EFFECT OF SUPPLEMENTAL CORN PROCESSING ON UTILIZATION AND INTAKE OF LOW QUALITY NATIVE GRASS HAY AND PERFORMANCE OF BEEF COWS

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Bachelor of Science

Oklahoma State University

Stillwater, Oklahoma

1985

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirement for
the Degree of
MASTER OF SCIENCE
December, 1991

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ON UTILIZATION AND INTAKE OF LOW QUALITY
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ACKNOWLEDGEMENTS

I wish like to thank Dr. Chuck Hibberd for his guidance and assistance in the development of this thesis. His friendship and timely advice were invaluable. His ability to procure a financial assistantship during a time when none were made available was greatly appreciated.

Special thanks to Kathy Swenson, Ron Scott and William Chan during the collection of data and laboratory analysis during these trials. The long hours of lab work were made tolerable by the friendship and humor I shared with co-workers.

To the members of my committee, Dr. Ted McCollum and Dr. Archie Clutter, thank you for taking the time to evaluate my performance while attending OSU.

To Dr. Stanley Gilliland, your warmth, friendship, motivation and encouragement will never be forgotten.

Lastly , I wish to thank my wife Terri, children, Gregory and Dillon and both our parents for all their support.

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CHAPTER I

INTRODUCTION

Dormant native grass in Oklahoma provides an inexpensive source of energy for grazing livestock. Following calving in September or October, fall calving beef cows experience a forage base that is declining in nutritional quality (4% CP, 40% TDN) due to forage maturation, selective consumption of leaf and leaching of nutrients by precipitation. In addition, the additive effects of lactational demands and adverse weather conditions exact further nutritional stress on the cow. Under these conditions, protein supplementation is necessary (NRC, 1984). Decreased forage quality coupled with increased physiological demands may necessitate energy supplementation as well. Although consumed forage can supply a major portion of the energy requirement of a lactating cow, a supplemental energy source such as corn also may be needed. With inadequate supplementation, cows may lose body weight and condition and experience extended postpartum intervals, decreased conception rates and reduced milk production (Rakestraw et al., 1986).

Traditional energy supplements are composed of oilseed meals such as cottonseed or soybean meal blended with a cereal grain such as corn, milo or wheat. Cereal grains contain a large quantity of starch (Hibberd et al., 1982) that has been shown to decrease forage digestibility and intake (Chase and Hibberd, 1987). Recently, a group of low-starch, byproduct feeds such as soybean hulls, corn gluten feed or wheat middlings have been investigated as energy

supplements (Martin and Hibberd, 1990; Trautman, 1987; Ovenell et al., 1990; Fleck et al., 1987).

Grain processing increases starch fermentation rate by increasing surface area and disrupting the protein matrix surrounding the starch granules (Galyean, 1977). Ground grains decrease ruminal pH to a greater extent than whole grains (Orskov and Fraser, 1975). Reduced pH is associated with decreased fiber fermentation although the effects may be transitory because of the rapid degradation of starch in ground grain. Reductions in ruminal pH will be less dramatic, but may be extended for a longer period of time. Consequently, coarsely processed grains may reduce fiber digestion to a greater extent than ground grains (Owens and Goetsch, 1988).

Although grain processing responses with high concentrate diets have been well documented, the effects of supplemental grain processing on forage utilization and cow/calf performance are unknown. The objectives of this research were: 1) to determine the effect of supplemental grain processing on forage utilization and intake, and 2) to evaluate the impact of supplemental grain processing on the performance of lactating beef cows grazing dormant native grass.

CHAPTER II

REVIEW OF LITERATURE

Nutritional Status of Lactating Beef Cows

Productivity of beef cows grazing native range is dependant upon their ability to consume and digest enough forage to meet their nutritional requirements. The protein content of native grass is at its lowest level during the dormant season averaging approximately 2.5% (Waller et al., 1972). Along with the decrease in protein is an increase in the fibrous portion of the plant. Ruminal bacteria can obtain energy from the digestion of the fibrous portion of the plant (hemicellulose and cellulose). During the growing season, crude fiber content is approximately 30%. During late summer and early fall, however, the fiber content of the grass increases to approximately 40%. As the plant matures, it becomes more difficult for the bacteria to digest, mainly due to increased lignification.

Nutritional requirements of the beef cow depend on the animal's stage of production. A gestating beef cow requires 703 g of protein. The added stress of providing an ample supply of milk for her calf during the winter months can increase her protein requirement by approximately 30%. A 450 kg lactating beef cow requires 911 g of protein and 5.3 kg of TDN per day (NRC, 1984). To meet her requirements from the forage alone, a cow would need to consume 30 kg of forage to meet her protein requirement and 14 kg of forage to meet her energy requirements. Because the average lactating cow will only consume

approximately 2.0 % BW or 9.2 kg of forage, she will be deficient in protein (586 g) and TDN (1.78 kg).

Under normal conditions, protein and energy supplements are needed to satisfy the nutrient deficiencies of the animal. The correct supplementation program depends upon the resources available. With gestating cows grazing an ample forage base, the standard practice is to feed approximately .5-1 kg/head/day of a high protein supplement composed of soybean or cottonseed meal. High protein oilseed meals such as these provide ruminal ammonia from the breakdown of protein. This ammonia is utilized by the bacteria to synthesize new bacteria. In this process, fibrous feeds are fermented more efficiently to produce volatile fatty acids for use as an energy source by the cow.

The use of high fiber, moderate protein by-product feeds such as wheat midds, corn gluten feed or soybean hulls has gained popularity because they are economical feed sources. In addition, digestible fiber feeds have more desirable effects on intake and digestion of forages when compared to grain-based supplements (Martin and Hibberd, 1990; Trautman et al., 1987; Ovenell and Lusby, 1991). Martin et al. (1990) fed graded levels of soybean hulls (1 to 3 kg) to cows fed low quality grass hay and observed an increase in total OM digestion from 45.8% to 48.6% when compared to the cottonseed meal control. This suggests that the soybean hulls were more digestible than the hay and did not interfere with hay digestion. There was a linear increase in digestible OM intake with the addition of hulls to the diet. A slight decrease in hay intake (.64 kg) was observed with the addition of 3 kg of hulls which suggests that the substitution rate of soybean hulls for hay was low. Trautman et al. (1987) studied the effect of corn vs soybean hull supplements on lactating cows grazing dormant native grass. Compared to a cottonseed meal control, corn/cottonseed meal supplements decreased NDF digestibility while soybean hull supplements

increased digestibility. Ovenell et al. (1991) reported no difference in DM digestibility when comparing wheat midds to soybean meal or a 22% corn, 76% soybean meal blend. Dry matter intake was reduced when cows were fed the wheat midds or the corn/soybean meal supplement.

Another option for cow / calf producers is to use grain-based supplements to extend the forage that is available for the animal or to increase energy intake during lactation or inclement weather. Grain-based feeds are commonly fed at a rate of 2 to 4 kg per head per day. Grain supplementation when fed in excess of .3% BW has been shown to decrease the digestibility of the consumed forage (Kartchner, 1981; Chase and Hibberd;Clanton et al., 1989). One must use caution when feeding grain to cattle grazing dormant grass. If protein is deficient, supplementation with energy feeds may result in lower cattle performance (Rush et al.,1986).

Utilization of Low Quality Forages

With a well-managed beef cattle operation, producers should have an ample supply of forage for winter grazing. This forage provides an inexpensive source of energy for the cows. To maximize resource efficiency, the forage should be utilized efficiently. Supplementation is a management tool producers can use to alter the efficiency of forage utilization.

Supplemental protein improves forage utilization and intake (McCollum and Galyean, 1985). This response has been associated with an increase in forage digestibility (Rittenhouse et al., 1970), rate of digestion (Barton and Hibberd, 1984; Canton, 1988) and rate of passage (McCollum and Galyean, 1985). To observe these responses, however, the CP content of the forage is usually less than 6% (Kartchner, 1980).

The process by which these changes occur is dependant upon a series of

events occurring in the rumen of the cow. When protein enters the rumen, a portion is degraded to amino acids and ammonia by the bacteria for use as nitrogen sources to synthesize amino acids for microbial protein. With inadequate ruminal degradable protein, the supply of ammonia can become insufficient resulting in inefficient bacterial growth and decreased rate and extent of OM digestion (Scott et al., 1990).

Microbial growth is also dependant upon the store of ruminally fermentable carbohydrate (Nocek and Russell, 1988). If fermentable carbohydrates are inadequate, amino acids will be catabolized as an energy source. Because protein feeds may be more expensive than carbohydrates, utilization of protein as an energy source may economically inefficient.

With lactating cows grazing dormant native grass, the energy demands of the cow are usually not satisfied with protein supplementation alone. Consequently, high energy, low protein supplements are often used. Decreased forage intake and digestibility are frequently observed when feeding supplements containing high levels of starch (Henning, 1980; van der Linden, 1984; Chase and Hibberd, 1987; Sanson and Clanton, 1989). Henning et al. (1980) observed a linear decrease in maize straw intake as well as cellulose and hemicellulose digestibility when the proportion of maize pellets in the diet exceeded 78 g/kg total ration. This response was not predicated by a drop in ruminal pH. Orskov et al. (1982) also reported decreased fiber digestion in vivo with readily fermentable carbohydrates without a reduction in ruminal pH.

Sanson and Clanton (1989) observed a linear decrease in hay DM intake and digestibility as level of corn in the diet was increased. This is in agreement with Chase and Hibberd (1987) who reported a linear decrease in hemicellulose and cellulose digestion as the amount of ground corn in the diet was increased. Hemicellulose digestibility was decreased by 56% compared to the cottonseed

meal control when 3 kg of a corn supplement was fed. Digestible OM intake was highest for animals supplemented with 1 kg of corn while no improvement was observed between the control and cattle fed 2 or 3 kg of corn. These negative associative effects represent a major drawback to the feeding of high levels of cereal grains as range supplements.

Balancing the nitrogen to energy ratio may result in optimal utilization of substrates. If there is a deficiency in protein, then carbohydrate digestibility may be limited. When fermentable carbohydrates are insufficient, protein N can be lost as ruminal ammonia (Nocek et al., 1988). When protein intake is high, energy supplementation results in the capture of released nitrogen resulting in increased microbial nitrogen flow to the duodenum (Owens and Zinn, 1988). Zorrilla-Rios et al. (1985) found that energy supplementation to sheep fed a diet of wheat straw and urea resulted in increased nitrogen retention. Limited research has shown that with sufficient levels of protein to supply ammonia and branched chain volatile fatty acids for the growth of cellulolytic bacteria, forage utilization was still decreased with grain supplementation (Henning et al., 1980).

Production Responses to Grain Supplementation

Fall calving beef cows generally are in good body condition at calving due to forage quality through the summer months. A reduction in condition and body weight usually transpires post calving due to the decline in forage quality and the increased nutrient requirements for lactation. Research has shown that the decline in body condition and weight loss can be minimized with supplementation (Turman et al., 1964; Clanton and Zimmerman, 1968; Kropp et al., 1973). Wiltbank et al. (1962) examined the effects of energy level on body weight and condition of cows. Cows maintained on high levels of energy gained weight and maintained their condition while cows fed a low level of energy lost weight and

were thin at calving. A similar trend was seen postcalving as well illustrating that body weight and condition score are influenced by level of energy in the diet.

The interval to estrus of the postpartum beef cow can vary from 46 to 168 days (Dunn and Kaltenbach, 1980). Body condition and weight loss have a strong influence on the interval to estrus (Turman et al., 1964; Dunn et al., 1969; Bellows et al., 1978; Wettemann et al., 1980). Weight loss during late gestation due to deficient energy intake may extend the postpartum interval to estrus (Kropp et al., 1972; Wyatt et al., 1977). Rakestraw et al. (1986) observed an increase in the number of days from calving to first estrus when body weight and condition fell prior to breeding season. Wiltbank et al. (1962) observed that a higher proportion of cows receiving the high energy ration prior to calving had cycled by 90 days postcalving and exhibited estrus sooner after calving.

Reproductive performance of cattle is influenced by dietary energy intake both pre- and postpartum (Wiltbank et al., 1962; Mobley et al., 1983; Hancock et al., 1985; Richards et al., 1986). Wettemann et al. (1980) observed 85 and 70.6% pregnancy rates for cows maintained on moderate and low levels of nutrition precalving, respectively. Richards et al. (1986) found that the mean interval to estrus was 61 vs 49 d and mean interval to pregnancy was 90 vs 84 d for cows calving in a body condition score of <4 or >5, respectively. This clearly shows that adequate body condition at calving, as the result of proper prepartum nutrition, has a strong influence on early return to estrus.

If milk production can be increased or if the rate of decline in milk production can be slowed with proper feeding, calf weaning weights could be improved. With lactating beef cows, Lee et al. (1985) noticed the rate at which milk yield declined was reduced by protein supplementation. This also resulted in a significant difference in calf growth 47 days postpartum. Bartle et al. (1984) fed lactating Hereford and Hereford x Angus cows either 120 or 100% of the NRC

energy recommendations and examined milk production. Cows fed the 120% diet produced .2 kg more milk per day. In addition, there was only a decrease of .05 vs .45 kg/wk when compared to the cows fed the 100% energy diet. Final calf weights did not differ significantly, however, possibly due to creep feed availability during the trial.

Pounds of calf weaned is one of the most important commodities to a cow-calf producer, and milk production by beef cows accounts for 40 to 60% of the variance in weaning weights (Rutledge et al., 1971; Butson et al., 1980). Boggs et al. (1980) examined the effects of milk intake on calf performance. The study showed that each additional kg of milk per day added 7.20 kg to the 205-day adjusted weaning weight.

Ruminal Environment

Carbohydrates are the major energy source in the diets of ruminants. In addition to forage carbohydrates, grazing ruminants also benefit from supplemental carbohydrates. The production responses from energy supplementation are partly the result of metabolism of supplemental carbohydrates. (Fahey and Berger, 1988).

Because supplemental carbohydrates are frequently highly fermentable, the ruminal environment can be significantly affected. The fermentation of readily available carbohydrates in the rumen results in a decrease in ruminal pH (Orskov, 1982; Chase and Hibberd, 1987; Mould and Orskov, 1983; Orskov and Fraser, 1975; Sanson and Clanton, 1990). The rate and extent of acid production during fermentation of readily fermentable carbohydrates may reduce the activity of cellulolytic bacteria (Goetsch and Owens, 1987) which may result in decreased forage utilization.

Factors associated with the decrease in ruminal pH include grain particle

size, level and type of supplement, mastication, rumination time and buffering capacity of the forage. Mould et al.(1983) studied the effect of ruminal pH on forage intake and digestibility. With continuous ruminal infusion of an acid solution, pH levels were reduced from 6.6 to below 6.0. In situ hay digestibility was decreased from 30 to 9%. According to Mould and Orskov (1983), this decrease in digestibility is brought about by two factors: 1) decreasing pH, which affects the activity, growth and ability of cellulolytic bacteria to attach to forage fibers, and 2) a starch effect, where dry matter degradation was not altered by increasing ruminal pH of sheep offered a concentrate supplement. The lack of response in cellulose digestion when pH levels were corrected may be due to the microbes' preference for readily fermentable sugars rather than the relatively complex structures of cellulose (Mould and Orskov, 1983).

Orskov and Fraser (1975) examined the effect of whole or pelleted on ruminal pH. With whole barley diets, there was little variation in pH associated with feeding time. With the pelleted diet, however, pH values declined from 7.0 to 5.2-5.3 within two hours postfeeding. Along with the decline in pH, digestion of grass hay decreased from 625 mg DM/g incubated to only 423 mg DM/g incubated. Perhaps a more desirable pH for the whole barley improved the survival of cellulolytic bacteria which resulted in normal fermentation of the grass hay.

When Sanson et al. (1990) fed protein supplements with increasing quantities of corn grain, ruminal fluid pH decreased with increased levels of corn. At three h post-feeding, pH dropped below 6.0 which coincided with decreased fiber digestion. When Chase and Hibberd (1987), fed increasing quantities of corn, ruminal pH also decreased, but never below the critical pH of 6.2, as established by Orskov (1982). Fiber intake and digestion, however, also decreased.

Erfle (1982) examined the effect of pH on ruminal fermentation via continuous culture. The major impact was on ammonia concentration. Ammonia levels decreased from 5.9 mmoles/day to .2 mmoles/day at pH 7 and 5, respectively. The author states that ability of mixed rumen cultures to liberate ammonia from amino acids is greatly inhibited. Deaminase activity was measured during pH 5 fermentation and was found to be 10% of the activity at pH 7.

Ruminal Ammonia Concentrations

Starch supplies a readily available source of energy for ruminal microbes. The accumulation of ammonia is determined by the level of fermentable energy (Satter and Slyter, 1974). In a pH controlled environment with isonitrogenous diets, Stern et al. (1978) observed a decrease in ammonia concentration accompanied by increased microbial growth with increasing levels of starch in vitro. The low level of ammonia was associated with increased flow of microbial N, indicating that utilization of ammonia nitrogen was improved when readily fermentable carbohydrates were available. When feeding sheep whole barley diets, Mehrez et al. (1977) observed increased ruminal fermentation of barley with increasing levels of ammonia.

Volatile Fatty Acid Concentrations

The majority of VFA's produced by ruminal fermentation are absorbed from the rumen and utilized by the host as a source of metabolizable energy. Volatile fatty acid production is influenced by the type of substrate fermented. With all forage diets, the ratio of acetate, propionate and butyrate is generally 65:25:10, respectively and 55:35:10 for high concentrate diets (Fahey and Berger, 1988). When comparing energetic efficiency between roughage and concentrate diets, there is an inverse relationship between propionate and methane

production (Fahey and Berger, 1988). When glucose is converted to acetate and butyrate, the byproducts are CO_2 and H_2. With the excess hydrogen in the rumen, these byproducts will be reduced to methane which will be eructated resulting in an energy loss. With the production of propionate, however, all the carbon and hydrogen are retained thereby increasing the metabolizable energy of the diet (Van Soest, 1987).

Chase and Hibberd (1987) found that total VFA concentrations or molar proportions of propionate in the rumen did not differ with increasing levels of supplemental corn. As supplemental corn increased, molar proportions of acetate decreased linearly while butyrate increased linearly. Also, the ratio of acetate to propionate tended to decrease linearly with higher levels of corn in the diet.

Caton et al. (1988) examined the effect of protein supplementation on ruminal fermentation with steers grazing dormant grass. Volatile fatty acid concentrations peaked with the highest ammonia level. When Redman et al. (1980) fed growing steers urea, casein, formaldehyde-treated casein or a 50:50 treated untreated blend, total ruminal VFA concentrations were higher for all diets except for the urea- supplemented diet which also had higher propionate and lower acetate. Ruminal ammonia concentrations were much higher for the steers fed the urea or casein than the protected casein or control diets.

Rate and Extent of Fiber Digestion

Rate and extent of digestion in ruminants are essentially a function of the diet (Van Soest, 1987). Rate of digestion, which is the amount of feed digested in a given period, is influenced by composition of the diet. The extent of digestion is determined by ruminal retention time and rate of digestion (Faichney et al., 1986). Hannah et al. (1990) substituted various levels of corn for alfalfa haylage.

Increasing the grain level resulted in decreased rate of in situ haylage digestion, yet potential extent of digestion was not affected. Dixon (1986) found that when various concentrates were fed in combination with tropical forages, supplements had a much greater negative effect on rate of digestion of low quality forages than of highly digestible forages.

Mould et al. (1983) combined different types of roughages with whole or pelleted grains. Extent of fiber digestion varied with the type of roughage fed and the roughage with the lowest digestibility had the greatest reduction in rate of digestion. Similar results were observed by Jones et al. (1988) when comparing the effect of grain supplementation on cool or warm season grasses. Ruminal NDF digestion of orchardgrass / corn was greater than bermudagrass / corn.

Miller and Muntifering (1985) determined the effect of dietary concentrate (0, 20, 40, 60 or 80% cracked corn with fescue hay) on ruminal fiber digestion in vivo. The presence of grain reduced rate of forage fiber digestion. The potential extent of digestion was higher for all diets except when corn comprised 80% of the diet. Chase and Hibberd (1987) also reported a linear decrease in ruminal disappearance of hay and NDF from dacron bags with increasing corn supplementation of native grass hay .

With restricted forage intake, Hall et al. (1990) observed that neither ruminal nor total tract NDF digestion were affected by grain supplementation. This may have been due to the low level of intake which would result in longer ruminal residence time for digesta.

The use of grain supplements reduces fiber digestion in forage-based diets (Kartchner,1981; Chase and Hibberd, 1987). This decrease in rate and extent of digestion may be due to the low pH of grain-fed animals which would decrease the activity of the cellulolytic bacteria or competition between cellulolytic and non-cellulolytic bacteria for specific nutrients.

Microbial Protein Synthesis

Metabolizable protein is supplied to the ruminant from two sources: 1) dietary protein from ingested feed or plant material that escapes ruminal degradation, and 2) ruminally synthesized microbial protein (Stock et al., 1986). These two sources constitute the major supply of amino acids to the animal. Microbial growth, when other nutrients are adequate, is dependant upon an energy source which can supply ATP for protein synthesis (Nocek and Russell, 1988). Most of this energy may come from the fermentation of dietary OM. With low quality forages, however, microbial protein synthesis is restricted with protein supplementation alone, due to low available energy. Efficient utilization of ruminal N may be dependant upon rate of OM fermentation. Herrera-Saldana et al. (1990) used lactating Holstein cows to examine the effect of synchronization of ruminal protein and starch degradation on microbial protein synthesis. Diets providing a synchronized rapid degradability in the rumen (ie, barley and cottonseed meal) resulted in more microbial N (g / kg) than unsynchronized or less degradable synchronized diets.

Increasing ruminal degradable protein increases OM digestion (Scott et al., 1990) possibly increasing substrate availability (peptides, branched chain VFA's and ammonia) for cellulolytic bacterial synthesis. The addition of cottonseed meal to a corn-based supplement increased digestible OM intake (49%) on low quality native grass (Hibberd et al., 1987). If ruminal nitrogen level is not adequate, fermentation may still occur, however, with reduced ATP production (Nocek and Russell, 1988). Hussein et al. (1991) fed sheep either fish meal or soybean meal with corn or barley to determine their impact on microbial protein synthesis. There was a protein source effect on microbial efficiency with the use of soybean meal over the fish meal (37 vs 24.5 g N/Kg truly digested OM). There was an

interaction between dietary carbohydrate and protein source for OM digestion. Apparent digestion in the rumen was greatest for the fish meal and barley diet which was 63 vs 46.7% for the three remaining diets which did not differ. With increased microbial growth, ruminants benefit from increased energy supply and increased microbial protein flow to the small intestine.

Rate of Passage

The flow of undigested feedstuffs through the digestive tract of an animal is referred to as passage (Van Soest, 1987). Competition exists between digestion and passage rate for removal of digesta from the rumen. Passage rate is influenced by intake, physical form and composition of diet. It has been shown that grinding of forages as well as grains will increase passage rate (Thompson and Beever, 1980). Guthrie and Wagner (1988) examined the effect of graded levels of soybean meal on passage rate of prairie hay. With increasing quantities of soybean meal, there was a linear increase in particulate passage rate from 2.08 %/h for control to 3.47 %/h for heifers fed 362 g soybean meal / d. McCollum and Galyean (1985) also observed increased passage rate when cottonseed meal was fed to cattle consuming prairie hay.

Jones et al. (1988) studied the effect of forage type with or without supplemental grain on digestion of forage. With forage intake at 1.5% of body weight (396 kg), no difference was observed in particulate passage rate when comparing bermudagrass to orchardgrass with or without .3% BW corn supplementation. In contrast, Brake et al. (1989) noticed increased particulate and fluid passage rate with the addition of barley or corn to a bermudagrass hay or orchardgrass hay diet. This difference may be due to increased intake due to supplementation (1.2% vs 1.8% BW daily). Chase and Hibberd (1987) observed a

linear decrease in particulate passage rate with increasing levels of supplemental corn.

Grain Processing

The nutritive value of feed grains can be influenced by processing (Galyean et al., 1977; Cole et al., 1975). Energy intake, site and extent of digestion and utilization of absorbed nutrients are manipulated with grain processing (Gill et al., 1980). However, the type of grain and its physical properties will determine the benefits obtained from processing. Waldo (1973) suggests that processing of grains that are resistant to ruminal degradation such as corn or sorghum will increase the extent of ruminal starch digestion. Galyean et al. (1975) observed improved starch digestion when comparing steam flaked or ground high moisture corn to ground corn or propionic acid high moisture corn. Grains such as barley and wheat can be efficiently utilized with minimal processing. This may be due to the soluble protein matrix which would improve microbial penetration.

Site and extent of starch digestion, which influences feed efficiency and gain, is influenced by particle size and moisture content of grains (Gill et al., 1980; Kim and Owens, 1985). Association of the small particles with the liquid fraction may increase ruminal escape. The starch is then digested and absorbed as glucose in the small intestine. McNeill et al. (1971) researched different methods of processing for sorghum such as grinding, flaking, reconstituting or micronizing and their effect on site of digestion. Increasing surface area resulted in nearly complete total tract disappearance for all treatments. Galyean (1977) examined corn particle size and its impact on site of digestion in steers. Ruminal starch digestion was lowest for the whole corn diet and similar for the three ground corn treatments. Therefore, ruminal outflow of starch, as well as site of digestion, may be influenced by grain particle size.

CHAPTER III

EFFECT OF SUPPLEMENTAL CORN PROCESSING ON UTILIZATION AND INTAKE OF LOW QUALITY NATIVE GRASS HAY AND PERFORMANCE OF BEEF COWS

Abstract

Two studies were conducted to evaluate the effect of supplemental grain processing on forage utilization and cattle performance. Supplemental treatments for both studies included: 1) cottonseed meal control, 1.5 kg/d, 2) whole corn blended with pelleted cottonseed meal, 2.8 kg/d, 3) coarsely cracked corn blended with pelleted and crumbled cottonseed meal, 2.8 kg/d, 4) ground corn blended with unprocessed cottonseed meal, 2.8 kg/d, 5) ground corn blended with cottonseed meal to make a complete pellet, 2.8 kg/d. In experiment 1, five mature Limousin x Hereford/Angus beef cows (625 kg) were utilized in a 5 x 5 latin square to examine the effect of grain processing on utilization and intake of coarsely chopped low quality native grass hay (4.1% CP, 75.1% NDF). Hay OM intake tended ($P<.10$) to be higher for the control supplement. Ruminal OM disappearance decreased ($P<.05$) for the ground corn (4.79 kg/d) compared to cracked or pelleted corn (average 5.62 kg/d). Total tract NDF digestibility was not affected ($P=.14$) by treatment. Duodenal starch flow was higher ($P<.05$) for the ground corn than for the other corn supplements. Increased duodenal starch and protein flow with ground corn suggests that a portion of small particles may

evade ruminal fermentation. Total tract starch digestion was reduced ($P<.05$) for the whole (80.4%) and cracked (86.2%) corn supplements compared to the pelleted (94.4%) and ground (96.8%) corn supplements. Nitrogen intake tended ($P<.10$) to be greater for the cottonseed meal control. Microbial efficiency tended ($P<.10$) to be higher for the whole or ground supplements compared to the pelleted supplement. Ruminal ammonia was increased ($P<.05$) for whole corn compared to ground corn. Rate and extent of in situ hay disappearance were reduced ($P<.05$) with corn supplementation. In experiment 2, 76 lactating beef cows, blocked by calf age and calf sex, were randomly assigned to the four corn supplements described above for a 105-d trial. Cow weight change was not affected ($P=.24$) by supplemental corn processing. Calf weight gain, however, tended ($P<.10$) to be lower for cracked corn compared to others. Although the starch digestibility of the whole corn supplement was reduced, digestible OM intake and cow performance were not affected suggesting that supplemental grain need not be processed prior to feeding.

(Key Words: Beef Cattle, Grain Processing, Corn, Starch)

Introduction

Following calving in September or October, fall calving beef cows grazing native tallgrass pastures experience a forage base that is declining in nutritional quality (Waller et al., 1972). Under these conditions, protein and/or energy supplementation may be necessary (NRC, 1984). Energy supplements are frequently composed of oilseed meals such as cottonseed or soybean meal blended with a cereal grain such as corn, milo or wheat. Cereal grains contain a large quantity of starch (Hibberd et al., 1982) that has been shown to decrease forage digestibility and intake (Chase and Hibberd, 1987; Sanson and Clanton, 1989).

Grain processing increases starch fermentation rate by increasing surface area and disrupting the protein matrix surrounding the starch granules (Galyean, 1977). Increased starch fermentation may alter the ruminal environment so that the deleterious effects of grain supplementation are exaggerated. Whole corn supplementation may minimize deleterious effects and also provide an economic advantage to the producer. Although grain processing responses with high concentrate diets have been well documented (Gill et al.,1980), the effects of supplemental grain processing on forage utilization and cow/calf performance are unknown. The objectives of this research were: 1) to determine the effect of supplemental grain processing on the forage intake and site and extent of forage utilization, and 2) to evaluate the impact of supplemental grain processing on the performance of lactating beef cows grazing dormant native grass.

Materials and Methods

Experiment 1

Five mature non-pregnant, non-lactating Limousin x Hereford/Angus beef cows (625 kg) fitted with ruminal and duodenal cannulae were used in a 5 x 5 latin square. Animals were individually housed in concrete slatted pens (4.7 x 2.3 m) with free access to fresh water. Five supplements (Table 1) were formulated to meet the protein requirement of a 450 kg lactating cow (NRC, 1984). Corn was fed whole, coarsely cracked, ground or ground and pelleted. Supplemental treatments included: 1) control (cottonseed meal); 2) whole shelled corn blended with pelleted cottonseed meal; 3) coarsely cracked corn blended with pelleted and crumbled cottonseed meal; 4) ground corn blended with unprocessed cottonseed meal; 5) ground corn blended with cottonseed meal to make a

TABLE I

SUPPLEMENT COMPOSITION (DM BASIS) AND DAILY INTAKE OF SUPPLEMENTAL CHEMICAL COMPONENTS

	Supplements	
	Control	Processed corn
Feeds, %		
Cottonseed meal	93.44	41.60
Corn		54.94
Dicalcium phosphate	.23	
Cane molasses	3.47	2.00
Vitamin A-30	.08	.04
Sodium sulfate	1.08	.43
Trace mineralized salt[a]	1.70	.98
Intake, g/d		
Total DM	1,546.8	2,756.5
CP	630.5	619.4
Starch	14.4	1,101.2
Total digestible nutrients[b]	73.3	83.0

[a]Trace mineralized salt composed of 16% zinc, 12% iron, 3% magnesium, 1% copper, 1% potassium, .6% iodine .3% cobalt and 1% mineral oil.

[b]Estimated from NRC (1984).

complete pellet. The chemical composition of the corn supplements was very similar (Table II). Coarsely chopped (5-cm screen) native grass hay (4.1% CP, 75.1% NDF; Table II) was offered free choice. At 0800 each day, hay feeders were removed and supplements fed. Hay feeders were weighed and fresh hay amounting to the previous day's intake plus 4.5 kg was fed following supplement consumption. Hay refusals were discarded during the sampling period.

Cows were adapted to diets for 14 d followed by one week of intensive sampling. On d 16 through 18, hay and supplement samples were taken. Hay intake was measured on d 16 through 18. Hay refusals were weighed and subsampled (10%/d). To evaluate effects of corn processing on total tract passage rate, cows were dosed with 250 g ytterbium-labeled native grass hay on d 15 (Teeter et al., 1984). An initial fecal composite (0 hour) and timed fecal samples were collected to represent 24, 36, 48, 60, 72 and 96 h after Yb dosing. Fecal samples were dried (55° C) and stored (25° C) for later analysis.

To evaluate the effect of corn processing on rate and extent of hay degradation in the rumen, approximately 4.9 g of native grass hay, ground through a 5-mm screen, were placed in 10 x 20 cm dacron bags[1]. Bags were attached to weighted strings and suspended in the rumen of each cow for 96, 48, 24, 12, 6 and 0 h. All bags were removed simultaneously from the rumen, placed in buckets of tap water, rinsed until effluent was clear and dried (100° C). Rate of disappearance was estimated from the regression of the natural logarithm of percentage digestible hay remaining over time. Lag time was calculated as (4.60 - intercept)/ rate.

Digesta sampling was conducted on d 17 through 19. Duodenal (500 ml) and fecal (450 g as-is) samples were collected to represent every 4 h on a 24-h

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[1]Ankom, Fairport, NY.

TABLE II

CHEMICAL COMPOSITION OF NATIVE GRASS HAY AND SUPPLEMENTS

			Processing Method			
	Hay[a]	Control	Whole	Cracked	Ground	Pelleted
	% (DM basis)					
CP	4.09	40.75	22.62	22.44	22.44	22.31
NDF	75.1	25.09	23.06	23.51	20.07	20.72
Starch	1.32	.93	41.24	40.19	39.32	39.04
Ash	6.45	9.18	4.14	4.55	4.91	4.42
AIA	4.15	.089	.050	.072	.100	.077

[a]Native grass hay composed of Schizachyrium scoparium, Andropogon gerardi, Panicum virgatum and Sorghastrum nutans.

clock with no two samples being collected within 8 h of each other. Samples were immediately analyzed for pH with a combination electrode, composited by pen, refrigerated (1° C) and later subsampled. To evaluate ruminal fluid kinetics, Co EDTA (500 ml; 1 g Co; Uden et al., 1980) was dosed in 5 ruminal locations before supplement feeding on d 20. Ruminal sampling was performed at 0, 1, 2, 3, 4, 5, 6, 8, 10, 12, 18 and 24 h post-feeding. Ruminal samples (500 ml) were analyzed for pH, strained through four layers of cheesecloth, acidified (1 ml 20% H_2SO_4/50 ml ruminal fluid) and then frozen (-15° C). Additional ruminal samples (1,000 ml) were collected at 0, 6, 12 and 18 h post-dosing for microbial isolation. Ruminal samples were strained and added to a composite bottle (400 ml of fluid:100 ml 10% formalin) and refrigerated (1° C). Composite fluid was centrifuged at 1,000 x g for 5 min to remove feed particles and protozoa and the supernatant was recentrifuged at 20,000 x g for 20 min. The supernatant was discarded and the remaining pellet was resuspended and recentrifuged in: 1) a saline solution, and 2) distilled H_2O. The final pellet was frozen, lyophilized and stored in airtight containers for analysis (25° C). The bacterial pellet was measured for purine (Zinn and Owens 1982) and N (AOAC, 1975) content. Purine:N ratio from the bacterial pellet used in conjunction with purine content of duodenal digesta was used to estimate bacterial N flow to the duodenum. Microbial efficiency was determined by bacterial N flow to the duodenum divided by the true OM disappearance in the rumen.

On day 21, cows were ruminally evacuated starting 5 h after supplement feeding. Particulate and liquid fractions were separated by screening. Duplicate subsamples (250 g as is) of particulate and liquid fractions were frozen (-15° C) prior to lyophilization.

Supplement, hay, hay refusal and digesta composites were ground and analyzed for dry matter (DM), ash, crude protein (CP; N x 6.25), neutral detergent

fiber (NDF) and acid insoluble ash (AIA, 2N HCL method; Van Keulen and Young, 1977). Starch content of hay, supplement and digesta samples was determined (MacRae and Armstrong, 1968). Acid insoluble ash ratios were used to estimate fecal output and nutrient digestibility. Ammonia content of digesta and fecal samples was performed by magnesium oxide distillation (AOAC, 1975) and used to determine ammonia flow to the duodenum and feces.

Timed fecal samples were ground (1-mm). Dry matter content was determined (100° C, 24 h) followed by ashing (500° C, 8 h). Ytterbium extraction of timed fecal samples was performed with EDTA (Hart and Polan, 1984). Diluted samples were analyzed for ytterbium concentration by atomic absorption spectrophotometry using a nitrous oxide-acetylene flame. Particulate passage rate was determined from the slope of the regression of the natural logarithm of Yb concentration over time. Since the 24 and 36 h values were on the upslope of the curve only 48, 60, 72 and 96 h sample values were used in the analysis.

Timed ruminal fluid samples were analyzed for ammonia concentration with the phenol-hypochlorite assay (Broderick and Kang, 1980). Cobalt concentrations of timed ruminal fluid samples were determined by atomic absorption spectrophotometry (Chase and Hibberd, 1987). Liquid dilution rate was estimated as the regression of the natural logarithm of cobalt concentration over time.

Data were subjected to least squares analysis with period, animal and treatment included in the model. A single contrast was conducted to evaluate the cottonseed control vs the average of the corn supplements. Within corn supplements, differences between least square treatment means were detected by LSD (Steel and Torrie, 1980). Ruminal data were analyzed as a split plot over time with the effects of period, treatment, and cow tested with period X treatment X cow and hour with the residual. A repeated measures analysis was conducted

to determine an adjusted P value (Huynh and Felt, 1976) for treatment X hour. Differences between least square treatment means at each sampling time were detected by LSD.

Experiment 2

Seventy-six lactating crossbred cows (average weight 511 kg) were blocked by calf age and calf sex to one of four treatments for a 105-d study. Treatments were identical to Trial 1 with the exception that the cottonseed meal control was not used. Supplements were formulated to meet the protein requirement of a 450 kg lactating cow (NRC, 1984). A salt / mineral premix (50 % trace mineralized salt[2], 45% dicalcium phosphate, 5% potassium chloride) was offered free choice. Animals were individually fed their respective supplements at 0800 h each day. Supplement intake was adjusted so that the 7-d supplement allowance was fed in 5 days. Cattle grazed a 120 ha dormant native grass pasture composed of little bluestem (Schizachyrium scoparium), big bluestem (Andropogon gerardi), switchgrass (Panicum virgatum) and indiangrass (Sorghastrum nutans).

Prior to the initiation of the study, cows were individually fed cottonseed meal (1.2 kg / hd / day) for 5 consecutive days. Initial cow weight and body condition scores were evaluated after a 24-h fast. Four independent condition scores were averaged for each cow. Initial and subsequent calf weights were taken after a 6-h fast. Interim cow weights and body condition scores were evaluated every 3 weeks following an 8-h fast. At the conclusion of the study, cows were individually fed cottonseed meal for 5 consecutive days and weighed following a 24-h fast. To evaluate forage quality, three esophageally fistulated

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[2]TM salt composed of 16% zinc, 12% iron, 3% magnesium, 1% copper, 1% potassium, .6% iodine, .3% cobalt and 1% mineral oil.

steers were used to obtain diet samples every 21 d. Esophageal masticates were immediately placed on ice for transport to the laboratory and stored at -15° C prior to lyophilization. Dried masticate samples were ground (1 mm) and analyzed for DM, CP NDF and ash (AOAC, 1975).

Cow and calf performance data were subjected to least squares analysis with cow age, calf sex, treatment and sex x treatment included in the model. Calf age was included as a covariate. Differences between least squares treatment means were detected by LSD (Steel and Torrie, 1980).

Experiment 3

Two Hereford steers (750 kg) were used to evaluate the degradation of whole shelled corn in the digestive tract. Animals were individually housed in concrete slatted pens (4.7 x 2.3 m) with free access to fresh water. Coarsely chopped (5-cm screen) native grass hay was offered free choice. The supplement consisted of whole shelled corn blended with pelleted cottonseed meal. The corn was screened to remove broken and cracked kernels, followed by visual inspection to remove additional damaged kernels. Corn kernels (12) were randomly selected and weighed to estimate whole kernels / kg and whole kernel intake. Supplements were fed at 0800 each day. Hay feeders were weighed and fresh hay amounting to the previous day's intake plus 4.5 kg was fed following supplement consumption. Hay refusals were discarded during the sampling period. Steers were adapted to diets for 12 d followed by 3 d of sampling. On d 13 through 15, hay and supplement samples were taken. Hay intake was measured on d 13 through 15. Hay refusals were weighed and subsampled (10%/d). Total fecal collection was performed on d 13 - 15. A 10 % subsample was taken to measure whole kernel survival through the digestive

tract. Duplicate fecal samples (350 g as is) were taken daily to estimate total tract starch disappearance.

Results and Discussion

Experiment 1

Total OM intake was not affected (P=.12) by treatment (Table III). Hay OM intake tended (P<.10) to be higher for the cottonseed meal control (9.4 kg/d) than the corn-based supplements (average 8.6 kg/d). Depressed hay intake with grain supplementation has been documented (Chase and Hibberd, 1987; DelCurto et al., 1990). Compared to previous studies, the depression in hay intake observed in this study is small which may be due to the low level of supplemental corn (.3% BW). Low level energy supplementation, less than .35% BW, when protein is not limiting, may not decrease forage intake (Clanton and Sanson, 1990; Pordomingo et al., 1991). There was no significant change in hay OM intake associated with corn processing method.

Total OM flow to the duodenum was not affected (P=.36) by treatment (Table III). Although not significant, microbial OM flow to the duodenum appeared to increase with corn supplementation. Ruminal OM disappearance, corrected for microbial OM, tended to be lower (P<.10) for the control (4.80 kg/d) compared to the corn-based supplements (average 5.55 kg/d). Ruminal OM disappearance was decreased (P<.05) for ground corn (4.79 kg/d) compared to cracked or pelleted supplements (average 5.62 kg/d). The small particle size of the ground corn supplement may have increased ruminal evasion and reduced the quantity of supplement degraded in the rumen and the beneficial effects of supplemental protein on ruminal fiber fermentation.

TABLE III

EFFECT OF SUPPLEMENTAL GRAIN PROCESSING ON OM INTAKE AND DIGESTION IN BEEF COWS FED LOW QUALITY NATIVE GRASS HAY

		Processing Method				
Item	Control	Whole	Cracked	Ground	Pellet	SE
Intake						
Total, kg/d	10.81	10.89	11.73	10.88	11.34	.408
Hay OM:						
kg/d[a]	9.40	8.25	9.09	8.26	8.71	.407
% of BW	1.45	1.33	1.42	1.29	1.32	.078
Flow, kg/d						
To the duodenum	6.00	5.60	6.11	6.09	5.73	.361
True[d]	4.82	4.16	4.65	4.78	4.42	.320
Microbial	1.19	1.45	1.46	1.31	1.32	.110
To the feces	4.68	4.31[c]	5.00[b]	4.55[bc]	4.41[bc]	.272
Disappearance, kg/d						
Ruminal[a]	4.80	5.28[ef]	5.62[e]	4.79[f]	5.61[e]	.238
Lower gut	1.33	1.29[bc]	1.10[c]	1.54[b]	1.32[bc]	.145
Total tract[a]	6.13	6.57[bc]	6.73[bc]	6.33[c]	6.93[b]	.221
Digestibility, % of intake						
Rumen	45.0	48.7[bc]	48.0[bc]	43.9[c]	49.3[b]	1.97
Lower gut	12.2	11.8[b]	9.5[c]	14.1[b]	11.8[b]	1.22
Total tract	57.2	60.5[bc]	57.4[c]	58.0[bc]	61.1[b]	1.29
Digestibility, % of total						
Ruminal	78.5	80.5[ef]	83.5[e]	75.6[f]	80.5[ef]	2.21
Lower gut	22.2	23.1[ef]	18.1[f]	25.1[e]	22.6[ef]	1.86

[a]Control vs average of corn supplements ($P<.10$).

[b,c]Means in a row with different superscripts differ ($P<.10$).

[d]Corrected for microbial OM.

[e,f]Means in a row with different superscripts differ ($P<.05$).

Total tract OM disappearance was increased (P<.10) with grain supplementation (avg. 6.6 kg/d) compared to the cottonseed meal control (6.1 kg/d; Table III). Chase and Hibberd (1987) also observed a slight increase in total tract OM disappearance with low levels (1 kg/d) of corn supplementation. Within corn supplements, total tract OM disappearance was lower (P<.10) for ground compared to pelleted corn. Because the only difference between these two treatments is the pelleting process, perhaps pelleting reduces the deleterious effects of starch on forage utilization.

Ruminal OM digestibility (% of intake) tended to be lower (P<.10) for the ground corn supplement when compared to the pelleted supplement (43.9% vs 49.3 %; Table III). Compared to the cottonseed meal control, corn supplementation did not alter total tract OM digestibility. Within corn processing methods, total tract OM digestibility was lower (P<.05) for cracked compared to pelleted corn (57.4% vs 61.1%) while whole and ground corn treatments were intermediate. Due to the high digestibility of grain-based supplements, intake and digestion of OM should be improved, however, negative associative effects on hay digestion may have minimized the potential benefit of the grain-based supplements.

Ruminal NDF disappearance and digestibility tended to be lower (P<.10) for ground corn than for other corn processing treatments (Table IV). Total tract NDF digestibility (% of intake), however, was not affected (P=.14) by treatment. Although ground corn may decrease ruminal NDF digestibility, increased disappearance of NDF in the lower gut compensated so that total tract digestibility was not affected.

DelCurto et al. (1990) fed a 60% grain sorghum-40% soybean meal (low protein, high energy) supplement and observed similar NDF digestion when compared to a high protein, high energy ration. When feeding high energy

TABLE IV

EFFECT OF SUPPLEMENTAL GRAIN PROCESSING ON NDF INTAKE AND DIGESTION IN BEEF COWS FED LOW QUALITY NATIVE GRASS HAY

		Processing Method				
Item	Control	Whole	Cracked	Ground	Pellet	SE
Intake, kg/d	7.97	7.25	8.01	7.23	7.56	.337
Flow, kg/d						
To the duodenum	3.64	3.29	3.61	3.64	3.42	.228
To the feces	3.35	2.99[b]	3.56[a]	3.20[ab]	3.17[ab]	.216
Disappearance, kg/d						
Ruminal	4.34	3.96[cd]	4.41[c]	3.59[d]	4.14[cd]	.213
Lower gut	.28	.30[ab]	.04[b]	.44[a]	.24[ab]	.110
Total tract	4.62	4.26	4.45	4.03	4.38	.205
Digestibility, % of intake						
Rumen	54.9	54.6[c]	55.1[c]	49.4[d]	54.5[c]	1.93
Lower gut	3.4	4.2[cd]	.5[d]	5.9[c]	3.3[cd]	1.57
Total tract	58.4	58.8	55.6	55.3	57.8	1.63
Digestibility, % of total						
Ruminal	94.0	92.9[ab]	99.1[a]	89.3[b]	94.5[ab]	2.68
Lower gut	13.0	15.6[ab]	1.7[b]	20.5[a]	10.8[ab]	5.45

[a,b]Means in a row with different superscripts differ ($P<.05$).

[c,d]Means in a row with different superscripts differ ($P<.10$).

supplements, however, NDF digestion tended to be depressed. In their study, moderate protein supplements (22% CP) fed at .6% BW increased both intake and utilization of low quality forage. The corn treatments in the present trial contained 21% CP and were fed at the rate of .6% of BW.

Although formulated to be similar, starch intake (Table V) was greater ($P<.05$) for the whole and cracked supplements than for the ground or pelleted supplements. Duodenal starch flow was higher ($P<.05$) for the ground corn than for whole, cracked, pelleted or control supplements. Ewing et al. (1986) observed that as corn particle size was reduced, rate of passage of corn was increased. Association of smaller corn particles with the ruminal liquid fraction may have increased ruminal outflow of the ground corn. Consequently, ruminal digestibility, as a % of intake, was lower ($P<.05$) for the ground corn than the whole, cracked or pelleted supplements (71.7 vs 94.1, 86.1 and 79.2%, respectively).

Sampling technique or cannula design may have prevented accurate data collection for the whole corn treatment and, to a lesser extent, the cracked corn treatment. The accumulation of whole corn in the bottom of the rumen may contribute to uneven outflow of whole corn from the rumen, resulting in inaccurate estimation of ruminal whole corn starch digestion. Results indicate starch synthesis occurred in the lower gut of cows fed the whole and cracked corn supplements. In contrast, with ground or pelleted corn supplements, lower gut starch digestion averaged 83.9%. The use of a reentrant duodenal cannula to ensure representative sampling may aid in accurate data collection when feeding whole grains.

Fecal starch flow was greatest ($P<.05$) for the whole (247.1 g/d) and cracked (170.6 g/d) corn supplements compared to 67.2 and 38.6 g/d for the ground and pelleted supplements, respectively. Total tract starch digestion was reduced ($P<.05$) for the whole (80.4%) and cracked (86.2%) corn supplements

TABLE V

EFFECT OF SUPPLEMENTAL GRAIN PROCESSING ON STARCH INTAKE AND DIGESTION IN BEEF COWS FED LOW QUALITY NATIVE GRASS HAY

		Processing Method				
Item	Control	Whole	Cracked	Ground	Pellet	SE
Intake, g/d[a]	147.4	1,252.1[b]	1,240.5[b]	1,199.1[c]	1,198.3[c]	5.80
Flow, g/d						
To the duodenum[a]	20.7	74.5[e]	172.3[d]	339.3[b]	249.3[c]	24.21
To the feces[a]	12.5	247.1[b]	170.6[b]	67.2[c]	38.6[c]	26.13
Disappearance, g/d						
Ruminal[a]	126.7	1,177.6[b]	1,068.3[c]	859.8[e]	949.0[d]	22.55
Lower gut[a]	8.2	-172.6[d]	1.6[c]	272.1[b]	210.7[b]	27.33
Total tract[a]	134.9	1,005.0[d]	1,069.9[cd]	1,131.9[bc]	1,159.7[b]	23.61
Digestibility, % of intake						
Ruminal	86.8	94.1[b]	86.1[bc]	71.7[d]	79.2[cd]	4.03
Lower gut	5.8	-13.7[h]	.1[g]	22.7[f]	17.5[f]	3.13
Total tract	92.1	80.4[c]	86.2[c]	94.4[b]	96.8[b]	2.53
Digestibility, % of total						
Entering:						
Rumen	93.7	117.7[b]	100.1[c]	75.7[d]	81.8[d]	3.70
Lower gut	-1.5	-555.0[c]	-20.4[b]	87.1[b]	88.1[b]	125.55
Fecal pH[a]	6.61	6.45[a]	6.34[b]	6.15[c]	6.32[b]	.027

[a]Control vs average of corn supplements ($P<.05$).

[b,c,d,e]Means in a row with different superscripts differ ($P<.05$).

[f,g,h]Means in a row with different superscripts differ ($P<.10$).

compared to the pelleted (94.4%) and ground (96.8%) corn supplements. Fecal pH (Table V) was lower ($P<.05$) for ground corn than for whole, cracked or pelleted corn supplements (6.15 vs 6.45, 6.34 and 6.32, respectively) suggesting that lower gut starch fermentation may have been increased with ground corn.

Nitrogen intake tended to be greater ($P<.10$) for the cottonseed meal control (164.3 g/d) compared to the corn-based supplements (156.7 g/d; Table VI). Total N intake was affected by supplemental corn processing. Most of these differences, however, were due to changes in hay intake. Ammonia ($P<.10$) and feed N ($P<.05$) flow to the duodenum were increased with cottonseed meal compared to the corn supplements. In addition, bacterial N flow was reduced ($P<.05$) with cottonseed meal supplementation. Perhaps ruminal available energy rather than ammonia limited the growth of microorganisms on the cottonseed meal control. Bacterial N flow to the duodenum tended ($P<.10$) to be higher for whole (107.9 g/d) or cracked corn (108.5 g/d) compared to the ground and pelleted supplements (97.0 and 96.8 g/d, respectively). Increased bacterial N flow with the coarser whole and cracked corn may be due to an extended release of ammonia and energy as these larger particles are degraded more slowly in the rumen. However, lack of dilution effect with whole corn may have overestimated bacterial N flow to the duodenum. In addition, rapid ammonia utilization by bacteria on the ground or pelleted supplements could have created a ruminal ammonia deficiency which may have restricted microbial growth. Herrera-Saldina (1990) suggests there is an optimal rate of degradation for protein and carbohydrates which should maximize microbial protein synthesis. There was a trend towards increased ($P<.10$) microbial efficiency, (bacterial N / kg of OM truly fermented), for the whole or ground supplements (16.2 and 16.0) compared to the pelleted supplement (14.3).

TABLE VI

EFFECT OF SUPPLEMENTAL GRAIN PROCESSING ON NITROGEN INTAKE AND DIGESTION IN BEEF COWS FED LOW QUALITY NATIVE GRASS HAY

		Processing Method				
Item	Control	Whole	Cracked	Ground	Pellet	SE
Intake, g/d[a]	164.3	155.0[bc]	160.8[b]	153.5[c]	157.3[bc]	2.89
Total flow, g/d						
To the duodenum	193.3	177.5	185.4	185.8	170.0	8.78
NH_3-N[a]	6.2	4.9	4.9	4.7	4.3	.38
NAN	187.1	172.6	180.6	181.1	165.8	8.61
Bacterial N[d]	91.7	107.9[b]	108.5[b]	97.0[c]	96.8[c]	3.78
Feed N[d]	95.5	64.7[c]	72.0[c]	84.1[b]	69.0[c]	7.55
To the feces	87.6	80.4[c]	90.9[b]	90.8[b]	79.2[c]	4.02
NH_3-N	1.2	1.2	1.2	1.2	1.2	.08
NAN	86.3	79.2[c]	89.7[b]	89.6[b]	78.0[c]	3.99
N efficiency, % of intake	116.8	113.7[bc]	115.1[bc]	121.0[b]	108.3[c]	4.17
Feed N bypass, % of intake[d]	57.9	41.4[c]	44.7[bc]	55.1[b]	44.2[bc]	4.24
Microbial efficiency[e]	15.4	16.2[b]	15.4[bc]	16.0[b]	14.3[c]	.66
NAN disappearance, g/d						
Ruminal	-22.8	-17.5[bc]	-19.7[bc]	-27.5[b]	-8.5[c]	6.65
Lower gut	100.8	93.4	90.9	91.5	87.8	6.69
Total tract	78.0	75.8[e]	71.1[ef]	64.0[f]	79.3[e]	3.43

TABLE VI (Continued)

Item	Control	Processing Method				SE
		Whole	Cracked	Ground	Pellet	
NAN digestibility, % of intake						
Rumen	-13.0	-10.5[bc]	-12.1[bc]	-17.9[b]	-5.6[c]	4.09
Lower gut[a]	60.8	59.2	56.7	59.7	55.7	3.28
Total tract	47.8	48.6[f]	44.6[fg]	41.8[g]	50.1[f]	2.05
Digestibility, % of total						
Ruminal	-39.9	-19.1[fg]	-33.0[fg]	-66.8[f]	-10.8[g]	15.85
Lower gut	122.2	106.8[fg]	118.6[fg]	140.3[f]	102.8[g]	11.6

[a]Control vs average of corn supplements (P<.10).

[b,c]Means in a row with different superscripts differ (P<.10).

[d]Control vs average of corn supplements (P<.05).

[e]g microbial N/kg OM truly fermented.

[f,g]Means in a row with different superscripts differ (P<.05).

Within corn treatments, feed N flow was increased ($P<.10$) for ground corn compared to the other supplements (84.1 vs an average of 68.6 g/d). This response provides further evidence that the ground corn supplement evaded the rumen. Feed N bypass (% of intake) was greater ($P<.05$) for cottonseed meal than corn-based supplements. This response contrasts with published data (NRC, 1985). Because the cottonseed control was fed as a meal, increased bypass may be more attributable to flow than actual ruminal degradability.

Total tract NAN disappearance was lower ($P<.05$) for ground corn (64.0 g/d) compared to whole or cracked corn supplements (75.8 and 79.3 g/d, respectively; Table VI). Lower gut NAN digestibility tended to be higher for the cottonseed meal control than for the corn supplements (54.2% vs an average of 51.2%). Total tract NAN digestibility was lower ($P<.05$) for ground corn compared to whole or pelleted corn supplements. Lower gut NAN was higher ($P<.05$) for ground corn (140.3) compared to pelleted corn (102.8).

Treatment differences in ruminal ammonia concentrations were influenced by sampling time (time x treatment interaction, $P<.0001$; Figure 1). Ruminal ammonia concentrations peaked at 1 h postsupplementation for the ground and pelleted supplements while other treatments peaked 2 to 3 h post supplementation. Ruminal protein degradation may have been enhanced with ground or pelleted corn resulting in a rapid increase in ammonia concentrations. After the peak, ruminal ammonia concentrations declined steadily, reaching pre-feeding levels by 12 h after feeding. With ground or pelleted corn, ruminal ammonia concentrations were below the minimal level of 2-5 mg/dl, recommended by Satter and Slyter (1974), by 4 h postfeeding and remained below 1 mg/dl for an additional 14 h. Whole corn supplementation consistently increased ($P<.05$) ruminal ammonia concentrations throughout the day

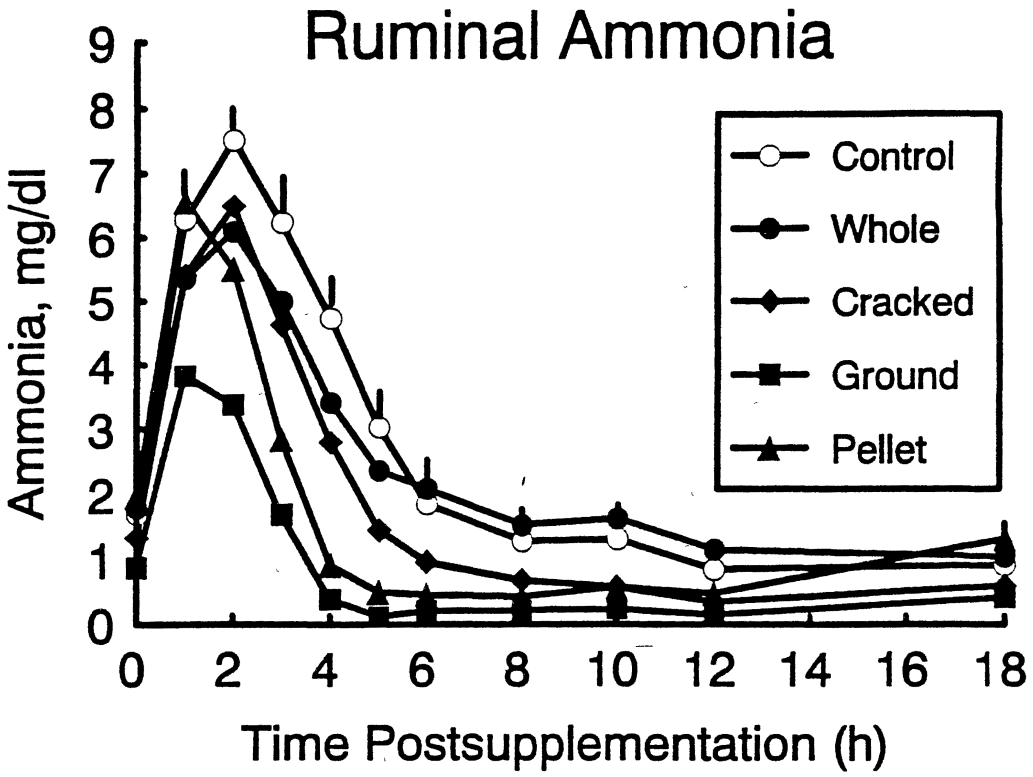

Figure 1. Effect of Grain Processing on Ruminal Ammonia

compared to ground corn. This response may be due to an extended availability of whole corn protein and energy due to reduced rate of corn fermentation.

Ruminal pH (Figure 2) was lower ($P<.05$) at 0 and 1 h postfeeding for whole corn supplements than the ground and pelleted supplements. Corn processing did not influence ruminal pH from 2 to 5 h after feeding. Ruminal pH for whole and cracked corn supplements appeared to be lower from 6 through 18 h after feeding. Reduced ruminal pH with coarsely processed corn may be due to extended starch availability and slower energy release than with less processed grains. In contrast, Mould et al. (1983) observed lower ruminal pH values for ground and pelleted or whole and pelleted barley when compared to whole grain, but only when the level of barley was 75% of the ration, or greater.

Compared to the cottonseed meal control, hay DM disappearance from dacron bags was reduced ($P<.05$) with corn supplementation at all incubation times (Table VII). Rate of disappearance (%/h) was also greater ($P<.05$) for the cottonseed meal control. Increased ruminal ammonia concentrations with the control may have stimulated fiber digestion by cellulolytic bacteria. Within corn supplements, disappearance rate tended to increase ($P<.10$) with cracked corn compared to ground or pelleted supplements (3.43 vs 3.08 and 3.00, respectively). The rapid fermentation of ground or pelleted corn may decrease activity of cellulolytic bacteria, therefore reducing rate of disappearance. There was a trend towards reduced lag time with cottonseed meal compared to corn-based supplements (4.12 vs an average of 5.73 h), suggesting bacterial colonization on hay fibers may be accelerated with protein supplementation.

Compared to the corn supplements, cottonseed meal supplementation did not affect particulate passage rate (Table VIII). In contrast, Chase and Hibberd (1987) observed that increasing level of corn grain decreased particulate passage rate. Particulate passage rate tended ($P<.10$) to be higher for cracked or ground

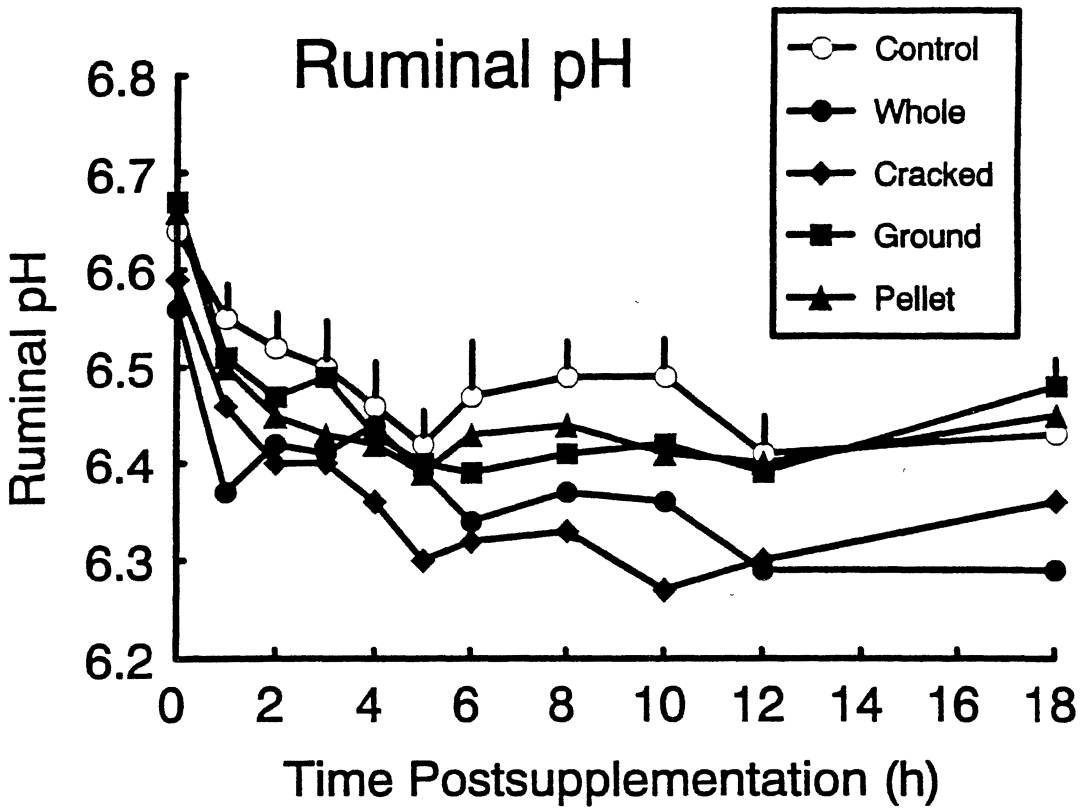

Figure 2. Effect of Grain Processing on Ruminal pH

TABLE VII

EFFECT OF SUPPLEMENTAL GRAIN PROCESSING ON THE DEGRADATION OF HAY IN DACRON BAGS INCUBATED IN THE RUMEN OF BEEF COWS

		Processing Method				
Item	Control	Whole	Cracked	Ground	Pelleted	SE
Incubation time, h						
6[a]	27.36	26.18	25.55	25.62	25.78	.38
12[a]	34.17	32.94[b]	32.37[b]	29.85[c]	31.81[b]	.47
24[a]	45.19	44.48[b]	43.48[bc]	39.76[d]	41.41[cd]	.87
48[a]	64.92	61.57[bc]	62.17[b]	59.83[d]	60.32[cd]	.48
96[a]	75.05	74.58	73.78	73.76	74.50	.37
Rate of disappearance, %/h[a]	3.73	3.19[ef]	3.43[e]	3.08[f]	3.00[f]	.14
Lag time, h[g]	4.12	6.37	4.78	5.36	6.41	.68

[a]Control vs average of corn supplements ($P<.05$).

[b,c,d]Means in a row with different superscripts differ ($P<.05$).

[e,f]Means in a row with different superscripts differ ($P<.10$).

[g]Control vs average of corn supplements ($P<.10$).

TABLE VIII

EFFECT OF SUPPLEMENTAL GRAIN PROCESSING ON DIGESTA PASSAGE IN BEEF COWS FED LOW QUALITY NATIVE GRASS HAY

		Processing Method				
Item	Control	Whole	Cracked	Ground	Pellet	SE
Particulate passage rate, %/h	2.3	2.2[b]	2.7[a]	2.6[a]	2.5[ab]	.17
Liquid dilution rate, %/h	9.4	8.6	9.4	9.2	9.8	.50
Liquid flow rate, l/h	8.0	8.6	9.0	9.4	9.3	.94
Ruminal volume, l	86.5	101.3	99.5	102.1	96.2	12.1
Liquid turnover time, h	10.8	12.1[c]	11.1[cd]	11.1[cd]	10.3[c]	.54

[a,b]Means in a row with different superscripts differ ($P<.10$).

[c,d]Means in a row with different superscripts differ ($P<.05$).

corn supplements compared to whole corn. Ruminal liquid kinetics were not affected by treatment with the exception of turnover time. Turnover time (h) was increased ($P<.05$) with whole corn compared to pelleted corn (12.1 vs 10.3).

Experiment 2

The CP content (OM basis) of esophageal masticates decreased from 5% on December 20 to 4% by January 31 (Figure 3). In contrast, the NDF content of esophageal masticates appeared to increase (Figure 4). These changes in chemical composition are typical of trends documented by Waller et al. (1962). Continuous grazing coupled with leaching of plant nutrients reduced the nutritional quality of the standing forage crop as the season progressed. Cow weight change during the 105-d experiment was not affected ($P=.24$) by treatment (Table IX). Cows fed the cracked corn supplement tended to lose less body condition (-.61 units) compared to cows fed the whole corn supplement (-.81 units). Calf weight gain tended to be reduced ($P<.10$) for the cracked corn compared to the other supplements.

Experiment 3

Whole corn disappearance through the tract averaged 71.7% while total tract starch disappearance averaged 62.9% (Table X). Fecal starch output was 404 g/d while fecal whole kernel starch was 349 g/d. Consequently, 86.4 % of the fecal starch was associated with the whole kernels. This suggests that minimal starch degradation occurs in whole corn kernels and that chewing and rumination may play a vital role in making the corn starch available.

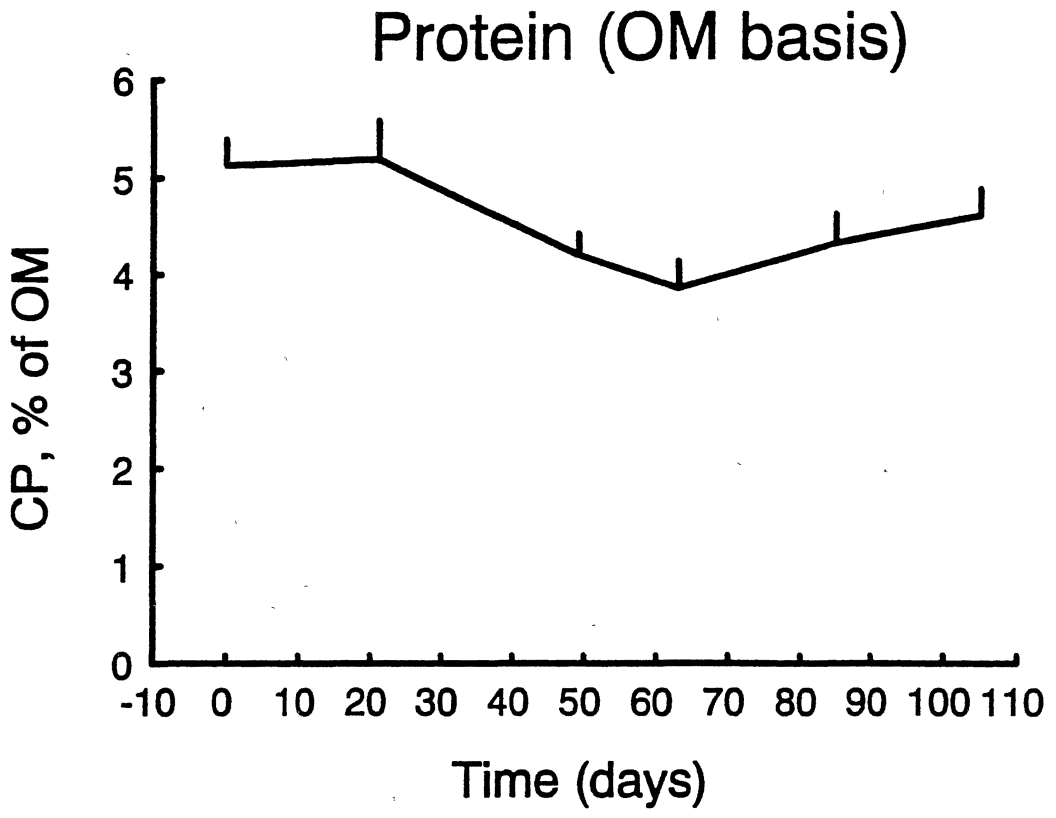

Figure 3. Seasonal Changes in CP Composition of Dormant Native Grass

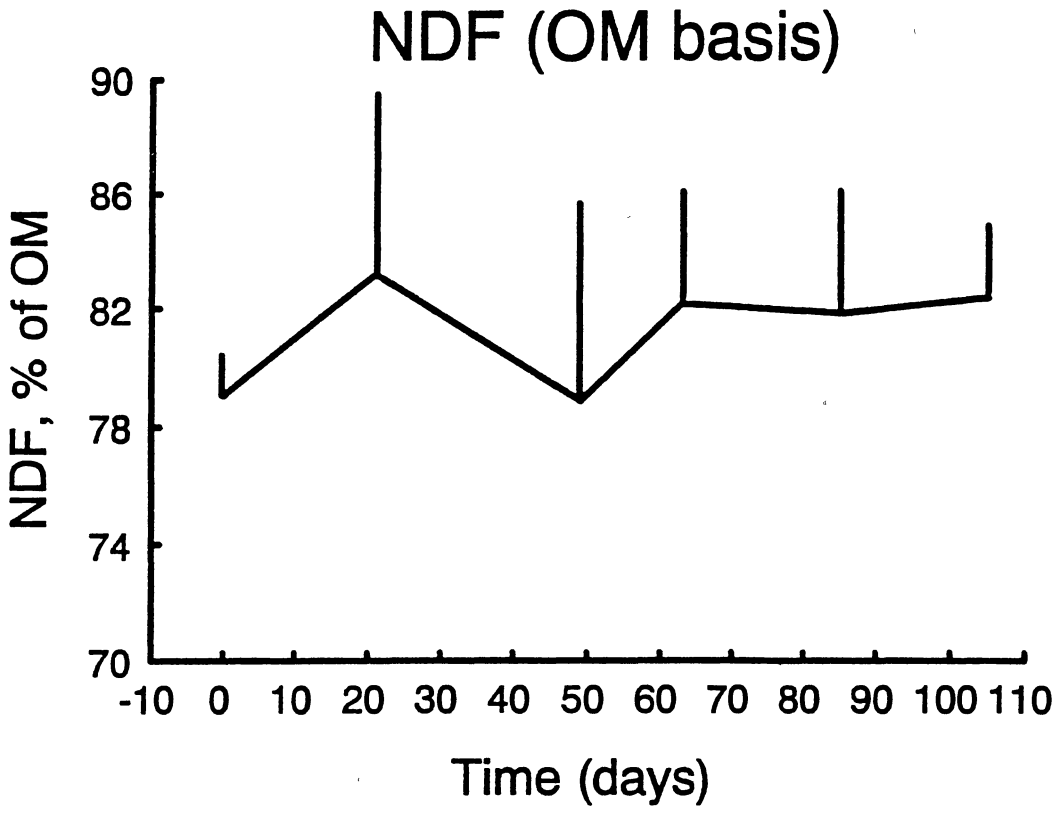

Figure 4. Seasonal Changes in NDF Composition of Dormant Native Grass

TABLE IX

EFFECT OF SUPPLEMENTAL GRAIN PROCESSING ON THE PERFORMANCE OF LACTATING BEEF COWS AND THEIR CALVES GRAZING DORMANT NATIVE RANGE

	Processing Method				
	Whole	Cracked	Ground	Pellet	SE
Cow body weight, kg					
Day 0	483.73	493.52	487.25	485.78	11.12
Day 105	409.62	420.13	424.17	415.82	9.30
Change	-74.11	-69.36	-67.12	-69.96	4.30
Cow body condition, units					
Day 0	5.51	5.61	5.55	5.49	.09
Day 105	4.70[b]	5.00[a]	4.82[ab]	4.83[ab]	.12
Change	-0.81[b]	-0.61[a]	-0.73[ab]	-0.66[a]	.07
Calf weight, kg					
Day 0	87.90[d]	80.22[c]	84.33[cd]	86.30[d]	1.99
Day 105	153.02[d]	141.35[c]	149.67[d]	154.18[d]	3.16
Change	65.12[a]	61.13[b]	65.34[a]	67.87[a]	1.82

[a,b]Means within a row with different superscripts differ ($P<.10$).

[c,d]Means within a row with different superscripts differ ($P<.05$).

TABLE X

EFFECT OF RUMINATION ON WHOLE CORN APPEARANCE IN FECES AND FECAL STARCH CONTENT

Item	Whole Kernels	Starch
Consumed	5,330	1,087 g/d
In feces	1,506	404 g/d
Disappearance	71.73 %	62.88 %
Fecal starch		404 g/d
Fecal whole kernel starch		349 g/d
Fecal starch in whole kernels		86.4 %

Implications

Although supplementation with whole corn reduced total tract starch digestion, digestible OM intake and cow performance were not affected. Consequently, the use of whole corn in range supplements may be justified if significant feed processing savings can be realized. This study also suggests that the site of digestion of supplements can be affected by particle size. Increased starch and feed nitrogen flow to the duodenum suggests that a significant portion of ground corn evades ruminal fermentation. This implies that particle size could be used to help direct nutrients to the rumen or the intestines.

CHAPTER IV

SUMMARY AND CONCLUSIONS

Energy supplements are composed of oilseed meals such as soybean or cottonseed meal blended with grains such as milo, corn or wheat. The starch in cereal grains supplies a readily available source of energy for the lactating beef cow. Supplements containing high levels of cereal grains, however, have been shown to decrease forage digestibility and intake (Chase and Hibberd, 1987). Decreased forage utilization with grain supplementation may be due to a sudden decrease in ruminal pH (Orskov and Fraser, 1975) which may decrease activity of cellulolytic bacteria (Mould et al., 1983). Alternatively, decreased ruminal ammonia concentration due to competition between amylolytic and cellulolytic bacteria may be responsible (Yokoyama and Johnson, 1988). In the current study, low level grain supplementation (<.3% BW) did not affect forage digestibility and intake. Perhaps the energy release from the starch was slow enough that cellulytic activity was not limited. Our studies support the theory that low levels of grain with adequate CP will maintain forage intake and utilization. The different methods of supplemental corn processing appear to affect forage utilization in unique ways. With whole shelled corn, total tract starch digestion was decreased approximately 15 %, yet minimal effects on cow/calf performance were observed. Bacterial N flow to the duodenum tended to increase with whole or cracked corn, however forage utilization was not affected. Site of starch digestion may possibly be influenced with processing. Ground corn appeared to evade ruminal fermentation, therefore increasing the chance of being digested in

the intestines. Due to the findings in the present studies, it appears that the method of processing corn for range supplements should be based primarily on cost.

Literature Cited

AOAC. 1975. Official Methods of Analysis (12th Ed.). Association of Official Analytical Chemists, Washington,DC.

Bartle, S.J., J.R. Males and R.L. Preston. 1984. Effect of energy intake on the postpartum interval in beef cows and the adequacy of the cow's milk production for calf growth. J. Anim. Sci. 58:1068.

Barton, K.J. and C.A. Hibberd. 1984. Effects of protein supplementation on ruminal fermentation of low quality native grass hay in steers. Okla. Agr. Exp. Sta. Res. Rep. MP-116:168.

Bellows, R.A. and R.E. Short. 1978. Effects of precalving feed level on birth weight, calving difficulty and subsequent fertility. J. Anim. Sci. 46:1522.

Boggs, D.L., E.F. Smith, R.R. Schalles, B.E. Brent, L.R. Corah and R.J. Pritt. 1980. Effects of milk and forage intake on calf performance. J. Anim. Sci. 51:550.

Broderick, G.A. and J.H. Kang. 1980. Automated simultaneous determination of ammonia and total amino acids in ruminal fluid and in vitro media. J. Dairy Sci. 63:64.

Butson, S., R.T. Borg and R.T. Hardin. 1980. Factors influencing weaning weights of range and dairy-beef calves. Can. J. Anim. Sci. 60:127.

Canton J.S., A.S. Freeman and M.L. Galyean. 1988. Influence of protein supplementation on forage intake, passage rates in steers grazing dormant blue gramma rangeland. J. Anim. Sci. 66:2262.

Cecava, M.J., N.R. Merchen, L.L. Berger, R.I. Mackie and G.C. Fahey Jr. 1991. Effects of dietary energy level and protein source on nutrient digestion and ruminal nitrogen metabolism in steers. J. Anim. Sci. 69:2230.

Chase, C.C. and C.A. Hibberd. 1987. Utilization of low-quality native grass hay by beef cows fed increasing quantities of corn grain. J. Anim. Sci. 65:557.

Clanton, D.C. and D.R. Zimmerman. 1968. Symposium on pasture methods for maximum production in beef cattle: Protein and energy requirements for female beef cattle. J.Anim. Sci. 27:122.

Colucci, P.E., L.E. Chase and P.J. VanSoest. 1982. Feed intake, apparent digestibility, and rate of particulate passage in dairy cattle. J. Dairy Sci. 65:1445.

Dixon, R.M. 1986. Effects of dietary concentrates on rumen digestion of fibrous feedstuffs. Anim. Feed Sci. and Tech. 14:193.

Dunn, T.G., J.E. Ingalls, D.R. Zimmerman and J.N. Wiltbank. 1969. Reproductive performance of two-year-old Hereford and Angus heifers as influenced by pre and post calving energy intake. J. Anim. Sci. 29:719.

Erfle, J.D., R.J. Boila, R.M. Teather, S. Mahadevan and F.D. Saver. 1982. Effect of pH on fermentation characteristics and protein degradation by rumen microorganisms in vitro. J. Dairy Sci. 65:1457.

Fahey Jr, G.C. and L.L. Berger. 1988. Carbohydrate nutrition of ruminants. in The Ruminant Animal- digestive physiology and nutrition. D.C. Church (Ed.). Prentice Hall. Englewood Cliffs, New Jersey.

Faichney, G.J. and S.G. Gherardi. 1986. Relationships between organic matter digestibility, dry-matter intake and solute mean retention times in sheep given a ground and pelleted diet. J. Agr. Sci. (Camb.) 106:219.

Fraser, C. and E.R. Orskov. 1974. Creeal processing and food utilization by sheep. 1. The effects of processing on utilization of barley by early-weaned lambs. Anim. Prod. 18:75.

Galyean, M.L., D.G. Wagner and F.N. Owens. 1979. Level of feed intake and site and extent of digestion of high concentrate diets by steers. J. Anim. Sci. 49:199.

Galyean, M.L. 1977. Partitioning digestion with lignin as a marker. I. Influence of corn particle size on site and extent of digestion in steers. PhD. Dissertation. Oklahoma State Univ., Stillwater.

Gill, D.R., F.N. Owens, J.J. Martin, R.J. Hillier, R.A. Zinn and D.E. Williams. 1980. Corn processing method and phase feeding of steers. Okla. Agr. Exp. Sta. Res. Rep. MP-107:138.

Goestch, A.L. and F.N. Owens. 1987. Impact of forage characteristics on microbial fermentation and ruminant performance. Proc. Grazing Livestock Nutrition Conference. p. 55.

Guthrie, M.J. and D.G. Wagner. 1988. Influence of protein or grain supplementation and increasing levels of soybean meal on intake, utilization and passage rate of prairie hay in beef steers and heifers. J. Anim. Sci. 66:1529.

Hanna, S.M., J.A. Paterson, J.E. Williams, M.S. Kerley and J.L.Miner. 1990. Effects of increasing dietary levels of endophyte-infected tall fescue seed on diet digestibility and ruminal kinetics in sheep. J. Anim. Sci. 68:1693.

Hancock, K.L., J.R. Kropp, K.S. Lusby, R.P. Wettemann, D.S. Buchanan and C. Worthington. 1985. The influence of postpartum nutrition and weaning age of calves on cow body condition, estrus, conception rate and calf performance of fall-calving cows. Okla. Agr. Exp. Sta. Res Rep. MP-117:180.

Hart, S.P. and C.E. Polan. 1984. Simultaneous extraction and determination of ytterbium and cobalt EDTA in feces. J. Dairy Sci. 67:888.

Henning, P.A., Y. van der Linden, M.E. Mattheyse, W.K. Nuahaus and H.M. Schwartz. 1980. Factors affecting the intake and digestion of roughage by sheep fed maize straw supplemented with maize grain. J. Agric. Sci. (Camb.). 94:565.

Herrare-Saldana, R., R. Gomez-Alarcon, M. Torabi and J.T. Huber. 1990. Influence of synchronizing protein and starch degradation in the rumen on nutrient utilization and microbial protein synthesis. J. Dairy Sci. 73:142.

Hibberd, C.A., D.G. Wagner, R.L. Schemm, E.D. Mitchell,Jr., R.L. Hintz and D.E. Weibel. 1982. Nutritive characteristics of different varieties of sorghum and corn grains. J. Anim. Sci. 55:665

Hibberd, C.A., C.C.Chase and L.D. Bourquin. 1987. Added cottonseed meal for beef heifers consuming corn-supplemented low-quality native grass hay diets. Okla. Agr. Exp. Sta. Res. Rep. MP-119:275.

Hibberd, C. A., and S.K. Martin. 1990. Substitution of corn gluten meal for soybean meal in range supplements on intake and utilization of low quality native grass hay by steers. Okla. Agr. Exp. Sta. Res. Rep. MP-129:28.

Hodgson,J.C., P.C. Thomas and A.G. Wilson. 1976. The influence of the level of feeding on fermentation in the rumen of sheep receiving a diet of ground barley, ground hay and flaked maize. J. Agric. Sci. (Camb.). 87:927.

Hussein, H.S., R.M. Jordan and M.D. Storm. 1991. Ruminal protein metabolism and intestinal amino acid utilization as affected by dietary protein and carbohydrate sources in sheep. J. Anim. Sci. 69:2134.

Huyne, H. and L.S. Feldt. 1976. Estimation of the box correction for degrees of freedom from sample data in the randomized block and split plot designs. J. Educ. Stat. 1:69.

Jones, A.L., A.L. Goetsch, S.R. Stokes and M. Colberg. 1988. Intake and digestion in cattle fed warm- or cool-season grass hay with or without supplemental grain. J. Anim. Sci. 66:194.

Judkins, M.B., J.D. Wallace, M.L. Galyean, L.J. Krysl and E.E. Parker. 1987. Passage rates, rumen fermentation and weight change in protein supplemented grazing cattle. J. Range Mgt. 40:100.

Kartchner, R.J. 1980. Effects of protein and energy supplementation of cows grazing native winter range on forage intake and digestibility. J.Anim. Sci. 51:432.

Kim, Y.K. and F.N. Owens. 1985. Starch digestion by feedlot cattle: influence of roughage and intake level and particle size. Okla. Agr. Exp. Sta. Res. Rep. MP-117:298.

Kropp, J. R.,D.F. Stephanes, J.W. Holloway, L. Knori, J.V. Whiteman and R. Totusek. 1972. The performance of two-year-old Hereford, Hereford x Holstein and Holstein females as influenced by level of winter supplement under range conditions. Okla. Agr. Exp. Sta. Res. Rep. MP-87:26.

Kropp, J. R.,D.F. Stephanes, J.W. Holloway, J.V. Whiteman L. Knori and R. Totusek. 1973. Performance on range and in drylot of two-year-old Hereford, Hereford x Holstein and Holstein females as influenced by level of winter supplementation. J. Anim. Sci. 37:1222.

Lee, G.J., D.W. Hennessy, P.J. Williamson, J.V. Nolan, T.J. Kempton and R.A. Leng. 1985. Responses to protein meal supplements by lactating beef cattle given a low-quality pasture hay. Aust J. Agric. Res. 36:729.

Macrae, J.C. and D.G. Armstrong. 1968. Enzyme method for determination of α-linked glucose polymers in biological materials. J. Sci. Food Agr. 19:578.

Martin, S.K. and C.A. Hibberd. 1987. Intake and digestibility of low-quality native grass hay by beef cows fed graded levels of soybean hulls. Okla. Agr. Exp. Sta. Res. Rep. Mp-119:268.

McCollum, F.T. and M.L. Galyean. 1985. Influence of cottonseed meal supplementation on voluntary intake, rumen fermentation and rate of passage of prairie hay in beef steers. J. Anim. Sci. 60:570.

McNeill, J.W., G.D. Potter and J.K. Riggs. 1971. Ruminal and postruminal carbohydrate utilization in steers fed processed sorghum grain. J. Anim Sci. 33:1371.

Merchen, N.R., J.L. Firkins and L.L. Berger. 1986. Effect bacterial protein synthesis and duodenal amino acid flows in sheep. J. Anim Sci. 62:216.

Mertens, D.R. and L.O. Ely. 1982. Relationship of rate and extent of digestion to forage utilization. A dynamic model evaluation. J. Anim. Sci. 54:895.

Miller, B.G. and R.B. Muntifering. 1985. Effects of forage:concentrates on kinetics of forage fiber digestion in vivo. J. Dairy Sci. 68:40.

Mobely, J.S., R. P. Wettemann, K.S. Lusby, B.R. Pratt and E.J. Turman. 1983. Influence of prepartum nutrition on concentrations of estrone, estradiol, estrone sulfate and progesterone in the plasma of range cows. Okla. Agr. Exp. Sta. Res. Rep. MP-114:132.

Moe, P.W., H.F. Tyrell and N.W. Hooven,Jr. 1973. Physical form and energy value of corn grain. J. Dairy Sci. 56:1289.

Mould, F.L. and E.R. Orskov. 1984. Manipulation of the rumen fluid pH and its influence on cellulolysis in sacco, dry matter degradation and the rumen microflora of sheep offered either hay or concentrate. Anim. Feed Sci. Technol. 10:1

Mould, F.L., E.R. Orskov and S.O. Mann. 1983. Associative effects of mixed feeds. I. Effects of type and level of supplementation and the influence of the rumen fluid pH on cellulolysis in vivo and dry matter digestion of various roughages. Anim. Feed Sci. Technol. 10:15.

Mould, F.L., E.R. Orskov and S.A. Gauld. 1983. Associative effects of mixed feeds. II. The effect of dietary addition of bicarbonate salts on the voluntary intake and digestibility of diets containing various proportions of hay and barley. Anim. Feed Sci. Technol. 10:31.

Nocek, J.E. and J.B. Russell. 1988. Protein and energy as an integrated system. Relationship of ruminal protein and carbohydrate availability to microbial synthesis and milk production. J. Dairy Sci. 71:2070.

NRC. 1984. Nutrient Requirements of Domestic Animals. Nutrient Requirements of Beef Cattle (6th Ed.). National Academy of Sciences - National Research Council, Washington, DC.

NRC. 1985. Ruminant Nitrogen Usage. National Academy of Sciences - National Research Council, Washington, DC.

Orskov, E.R., W.P. Flatt and P.W. Moe. 1968. Fermentation balance approach to estimate extent of fermentation and efficiency of volatile fatty acid formation in ruminants. J. Dairy Sci. 51:1429.

Orskov, E.R., C. Fraser and I. McHattie. 1974. Cereal processing and food utilization by sheep. A note on the effects of feeding unprocessed barley, maize, oats and wheat on food utilization by early-weaned lambs. Anim. Prod. 18:85.

Orskov, E.R. and C. Fraser. 1975. The effects of processing of barley based supplements on rumen pH, rate of digestion, and voluntary intake of dried grass in sheep. Br. J. Nutr. 34:493.

Orskov , E.R. 1982. Protein Nutrition in Ruminants. Academic Press Inc., New York, New York.

Ovenell, K.H., K.S. Lusby, G.W. Horn and R.W. McNew. 1990. Effects of lactational status on forage intake, digestibility and particulate passage rate of beef cows supplemented with soybean meal, wheat midds and corn / soybean meal. Okla. Agr. Exp. Sta. Res. Rep. MP-129:44.

Owens, F.N. and A.L. Goestch. 1988. Ruminal Fermentation. In: D.C. Church (Ed.) The Ruminant Animal - Digestive Physiology and Nutrition. Prentice Hall, Englewood Cliffs, New Jersey.

Owens, F.N. and R.A. Zinn. 1988. Protein Metabolism of Ruminant Animals. In: D.C. Church (Ed.) The Ruminant Animal - Digestive Physiology and Nutrition. Prentice Hall, Englewood Cliffs, New Jersey.

Pordomingo, A.J., J.D. Wallace, A.S. Freeman and M.L. Galyean. 1991 Supplemental corn grain for steers grazing native rangeland during summer. J. Anim Sci. 69:1678.

Rakestraw, J. K.S. Lusby, R.P. Wettemann and J.J. Wagner. 1986 Postpartum weight and body condition loss and performance of fall-calving cows. Theriogenology. 26:461

Redman, R.G., R.C. Kellaway and J. Leibholz. 1980. Utilization of low quality roughages : effects of urea and protein supplements of differing solubility on digesta flows, intake and growth rate of cattle eating oaten chaff. Br. J. Nutr. 44:343.

Richards, M.W., J.C. Spitzer and M.B. Warner. 1986. Effect of varying levels of postpartum nutrition and body condition at calving on subsequent reproductive performance in beef cattle. J.Anim. Sci. 62:300.

Rittenhouse, L.R., D.C. Clanton and C.L. Streeter. 1970. Intake and digestibility of winter-range forage by cattle with and without supplements. J. Anim. Sci. 31:1215.

Rode, L.M., D.C. Weakley and L.D. Satter. 1985. Effect of forage amount and particle size in diets of lactating dairy cows on site of digestion and microbial protein synthesis. Can J. Anim. Sci. 65:101.

Rush, I.G., D.C. Clanton, T.J. Berg and A. Applegarth. 1987. Ear corn for cows grazing sandhills winter range and fed meadow hay. Neb. Beef Cattle Report. MP 52:36.

Rutledge, J.J., W.W. Robison, W.T. Ahlschwede and J.E. Legates. 1971. Milk yield and its influence on 205-day weight of beef calves. J.Anim. Sci. 33:563.

Sanson, D.W. and D.C. Clanton. 1989. Intake and digestibility of low quality meadow hay by cattle receiving various levels of whole shell corn. J. Anim. Sci. 67:2854.

Sanson, D.W., D.C. Clanton and I.G. Rush. 1990. Intake and digestion of low quality meadow hay by steers and performance of cows on native range

when fed protein supplements containing various levels of corn. J. Anim. Sci. 68:595.

Santos, K.A., M.D. Stern and L.D. Satter. 1984. Protein degradation in the rumen and amino acid absorption in the small intestine of lactating dairy cattle fed various protein sources. J. Anim. Sci. 58:224.

Satter, L.D. and L.L. Slyter. 1974. Effects of ammonia concentration on rumen microbial protein production in vitro. Br. J. Nutr. 32:199.

Scott, R.R. and C.A. Hibberd. 1990. Incremental levels of supplemental ruminal degradable protein for beef cows fed low quality native grass hay. Okla. Agr. Exp. Sta. Res. Rep. MP-129:57.

Steel, R.G.D. and J.H. Torrie. 1980. Principles and procedures of Statistics (2nd Ed.). McGraw-Hill Book Co., New York.

Stern, M.D., H. Hoover, C.F. Sniffen, B.A. Crooker and P.H. Knowlton. 1978. Effects of nonstructural carbohydrate, urea and soluble protein levels on microbial protein synthesis in continuous culture of rumen contents. J. Anim. Sci. 47:944.

Stock,R., T. Klopfenstein, D. Brink, R. Britton and D. Harmon. 1986. Whey as a source of rumen-degradable protein. 1. Effects on microbial protein production. J. Anim. Sci. 63:1561.

Sutton, J.D. 1981. Digestion and end-product formation in the rumen from production rations. In: Y. Ruckebush and P. Thivend (Ed.). Digestive Physiology and Metabolism in Ruminants. pp 271-290. Avi Pub. Co., Inc. Westport, Ct.

Teeter, R.G., F.N. Owens and T.L. Mader. 1984. Ytterbium chloride as a marker for particulate matter in the rumen. J. Anim. Sci. 58:465.

Trautman, B.D. 1987. Forage utilization and productivity of lactating beef cows fed cottonseed meal, corn or soybean hull supplements during the winter. M.S. Thesis. Okla. State Univ., Stillwater, Ok.

Turman, E.J., L.J. Smithson, L.S. Pope, R.E. Renbarger and D.F. Stephens. 1964. Effect of feed level before and after calving on the performance of two-year-old heifers. Okla. Agr. Exp. Sta. Res. Rep. MP-74:10.

Uden, P., P.E. Colucci and P.J. Van Soest. 1980. Investigation of chromium, cerium and cobalt as markers in digesta. Rate of passage studies. J. Sci. Food Agric. 31:625.

van der Linden, Y., N.O. van Gylswyk and H.M. Schwartz. 1984. Influence of supplementation of corn stover with corn grain on the fibrolytic bacteria in the rumen of sheep and their relation to the intake and digestion of fiber. J. Anim. Sci. 59:772.

Van Soest, P.J. 1987. Nutritional Ecology of the Ruminant. Cornell Univ. Press. Ithaca, New York.

Varga, G.A. and W.H. Hoover. 1983. Rate and extent of neutral detergent fiber degradation of feedstuffs in situ. J.Dairy Sci. 66:2109.

Vipond, J.E., E.A. Hunter and M.E. King. 1985. The utilization of whole and rolled cereals by ewes. Anim Prod. 40:297.

Waller, G.R., R.D. Morrison and A.B. Nelson. 1972. Chemical composition of native grasses in central Oklahoma from 1947 to 1962. Okla. Agr. Exp. Sta. Bull. B-67.

Welch, J.G. 1982. Rumination, particle size and passage from the rumen. J. Anim. Sci. 54:885.

Wettemann, R.P., K.S. Lusby and E.J. Turman. 1980. Influence of winter weight loss on calf birth weight and reproductive performance of range cows. Okla. Agr. Exp. Sta. Res. Rep. MP-107:176.

Wiltbank, J.N., W.W. Rowden, J.E. Ingalls, K.E. Gregory and R.M. Koch. 1962. Effect of energy level on reproductive phenomena of mature Hereford cows. J. Anim. Sci. 21:219.

Wyatt, R.D., M.B. Gould, J.V. Whiteman and R. Totusek. 1977. Effect of milk level and biological type on calf growth and performance. J. Anim. Sci. 45:1138.

Yokoyama, M.T. and K.A. Johnson. 1988. Microbiology of the Rumen and Intestine. In: D.C. Church (Ed.) The Ruminant Animal - Digestive Physiology and Nutrition. Prentice Hall, Englewood Cliffs, New Jersey.

Zorrilla-Rios, J., G.W. Horn, R.W. McNew and K.P. Poling. 1985. Energy supplementation of untreated and ammoniated wheat straw diets for sheep. Okla. Agr. Exp. Sta. Res. Rep. MP-117:146.

Zinn, R.A. and F.N. Owens. 1982. Rapid procedure for quantifying nucleic acid content of digesta. In F.N. Owens (Ed.) Protein Requirements for Cattle: Symposium. Oklahoma State Univ. MP-109:26.

APPENDIX

TABLE XI

EFFECT OF SUPPLEMENTAL GRAIN PROCESSING ON RUMINAL CHARACTERISTICS IN BEEF COWS FED LOW QUALITY NATIVE GRASS HAY

		Processing Method				
Item	Control	Whole	Cracked	Ground	Pelleted	SE
Dry matter disappearance, %/h	4.02	3.93	4.45	4.00	4.18	
DM fill						
kg	11.80	12.14	11.55	11.93	11.89	.52
% BW	1.83	1.86	1.82	1.87	1.90	.09
Liquid Fill						
kg	69.31	63.88	62.34	65.04	65.18	2.14
% BW	10.65	9.74	9.75	10.15	10.35	.37

TABLE XII

EFFECT OF SUPPLEMENTAL GRAIN PROCESSING ON HAY AND DIGESTIBLE OM INTAKE IN BEEF COWS FED LOW QUALITY NATIVE GRASS HAY

		Processing Method				
Item	Control	Whole	Cracked	Ground	Pellet	SE
HAY g/kg $BW^{.75}$	73.0	66.2	71.4	64.8	66.9	3.68
DOMI g/kg $BW^{.75}$	74.5	85.4	83.7	77.7	81.2	4.40

TABLE XIII

EFFECTS OF SUPPLEMENTAL GRAIN PROCESSING ON RUMINAL AMMONIA CONCENTRATIONS IN BEEF COWS FED LOW QUALITY NATIVE GRASS HAY

		Processing Method				
Hour	Control	Whole	Cracked	Ground	Pelleted	SE
0	1.68[ab]	1.78[ab]	1.33[ab]	0.87[b]	1.96[a]	.79
1	6.28[ab]	5.35[b]	5.41[b]	3.83[c]	6.56[a]	.79
2	7.52[a]	6.09[b]	6.49[ab]	3.38[c]	5.50[b]	.79
3	6.23[a]	4.99[b]	4.62[b]	1.68[d]	2.85[c]	.79
4	4.72[a]	3.41[b]	2.79[b]	0.40[c]	0.91[c]	.79
5	3.02[a]	2.35[ab]	1.44[bc]	0.12[d]	0.50[cd]	.79
6	1.85[ab]	2.08[a]	0.96[bc]	0.21[c]	0.46[c]	.79
8	1.28[ab]	1.52[a]	0.68[ab]	0.23[b]	0.43[ab]	.79
10	1.31[ab]	1.63[a]	0.58[ab]	0.24[b]	0.58[ab]	.79
12	0.85	1.15	0.35	0.15	0.48	.79
18	0.92	1.04[ab]	0.61[b]	0.42[b]	1.33[a]	.79

[a,b,c,d]Means in a row with different superscripts differ (P<.05).

TABLE XIV

EFFECT OF SUPPLEMENTAL GRAIN PROCESSING ON RUMINAL pH OF BEEF COWS FED LOW QUALITY NATIVE GRASS HAY

		Processing Method				
Hour	Control	Whole	Cracked	Ground	Pelleted	SE
0	6.64[ab]	6.56[b]	6.59[ab]	6.67[a]	6.66[a]	.006
1	6.55[a]	6.37[c]	6.46[bc]	6.51[ab]	6.50[ab]	.006
2	6.52[a]	6.42[b]	6.40[b]	6.47[ab]	6.45[ab]	.006
3	6.50[a]	6.41[ab]	6.40[b]	6.49[ab]	6.43[ab]	.006
4	6.46[a]	6.44[ab]	6.36[b]	6.43[ab]	6.42[ab]	.006
5	6.42[a]	6.39[ab]	6.30[b]	6.40[a]	6.39[ab]	.006
6	6.47[a]	6.34[bc]	6.32[c]	6.39[abc]	6.43[ab]	.006
8	6.49[a]	6.37[bc]	6.33[c]	6.41[abc]	6.44[ab]	.006
10	6.49[a]	6.36[bc]	6.27[c]	6.42[ab]	6.41[ab]	.006
12	6.41[a]	6.29[c]	6.30[bc]	6.39[ab]	6.40[a]	.006
18	6.43[ab]	6.29[c]	6.36[bc]	6.48[a]	6.45[a]	.006

[a,b,c,]Means in a row with different superscripts differ (P<.05).

TABLE XV

VOLATILE FATTY ACID CONCENTRATIONS IN RUMINAL FLUID[a]

		Processing Method				
	Control	Whole	Crack	Ground	Pellet	SE
VFA, mmol/l						
Acetate	77.4	81.1	70.6	71.6	74.2	5.18
Propionate	19.7	19.1	17.8	19.6	19.6	2.06
Isobutyrate[b]	2.25	2.42[c]	1.43[d]	1.50[d]	1.50[d]	.264
Butyrate	11.9	12.0	10.1	9.8	10.9	1.10
Isovalerate	1.16	1.29[b]	.85[c]	1.00[bc]	.95[bc]	.127
Valerate	.42	.57	.26	.47	.44	.113
Total	112.9	116.5	101.0	104.0	107.7	8.39
C_2:C_3	3.95	4.31	4.01	3.71	3.93	.194
VFA, mol/100 mol						
Acetate	68.6	69.8	69.9	69.2	69.2	.78
Propionate	17.6	16.3[d]	17.6[cd]	18.7[c]	18.0[cd]	.71
Isobutyrate	1.94	2.05[c]	1.44[d]	1.42[d]	1.37[d]	.188
Butyrate	10.5	10.3	9.9	9.3	10.2	.49
Isovalerate	1.01	1.11	.85	.96	.88	.086
Valerate	.36	.49	.26	.42	.40	.083

[a]Volatile fatty acid concentrations were determined on ruminal samples collected 4 h postsupplementation. Subsamples (2 ml) were combined with .333 ml of 25% metaphosphoric acid containing 2-ethylbutyric acid (internal standard) and centrifuged (20,000 x g, 20 min). The supernatant fluid (1 ul) was injected into a Perkin Elmer AutoSystem gas chromatograph (Perkin Elmer, Norwalk, CT.) equipped with a spiral J & W fused silica Megabore column (30 m x .533 mm; acidified (TPA) polyethylene glycol liquid phase; 1.0 um film thickness, J & W Scientific, Folsom, CA.). Helium served as the mobile phase with a flow rate of 40 ml/min. Column temperature was programmed to increase from 110° to 235° C in three stepwise increments. Inlet port and detector temperatures were both 250° C.

[b]Control vs average of corn processing methods ($P<.10$).

[cd]Means within a row with different superscripts differ ($P<.05$).

TABLE XVI

EFFECT OF SUPPLEMENTAL GRAIN PROCESSING ON MEAN WEIGHT AND BODY CONDITION OF LACTATING BEEF COWS GRAZING DORMANT NATIVE GRASS

	Processing Method				
	Whole	Cracked	Ground	Pellet	SE
Cow body weight, kg					
Day 0	507.3	517.1	510.3	510.0	11.48
Day 21	503.6	501.1	499.4	497.6	12.03
Day 49	479.6	482.9	470.8	473.1	10.91
Day 63	461.3	468.4	461.4	460.8	10.78
Day 85	447.2	459.1	445.9	448.5	10.32
Day 105	433.6	447.4	438.8	437.5	9.91
Cow weight change, kg					
Day 21	-3.7[a]	-16.0[b]	-11.0[b]	-12.4[b]	2.94
Day 49	-27.7[a]	-34.2[ab]	-39.6[b]	-36.9[b]	3.31
Day 63	-46.0	-48.7	-49.0	-49.3	3.62
Day 85	-60.1	-58.0	-64.5	-61.5	3.97
Day 105	-73.6	-69.6	-71.5	-72.5	4.84
Cow body condition, units					
Day 0	5.51	5.61	5.55	5.49	.09
Day 21	5.26	5.41	5.33	5.34	.08
Day 49	5.10	5.17	5.09	5.12	.08
Day 63	4.98[a]	5.23[b]	5.10[ab]	5.11[ab]	.09
Day 85	4.77[a]	5.10[b]	4.86[ab]	4.87[ab]	.11
Day 105	4.70[a]	5.00[b]	4.82[ab]	4.83[ab]	.12
Cow body condition change, units					
Day 21	-0.26[b]	-0.20[ab]	-0.21[ab]	-0.15[a]	.04
Day 49	-0.41	-0.44	-0.45	-0.38	.05
Day 63	-0.54[b]	-0.38[a]	-0.44[ab]	-0.40[a]	.05
Day 85	-0.74[b]	-0.51[a]	-0.69[b]	-0.62[ab]	.05
Day 105	-0.81[b]	-0.61[a]	-0.73[ab]	-0.66[ab]	.07

[a,b]Means within a row with different superscripts differ (P<.05).

TABLE XVII

EFFECT OF SUPPLEMENTAL GRAIN PROCESSING ON MEAN WEIGHT CHANGE OF CALVES GRAZING DORMANT NATIVE GRASS

	Processing Method				
	Whole	Cracked	Ground	Pellet	SE
Calf weight, kg					
Day 0	87.9[b]	80.2[a]	84.3[ab]	86.3[b]	1.99
Day 21	103.7[b]	94.1[a]	100.2[b]	102.0[b]	2.22
Day 49	120.0[b]	109.6[a]	116.0[b]	118.0[b]	2.53
Day 63	130.1[b]	119.2[a]	125.8[b]	128.4[b]	2.71
Day 85	142.1[b]	131.3a	139.0[b]	141.4[b]	2.87
Day 105	153.0[b]	141.4[a]	149.7[b]	154.2[b]	3.16
Calf weight gain, kg					
Day 21	15.8[b]	13.9[a]	15.9[b]	15.7[b]	.52
Day 49	32.1[b]	29.4[a]	31.7[b]	31.7[b]	.99
Day 63	42.2[b]	38.9[a]	41.5[ab]	42.1[b]	1.23
Day 85	54.2[ab]	51.1[a]	54.6[b]	55.0[b]	1.43
Day 105	65.1[ab]	61.1[a]	65.3[b]	67.9[b]	1.82

[a,b]Means within a row with different superscripts differ (P<.05).

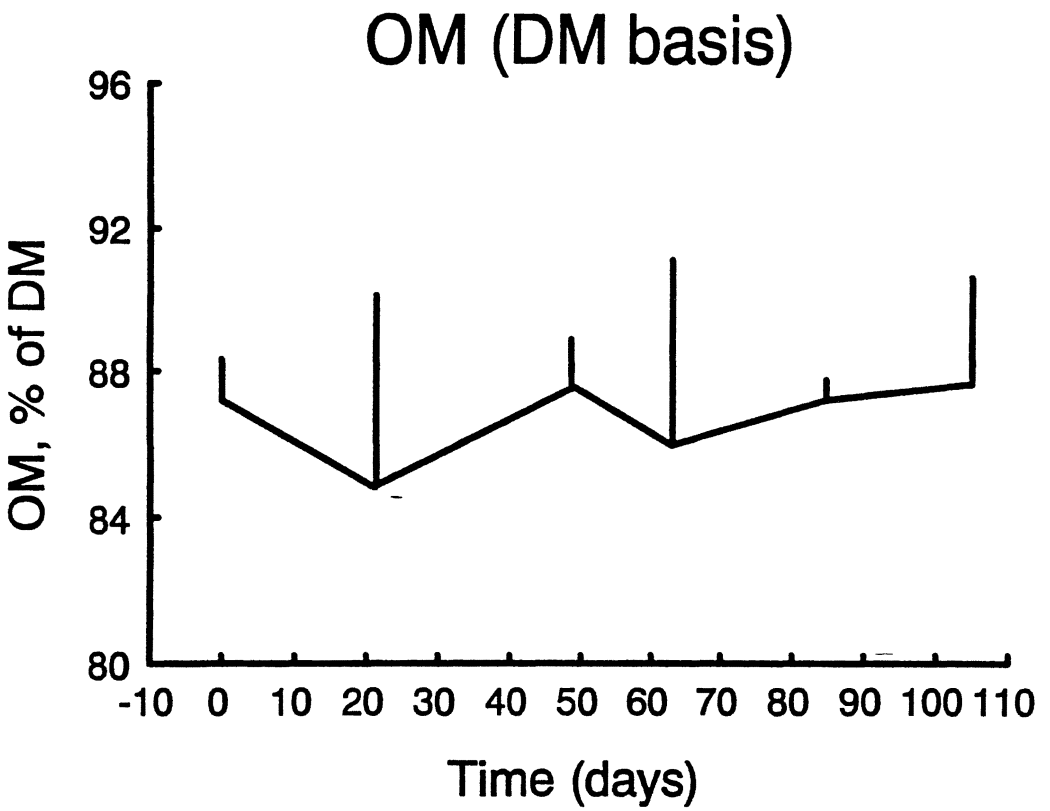

Figure 5. Seasonal Changes in OM Composition of Dormant Native Grass

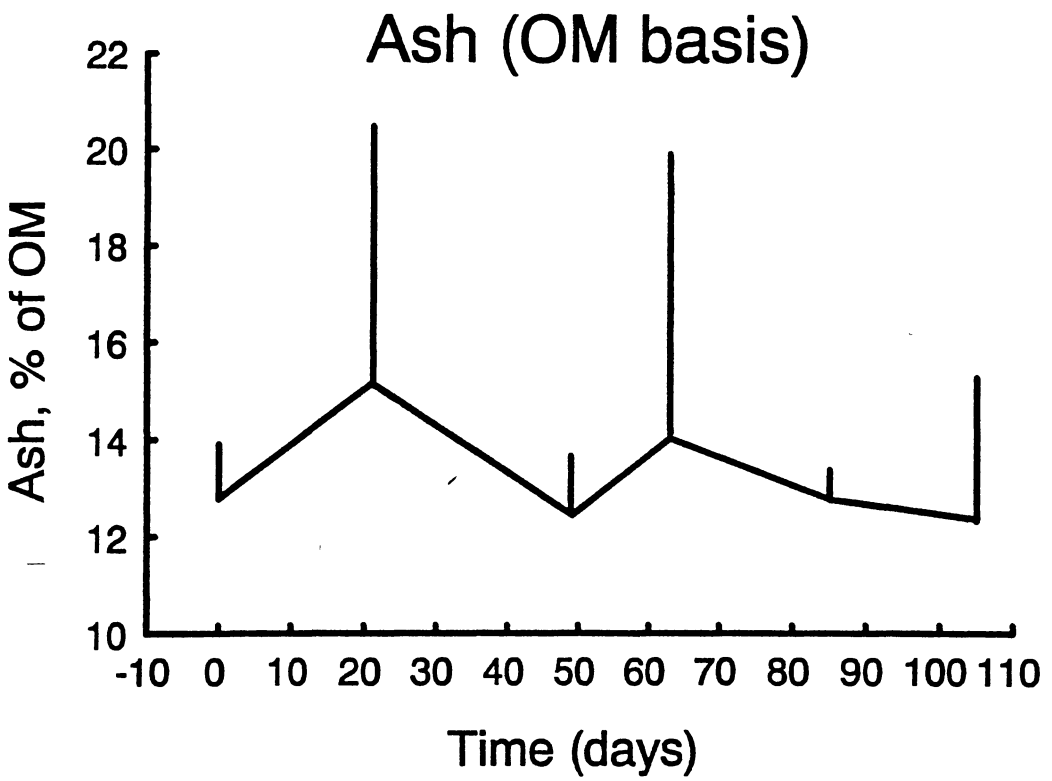

Figure 6. Seasonal Changes in Ash Composition of Dormant Native Grass

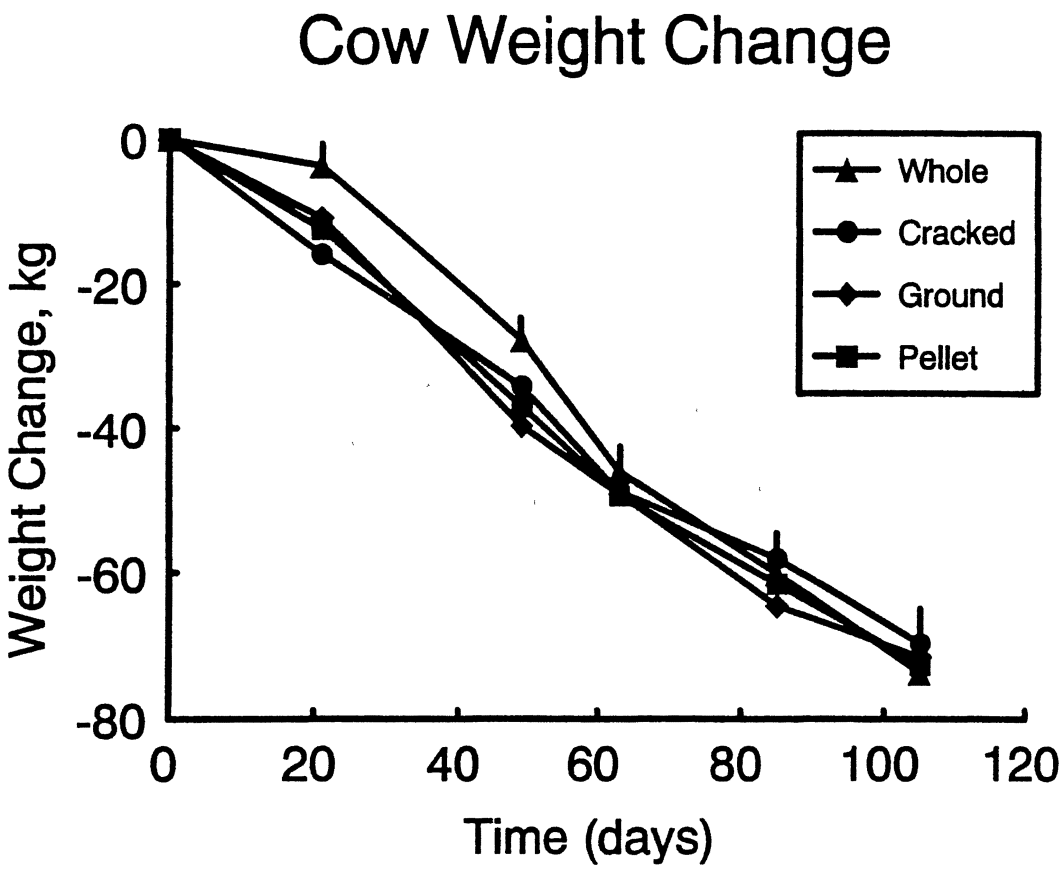

Figure 7. Seasonal Cow Weight Changes in Response to Processed Corn Supplementation

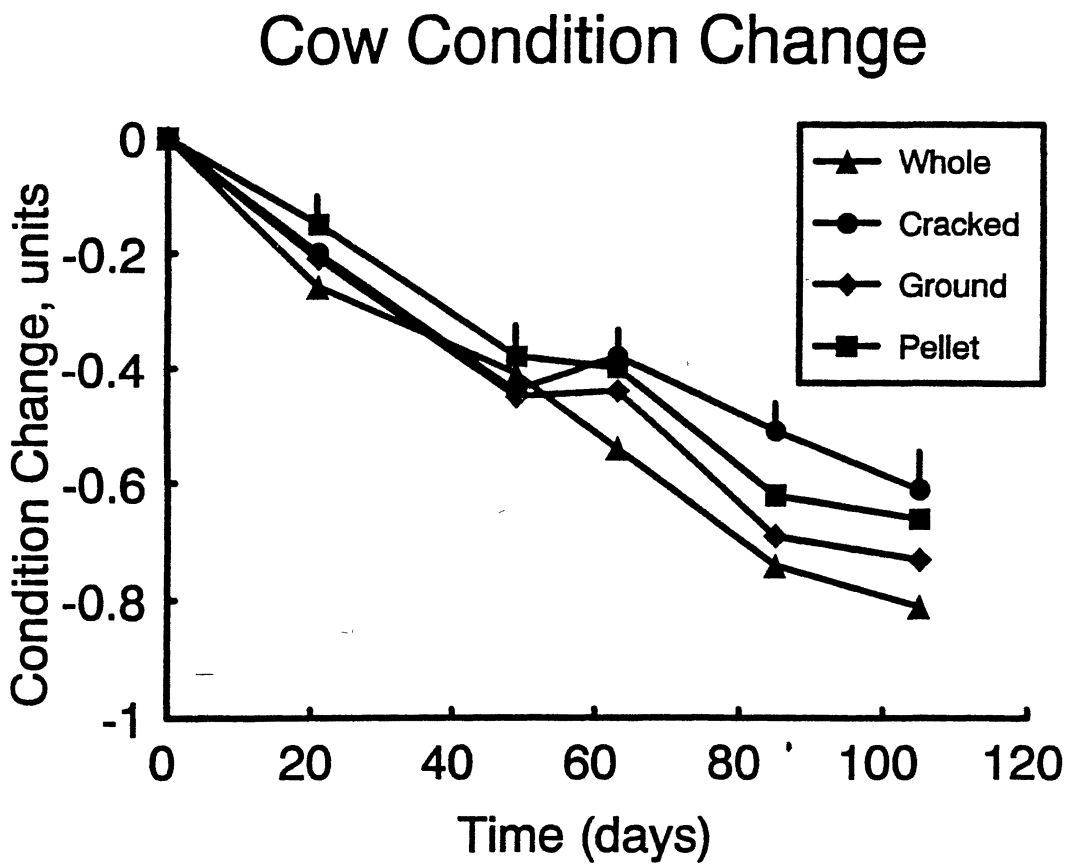

Figure 8. Seasonal Cow Condition Changes in Response to Processed Corn Supplementation

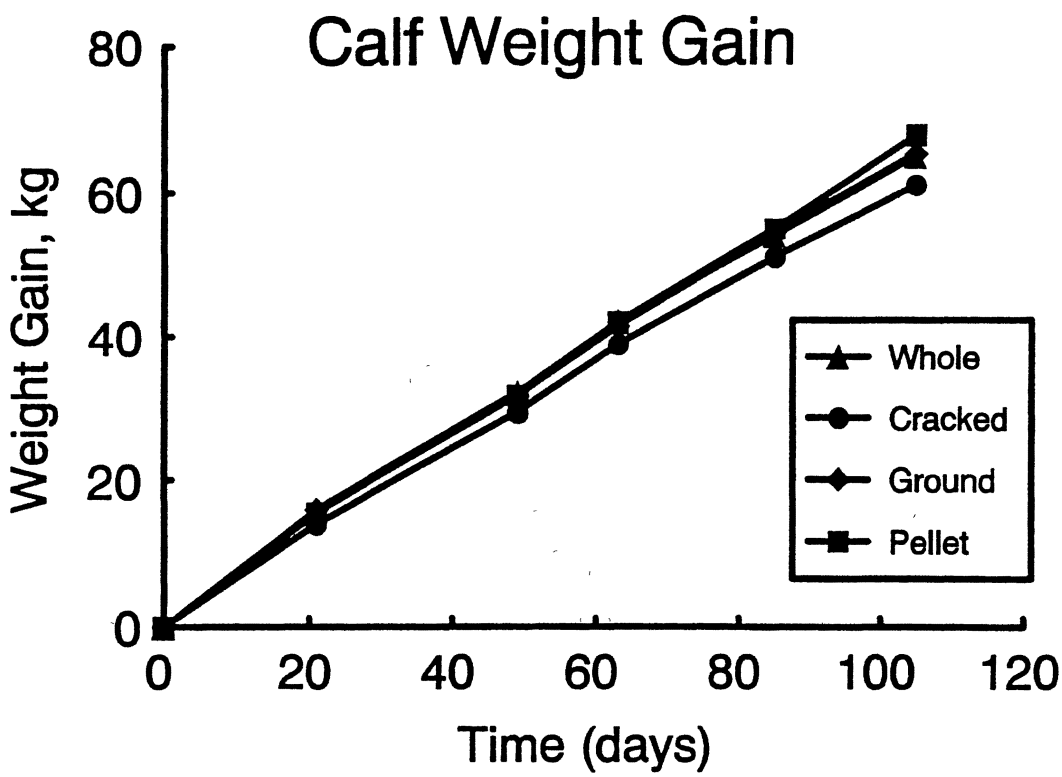

Figure 9. Seasonal Calf Weight Gains in Response to Processed Corn Supplementation

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