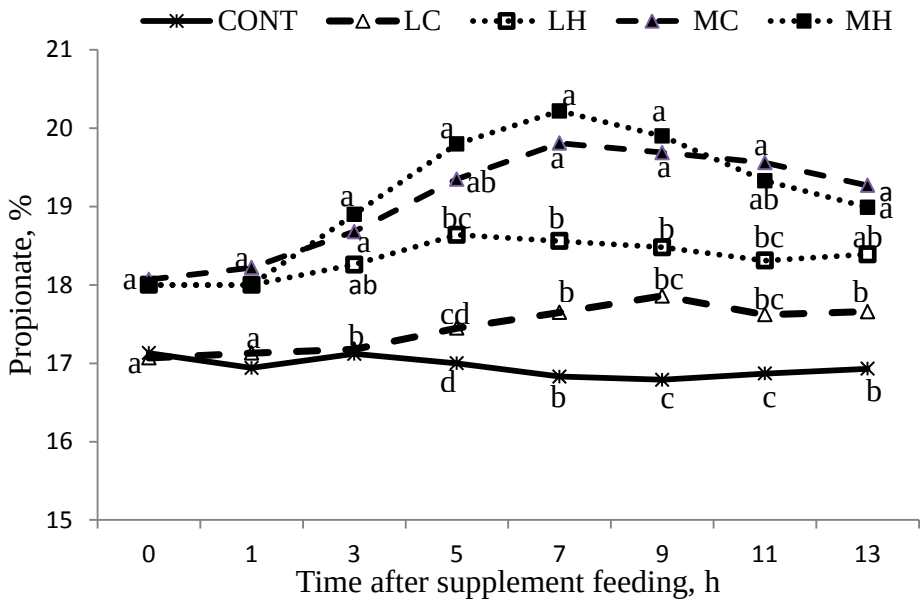

Figure 5. Ruminal % propionate in lactating, ruminally-cannulated beef cows offered medium-quality bermudagrass hay supplemented with either corn or hominy. Sampling time × treatment effect ($P < 0.05$). [a-c]Means with different letters differ within a time. SE = 0.42.

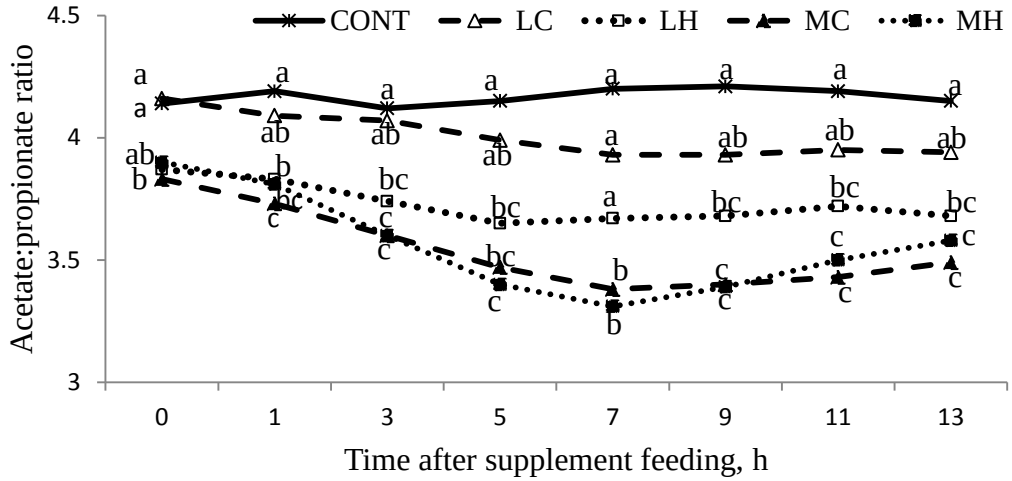

Figure 6. Ruminal acetate:propionate ratio in lactating, ruminally-cannulated cows beef cows offered medium-quality bermudagrass supplemented with either corn or hominy. Sampling time × treatment ($P < 0.05$). [a-c]Means with different letters differ within a time. SE = 0.11.

CHAPTER IV

CONCLUSION

Beef cows in lactation require additional energy in instances where forage quality is limiting. Supplementation with energy sources such as corn has been practiced over the years in order to meet the animal nutrient requirements. However, the use of corn as a supplemental feedstuff for cattle is facing growing competition from the ethanol industry and from domestic use. Hominy feed is a co-product from dry corn milling and has the potential to replace corn as a supplemental feedstuff for lactating beef cows. Based on our research, hominy feed or corn can be fed at levels up to 0.50% BW as a supplement for lactating beef cows consuming medium-quality bermudagrass hay without affecting intake or digestibility. However, digestible dry matter intake was increased with both corn and hominy when fed at levels up to 0.50% of BW. The potentially degradable hay fraction was increased, and the undegradable fraction was decreased in cows offered hominy feed at 0.25% of BW. Ruminal measurements were similar for both levels of hominy feed and corn supplementation. Therefore, hominy feed can be used as an alternative feed to corn as an energy supplement without having negative effect on measurements that are potential indicators of animal performance.