CORN GLUTEN FEED AS A SOURCE OF SUPPLEMENTAL PROTEIN FOR BEEF CATTLE FED PRAIRIE HAY

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CHAPTER I

INTRODUCTION

Until recently only small amounts of co-products of the corn wet-milling industry have been utilized in the United States. About 7% of the corn produced annually in the United States undergoes a wet milling process to extract the starch and oil. One major by-product or co-product of this process is corn gluten feed (CGF). For every bushel (25 kg) of corn wet milled, 4.2 kg (16%) CGF is produced. This means that a vast amount (5 to 6 billion kg) of corn gluten feed is produced by the corn milling industry in the U.S. each year.

Corn gluten feed, in both the wet and the dried form, is increasing in popularity and availability as a livestock feedstuff. Wet corn gluten feed is fresh from the wet milling process. Dried corn gluten feed is obtained by drying wet corn gluten feed to approximately 10% moisture. Dried CGF has been used as a feedstuff in dairy cattle rations and in commercial concentrates and supplements for many years. Because it has fewer storage and handling problems, and transportation cost is lower, the dried form is preferred to the wet form (MacLeod, 1984). Due to increased production and decreased export demand for CGF, it has become important to develop new uses for CGF in the U.S. CGF often is a least-cost ingredient as a source of protein in diets for ruminant animals. Protein supplements for ruminant animals are of special concern because they are usually the most expensive ingredients of the diet. Although protein supplements compose only small portion of the diet, they need to be added to low quality roughages to obtain satisfactory performance from ruminant animals.

Low quality roughages are used extensively in the U.S. beef cattle industry. Greater use of roughage helps to reduce grain feeding and helps relieve the world demand on grains. Ideally, only protein sources which are not in high demand for human use should be fed to cattle. Soybean protein, because of its high quality, is used extensively in human as well as nonruminant animal diets. Corn gluten feed, in contrast, is poorly used by nonruminants because it is high in fiber and low in protein quality. Its high fiber content potentially can be used by cattle and it should be useful as an energy and protein supplementation for cattle utilizing low quality forages. In addition, it helps to stabilize the feed supply, to reduce cost and to increase animal production.

Published information is limited on the utilization, ruminal degradation, and animal response to dry corn gluten feed. Research is needed to determine the limits to and the response from this product in ruminant rations. Concerns about CGF include the variation in its chemical composition, the extent of protein escape from the rumen, and its potential energy value in beef cow or stocker diets. These studies were designed to acquire more information on these questions.

CHAPTER II

LITERATURE REVIEW

Low Quality Roughages

Utilization

Roughages are bulky materials of plant origin which are generally high in fiber constituents. Fiber is a structural component of plants and is a biological rather than a chemical entity. The constituents of fiber include the structural components of plant cell wall, namely cellulose, hemicellulose and lignin (Van Soest, 1982). Grasses in the late vegetative stage, cereal straws and other agricultural residues usually have low nutritive value due to their high lignification of cell walls, high total fiber and low protein and soluble carbohydrate contents. These often are classified as low quality roughages. Low quality roughages usually are plentiful and available, so they are commonly fed to or grazed by cattle all over the world. Methods are needed to improve utilization and animal performance on such feeds (Arelovich, 1983).

Roughage utilization has been improved by several methods in the past few years. First, it can be improved through chemical treatment. Klopfenstein (1978) reviewed the treatment of low quality roughages with caustic chemicals such as sodium hydroxide, ammonium hydroxide, calcium hydroxide, and potassium hydroxide. He concluded that alkalinization improved feed intake (37%), digestibilities of DM, NDF and ADF, and rate (2.3 fold) and efficiency of gain. Improvement, however, depends on the roughage involved and level of chemical treatment. Alkalinization seems most useful for monocotyledenous forages. Oxidation or ozonation to delignify low quality forages may have more potential with dicotyledenous forages.

Nonprotein nitrogen sources can be added to low quality roughages as another chemical treatment. Adding urea (Umunna , 1982), biuret (Martin et al., 1981), or ammonia (Klopfenstein, 1981) have been extensively studied. Improvements depend on the level of treatment. Besides alkalinizing the roughages, these compounds supply ruminal microbes with ammonia and thereby provide nutrients for ruminants.

Physical treatment such as grinding and/or pelleting helps to increase feed intake (Van Soest, 1982) of low quality roughages. Though grinding improves feed intake of low quality roughages, it decreases digestibility to some degree; usually digestible energy intake is greater for ground than unground low quality forages so that the proportional sacrifice in digestibility is less than the increase in intake. The reverse may be true for roughages of higher quality.

Supplementation of low quality roughages with plant protein concentrates is the oldest and simplest method for most feeders to use. Intake of low quality forage apparently is first limited by insufficient levels of N. Consequently, N supplements often are fed to animal consuming low quality forage to improve N status of the animals and to increase voluntary intake of forage (Ammerman et al., 1972). Supplementation with nonprotein nitrogen, though useful, usually is less beneficial than supplementation with plant protein. Energy supplements can serve as a carrier for N components and also may improve utilization of low quality forages under certain conditions.

Prairie Grasses

Native prairie grasses are grazed and harvested forages are fed to cattle widely in the U.S. Forages such as prairie hay frequently contain less than 7%

crude protein but are very rich in the structural components of the plant cell walls: cellulose, hemicellulose, and lignin. The content as well as degree of association of the fibrous portions will influence the nutritive value of forages (Burns, 1978).

Consumption of prairie hay (5.4% CP) by mature steers has been shown to increase substantially when supplemented with high protein (40% CP), starch based (20% CP) or low starch (20% CP) supplements (Arelovich, 1983). Moreover, DM digestibility and digestible DM intake increase. Similar responses were noted by Guthrie (1984) in a complementary trial feeding corn (14% CP) and SBM based supplements to mature steers on a prairie hay basal diet. However, Chase and Hibbered (1985) found that feeding more than .91 kg/d of corn to cows on a prairie hay basal diet depressed dry matter intake and ADF digestibility.

Supplementation

Because roughage is traditionally the major ingredient in most ruminant diets, the ruminant has evolved to utilize a high roughage diet. In recent years, supplements have been added to the diet to improve the utilization of low quality forages. Supplementation programs have stimulated research to improve the effects of specific dietary feed ingredients.

Cattle being fed low quality roughages usually receive supplements which are concentrated sources of protein or energy. Energy typically is provided through grains and their by-products, whereas oil seed meals contribute much of the protein and some energy. Protein supplementation may be provided from natural protein of plant or animal origin or from nonprotein nitrogen (NPN) sources such as urea or biuret.

Supplementing low quality roughages with true protein usually produces positive effects (McCollum and Galyean, 1985) through increasing total dry matter intake and digestibility. The nitrogen needs of the ruminal microflora must be met first. This in turn will increase the rate of cellulose digestion. As examples, SBM supplementation of straw increased feed intake by lambs (Hdjipanayiotou et al., 1975). Similarly, cottonseed meal supplementation increased intake of with range hay (Hennessey et al., 1983).

Associative Effects of Supplementation

An associative effect means that the value for a mixed diet is different from the mathematical average of two feeds when fed singly. This interaction between feeds is quite common and often can lead one to under- or over-estimate the value of a supplement. In particular, starch and protein ingredients may interact with low quality roughages causing either negative or positive effects (Van Soest, 1982). Supplementing straw with a protein supplement should have a positive associative effect due to the addition of nitrogen which improves utilization of the straw. On the other hand, a negative associative effect is observed when high grain diets are diluted by pelleted or finely chopped forage sources (Chappell and Fontenot, 1968). Associative effects were first demonstrated by Ewing and Ellis (1915) who found that digestibility of corn silage could be changed by addition of starch to the diet. Interactions of starch can be either beneficial or detrimental due to the physical and chemical composition of the diet, level of intake, concentrate to roughage ratio, and presence of feed additives (Rust, 1983). Measuring an associative effect requires feeding the supplement without roughage. This requires excellent management to avoid digestive disturbances during the experiment.

The associative effects can be conflicting when an energy source is added to high roughage rations. Generally, the addition of readily available carbohydrates to a forage diet depresses digestibility of the fibrous fraction of the diet. Tyrrell and Moe (1975) reported that the digestibility of cellulose and hemicellulose was depressed 2 to 3 times at high levels of feed intake; this in turn depress DM digestibility. Although not obtained in the same experiment, the digestibility of corn has been reported to be 80% for whole corn (Byers, 1974), 84.4% for cracked corn (Joanning et al., 1981) and 86.4% for crimped corn (Vance and Preston, 1971). The TDN value of corn has been reported to be 89-94% (Church, 1977). Which digestibility value is appropriate to use when computing the value of corn in a mixed diet has not been answered. Vance et al. (1972) reported a curvilinear change in digestibility as corn silage was added to an all corn diet. McDonnell (1982) fed corn to lambs at various levels (0, 25, 50, 75, and 100%) in an ensiled corn stover diet. Neutral detergent fiber (NDF) digestibility increased as corn level decreased in the diet. In a study by Tyrrell and Moe (1975), the available net energy to the animal did not change as corn level increased from 30% to 60% in a corn silage ration presumably because NDF digestibility decreased as starch was added.

Much of the decrease in digestibility from associative effects has been attributed to a decline in fiber digestion. With increased grain in the diet rumen pH declines (Church, 1977) and in the rumen, the microbial population fermenting cellulose becomes less active (Hungate, 1966). This shift seems most drastic when pH falls below 6.0 (Slyter et al., 1979). Ruminal pH can drop to 5.4 in cattle fed high levels of grain (Fulton et al., 1979). Arelovich (1983) noted that added starch decreased acid detergent fiber (ADF) and cellulose digestibilities of native hay as rumen pH dropped from 6.68 to 6.63. Alterations in fermentation of NDF at low pH can be attributed to the change in rumen pH itself, not various allied factors (Slyter et al., 1979). Even though similar amounts of protein were provided daily from either corn grain (13% CP) or SBM (32% CP), the added grain depressed cellulose digestibility (Guthrie, 1984). Ruminal ammonia was also depressed by the added grain. Both prairie hay intake and fiber digestibility were depressed when more than .91 kg/day of corn was fed to heifers (Chase and Hibberd, 1985) but, again, ruminal ammonia may have become limiting. The above responses are examples of negative associative effects.

One approach to alleviate negative associative effects caused by low ruminal pH or ammonia is to supplement with by-products which are high in digestible N and fiber but which are low in readily available energy sources. Such a supplement may help the ruminal cellulolytic bacteria to meet their ammonia requirement without depressing ruminal pH and causing undesirable shifts in the microflora population. Fiber from such a supplement should be well digested if an adequate pH is maintained. It may also improve forage intake. Because added ammonia increases rate of fiber digestion and intake of digestible energy should be increased by such supplements causing a positive associative effect. Such by-products come primarily from human food industry as a result of processing of corn, wheat, barley or soybean meal.

The Corn Kernel

Corn (Zea mays) is the grain produced in the greatest quantity in the U.S.A. Most of the corn produced (4.3 billion bushels) is fed to cattle, hogs and poultry. However, about 1 billion bushels are converted into either high fructose sweeteners, flour, starch, cereal, alcohol for fuel and liquor or other industrial products.

The corn kernel is a pod containing the germ (embryo) which is surrounded by starch which can serve as an energy source during germination. Oil, sugar and enzymes necessary for germination are contained in the germ. However, plant breeders through selection have developed grain of which 80% of the kernel is storage components of endosperm. Endosperm is about 80% starch and 10% protein plus other substances such as xanthophyll pigments. The whole kernel is wrapped in a protective skin-like package composed primarily of hemicellulose, called the pericarp.

A sliced kernel is illustrated in Figure 1. Starch is located at the top, sides and the center of the kernel. It is the most abundant constituent and is used in making starches and sweeteners. Gluten is the darker portion inside the kernel that contains most of the protein of the kernel mixed with starch. Much of this residue becomes a component of corn gluten meal. The hull or the kernel skin is rich in fiber and usually goes into corn gluten feed. Up to 16% of the kernel is water and water soluble components which become part of the steep liquor. Soluble nutrients including B-complex vitamins, are concentrated in this product. The germ at the bottom center of the kernel contains oil that makes up about 4% of the kernel. The germ is found in corn germ meal or corn gluten feed.

The corn processed to produce human food ingredients is processed by three major industries: the corn refiners, which produce starch, sweeteners, corn oil and alcohol; the dry millers, which produce corn flour and grits; and the corn distillers, which produce beverage and industrial alcohol. Of these, the corn refining industry is the largest, producing both human food ingredients and extracted residue by-products which are used as supplements for farm animals. Different manufacturing processes are used by each of these industries.

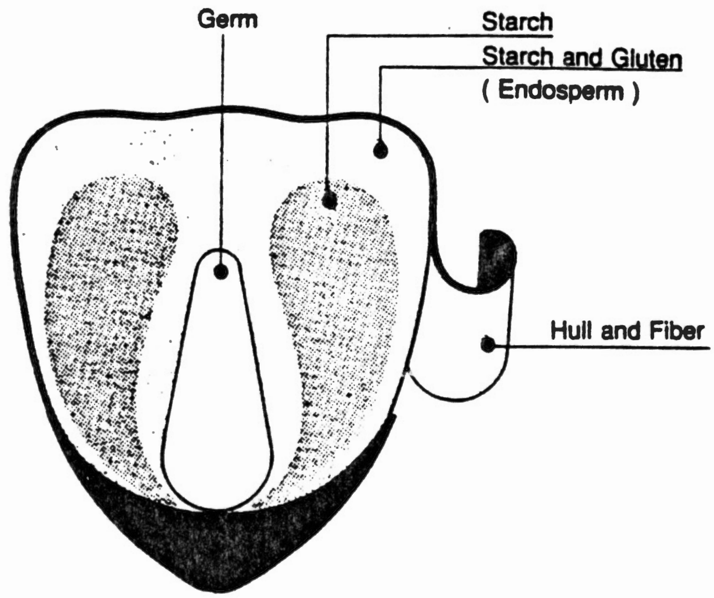


Figure 1. A Kernel of Corn Sliced Lengthwise From Top to Bottom
Adapted from Corn Refiners Association (1975)

Corn Wet Milling

The corn refining or wet milling process begins when shelled corn is soaked or steeped in water for 30-45 hours at 120-130°F (Figure 2). Steeping helps the kernel to absorb up to 45% moisture which simplifies separation of the components and to aid recovery of solubles (Watson, 1974). Adding sulfur dioxide to the steeping liquor aids water uptake and prevents the germ from initiating growth while allowing lactic acid bacteria to convert sugar to lactic acid, which has a pH near 4. During the steeping process, about 6% of the corn components dissolve and are recovered in steepwater. When the steeping process is completed, the steepwater is drawn off and evaporated to a heavy liquor (corn steep liquor) containing 40-50% solids and 41% CP on DM basis (Corn Refiners Association, 1975). This by-product can be used directly as a feed additive or it can be mixed with products of other steps such as corn bran and corn germ meal to form corn gluten feed (Corn Refiners Association, 1975). Mixing with other products can simplify drying and product handling.

In the subsequent milling process, the swollen corn kernel is coarse-milled to remove the germ. The germ is separated by flotation to minimize damage to the germ and maximize recovery of oil. The germ is further processed to remove oil. The residue is dried and can be sold as a corn germ meal or added back as a component of corn gluten feed (Watson, 1974).

After the germ is removed, the residual kernel (endosperm) is ground to pulverize the endosperm particles. The remaining starch, gluten, and fibrous portions are separated using screens and centrifugation. Starch and gluten slurry are separated by their differences in density. The fibrous portion (corn bran) containing 11% crude protein can be sold alone or mixed into CGF. The gluten is dried and becomes part of the gluten meal (Watson, 1974).

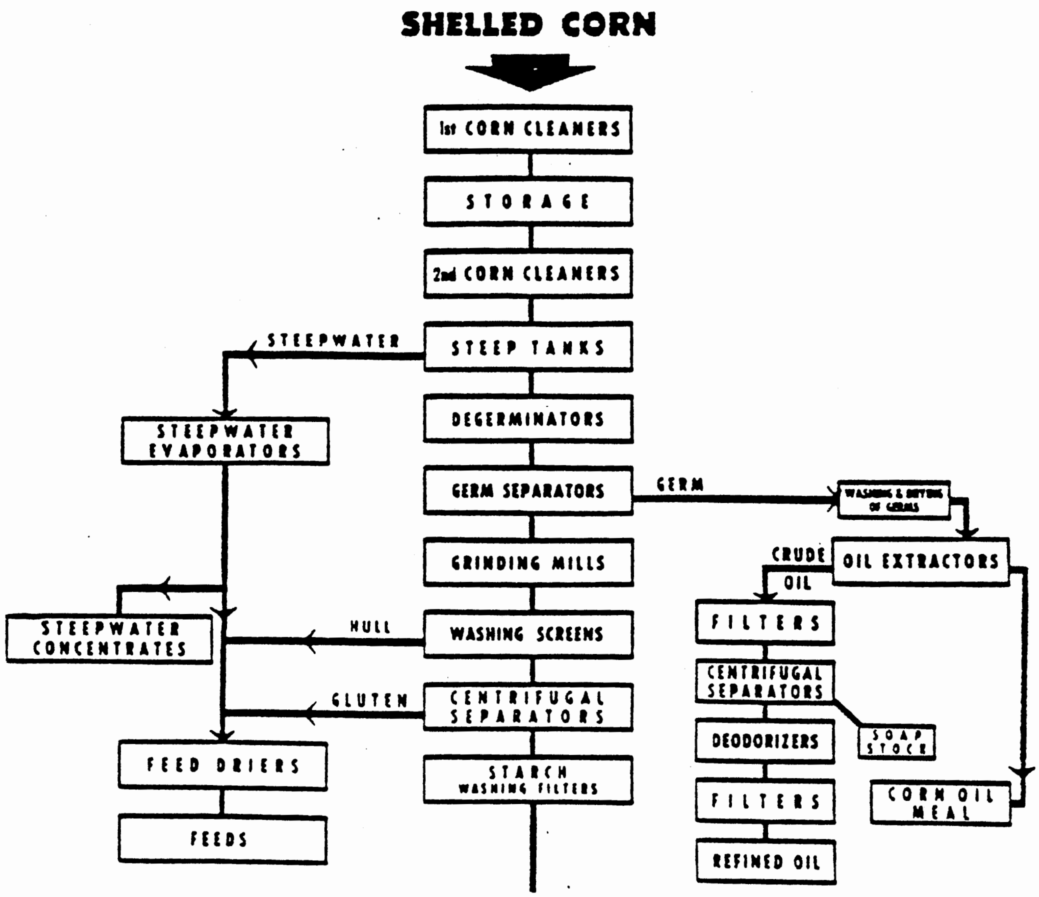


Figure 2. The Corn Refining Process Adapted From Corn Refiners Association (1974)

The starch is washed to reduce its protein content and marketed dried as starch or chemically modified to produce industrial products. Starch may be converted into corn syrup or dextrose (Weigel, 1986).

According to Long (1985), a bushel of corn yields 14.3 kg starch, 1.6 kg germ, 4.2 kg gluten feed and 1.2 kg gluten meal. Starch is the principal product in this process. It is used in food and industrial starches, high fructose corn syrups, conventional corn syrups, dextrose, fuel and beverage alcohol, and several chemicals. Another major product from the wet milling process is corn oil which is extracted from the germ for human consumption. The residuals, which consist of variable quantities of by-products obtained at different processing steps, go into corn gluten feed and corn gluten meal for livestock consumption.

Generally, the major co-products resulting from starch production are steepwater, germ meal, bran and gluten. Mixtures of these fractions are the components of four major feedstuffs: corn gluten feed, corn gluten meal, corn germ meal, and condensed fermented corn steep liquor.

Alcohol Fermentation Process

Corn distillers produce beverage and industrial alcohol. First the corn kernel is soaked long enough to ferment it. Added enzymes convert starch to dextrose. Dextrose is fermented into fuel or beverage alcohol (Livezey, 1985). Ethyl alcohol is removed by distillation leaving "spent" stillage (5-10% DM) as a co-product (Trenkle, 1985b). This stillage can be processed into distillers grains (DG); distillers solubles (DS); and distillers grains with solubles (DGS). The alcohol fermentation industry by-products (DG) contain most of the same fractions of the corn kernel as does CGF, but DG are higher in gluten and oil than CGF (Corn Refiners Association, 1975).

Distillers grains, the solid portion separated from the spent stillage, contain unfermented carbohydrates, the fibrous fraction and the insoluble portion of the grain protein. DG are marketed as wet (20-25% DM) or dry (94% DM) livestock feeds.

Distillers solubles are the remaining liquid portion of the spent stillage after DG removal. DS are the unfermented soluble nutrients from the corn kernel. This product is usually condensed to 90-94% DM.

Distillers grains with solubles is a mixture of the spent stillage of DG and DS. This mixture usually is dewatered and dried to 90-93% DM, but it is available in the wet form (5-10% DM) or as a partially dried livestock feed.

Nutritional Problems of Wet Milling Products

Products of the corn wet milling industry can result in several nutritional problems due to added chemicals. During the steeping process, sulfur dioxide is converted to sulfurous acid which destroys thiamin (Trenkle, 1985b). Thiamin does not normally need to be supplemented in ruminant diets, but because the cost of this vitamin is low, it is recommended that thiamin be added to rations containing more than 50% CGF or condensed steepwater. Trenkle (1985a) recommended that 2.5 mg thiamin be added per kg of feed for ruminants.

Wet-milling by-products are characterized by their high phosphorus and low calcium content which may result in formation of urinary calculi. Calcium from ground limestone should be added to all rations containing corn by-products to increase the Ca:P ratio to 1-1.5 to 1. Corn co-products also have a high concentration of copper which might limit their level of use in sheep rations.

Composition of Wet-Milled Feed Products

The four feed products obtained from corn wet-milling are classified as protein supplements by NRC (1982) and have been described by the Corn Refiners Association (1975).

Corn Gluten Meal (CGM)

This product is a high protein, high energy ingredient containing protein (gluten) separated from the corn in the wet-milling process minimal quantities of starch and some fiber not recovered in the primary separation process. It is usually dried, ground and marketed as a meal at 60% protein and 90-93% dry matter (Trenkle, 1985a). This highly concentrated protein product is a valuable source of methionine which can complement other protein sources (Weigel, 1986). It is rich in xanthophyl pigment which may make the product desirable in poultry diets. CGM is a high ruminal escape protein which makes it an excellent feed ingredient for some ruminants.

Corn Germ Meal

This product consists of the corn germ from which the solubles have been removed during the steeping process and from which the corn oil has been extracted. It is commonly marketed at 20% crude protein after drying to about 90% DM (Trenkle, 1985a; Weigel, 1986). It is used in swine and poultry diets or added to CGF.

Corn Steep Water

Corn steepwater is also called condensed fermented corn extract, which is a condensate of the water extract obtained in the steeping process in the wet milling of corn. It is a high protein, high energy liquid, consisting of the soluble portions which are removed during the steeping process and is concentrated to be high in solids (40-50% DM) (Corn Refiners Association, 1975). It contains the water-soluble protein, carbohydrates, minerals and vitamins from the corn kernel as well as some microbial protein formed during fermentation. Corn steep liquor can be added with other corn ingredients to corn gluten feed as a source of nutrients in liquid supplements or as a binder in range blocks. It is a rich source of B-vitamins, minerals and unidentified growth factors (Weigel, 1986).

Corn Gluten Feed

The National Research Council (NRC) (1981) describes CGF as light to brown in color, free flowing, and having a characteristic gluten feed odor (fresh coffee-like or caramel). It is composed of the bran and fibrous portions of the corn kernel in combination with the starch and protein fractions not recovered in the primary separation process. Therefore, it is relatively high in fiber compared with corn grain. CGF may or may not contain added fermented corn extractives or corn gluten meal. CGF is provided in wet (40% DM) or dry (90-92% DM) forms. The dry form is frequently used in complete feeds or concentrates for dairy and beef cattle, poultry, swine, and as a carrier for added micro-nutrients (Corn Refiners Association, 1975).

The typical composition for corn gluten feed (DM) is 21.0% protein, 3.3% fat, 8.5% crude fiber, and 12.0% moisture (Long, 1985). Similarly, the National Research Council (1981) classified CGF as a "protein supplement" with minimum protein content of 20%.

The Corn Refiners Association (1975) classified CGF as a medium protein feed, Weigel (1986) considered CGF pellets to be an excellent source of protein, energy and minerals for beef cattle The composition of CGF is about two-thirds corn bran (11% CP) and one-third corn steep liquor (41% CP) on a DM basis; thus, steep liquor contributes about 65% of the total protein in CGF (Green et al., 1987).

Nitrogen in feeds can be divided into soluble and insoluble fractions in a buffered solution like rumen fluid. Soluble protein is generally highly degraded in the rumen. Among the corn by-products, corn gluten feed had the highest fraction of soluble protein (Firkins et al., 1984). Among 15 feedstuffs, nitrogen in CGF had the highest (51%) solubility (Waldo and Goering, 1979). In a further evaluation of the in situ ruminal degradation of protein from wet and dry corn by-products, nitrogen from wet corn gluten feed (WGF) and dry corn gluten feed (DGF) disappeared more rapidly than nitrogen from wet distillers grain and dry distillers grain (Firkins et al., 1985). This may be due to the use of a dilute acid in the wet milling process which hydrolyzes some CGF protein and to removal of some gluten (Corn Refiners Association, 1975). The drying technique also may affect the in situ disappearance of corn protein. WGF contains more soluble nitrogen than DGF (54 vs. 41% of N) (Firkins et al., 1985). With this in mind, the nature of the crude protein in both dry and wet corn gluten feed was examined by MacLeod and Grieve (1983). In his feeds, N in WGF was 71% soluble and in DGF the N was 30% soluble. However, 86% of the soluble nitrogen in each feed was non-protein nitrogen. He suggested that WGF protein was more highly degraded in the rumen than DGF. By placing these feeds in dacron bags in the rumen of rumen-fistulated cows, he estimated ruminal nitrogen degradation to be 66% for WGF and 36% for DGF. For WGF, ruminal protein degradation was lower than protein solubility.

As the corn refining industry has grown, corn gluten feed has received wider attention as a protein supplement. DeHaan et al. (1983) reported that

CGF had a comparative protein value of 71% that of soybean meal (SBM) when fed as a nitrogen source to growing steers. Their in vitro enzyme assay predicted that CGF protein would be more extensively degraded in the rumen than SBM. One must not confuse corn gluten feed with corn gluten meal. Ruminal escape is high and solubility is low for protein in corn gluten meal. Firkins et al. (1984) reported that the least insoluble protein of corn gluten feed was more soluble in modified Burrough's mineral mix than proteins for soybean meal which in turn was lower than distillers' grains.

Several workers have examined the nature of the nitrogen fraction of CGF compared with that of various protein supplements. Van Soest (1984) reported that the NPN content of CGF was 55% compared to only 13% for SBM. He also suggested that 2 to 5% of the protein in both CGF and SBM was not digestible due to binding of the nitrogen to the cell wall either occurring naturally in the grain or being formed during heat processing.

Corn Gluten Feed as Energy Source

Most past CGF research has concerned the value of CGF as an energy source for non-ruminants. For ruminants the energy value of wet CGF has been reported to be 85% TDN or 0.87 Mcal of net energy-lactation per kg of dry matter (Davis et al., 1985). This compares with 77% TDN and 0.85 Mcal NE/kg for dry CGF. At 70% of the diet or less, wet CGF has been reported to have about 93% the energy value of corn while dry CGF has about 85% the energy value of corn (Davis et al., 1985).

The high energy availability in CGF appears to be related to the high digestibilities of both the bran and the steep liquor. Neutral detergent fiber (NDF) has been proposed as an indicator of productive energy, bran has been reported to be digested at 6.2% per hour with an 87% extent of digestion while the rate of NDF digestion for dried CGF was 8.1% per hour with a 77% extent of digestion. This indicates that steep liquor enhanced the rate of NDF digestion (Green and Stock, 1985). Dry CGF is produced by drying steep liquor onto dried corn bran. Drying may increase the fragility of the bran; thus, during subsequent handling, grinding and pelleting, particle size may be reduced. A reduction in particle size may result in a faster rate of passage and may explain why dry CGF is less digestible than wet CGF.

Characterizing the fiber in CGF in an in vitro trial, DeHaan et al (1983) found CGF had both extensive (77.4%) and rapid rates (8.1%/h) of NDF disappearance. In a metabolism trial, lambs fed corn silage-based diets supplemented with either wet or dry corn gluten feed or soybean meal showed lower ADF digestibility (31.1%) for the dried CGF diet than for the wet CGF or SBM (46.8 and 48.8%, respectively). Similarly, NDF digestibility was lower for lambs fed dried CGF (Firkins et al., 1985). This indicates that although the hemicellulose was readily degraded, cellulose from dried CGF was less extensively degraded. Another possibility is that drying conditions resulted in a shift in cellulose of CGF from an amorphous to a more rigid structure. The presence of water in WCGF may cause cellulose to swell which increases its availability for microbial attack.

The drying of wet CGF not only decreases digestibility, but also may decrease animal performance. Green et al. (1987) reported that the feeding value (feed/gain) of wet CGF averaged 1.4% above the control corn diet while that of the dried CGF was 3.4% below the control diet when both by-products supplied 25-30% of the diets.

DeHaan et al. (1983) concluded that as CGF replaced corn silage in lamb diets, performance was improved due to an increase in the energy content of the diets. This in turn may be improved utilization of the fiber in corn silage due to a reduction of negative associate effects that might be present.

In a steer finishing trial, WCGF and DCGF were evaluated as energy sources. Firkins et al. (1985) fed diets (11.5% CP) composed of corn silage plus SBM, dried CGF or wet CGF. Both dry and wet CGF were included at 50% of the diet to serve as protein and energy sources. No differences in average daily gain were noticed among any of the 3 treatments although feed intake was higher and feed/gain was poorer for steers fed dried than wet CGF. Berger (1985) added wet or dry CGF at 50% of dietary DM cracked corn, SMB and oatlage based diets. Average daily gains were similar, though feed efficiency was lower with the dry CGF treatment. These data indicate that CGF can be substituted in high energy finishing diets without depressing performance. These data also suggest that wet CGF has 92 to 95% the energy value of whole shelled corn.

Trenkle (1986) noted that steers fed 1, 30, 50 and 70% CGF substituted for both corn and roughage ate 9.27, 9.77, 9.50, and 8.82 kg/d of DM and gained 1.3, 1.52, 1.51, and 1.42 kg/d, respectively. Steers which received levels of 30 and 50% CGF had greater intake, gained faster, and were more efficient. In a growth trial, heifers fed fescue hay and supplemented with corn/SBM or CGF had similar rates of gain (.70 kg/day) (Cordes et al., 1986). In the same study, the hay basal diets were supplemented either with 1.8 kg of dry CGF, corn plus urea, or a ratio of 1:1 CGF and corn plus urea . Average daily gains were .50 and .54 kg/d, respectively

Whether CGF can be used efficiently to improve the utilization of low quality roughages is not yet known. Studies are needed to test the potential value of CGF as a protein supplement in lower energy diets like prairie hay. Limited data have shown that protein supplementation with feeds like soybean meal can substantially improve intake and utilization of the prairie hay by cattle. Improvement has been noted with both or those fed prairie hay diets. Information is needed on the effects of CGF on intake and digestion variable with low quality hay diets.

CHAPTER III

EFFECTS OF SUPPLEMENTAL CORN GLUTEN FEED OR SOYBEAN MEAL ON INTAKE AND UTILIZATION OF PRAIRIE HAY BY BEEF HEIFERS

Summary

Fifteen crossbred heifers (320 kg) were used in three simultaneous 5X5 latin squares to determine the effect of supplementation with soybean meal (SBM), corn gluten feed (CGF) or blends of these two on intake and digestibility of medium quality prairie hay (4.9% crude protein [CP] on dry matter [DM] basis). Prairie hay, cut during the first half of July from a meadow harvested annually, was available ad libitum. Treatments included: 1) control, hay plus a mineral-vitamin mixture; 2) a soybean meal (SBM) based supplement (0.64 kg at 49.0% CP per day); 3) a blend with 2/3 of the CP from soybean meal plus 1/3 from CGF (.87 kg at 38.9% CP; 1/3 CGF); 4) a blend with 1/3 of the crude protein from soybean meal plus 2/3 from CGF (1.1 kg at 28.5% CP; 2/3 CGF); and 5) a CGF based supplement (1.4 kg at 23.0% CP). Each supplement was fed to provide 310 g of supplemental crude protein to each heifer each day. All four protein supplementation programs increased ($P<0.01$) intake of prairie hay, total dry matter and digestible dry matter, as well as digestibilities of organic matter, acid and neutral detergent fiber and crude protein. Ruminal NH_3 nitrogen concentrations also were increased ($P<.01$) by protein supplementation, with a linear ($P<.01$) increase being observed when CGF replaced SBM. Particulate passage rate of hay was increased ($P<.01$) by supplementation. Replacing SBM with CGF resulted in linear ($P<.01$) declines in forage intake and protein and cellulose digestibilities. CGF is an acceptable protein-energy supplement which helps to increase intake of medium quality roughages, and ADF digestion, although improvements were not as great as with SBM. In a second experiment, five fistulated heifers were used in a 5X5 latin square to evaluate disappearance of CGF from dacron bags in animals fed prairie hay plus either SBM, 1/3 CGF, 2/3 CGF or CGF supplements. Dacron bags were incubated in the rumen for 48, 36, 24, 18, and 12 hours. All supplemental programs increased ($P<.05$) dry matter disappearance up to 24 h. However, crude protein disappearance from CGF was not influenced by protein supplementation or protein supplement source. (Key words: Prairie Hay, Corn Gluten Feed, Soybean Meal, Protein).

Introduction

Intact protein supplements consistently increase forage intake and utilization of low quality low protein roughages (McCollum and Galyean, 1985). Such low quality forages would include winter range pasture, low quality grass hays and cereal straws. Supplementing such forages with cereal grain usually decreases intake of forage and digestibility of fiber fractions (Arelovich, 1983; Guthrie, 1984; Chase and Hibberd, 1985). Additional nitrogen supplementation may alleviate some of these inhibitory effects of starch or readily available carbohydrates in the diet (El-Shazly et al., 1961; Hennessey et al., 1981).

Recently, supplements low in starch, such as the grain by-products, have become of interest because they do not exert negative associative effects when fed with low quality roughages (Fleck et al., 1986). Corn gluten feed (CGF) is a by-product of wet-milling of corn to produce corn syrup. It includes the corn bran and condensed steepwater solubles. CGF contains about 22% crude protein, 2% ether extract and 9% crude fiber (Cooley, 1970), and is high in phosphorus and potassium. CGF has become more widely available over the last five years, and its use has increased greatly. As the corn refining industry has grown and the export market has diminished, CGF has found wider use in the U.S. as a protein supplement. DeHaan et al. (1983) reported that CGF had a protein value equal to 71% that of soybean meal (SBM) when fed to growing steers. They also reported that according to an in vitro enzyme assay, CGF protein should be more extensively degraded than SBM in the rumen. In a further evaluation of CGF, Firkins et al. (1985) reported that digestibilities of fiber and N by lambs were similar for wet CGF, dry CGF and SBM diets. This indicated that CGF furnished sufficient amounts of both N and energy for efficient microbial growth in the rumen.

Many studies have been conducted with CGF, but work has been very limited investigating its use in range supplements for beef cattle. Even less work has been conducted to determine the effects of CGF or various blends of CGF on intake and digestibility of medium quality range forages similar to those grazed by cattle during summer months.

The objectives of this study were to investigate the effects of equal amounts of supplemental protein from CGF and SBM and two blends of CGF and SBM on intake, digestibility, ruminal NH_3, rumen pH and rate of passage of medium quality prairie hay.

Materials and Methods

Experiment I

Fifteen yearling crossbred Angus-Hereford heifers (320 kg) were randomly allocated to slatted-floor individual pens in three simultaneous 5X5 latin squares. All animals received the same basal diet, medium quality prairie hay which was available ad libitum. The supplement treatments were: 1) control (cont) which consisted of a mineral and vitamin A supplement; 2) a SBM supplement; 3) a blend with one-third of the supplemental crude protein provided by CGF and two-thirds from SBM (1/3 CGF); 4) a blend with two-thirds of the supplemental protein provided by CGF and one-third from SBM (2/3 CGF), and 5) a CGF supplement.

The mineral and vitamin mixture was fed at a level of 50 g/day to all animals on all treatments. Protein supplements were fed once daily to provide an equal amount of total supplemental protein (.67 lb. or 300 g per day). The SBM, 1/3 CGF, 2/3 CGF, and CGF supplements (Table I) were fed at rates of .64, .87, 1.1, and 1.4 kg per day, respectively. Chromic oxide, an indigestible marker was administered as a mixture of 90% CSH, 5% Cr_3O_3 and 5% molasses, and was fed at a rate of 100 g DM twice daily. The composition of the supplements is shown in Table I, and the nutrient composition of the hay and supplements are in Table II. Supplements were prepared at the beginning of each period.

Each period in the latin square lasted 14 d with d 1 to 8 being used for adaptation. Prairie hay and supplements were sampled on days nine through 12. Rejected prairie hay was sampled on d 10 through 13. Grab fecal samples were collected twice daily (am and pm) on d 10 through 13. All samples for each animal in each period were placed in an individual plastic container and refrigerated until the end of the period.

The rumen of each animal was sampled via stomach tube on the last day of each period within two to four hours after the supplement was fed. Approximately 250 ml of ruminal fluid was obtained per animal. The pH of the ruminal fluid was measured immediately; then 200 ml fluid was acidified with 5 ml of 20% H_2SO_4 solution and frozen for later NH_3-N analysis.

The amount of prairie hay offered was recorded, and it was sampled daily. Samples were composited and subsampled at the end of each period for each animal. Hay refusals were collected for each animal during the four-d sampling phase. At the end of each period, samples were proportionately composited by animal and subsampled. Composited fecal samples were subsampled at the end of each period. Fecal subsamples were weighed and dried at 60 C for 96 h. All samples (feeds, refusals, and feces) were ground in a Wiley mill fitted with a 1 mm screen and stored in plastic bags in a freezer for later analysis.

All samples were analyzed for crude protein (NX6.25) by the macrokjeldahl method, DM and ash (AOAC, 1985) and NDF, ADF, and permanganate lignin (Goering and Van Soest, 1970). The CSH mix and fecal samples were analyzed for chromium (Fenton and Fenton, 1979). Ammonia-N was determined by the phenol-hypochlorite procedure (Broderick and Kang, 1980).

Rate of passage values were estimated using Ytterbium as an indigestible marker. Chopped prairie hay was labeled with Yb (Teeter et al., 1984) at a rate of 1 g of Yb on 200 g of hay with the supplement on d 9 (am) of each fecal collection period as a single pulse dose. Fecal samples were collected at zero (blank) and 36, 48, 60, 72, and 96 h post-dosing. Samples were dried at 60 C for 96 h, ground in a Wiley mill fitted with 1 mm screen and stored for Yb-analysis. The Yb-labeled hay and fecal samples were analyzed for Yb by atomic absorption spectroscopy (Teeter et al., 1984). Passage rates were calculated by regressing Ln marker concentration against time. Data were also statistically analyzed using the general linear models procedure of SAS

(SAS, 1979). Classes as variables included square, period, animal within period and treatment. Treatments were compared by orthogonal contrasts (Table III). The orthogonal contrasts included the effect of protein supplement action (0 vs. all protein supplements), and linear, quadratic and cubic effects of substituting CGF protein for SBM protein.

Experiment II

Dacron polyester bags containing corn gluten feed (CGF) were suspended in the rumen of five fistulated heifers fed prairie hay plus supplemental SBM, 1/3 CGF, 2/3 CGF or CGF in a 5X5 latin square to determine DM and CP disappearance of CGF from bags incubated in the rumen for different time periods. Prairie hay was fed ad libitum.

Dacron bags, 6x10 cm and pore size of 25-74 μm, were made of dacron polyester (Poli-Air R-1019; N. Erlanger, Blumgart & Co., Inc.). All bags were dried and weighed before 7 g of as-is CGF was placed in each bag. Five strings each containing 12 bags were sequentially suspended in the rumen of each heifer in each period beginning on d 10 through 12 for 48, 36, 24, 18 and 12 h. All the bags were retrieved from the rumen on d 12. Following retrieval, dacron bags were removed from strings, and each bag was washed under running water until the water was clear. The weight of the dry residual and crude protein content of the residual at each time was regressed over time (12-48) yielding a slope corresponding to rate of ruminal DM and CP disappearance (% h).

Results and Discussion

Supplemental protein increased ($P<.01$) intake of prairie hay, total DM, digestible DM, and crude protein (Table IV). Substitution of CGF for SBM linearly decreased (P<.01) intakes of prairie hay, DM, digestible DM and protein. Intake of prairie hay is illustrated in Figure 3. To determine whether all of the intake response was caused by increasing diet digestibility, daily intakes of indigestible DM (Table IV) were calculated. Intakes of indigestible DM, however, did not follow the DM intake response pattern suggesting the ruminal capacity or output of indigestible material was increased by protein supplementation.

Digestibility of DM, OM, crude protein, certain fiber components (NDF, ADF, hemicellulose, and cellulose) all increased (P<.01) with protein supplementation (Table V). Observed crude protein digestibilities can be compared to those expected based on the NRC (1978) equation:

$$\text{Digestibility} = (.9\ \text{CP} - 3)/\text{CP} * 100$$

Expected values match observed values quite closely. Note that expected digestibilities decreased with substitution of SBM by CGF in the supplement (Figure 4). This is because crude protein intake from the supplement was constant, whereas hay intake had decreased. Hence protein content of the diet decreased which caused expected protein digestibilities to decrease slightly. Because the decrease in crude protein digestibilities was even greater than expected, this suggests that true protein digestibility is lower for CGF than for SBM. Olivers et al. (1987) reported that when corn steep liquor was exposed to high drying temperatures, it was dark brown and heat damaged, and protein digestibility of CGF in lambs was low. That dark brown color presumably resulted from a Maillard type reaction which is a temperature dependent chemical reaction between reducing sugars and protein (Van Soest, 1982). Olivers et al. (1987) concluded that drying possibly reduced the stimulatory growth effect of steep liquor and its enhancement of fiber digestion. The batch of CGF used in our study was a dark brown and smelled like coffee, much like the description that Olivers et al. (1987) used. Therefore, the depression in protein and cellulose digestion as CGF replaced SBM in the supplement increased could be attributed to overheating of CGF during drying which resulted in a Maillard browning reaction. The nitrogen characterization of both CGF and SBM is presented in Table VI. Nondigestible nitrogen as predicted by pepsin insoluble N was 12.8% of total N which was relatively high though soluble N (28.9%) was low compared to other batches used in this study. This may support the theory that the dark color and burned smell reflects heat damage of protein.

Digestibility of crude protein and cellulose decreased linearly (P<.01) as CGF replaced SBM in the supplement (Table V). There also was a slight but not significant trend for digestibility of DM, OM and ADF, to decrease with increasing CGF in the supplement blends. Lignin digestibility in contrast, increased (P<.03) as CGF substituted for SBM in the supplements. This is presumably due to artifact lignin formation during heating or loss of lignin due to fine grinding (Fahey, Jr. and Jung, 1983).

Supplementation would be expected to improve DM digestibility because protein and/or energy in the supplement is more digestible than forages. A comparison of observed vs. expected diet DM digestibilities across treatments (Figure 5) indicates that added protein had a positive effect on digestibility (observed > expected) for all protein supplement treatments. Furthermore, these comparisons show the absence of a negative effect or forage digestibility that usually is associated with grain supplements.

Ruminal fluid pH 2-4 h postfeeding linearly (P<.05) was decreased (P<.01) by supplemental protein (Table VIII) and slightly depressed by substituting CGF for SBM. This probably is due to increased rumen fermentation due to addition of available carbohydrate from the CGF. Firkins et al. (1985) reported that ruminal pH 3 h postfeeding a control diet (75% ground alfalfa orchard grass hay and 25% cracked corn) was higher than the average ruminal pH of sheep supplemented with either dry CGF or wet CGF. Klopfenstein et al. (1985) reported a slight reduction in rumen pH when 25% of a corn cob and alfalfa ration was replaced by corn bran with no change in fiber digestion compared to corn diets. Because corn gluten feed is a source of highly digestible fiber and is low in starch, it should be a desirable protein supplement with low quality forages and should not depress fiber digestion as drastically as a grain supplement.

Ruminal ammonia levels 2-4 h postfeeding of the supplements were .6 mg/d with the unsupplemented diet and were increased (P<.01) with protein supplementation (Table VIII, Figure 5). Ruminal ammonia concentration also increased (P<.01) linearly as CGF replaced SBM in the supplement. Because ruminal ammonia was highest with the CGF supplement, one can suggest that protein from CGF was more extensively degraded in the rumen (DeHaan et al., 1983) or that ammonia was less completely utilized by ruminal microbes with CGF than SBM supplements.

Ammonia levels of cattle fed the control diet were so low that they probably restricted the synthesis of microbial protein (Satter and Slyter, 1974). However, even with protein supplementation, these values remained within the range (2-5 mg/dl) that Satter and Slyter (1974) recommended as a minimum for microbial growth. Ruminal ammonia concentrations of this study were higher than those reported by Arelovitch (1983) and Guthrie (1984) for cattle fed prairie hay supplemented with cottonseed meal (3.56 mg/l) and soybean meal (2.01 mg/dl).

The particulate rate of passage, determined by labeling chopped prairie hay with Yb, ranged from 2.0 to 3.35 percent per hour (Table VIII, Figure 7).

Supplemental protein increased ($P<.05$) passage rate with no significant differences among supplemental treatments. Rate of passage tended to be higher with more SBM in the protein supplement. McCollum and Galyean (1985) found that supplementing prairie hay with cottonseed meal increased particulate rate of passage from 2.9 to 4.5% h. Likewise, Guthrie (1984) reported that SBM supplementation increased particulate rate of passage of prairie hay from 2.1 to 3.5 percent per hour which are in excellent agreement with values in the present study. Increased fermentation rate and particulate rate of passage may be caused by the increase in voluntary intake of medium quality prairie hay, or it may have permitted intake to increase (McCollum and Galyean, 1985). Particulate rate of passage was positively ($P<.01$) correlated (correlation coefficient = .96) with the total dry matter intake across treatments. Whether this increase is due to an increased rate of fermentation from the added ammonia or feedback from an improved postruminal protein state is unknown.

Based on extent of total tract ADF digestion and rate of passage, one can calculate rates of ADF digestion in the rumen (Table VIII). Certain assumptions are necessary for this calculation including 1) that rates of digestion and passage are first order reactions and 2) rate of passage of ADF is equal to the particulate passage rate determined with Yb. Rate of digestion of ADF calculates to be almost doubled by protein supplementation and tended to be slightly higher with more SBM in the supplement.

One also can calculate ruminal ADF content from rate of passage and ruminal escape of ADF again assuming that reactions are first order. Protein supplementation reduced calculated ADF in the rumen by 12 to 20%. As a fraction of daily ADF intake, protein supplements reduced ruminal ADF from over 151% to a mean of 84% of daily ADF intake due to increases in rates of both digestion and passage. These differences need to be checked directly by ruminal evacuation.

The increased intake of medium quality prairie hay in this study must somehow be related to or influenced by the additional protein furnished by the supplements (Table VII). Smith and Warren (1986) reported that voluntary consumption of poor quality forage by lambs fed cottonseed meal and soybean meal increased by 67 and 46%, respectively. Similar responses in prairie hay intake with either CSM or SBM supplementation have been reported by others (Arelovitch, 1983; Guthrie, 1984; McCollum and Galyean, 1985). In our study, substitution of CGF for SBM slightly depressed prairie hay intake. This may be due to the higher supply of digestible energy supplied in CGF than SBM when fed isonitrogenously. Alterations in rumen fermentation patterns also suggest the possibility of metabolic changes from supplementation (Redman et al., 1980).

Ellis (1978) suggested that supplementation of very low crude protein forages with nitrogen should increase rate of forage digestion. Data from our study support this suggestion, in that extent of total tract digestion of DM, OM, CP, ADF, NDF, and cellulose all were increased by supplemental protein. Though lignin is theoretically indigestible, disappearance of lignin also tended to increase ($P<.01$) with protein supplementation.

In summary, our results suggest that CGF can be successfully used as a supplement for medium quality prairie hay. At levels up to 16.7% of the diet, CGF did not reduce fiber digestion, forage intake or alter fermentation patterns. Calculated daily intakes of ME (Mcal), based on NRC (1976) values, were 10.3, 17.0, 17.2, and 16.7 Mcal for the control, SBM, 1/3 CGF, 2/3 CGF, and CGF treatments, respectively. Our results illustrate that added protein can increase ADF digestion and total energy intake by beef heifers fed prairie hay.

Compared to protein from CGM, supplemental protein from SBM produced higher feed intakes, and rates and extents of digestion of fiber components.

Experiment II

The extent of in situ dry matter and crude protein disappearance after 12, 18, 24, 32 and 48 h of incubating CGF in the rumen are presented in Table IX. Compared to control diet, DM disappearance was increased ($P<.05$) after 24 h of incubation regardless of the protein supplement treatment (Figure 8). The average DM disappearance for animals receiving SBM was similar to that of animals receiving CGF after 32 h incubation, whereas extent of DM disappearance was slightly lower than for cattle fed CGF than those fed SBM. That difference could be due to the complete ruminal DM digestion of protein from CGF with the SBM supplement as protein in CGF is probably associated with the fibrous fraction.

The extent of N disappearance of CGF from the incubated dacron bags was not significantly different with any of the five diets (Figure 9, Table IX). N disappearance for CGF treatment ranged from 65.4 to 78.5% indicating that CGF is extensively digested in the rumen. This compares with 69.2 to 86.9% for the SBM treatment. But in situ protein loss from SBM is more continuous that with CGF. Results indicate that nitrogen of CGF incubated in heifers fed CGF needs more time than that of CGF incubated in the rumen of heifers fed SBM to be degraded equally in the rumen. However, these results might be related to the theory of Maillard reaction of having protein bound with sugars which in turn reduces the extent of protein degradation. The difference between CP and DM disappearance across time (Table IX) is very close to saline soluble-N (Table VI) which shows that almost 30% of CP disappearance is due to CGF solubility.

In general, the extent of CGF disappearance of DM and CP at various times of incubation was much greater from bags incubated in rumens of heifers fed supplements compared with unsupplemented heifers. That could be explained by a need for protein supplementation. Weakley (1983) demonstrated that as dietary roughage level increased, extent rate of protein degradation of protein increased in situ. In our study, protein from CGF was more extensively degraded after 24 h of ruminal incubation in heifers fed SBM, CGF or blends of CGF and SBM, suggesting that most of CGF protein needed more time to be degraded which agrees with the results in Table VI in that 58.3% of total N was nonsoluble degradable N type which takes longer to be degraded.

TABLE I

COMPOSITION AND INTAKE OF THE SUPPLEMENTS (DM BASIS)

Ingredient	Supplement[a] C	SBM	1/3 CGF	2/3 CGF	CGF
	g/day				
Soybean Meal		640	406	198	
Corn Gluten Feed			464	902	1400
Minearl and Vitamin Mixture[b]	50	50	50	50	50

[a]C = control; SBM = soybean meal; 1/3 CGF = corn gluten feed supply 1/3 of supplemental crude protein; 2/3 CGF = corn gluten feed supply 2/3 of supplemental crude protein; CGF = corn gluten feed.

[b]Contained: Dicalcium phosphate 42.2%, Kcl 18.1%, trace minerals 27.4% (.25% Mn, .2% Fe, .033% Cu, .0025% Co, .007% I, .005% Zn), Na_2SD_4 11.8% and vitamin A .5% (220 USP units/g).

TABLE II

CHEMICAL COMPOSITION OF HAY AND SUPPLEMENTS

Item[a]	Prairie Hay	SBM	CGF
		%	
Dry matter	91.7	89.4	90.1
Crude protein	4.9	49.0	23.0
Organic matter	93.3	90.5	90.2
Ash	6.7	9.5	9.8
Neutral detergent fiber	71.0	13.4	45.8
Acid detergent fiber	44.2	8.4	14.2
Lignin	8.6	1.4	2.3
Cellulose	32.2	8.0	6.9
Hemi-Cellulose	27.1	5.0	31.6

[a]Dry matter basis.

TABLE III

ORTHOGONAL CONTRASTS AMONG TREATMENTS MEANS

	Supplement[a]				
Ingredient	C	SBM	1/3 CGF	2/3 CGF	CGF
Control vs. Others	-4	1	1	1	1
Linear	0	-3	-1	1	3
Quadratic	0	1	-1	-1	1
Cubic	0	-1	3	-3	1

[a]C = control; SBM = soybean meal; 1/3 CGF = corn gluten feed supply 1/3 of supplemental crude protein; 2/3 CGF = corn gluten feed supply 2/3 of supplemental crude protein; CGF = corn gluten feed.

TABLE IV

INFLUENCE OF SUPPLEMENTAL SOYBEAN MEAL OR CORN GLUTEN FEED ON INTAKE BY HEIFERS

Item	Supplements					SE	Orthogonal Comparisons[a]			
	C	SBM	1/3 CGF	2/3 CGF	CGF		S	L	Q	C
Prairie hay DM										
kg/d	5.80[b]	8.63[c]	8.22[c]	7.78[cd]	7.03[cd]	.196	.0001	.0001	.39	.73
% of BW	1.1[b]	2.69[c]	2.56[c]	2.43[cd]	2.19[cd]	.061	.0001	.0001	.39	.73
Total DM										
kg	6.07[b]	9.54[c]	9.36[c]	9.21[c]	8.71[cd]	.197	.0001	.004	.42	.68
% of BW	1.89[b]	2.98[c]	2.92[c]	2.87[c]	2.72[cd]	.061	.0001	.004	.42	.68
Digestible DM										
kg	2.95[b]	5.29[c]	5.19[c]	5.03[c]	4.71[cd]	.124	.0001	.001	.36	.83
% of BW	.88[b]	1.65[c]	1.62[c]	1.57[c]	1.47[cd]	.039	.0001	.001	.36	.83
Indigestible DM										
kg/d	3.25[b]	4.25[c]	4.17[c]	4.17[c]	4.00[c]	.127	.0001	.19	.72	.66
% of BW	1.0[b]	1.3[c]	1.3[c]	1.3[c]	1.3[c]	.039	.0001	.19	.72	.66
Protein DM										
g/d	290[b]	745[c]	751	717[cd]	680[cde]	1.2	.0001	.0001	.08	.49

[a]Contrasts included: S for supplemented diets vs. control diet; L, Q and C for linear, quadratic and cubic effects of substituting SBM protein by CGF protein.

[bcde]Means in same row with difference superscripts differ (P<.05).

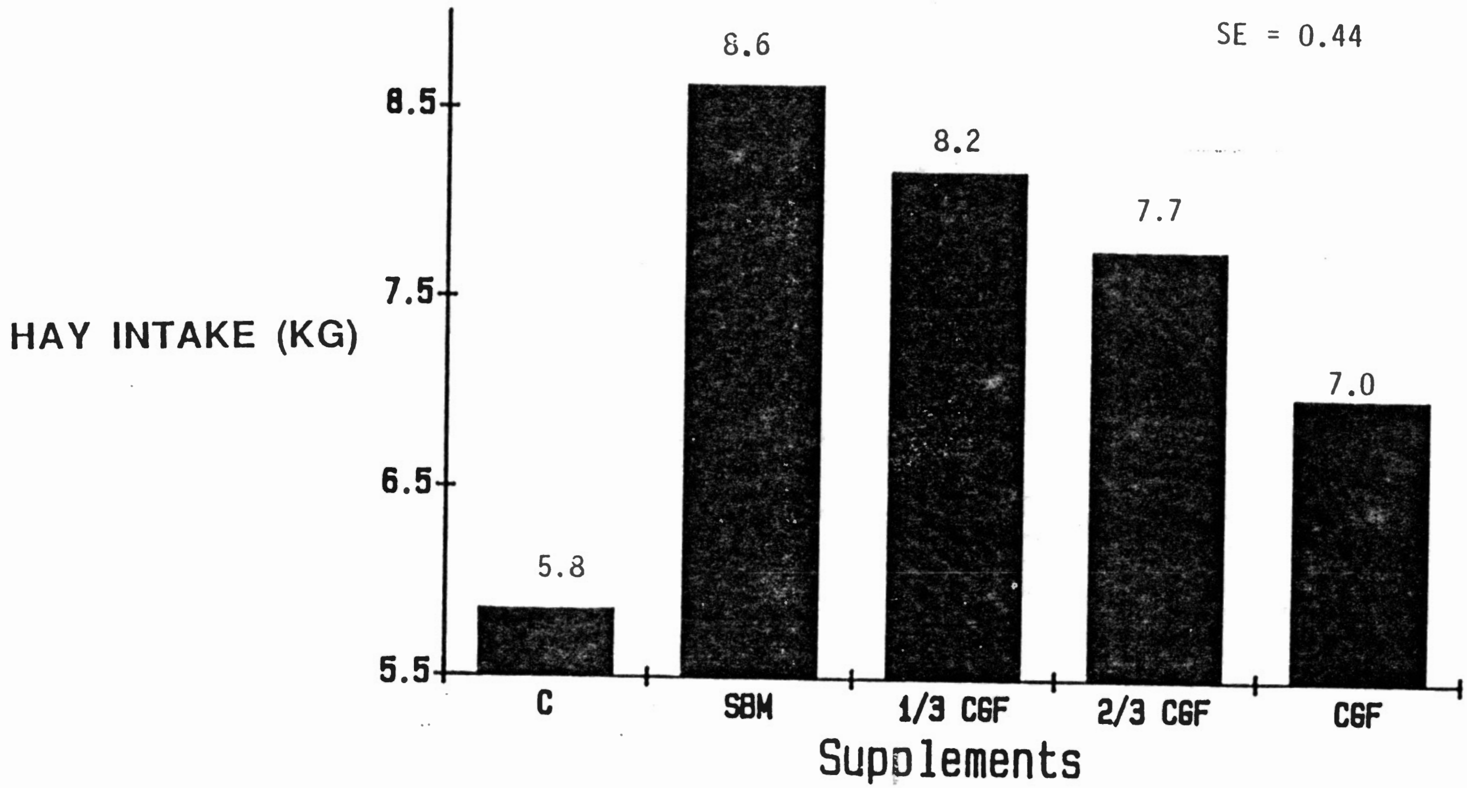


Figure 3. Influence of Supplement Source on Prairie Hay Intake

TABLE V

INFLUENCE OF SUPPLEMENTAL SOYBEAN MEAL OR CORN GLUTEN FEED ON DIGESTIBILITY BY HEIFERS

Component	Treatment					SE	Orthogonal Comparisons[a]			
	C	SBM	1/3 CGF	2/3 CGF	CGF		S	L	Q	C
	% Digestibility									
Total DM										
Observed	48.5[d]	55.5[e]	55.2[e]	54.7[e]	54.2[e]	.75	.0001	.19	.87	.91
Expected[b]		50.6	51.5	52.4	53.7					
Organic Matter	51.11[d]	58.13[e]	57.89[e]	57.60[f]	.5701[f]	.69	.0001	.24	.80	.94
Ash	3.49[d]	17.3[e]	17.06	13.73	16.34	2.54	.01	.58	.50	.40
Crude Protein										
Observed	23.64[d]	51.87[e]	50.52	46.52	45.06	1.38	.0001	.0002	.96	.40
Expected[c]	26.8	51.5	52.7	51.5	51.5	.58	.0001	.70	29	.16
Acid Detergent Fiber	37.7[d]	44.6[e]	44.5[e]	43.8[e]	43.4[e]	.87	.0001	.28	.92	.80
Neutral Detergent Fiber	47.6[d]	53.9[e]	54.8[e]	53.6[e]	53.2[e]	.78	.0001	.34	.39	.42
Hemicellulose	61.4	68.7	68.9	67.8	66.1	.81	.0001	.01	.22	.79

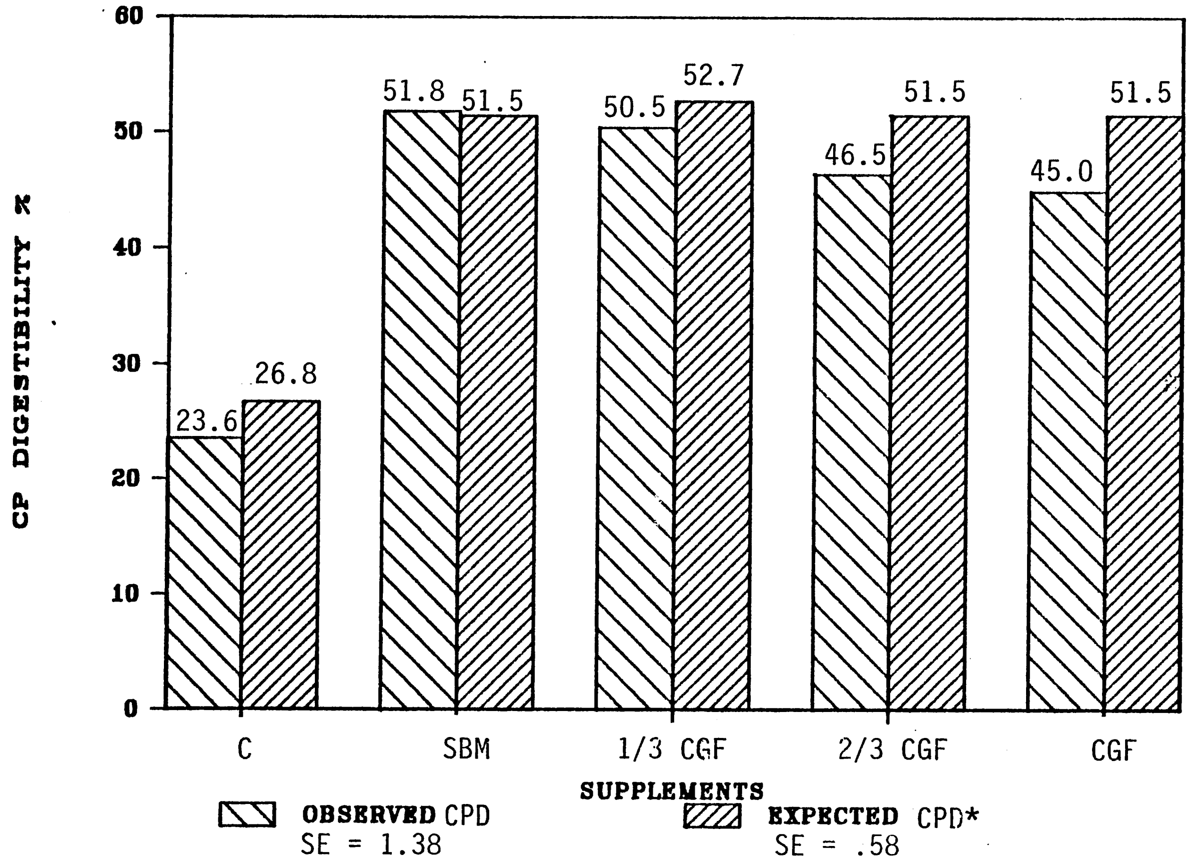
TABLE V (Continued)

Component	C	SBM	1/3 CGF	2/3 CGF	CGF	SE	S	L	Q	C
	Treatment						Orthogonal Comparisons[a]			
	% Digestibility									
Cellulose	51.1[d]	59.3[e]	58.7[e]	58.8[e]	56.4[f]	.83	.0001	.02	.27	.39
Lignin	11.7[d]	12.0[d]	16.8[d]	15.9[d]	19.2[f]	2.09	.07	.03	.72	.29

[a]Contrasts included: S for supplemented diets vs. control diet; L, Q and C for linear, quadratic and cubic effects of substituting SBM protein by CGF protein.

[c]Calculated from NRC (1984).

[def]Means in same row with different superscripts differ (P<.05).



*Expected digestibilities are based on values obtained from the NRC (1978) equation: Expected CP D = (.9 CP-3)/CP*100 where CP = percent of CP in total dry matter intake.

Figure 4. Comparison of Observed vs. Expected Diet Crude Protein Digestibilities

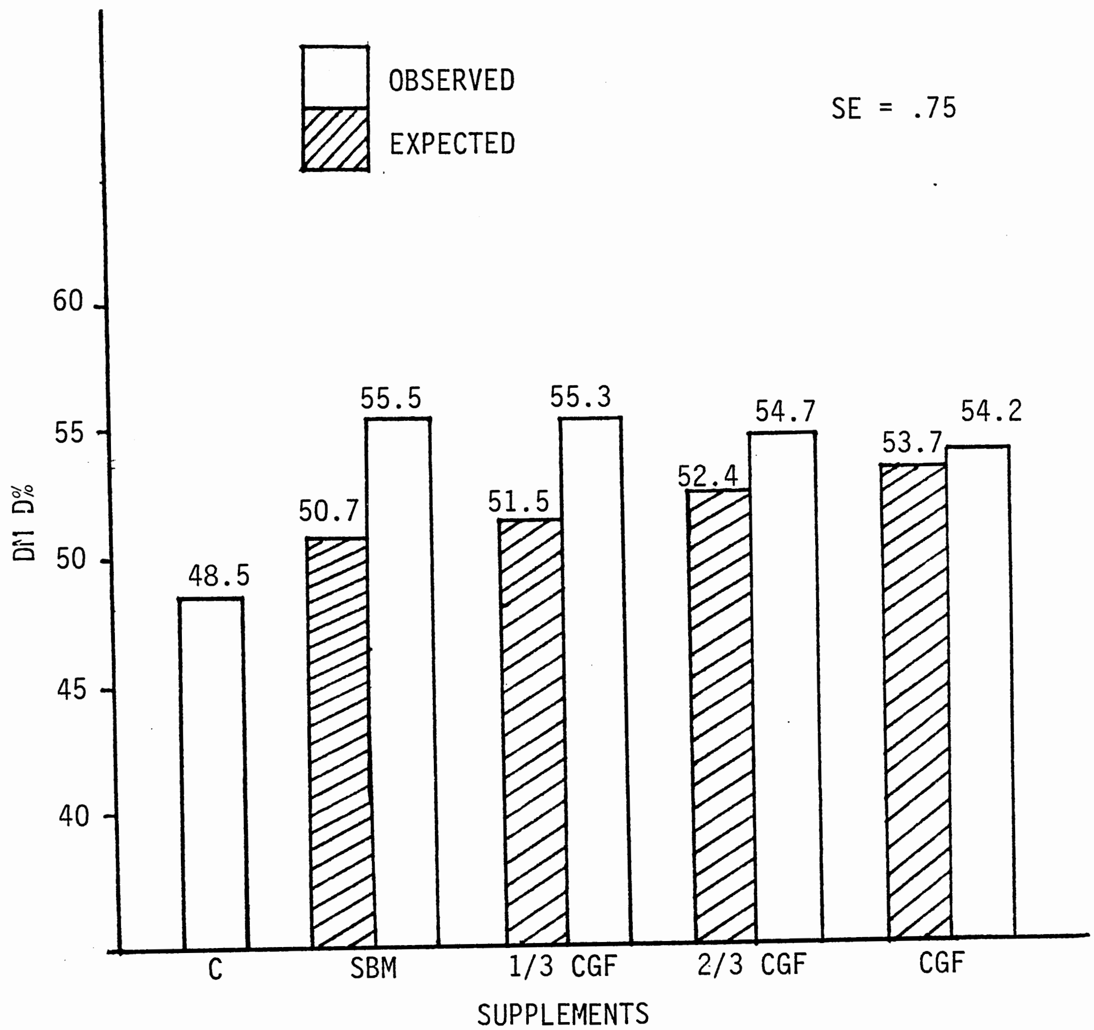


Figure 5. Comparison of Observed vs. Expected Diet Dry Matter (DM) Digestibilities. Expected Digestibilities are Based Upon Values Obtained for the Hay on the Control Treatment and 80% DM Digestibility for the Supplement.

TABLE VI

NITROGEN FRACTIONS OF CGF AND SBM

Protein Fractions	CGF	SBM
Total N, %	3.2	7.3
Ammonia -N[a]	5.3	2.1
Pepsin insoluble -N[a]	12.8	10.2
Saline soluble -N[a]	28.9	18.3
Nonsoluble degradable -N[ab]	58.3	71.5

[a]Percent of total N.

[b]Nonsoluble degradable N was calculated as the difference between total N and the combination of pepsin insoluble N plus saline soluble N.

TABLE VII

DAILY INTAKE OF PROTEIN AND ADF

Item	C	SBM	1/3 CGF	2/3 CGF	CGF	SE	S	L	Q	C
	-Supplements-						Orthogonal Comparisons[a]			
Protein Intake										
g/d	290[b]	745[c]	751[c]	717[c]	680d	.012	.0001	.0001	.08	.49
Daily CP as a %BW	.09[b]	.23[c]	.23[c]	.22[c]	.21[d]	.003	.0001	.0001	.08	.49
ADF intake										
kg/d	2.5[b]	3.8[c]	3.6[c]	3.5[c]	3.26[d]	.08	.0001	.0001	.46	.75
Daily ADF as a % of BW	.8[b]	1.2[c]	1.1[c]	1.1[c]	1.0[d]	.02	.0001	.0001	.46	.75

[a]Contrasts included: S for supplemented diets vs. control diet; L, Q and C for linear, quadratic and cubic effects of substituting SBM protein by CGF protein.

[bcd]Means in same row with different superscripts differ (P<.05).

TABLE VIII

INFLUENCE OF SUPPLEMENTAL SOYBEAN MEAL AND CORN GLUTEN FEED
ON POST RUMINAL PARAMETERS

	-Supplement-						Orthogonal Comparisons[a]			
Item	C	SBM	1/3 CGF	2/3 CGF	CGF	SE	S	L	Q	C
Ruminal Fluid pH	6.89[e]	6.81[f]	6.80[f]	6.79[f]	6.72[g]	0.03	.002	.05	.41	.69
Ruminal NH_3										
mg/dl	0.57[e]	2.31[f]	2.55[f]	3.42[g]	3.63[g]	.250	.0001	.0001	.94	.25
Particulate Passage										
rate/hour	2.09[e]	3.35[f]	3.34[f]	2.96[f]	3.13[g]	.185	.01	.2	.6	.3
		+60%	+60%	+42%	+50%					
Rate of ruminal ADF										
Digestion[b] h^{-1}	.99[e]	2.3[f]	2.2[f]	1.9[f]	2.0[f]	.16	.0001	.14	.68	.30
		+132%[c]	+129%[c]	+95%[c]	+106%[c]					
Ruminal ADF[d]										
g	3835[e]	3068[f]	2769[f]	3165[f]	3013[f]	257	.005	.84	.77	.28
% of daily intake	151[e]	80[f]	75[f]	90[f]	92[f]	.84	.0001	.20	.84	.36

[a]Contrasts included: S for supplemented diets vs. control diet; L, Q and C for linear, quadratic and cubic effects of substituting SBM protein by CGF protein.

[b]Calculated assuming that 90% of ADF digestion occurred in the rumen and that rate of passage of all ADF was proportional to particulate rate of passage.

[c]Percentage change from control supplement.

[d]Calculated as hourly ruminal ADF escape [(intake * % ADF) * (1-.9 ADF digestion)/24] divided by particulate passage rate.

[efg]Means in same row with different superscripts differ ($P<.05$).

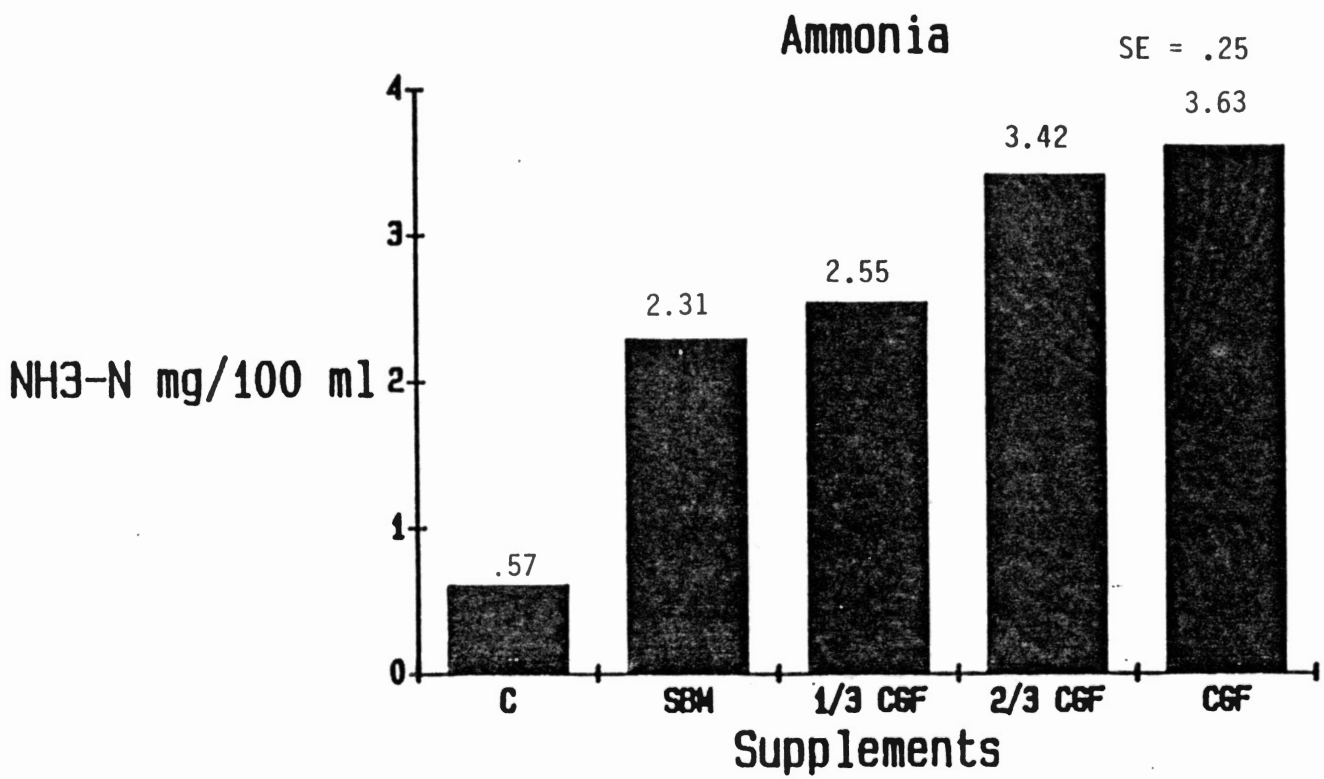


Figure 6. Ruminal Ammonia Concentrations

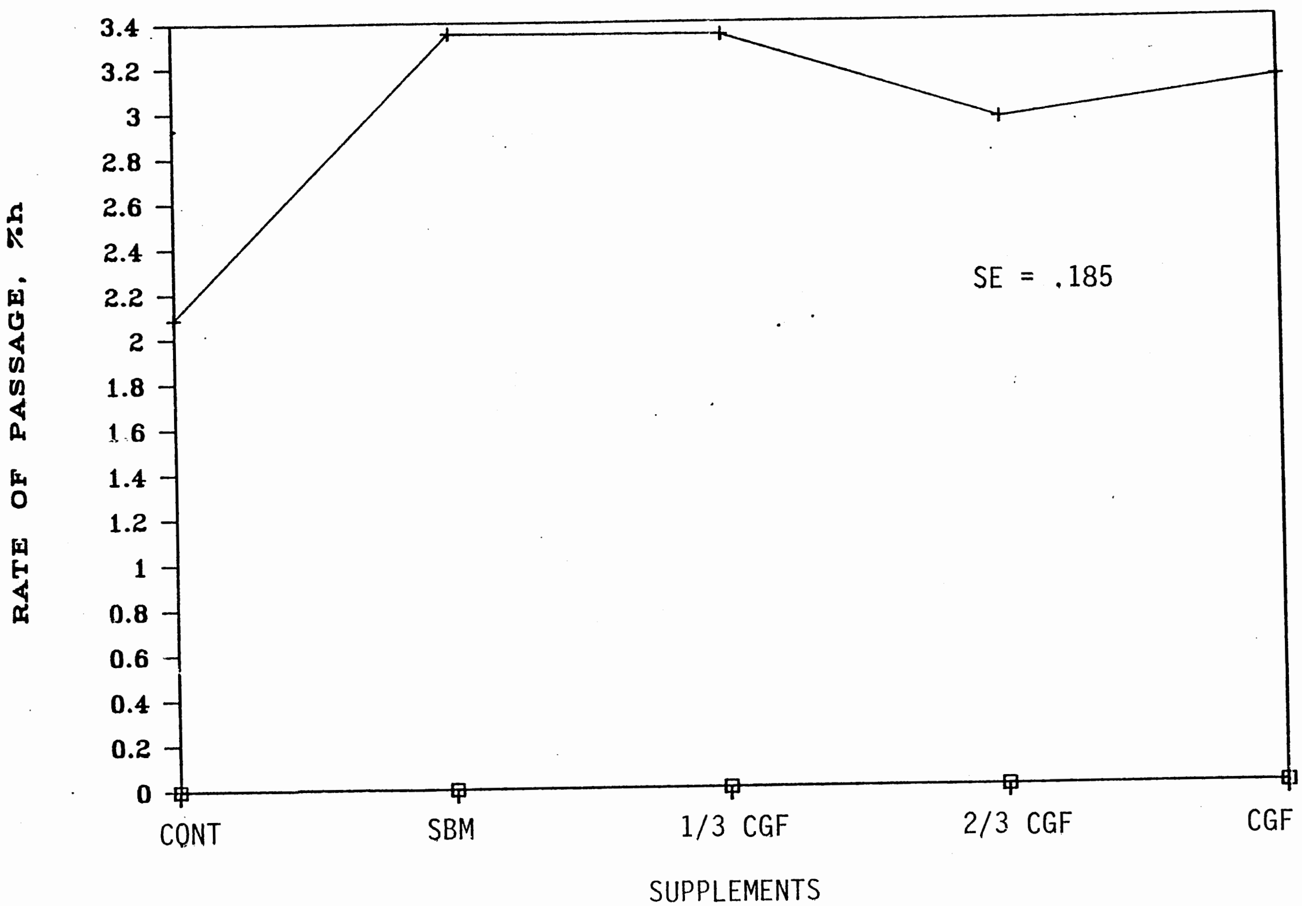


Figure 7. Particulate Rate of Passage (% h) as CGF Substituted for SBM Diets fed with Prairie Hay

TABLE IX

CORN GLUTEN FEED (CGF) EXTENT OF IN SITU DRY MATTER (DM) AND CRUDE PROTEIN (CP) DISAPPEARANCE IN HEIFERS FED SBM, CGF OR BLENDS OF CGF AND SBM WITH MEDIUM QUALITY PRAIRIE HAY

	Supplement						Orthogonal Comparisons[a]			
	C	SBM	1/3 CGF	2/3 CGF	CGF	SE	S	L	Q	C
	%									
DM Disappearance										
12	40.7	38.9	40.5	40.7	39.2	1.01	.46	.81	.14	.89
18	45.2	44.5	45.1	47.5	43.0	1.52	.92	.76	.12	.22
24	47.3[b]	48.0[b]	45.2[d]	48.3[b]	44.0[c]	1.03	.46	.08	.51	.01
32	50.9[b]	54.2	52.9	57.7[c]	56.0[c]	1.47	.02	.15	.88	.08
48	52.6[b]	60.5[c]	54.5[d]	63.0[c]	59.6[c]	1.98	.009	.52	.53	.01
CP Disappearance										
12	70.1	69.2	68.1	68.9	73.2	3.08	.59	.63	.42	.78
18	72.4	71.9	72.4	73.7	65.4	3.66	.73	.92	.16	.50
24	73.5	73.2	70.5	70.5	65.8	.96	.09	.01	.03	.18
32	66.2	76.0	71.9	75.3	78.4	4.85	.11	.35	.47	.71
48	72.8	86.9	75.7	69.8	78.5	6.20	.37	.52	.48	.64

[a]Contrasts included: S for supplemented diets vs. control diet; L, Q, and C for linear, quadratic and cubic effects of substituting SBM protein by CGF protein.

[bcd]Means in the same row with different superscripts differ (P<.05).

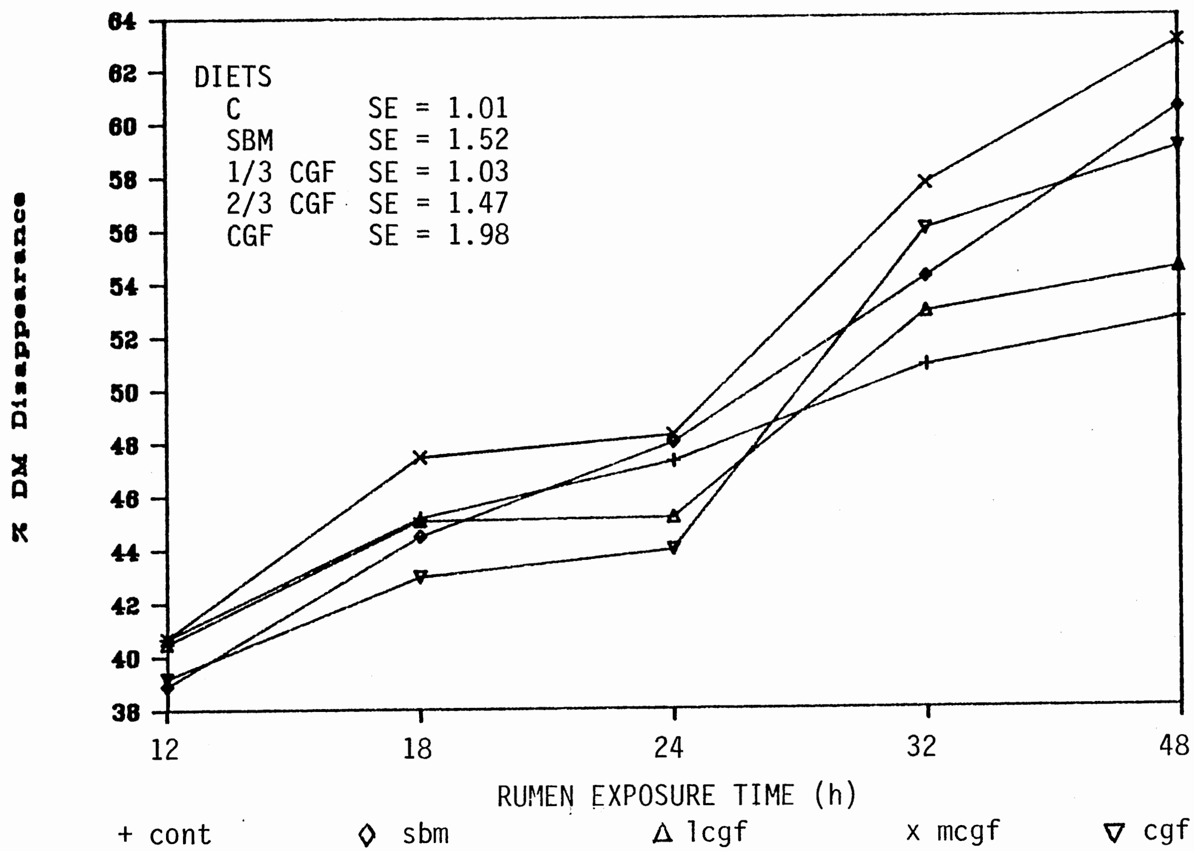


Figure 8. Rate of CGF DM Disappearance from Dacron Bags

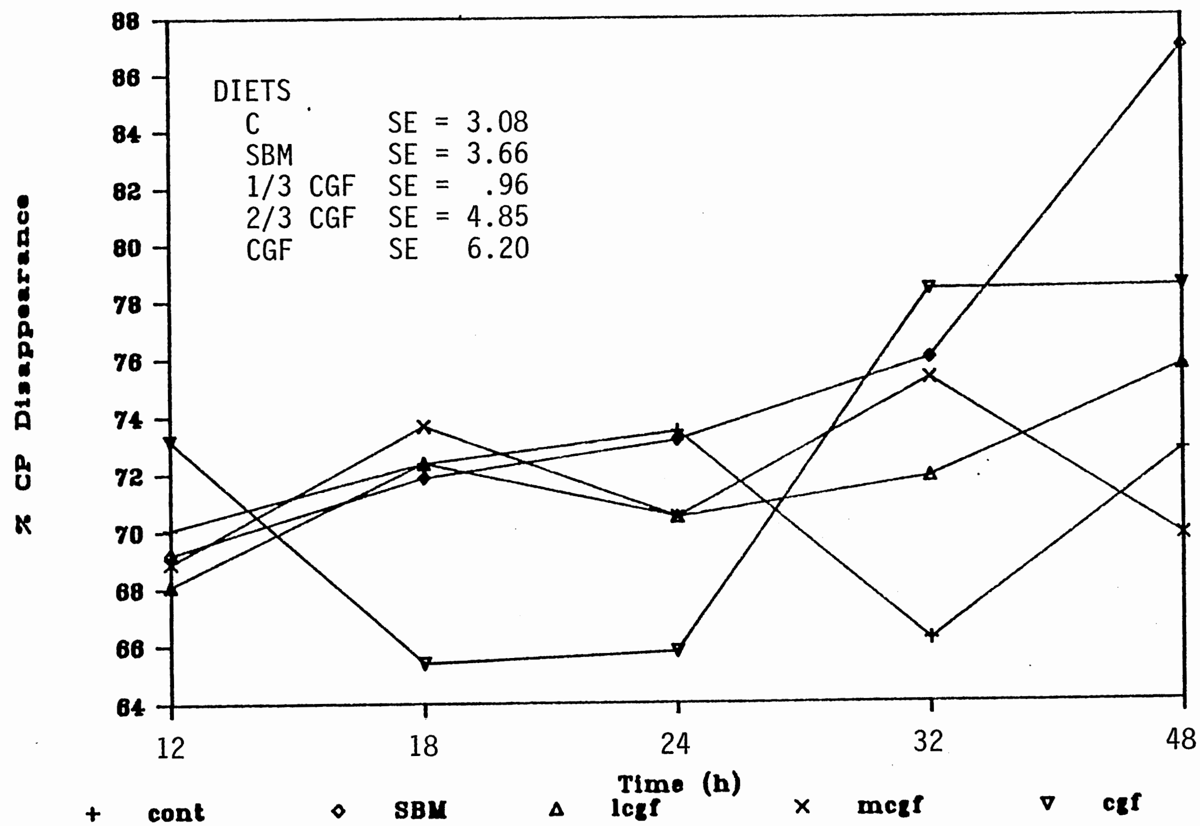


Figure 9. Rate of CGF CP Disappearance from Dacron Bags

CHAPTER IV

COMPARISON OF CORN GLUTEN FEED, SOYBEAN MEAL, AND COTTONSEED MEAL AS SUPPLEMENTS FOR BEEF HEIFERS FED PRAIRIE HAY

Abstract

Twelve 320 kg crossbred heifers were used in three simultaneous 4X4 latin squares to determine the effect of three supplemental sources of protein on intake and digestibility of low to medium quality (5.2% crude protein) prairie hay. Prairie hay was fed free choice. The four treatments included 1) control of prairie hay plus minerals and vitamin A mix (C); 2) a soybean meal supplement (SBM); 3) a cottonseed meal supplement (CSM), and 4) a corn gluten feed supplement (CGF). Daily dry matter intakes for these supplements were .76, .85, and 1.74 kg, respectively, to provide equal amounts of supplemental protein.

Heifers fed supplemental protein had higher (P<.01) intakes of forage, DM, digestible DM, and protein plus higher (P<.01) digestibilities of DM, OM, protein, NDF, ADF, cellulose, and hemicellulose. Voluntary intakes of hay were similar for the three protein supplements, and digestibilities of DM, OM, CP, ADF, NDF, cellulose and hemicellulose were not affected by type of supplement. However, forage intake was slightly (7%) lower with CGF than with SBM and CSM supplements, probably due to the higher amount of energy it supplied. Metabolizable energy intakes (Mcal/d) were 12.1, 19.1, 18.2, and

20.5 on the C, SBM, CSM and CGF, respectively. CGF is suitable as a protein supplement for beef heifers fed medium quality prairie hay.

Introduction

Beef cattle on native range grass are commonly supplemented during winter months to provide sufficient energy and protein to minimize weight loss and/or to improve performance. Protein concentrates are usually fed to increase intake and utilization of low quality roughage (Hennessey et al., 1981; McCollum and Galyean, 1985) under same conditions grain-based concentrates, on the other hand, may depress forage intake and cellulose digestion, especially if nitrogen is limiting or if high levels of grain are fed at one time. Medium quality forage such as native grass hays are often fed unsupplemented. Limited information on supplementation responses is available for such forages.

Removing flour or oil from grain by-products and oilseed meals leaves by-products which are high in protein but low in oil, starch and readily available carbohydrates. Such by-products may alleviate some of the negative associative effects sometimes encountered from feeding supplements containing cereal grains. Kartchner (1981) found that beef cows on winter range supplemented with isocaloric amount of barley or soybean meal (SBM) consumed more forage with SBM than with barley supplements. In a growing steer trial, DeHaan et al. (1983) reported that CGF has a comparative protein value at 71% of SBM. In the same trial, lambs consumed more feed and gained weight faster when CGF was substituted at 25 and 50% for either corn silage or corn. Smith and Warren (1986) reported that feeding SBM or cottonseed meal (CSM) to growing steers grazing an annual pasture increased growth rate. This appeared to be due not only to the metabolizable energy provided by the supplement, but also due to greater forage consumption. However, very limited information is available on animal responses to CGF compared to other supplements when supplemented with medium quality forage diets.

Therefore, this study was conducted to compare CGF with SBM and CSM as a source of supplemental protein for growing beef heifers consuming low-medium quality prairie hay. The objectives of this study were: 1) to determine the comparative protein supplement effects upon intake, utilization and ruminal parameters and 2) to estimate the rate of passage of the prairie hay under the different supplement regimes.

Materials and Methods

Twelve crossbred heifers (320 kg) were used in three simultaneous 4X4 latin squares to determine the effect of supplementation with CGF, SBM, or CSM on intake and digestibility of medium quality prairie hay. Prairie hay was cut during the first half of July from a meadow harvested annually. Chopped prairie hay was available ad libitum to all animals. The four treatments included: 1) control of prairie hay plus minerals and vitamin A mix (C); 2) a SBM based supplement (SBM); 3) a CSM based supplement (CSM), and 4) a CGF based supplement (CGF).

All heifers were housed individually in slatted-floor pens. Isonitrogenous amounts of each supplement were fed once daily at 0800 to provide equal amounts of supplemental crude protein (360 g/d). . The SBM, CSM, and CGF supplements were fed rates of .76, .85, and 1.74 kg per day, respectively. The mineral-vitamin mix was fed to all animals at a level of 50 g DM/day. The ingredient composition of the supplements is shown in Table X and the nutrient composition of the hay and supplements is in Table XI.

Fecal output was estimated using chromium oxide (Cr_2O_3) as an indigestible marker. Cottonseed hulls (95%) were labeled with Cr_2O_3 (5%) using molasses (5%) with water added at a rate of 20% of total DM. Labeled CSH (200 g DM) were fed twice each day.

Each period in the latin square lasted 14 d, with d 1 through 10 for adaptation and 11 through 14 for sampling. Hay and supplement samples were collected on d 9 through 12 and composited across days. Rejected prairie hay was collected on d 10 through 13, and fecal samples were collected twice daily (am and pm) on d 10 through 13. Fecal samples from each animal for each period was added to a plastic container and kept at 5 C until the end of each period when the composite sample was subsampled and dried at 60 C for 96 h. All dried samples were kept in plastic bags for later analysis.

Rumen fluid samples were collected via stomach tube at 2 to 4 h after supplement feeding on the last day of each period. Ruminal samples were acidified with 1 ml of 20% H_2SO_4 per 50 ml of fluid immediately after pH was determined. Acidified samples were frozen for later ammonia analysis by the phenolhypchlorite procedure (Brodric and Kang, 1980). Samples were also analyzed for volatile fatty acids (VFA) by gas chromatography (Erwin et al., 1961).

Hay intakes and refusals were recorded daily, and a sample of the daily hay refusal for each animal was collected during the four-day sampling phase and proportionally composited across days. All samples (feeds, refusals, and feces) were ground through a 1 mm screen in a Wiley mill. All samples were analyzed for dry matter (DM), ash, and crude protein (Nx6.25) by the Kjeldahl method (AOAC, 1975) and ADF, NDF and permanganate lignin (Goering and Van Soest, 1970). The labeled CSH and fecal samples were analyzed for chromium (Fenton and Fenton, 1979). Ammonia N was measured by the phenol-hypochlorite procedure (Broderick and Kang, 1980).

All heifers were dosed at the beginning of each sampling period (0800) on d 10 with 200 g (as-is) of Ytterbium (Yb) labelled native grass hay prepared by the immersion technique of Teeter et al. (1984). Fecal samples were collected at 0, 36, 48, 60, 72, and 96 h post dosing. Fecal samples were dried at 60°C for 96 h and ground through a Wiley mill fitted with 1 mm screen. All zero h samples were composited by period and used as a standard. Two g samples were dried, ashed and digested with a 20 ml 1:1 v/v mixture of 3N HC:3N HNO_3. Diluted samples were assayed by atomic absorption spectrophotometry for Yb. The Yb concentrations were regressed against time to determine the rate of passage of the particulate particles (McCollum, 1983).

The statistical analysis for this experiment included square, period, and animal within period as class variables. Treatments were compared using selected orthogonal contrasts (Table XII). The orthogonal contrasts were effects of supplementation (all vs. control), CGF vs. the SBM plus CSM and, finally, SBM vs. CSM.

Results and Discussion

Protein supplementation increased ($P<.01$) intake of hay, total DM, and digestible DM and crude protein (Table XIII). Increases in hay consumption were 39, 30 and 24% for SBM, CSM and CGF supplements, respectively (Figure 10). Guthrie et al. (1985) also reported a substantial improvement in prairie hay intake when supplemented with SBM (68%) or a 13% CP corn grain to supply equal total supplemental CP (37%). Likewise, Arelovich (1984) reported 23, 20 and 23% increases in prairie hay consumption when CSM or 20% CP, CSM plus wheat midds, or 20% CP CSM and ground wheat supplements were fed. This increase in prairie hay intake has been attributed to the extra protein furnished by the supplements (McCollum and Galyean, 1985). In their study, CSM supplementation increased daily prairie hay intake from 1.69 to 2.15% of body weight. Slightly lower forage consumption by heifers fed CGF than SBM in this trial agrees with the results of Fleck et al. (1986) who fed mature cows native grass hay. This may be due to the extra energy provided by the CGF supplement. Indigestible DM was calculated (Table XIII) to determine if the intake response could be attributed solely to increased diet digestibility. Because intakes of indigestible DM were very similar across the three supplemented diets, one might presume that gut fill of indigestible material restricted forage intake.

Digestibilities are presented in Table XIV. Protein supplementation substantially increased ($P<.01$) dry matter digestibilities of DM, OM, protein, NDF, ADF, hemicellulose and cellulose. However, no significant differences were observed among the three supplementation programs in digestibilities although values tended to be slightly greater with SBM or CSM than CGF supplementation. Moreover, observed digestibilities were higher than calculated expected values indicating the positive effects of protein supplementation (Figure 11). Whereas, observed crude protein digestibilities were quite similar to calculated expected values (Figure 12).

Lignin disappearance coefficients (Table XIV) were highly variable (SE = 9.55) and ranged between 0.93 to 9.77%. Lignin disappearance tended to be depressed by protein supplementation. However, lignin disappearance probably is an artifact caused by the analytical methods used for lignin analysis. Fahey and Jung (1983) indicated that choice of the analytical method and the extent of nutrient recovery may drastically alter apparent lignin disappearance.

Unsupplemented heifers had very low ruminal ammonia -N (.77 mg/dl) 2 to 4 h after feeding which increased (P<.01) with protein supplementation (Table XV, Figure 13). Supplementation with CGF produced higher (P<.01) ruminal NH_3-N than supplementation with SBM and CSM. This difference agrees with results of DeHaan et al. (1983) which showed that ammonia levels 4 h postfeeding were lower with SBM than CGF supplements. They suggested that protein from CGF is more rapidly or extensively degraded in the rumen than protein from SBM. Nitrogen characterization of supplements in this study (Table XVI) shows that CGF nitrogen is more soluble (saline soluble -N = 38.8) than CSM or SBM (saline soluble -N = 7.7 and 21.1),while the indigestible N content of CGF as reflected by pepsin insoluble N, is intermediate between values of CSM and SBM. Weakley (1983) reported that increasing ruminal ammonia levels to about 10 mg/dl should increase the digestion of organic matter in the rumen. Ruminal ammonia should not fall below 2 mg/dl for maximal microbial growth (Satter and Slyter, 1974). Therefore, based on previous literature, low ruminal ammonia concentrations may have limited the extent of ruminal digestion or microbial protein yield; this limitation was reduced by supplementating with any of these protein sources.

Ruminal fluid pH values were not influenced by supplementation 2 to 4 h postprandially although ruminal pH tended to be slightly reduced by supplemental protein (Table XV, indicating increased fermentation. Arelovich (1983) and Guthrie (1984) also found that ruminal fluid pH was not significantly altered by supplementation of native prairie hay with SBM, corn or cottonseed meal or a 13.4% CP corn-based supplement. McCollum and Galyean (1985) also reported no effect of CSM supplementation on ruminal pH in steers fed prairie hay. The current study shows that a supplement such as CGF which contains a readily digestible fiber may be fed at relatively high levels to provide supplemental protein with low quality forages while avoiding the depressions in rumen pH that might reduce the extent of fiber digestion. This contrasts with starchy grain supplements that might depress pH and ruminal digestion of fiber (Chase and Hibberd, 1985) if high levels are fed or diets are limiting in supplemental nitrogen.

Particulate rate of passage values in this experiment ranged from 1.76 to 3.31 percent/hour, being increased ($P<.01$) 88, 67, and 64% with SBM, CSM, and CGF, respectively (Table XV, Figure 14). No significant differences were detected among the three protein supplements. Similar responses in particulate passage rate to protein supplementation with prairie hay were found by Arelovich (1983), Guthrie (1984), McCollum and Galyean (1985), and Fleck et al. (1986), and in Chapter III of this dissertation.

Ellis (1978) suggested that supplementation of low crude protein forages with nitrogen would increase rate of forage digestion and particulate passage rate. These suggestions are supported by our data. The calculated ADF digestion rate was doubled or tripled by protein supplementation. The higher the rate of digestion and passage, the higher hay intake. Total DM intake and particulate rate of passage were positively correlated ($r = .96$) in this study. McCollum and Galyean (1985) concluded that an increase in the rate of particulate passage was the major factor which increased voluntary intake of low quality prairie hay. From our calculations, supplementation appeared to increase rate of digestion by 130 to 200%; whereas, rate of passage was increased by 64 to 88%. Thus, we would conclude that protein supplementation had even a greater effect on rate of digestion than it did on rate of passage. Ruminal volume or in situ measurements would help check this theory as the amount of ADF in the rumen calculates to be reduced by over 30% by protein supplements.

Total VFA concentration in ruminal fluid of heifers fed any of the three supplements tend to be greater (P<.67) at 2 - 4 h after feeding supplement than for unsupplemented heifers (Table XVII, Figure 15). The molar proportions of acetate and butyrate were similar for all diets, whereas that of propionate ranged from 12.2 to 20.3% on the control and SBM treatments, respectively. Although no significant differences were observed among treatments, VFA concentrations tended to decreased as SBM was replaced by CGF or CSM. Similar changes in propionate were reported by Firkins et al. (1985) when CGF was increased from 35 to 70% in lamb diets. CGF supplementation may improve utilization of dietary energy through increasing ruminal concentration of butyrate which reflects increasing ruminal fermentation products.

Calculated total metabolizable energy intakes based on NRC (1984) values for these feedstuffs were 12.1, 19.1, 18.2, and 20.5 Mcal/d for Control, SBM, CSM, and CGF, respectively. CGF is useful as an energy and protein supplement for beef heifers consuming low quality prairie hay.

TABLE X

COMPOSITION OF THE SUPPLEMENTS (DM BASIS)

Ingredient	Supplements[a] C	SBM	CSM	CGF
	g/d			
SBM	---	760	---	---
CSM	---	---	850	---
CGF	---	---	---	1740
Mineral and Vitamin Mixture[b]	50	50	50	50

[a]C = control; SBM = soybean meal; CSM = cottonseed meal; CGF = corn gluten feed.

[b]Contained: Dicalcium phosphate 42.2%, Kcl 18.1%, trace minerals 27.4% (.25% Mn, .2% Fe, .033% Cu, .0025% Co, .007% I, .005% Zn), Na_2SD_4 11.8% and vitamin A .5% (220 USP units/g).

TABLE XI

CHEMICAL COMPOSITION OF HAY AND SUPPLEMENTS

Item[a]	Prairie Hay	SBM	CSM	CGF
	------------------	-%	------------------	
Dry Matter	89.5	88.3	89.0	86.2
Organic Matter	93.6	93.0	92.1	92.1
Crude Protein	5.2	47.9	42.9	20.8
Acid Detergent Fiber	45.6	10.5	14.7	13.4
Nuetral Detergent Fiber	72.5	15.3	29.0	45.4
Ash	6.4	6.9	7.9	7.9
Lignin	8.4	1.7	4.4	1.6
Cellulose	34.4	8.5	10.2	10.8
Hemicellulose	26.9	4.7	14.4	32.0

[a]Dry matter basis.

TABLE XII

ORTHOGONAL CONTRASTS AMONG TREATMENT MEANS

	Supplements			
	C	SBM	CSM	CGF
Control vs. All	-3	1	1	1
CGF vs. SBM + CSM	0	.5	.5	-1
SBM vs. CSM	0	1	-1	0

TABLE XIII

INFLUENCE OF SUPPLEMENTAL SOYBEAN MEAL, COTTONSEED MEAL AND CORN GLUTEN FEED ON INTAKE BY HEIFERS

	Supplement					Orthogonal Comparisons[a]		
Item	C	SBM	CSM	CGF	SE	S	A	B
Prairie hay DM intake								
kg/d	6.8[b]	9.5[c]	8.9[cd]	8.5[cd]	.20	.0001	.01	.04
% of BW	2.1[b]	2.9[c]	2.7[cd]	2.6[cd]	.06	.0001	.01	.03
Total DM intake								
kg/d	7.1[b]	10.5[c]	10.5[cd]	10.5[cd]	.20	.0001	.28	.08
Digestible DM intake								
kg/d	3.1[b]	5.8[c]	5.4[c]	5.7[c]	.29	.0001	.72	.37
Indigestible DM intake								
kg/d	3.9[b]	4.7[c]	4.6[c]	4.8[c]	.25	.01	.65	.71
% of BW	1.2[b]	1.4[c]	1.4[c]	1.5[c]	.07	.01	.65	.71
Protein intake								
g/d	365[b]	864[c]	838[cd]	816[cd]	.01	.0001	.008	.07

[a]Comparisons included:.S for C versus all other treatments; A for CGF vs. SBM plus CSM; B for SBM vs. CSM.
[bcd]Means in same row with different superscripts differ ($P<.05$).

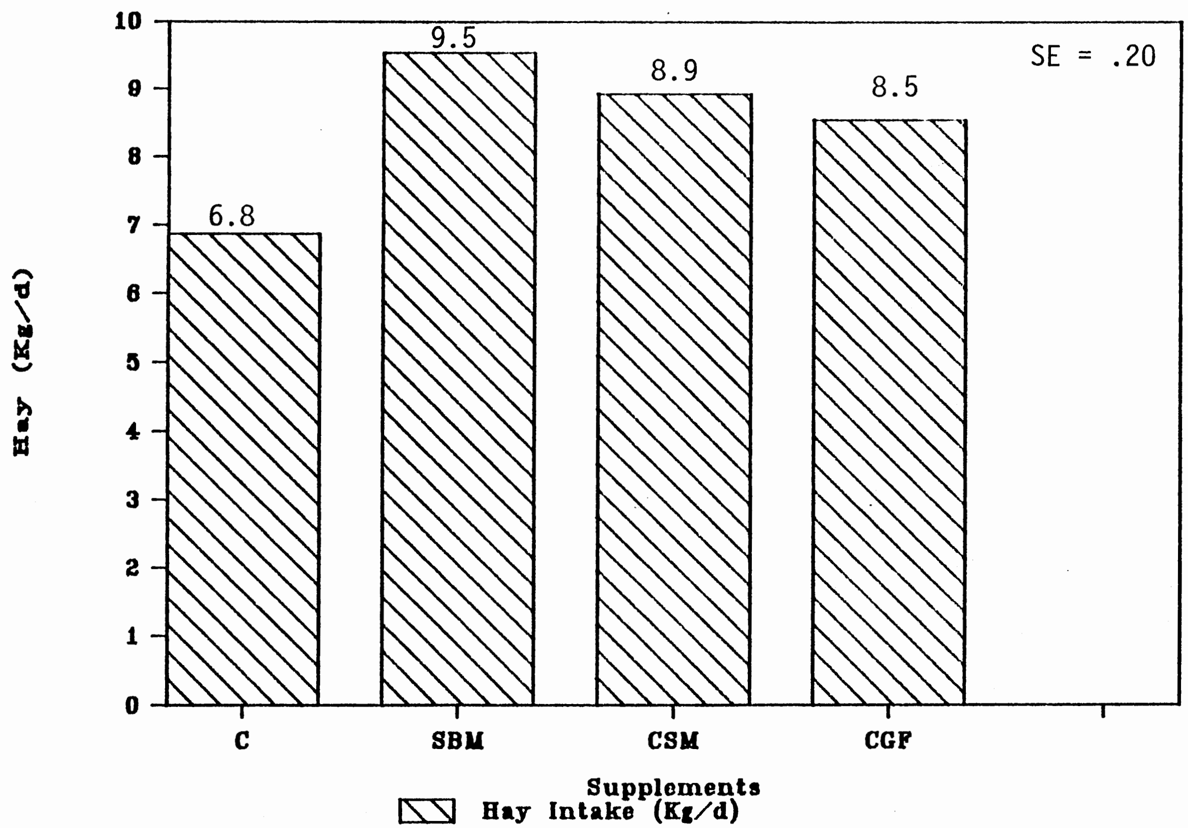


Figure 10. Daily Prairie Hay (DM) Intake of Heifers Fed Medium Quality Prairie Hay Supplemented with C, SBM, CSM, or CGF

TABLE XIV

INFLUENCE OF SUPPLEMENTAL SOYBEAN MEAL OR CORN GLUTEN FEED ON TOTAL TRACT DIGESTIBILITY BY HEIFERS

	Supplements					Orthogonal Comparisons[a]		
Component	C	SBM	CSM	CGF	SE	S	A	B
	% Digestibility							
Total DM								
Observed	44.3[b]	55.0[c]	54.6[c]	54.1[c]	2.71	.003	.82	.92
Expected		47.7	48.3	51.1				
Total OM	47.6[b]	57.7[c]	57.1[c]	56.8[c]	2.57	.003	.86	.87
Crude protein								
Observed	24.8[b]	55.8[c]	54.3[c]	51.5[c]	2.60	.0001	.01	.68
Expected	31.3	53.4	54.0	51.1	.35	.0001	.0001	.22
Neutral detergent fiber	43.7[b]	53.9[c]	52.8[c]	52.1[c]	2.74	.007	.72	.76
Acid detergent fiber	35.4[b]	47.5[c]	45.4[c]	44.4[c]	3.15	.009	.68	.64
Hemicellulose	57.9[b]	66.0[c]	64.7[c]	63.0[c]	2.27	.01	.40	.67

TABLE XIV (Continued)

Component	C	SBM	CSM	CGF	SE	S	A	B
	---------Supplements---------					Orthogonal Comparisons[a]		
	---------% Digestibility--------							
Cellulose	53.6[b]	63.4[c]	60.8[c]	60.8[c]	2.59	.01	.68	.48
Lignin	9.7	7.3	2.8	.9	9.55	.77	.63	.63

[a]Comparisons included:.S for C versus all other treatments; A for CGF vs. SBM plus CSM; B for SBM vs. CSM.
[bc]Means in same row with different superscripts differ (P<.05).

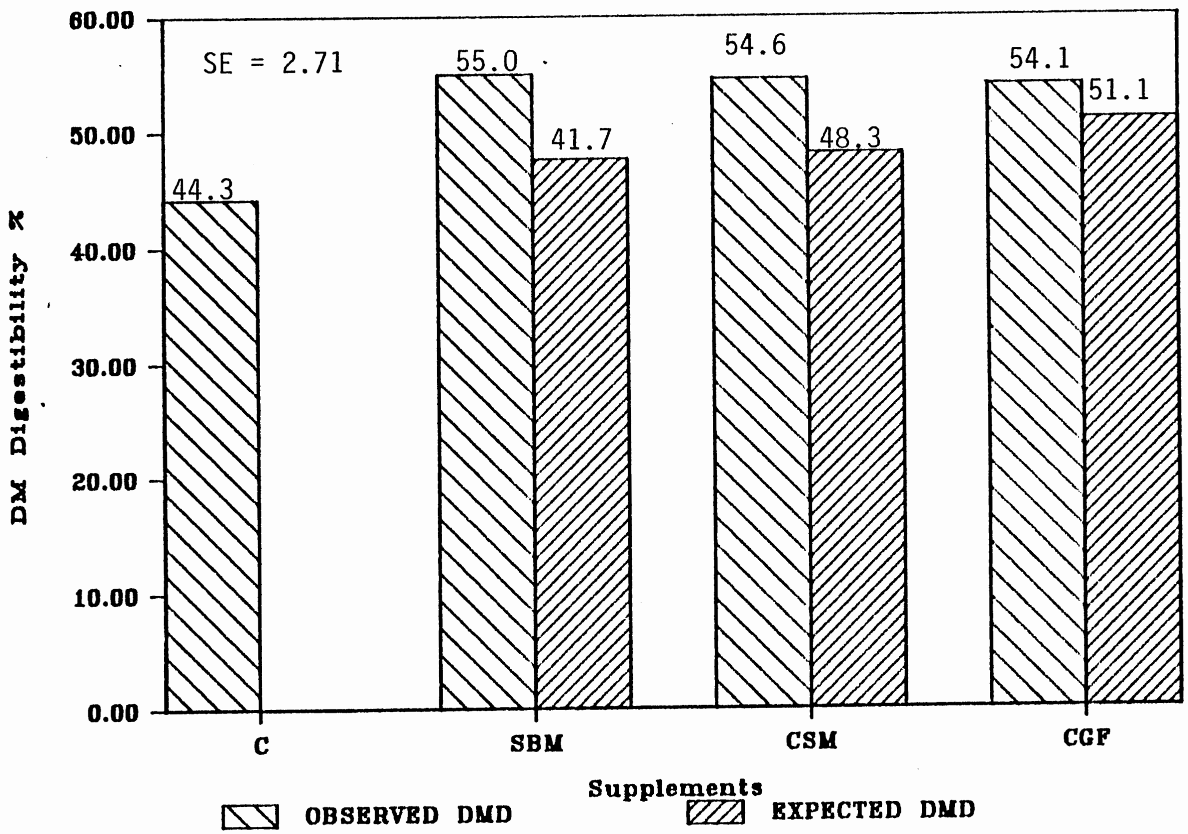


Figure 11. Comparison of Observed vs. Expected Diet Dry Matter Digestibilities. Expected Digestibilities are Based Upon Values Obtained for Hay on the Control Treatment and 80% DM Digestibilities for the CGF and SBM Supplements

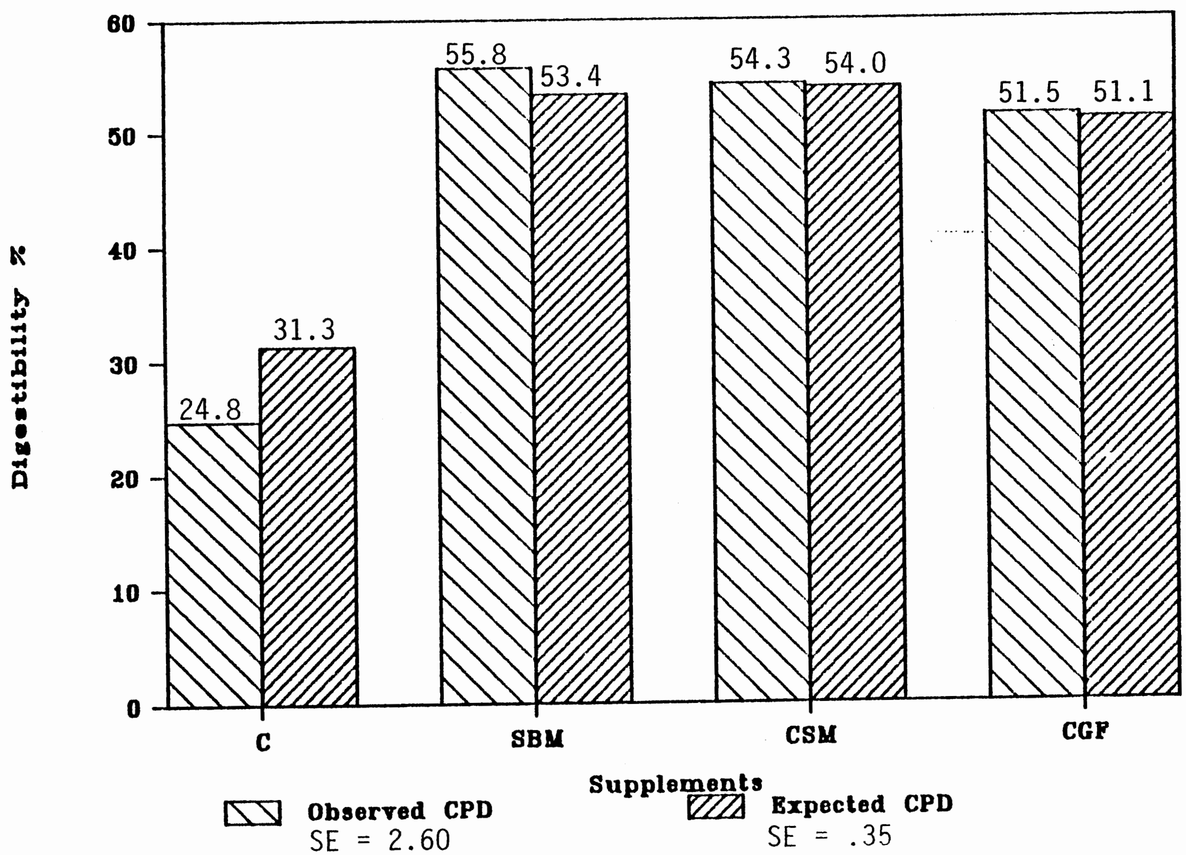


Figure 12. Observed Crude Protein Digestibility vs. Expected CP Digestibility

TABLE XV

INFLUENCE OF SUPPLEMENTAL SOYBEAN MEAL AND CORN GLUTEN FEED ON RUMINAL MEASUREMENTS TWO TO FOUR HOURS POSTPRANDIALLY

Item	C	SBM	CSM	CGF	SE	Orthogonal Comparisons[a]		
						S	A	B
Ruminal NH_3[a] mg/dl	.77[e]	3.36[f]	3.48[f]	5.27[fg]	.213	.0001	.0001	.69
Ruminal Fluid pH	7.0	7.0	6.4	6.8	.25	.89	.76	.15
Particulate Passage rate/hour	1.7[e]	3.3[f] +94%[c]	2.9[f] +70%[c]	2.8[f] +64%[c]	.19	.001	.31	.19
Rate of ruminal ADF Digestion[b] h^{-1}	.82[e]	2.48[f] +202%[c]	2.04[f] +149%[c]	1.92[f] +134%[c]	.279	.001	.29	.69
Ruminal ADF[d], g	5664[e]	3342[f]	3663[f]	3703[f]	365	.0001	.65	.53
% of daily intake	188[e]	76[f]	86[f]	91[f]	.125	.0001	.50	.60

[a]Contrasts included: S for supplemented diets vs. control diet; A, CGF vs. SBM plus CSM; B, SBM vs. CSM.
[b]Calculated assuming that 90% of ADF digestion occurred in the rumen and that rate of passage of all ADF was proportional to particulate rate of passage.
[c]Percentage change from control supplement.
[d]Calculated as hourly ruminal ADF escape [(intake * % ADF) * (1-.9 ADF digestion)/24] divided by particulate passage rate.
[ed]Means in same row with different superscripts differ (P<.05).

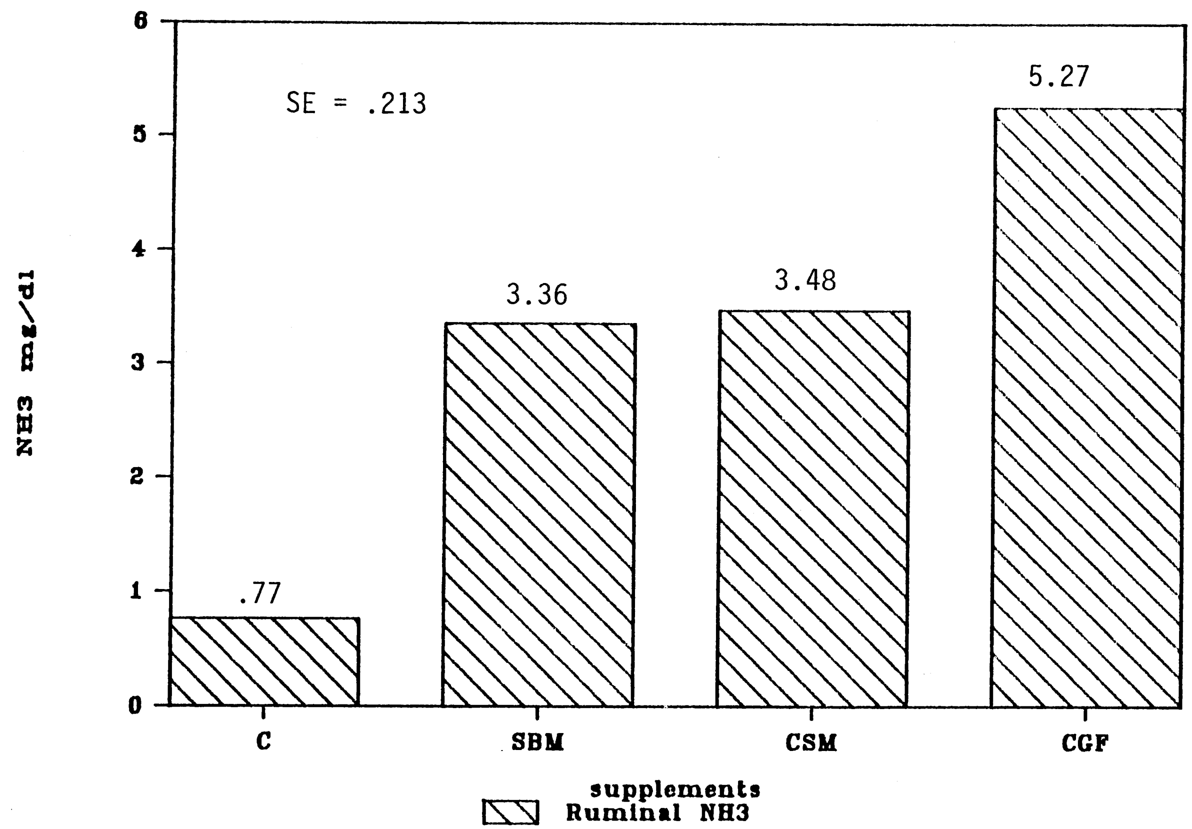


Figure 13. Ruminal Ammonia-N Concentrations 2-4 h Post Feeding

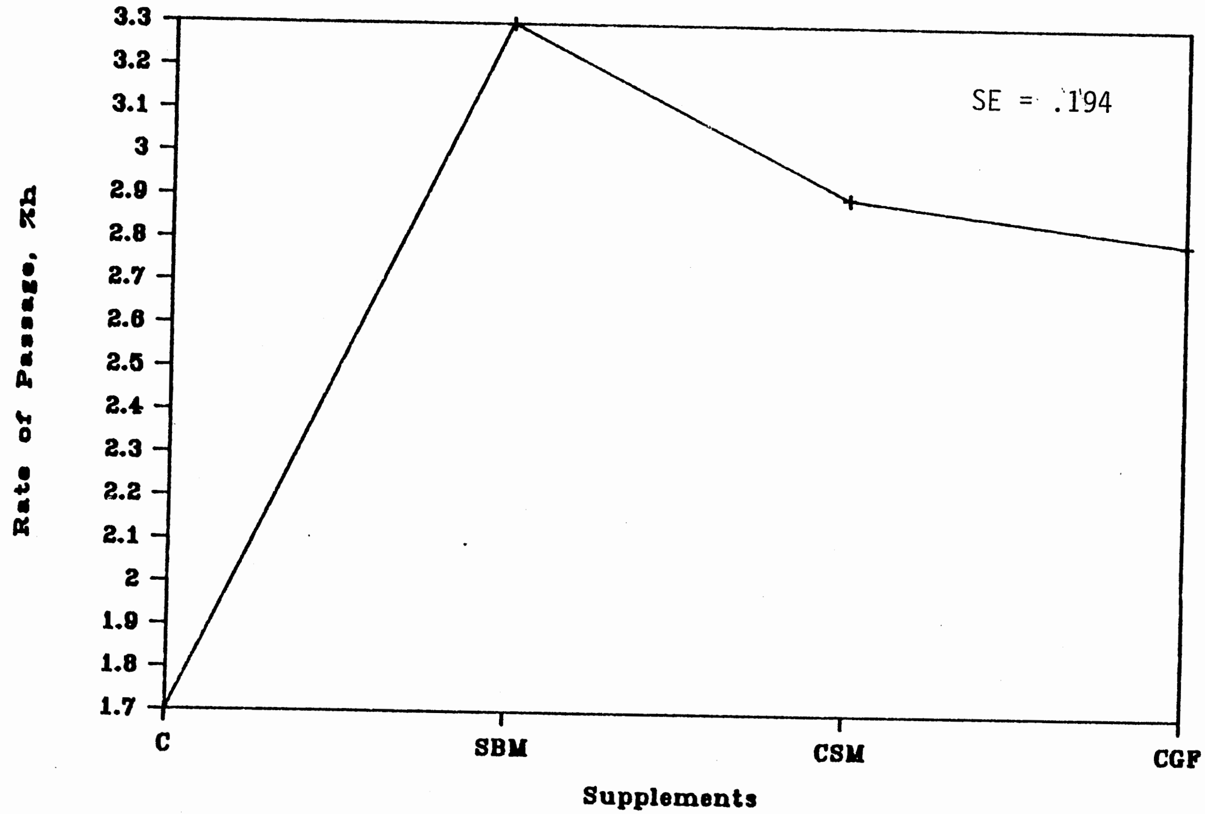


Figure 14. Particulate Rate of Passage

TABLE XVI

PROTEIN COMPOSITION OF SUPPLEMENTS

Protein Fractions	SBM	CSM	CGF
Total N, %	7.66	6.86	3.33
Ammonia -N[a]	1.7	1.9	1.7
Pepsin insoluble -N[a]	10.4	29.1	15.3
Saline soluble -N[a]	21.1	7.7	38.8
Nonsoluble degradable -N[ab]	68.5	63.2	45.9

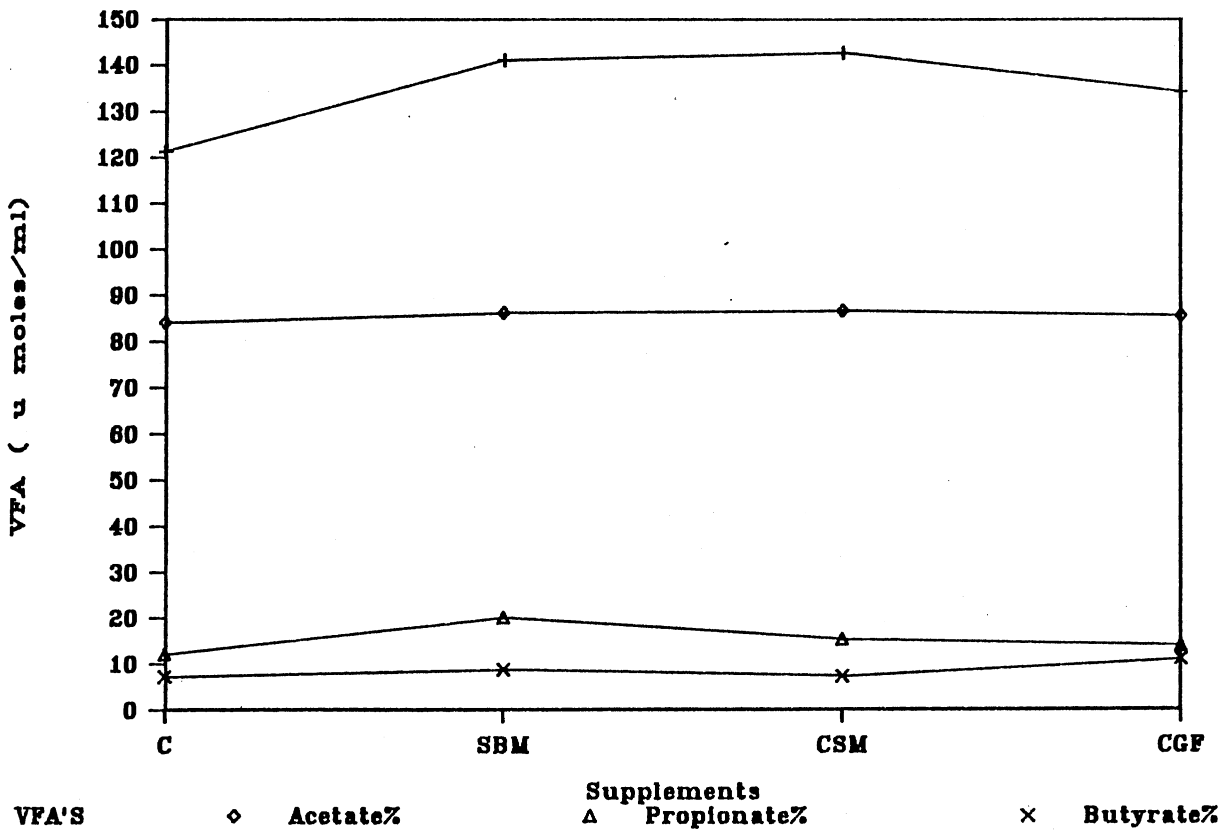
[a]Percent of total N.
[b]Nonsoluble degradable -N was calculated as the difference between total N and the combination of pepsin insoluble N plus saline soluble N.

TABLE XVII

RUMINAL VOLATILE FATTY ACID (VFA) CONCENTRATION AT TWO TO FOUR HOURS POST SUPPLEMENTATION

	Treatments					Orthogonal Comparisons[a]		
	C	SBM	CSM	CGF	SE	S	A	B
No. Heifers Samples	12	12	12	12				
Total VFA (u moles/ml)	121.5	141.3	142.9	134.4	29.99	.67	.97	.86
Acetate, %	84.2	86.3	86.7	85.6	19.1	.95	.98	.97
Propionate, %	12.2	20.3	15.4	14.1	6.32	.82	.57	.46
Butyrate, %	7.3	8.9	7.4	11.2	1.74	.75	.55	.33

[a]Orthogonal contrasts included: S for C vs. all other treatments; A for CGF vs. SBM plus CSM; B for SBM vs. CSM.



SE = 29.9 SE = 19.1 SE = 6.32 SE 1.74

Figure 15. Ruminal VFA Concentration at 2-4 h Post Feeding

CHAPTER V

EFFECT OF GRADED LEVELS OF CORN GLUTEN FEED ON PRAIRIE HAY INTAKE, DIGESTIBILITY, AND RUMINAL CHARACTERS OF HEIFERS

Abstract

Sixteen crossbred heifers (320 kg) were used in four simultaneous 4X4 latin squares to determine the effect of graded levels of corn gluten feed (CGF) supplementation on intake and digestibility of medium quality prairie hay (6.6% crude protein [CP]). Prairie hay was fed free choice. The four treatments were: 1) control hay plus minerals and vitamin A (C); 2) a CGF supplement to provide either a low level of supplemental protein (.58 kg/d at 26.6% CP; LL); 3) a medium level of supplemental protein (1.16 kg/d at 26.6% CP; ML) and 4) a high level of supplemental protein (1.74 kg/d at 26.6% CP; HL). The LL, ML and HL provided 155 g, 310 g and 464 g crude protein daily, respectively.

As level of CGF increased, intake of prairie hay, total dry matter and crude protein increased (P<.01) linearly. Digestibilities of DM, OM, CP, ADF, NDF, and cellulose also increased linearly (P<.01) with added CGF. Ruminal fluid pH values at various times after feeding supplements were very similar, but ruminal ammonia concentrations linearly increased (P<.01) as the level of CGF increased. As supplementation increased, particulate rate of passage from the rumen linearly increased (P<.01). Likewise, cotton thread disappearance from dacron bags was linearly increased (P<.01) by supplementation. The number of protozoa in ruminal samples decreased (P<.01) with increasing CGF.

Introduction

Protein supplementation often increases intake and improves utilization of low quality roughages (McCollum and Galyean, 1985). Grain supplementation programs, in contrast, often produce no positive effect, or perhaps even a decrease in intake and/or utilization presumably because starch alters the activity of the ruminal microbial population (Van Soest, 1982). High levels of supplemental starch and/or low levels of supplemental nitrogen appear to increase negative effects (Chase and Hibberd, 1987). Feedstuffs that are high in fiber and protein, but low in starch such as the grain by-products, may alleviate potential negative effects of grain supplementation (Van Soest, 1982).

Corn gluten feed (CGF), a by-product of corn milling industry, has become more abundant and can economically compete with cereal grains and oilseed meals as a source of energy and protein. CGF has increased DM intake and digestibility and animal performance compared to a corn plus urea supplement when fed with hay diets (Cordes et al., 1986). Added CGF improved fiber digestion, forage intake, and animal performance.

In a finishing trial, Berger (1985) concluded that CGF can substitute for corn in a high energy finishing ration without depressing animal performance. In a steer growth trial, Trenkle (1986) reported that substituting CGF for 0, 30, 50, or 70% of corn and roughage diet resulted in daily gains of 1.30, 1.52, 1.51, and 1.42 kg/d at respective feed efficiencies of 7.15, 6.40, 6.21, and 6.20. Feed intakes were 9.27, 9.77, 9.50, and 8.82 kg/d. Though substitution at 70% reduced DM intake, performance remained satisfactory. Diets containing 20 to 90% CGF have been successfully fed to finishing cattle (Trenkle, 1985a). At high levels, CGF contains sufficient roughage to prevent digestive problems often associated with feeding high concentrate rations to cattle.

According to Trenkle (1985a), CGF can be considered a source of supplemental protein, energy and phosphorus for ruminants. However, little data is available reporting the effects of graded levels of CGF protein supplementation on forage intake and utilization, and on rate of passage of low quality roughages. The objectives of this study were: 1) to investigate the effects of graded levels of CGF protein supplementation on forage intake and utilization and on ruminal characteristics of heifers consuming medium quality prairie hay, and 2) to assess the effect of graded levels of CGF protein on fiber disappearance from dacron bags, rumen volume and dry matter.

Materials and Methods

Sixteen crossbred Angus-Hereford heifers (320 kg) were used in four simultaneous 4X4 latin squares. Four of these heifers had large ruminal, in addition to duodenal cannulas. All animals had ad libitum access to the same basal diet of medium quality prairie hay. The prairie hay was cut during the first half of July from a meadow harvested annually. Treatments and supplements included: 1) control of hay plus minerals and vitamin A (C); 2) Cont. plus a low level of supplemental protein (LL) from CGF (26% CP); 3) Cont. plus a medium level of CGF (ML), and 4) Cont. plus a high level of CGF (HL).

The mineral-vitamin mix was fed to each animals at the level of 50g DM/day. CGF was fed to provided 150, 300, and 450 g of supplemental crude protein (CP) per day for the LL, ML, and HL treatments, respectively. These supplements were fed once daily at the rate of 0.58, 1.16, and 1.74 kg per day.

Chromic oxide, an indigestible marker, was used to estimate fecal output. Cottonseed hulls (CSH) labeled with chromic oxide were fed at a rate of 121 g DM twice daily. The composition of this carrier (as fed basis) was 95% CSH, 5% Cr_3O_3 and 5% molasses with 20% tap water of total DM being used to premix molasses and Cr_3O_3 before mixing it with the CSH.

The ingredient composition of the supplements is shown in Table XVIII, and the nutrient composition of the hay and the supplements is presented in Table XIX. The supplements were prepared at the beginning of the experiment for the entire experiment.

Each period of the latin square lasted 14 d with d 1 through 8 being used for adaptation. Prairie hay and CGF were sampled on d 9 through 12. Rejected prairie hay and fecal samples were collected twice daily (am and pm) on d 10 through 13. Fecal samples from each animal were accumulated in one plastic container for each period and held at 0 C until processing at the end of each period.

Ruminal fluid samples were obtained via stomach tube 2 to 3 h after the protein supplement was fed on d 13. Ruminal fluid pH was determined immediately after sampling. Samples were acidified with 20% sulfuric acid (ml/50ml of rumen fluid) and frozen for later NH_3-N analysis.

Hay intakes were recorded daily, and a sample of the daily refusal for each animal was collected during the four days and composited proportionately at the end of each period. Composited fecal samples of each animal were subsampled at the end of each period, weighed and dried at 60°C for 96 h All samples (feeds, refusals, and feces) were ground in a Wiley mill fitted with a 1 mm screen and frozen for later analysis.

Samples were analyzed for crude protein (Nx6.25) by the Kjeldahl method, for dry matter (DM) and ash (AOAC, 1975), and for ADF, NDF, cellulose, and permanganate lignin (Goering and Van Soest, 1970). The Cr labeled CSH and fecal samples were analyzed for chromium (Fenton and

Fenton, 1979). Ammonia N was measured by the phenol-hypochlorite procedure (Broderick and Kang, 1980).

Rate of passage of hay was measured using ytterbium (Yb) as an indigestible marker. Prairie hay was labelled with Yb (Teeter et al., 1984), and 198 g of labeled hay containing .5 g of Yb were fed with the supplements as a single pulse dose on day 10 of each period. Fecal samples were obtained 0, 36, 48, 60, 72 and 96 h post-dosing. Fecal samples were dried at 60 C for 96 h. Each sample was stored in a plastic bag for later Yb analysis. These samples were ground, ashed, digested in 1:1 v/v mixture of 3N nitric and 3N hydrochloric acid overnight, and diluted appropriately. The Yb content of each sample was determined by atomic absorption spectroscopy. Rate of passage values were determined as the slope of the regression of the natural logarithm of the marker concentration against sampling time (McCollum, 1983).

Four heifers fitted with permanent rumen and duodenal cannulae (4 cm distal to the pylorus) were used in this trial and received each treatment in a latin sqaure during the course of the trial. To estimate celluloytic activity, dacron polyester bags containing cotton thread were suspended in the rumens of the cannulated heifers receiving the test diets over the trial periods to determine DM disappearance of the cotton threads. Dacron bags (6x10 cm; pore size 25-74 um) contained .5 g of cotton thread (241 cm, cotton perl #5, Dolfus Mieg + Cie-Paris) rolled into a coil (2 cm diameter). Coiled threads were weighed and one was placed into each of 80 dacron bags. Five strings (10 bags per string) were sequentially suspended in the rumen of each heifer in each period beginning on d 9 through 13 for 96, 72, 48, 36, and 24 h. All the bags were retrieved from the rumen on d 13. Following retrieval, dacron bags were opened and each cotton thread was removed and washed under running water until the thread was clean. The weight of the residual thread at each time was regressed over time (24-96 h) yielding a slope corresponding to rate of ruminal cotton thread disappearance (%h).

Duodenal samples were collected on day 9 through 11 every 8 h and stored at 5 C until processed. Samples from each animal were composited at the end of each period, and this composite was subsampled and stored at -20 C. Digesta were dried using a lyophilizer prior to grinding through a 1 mm screen in a laboratory Wiley mill. Digesta samples were analyzed for DM, ash, Kjeldhal and NH_3-N (AOAC, 1975) and ADF and NDF and lignin (Goering and Van Soest, 1970).

Ruminal samples were obtained from cannulated heifers every 2 h on day 13 of each period to measure pH. The rumen was evacuated 5 hours post-feeding on the last day of each period to measure fluid and particulate fractions and rumen volume. The rumen contents were weighed, subsampled and returned to the rumen. Ruminal subsamples were dried at 90 C for 72 h to determine their dry matter content.

Data were analyzed as least square means of variance following the general linear models procedure of SAS (SAS, 1979). Classes as variables included square, period, animal, and treatment. Treatments were compared by orthogonal contrasts. Orthogonal contrasts included the effect of protein supplement action (0 vs. all protein levels), and linear, quadratic and cubic effects of increasing CGF protein levels. Least square means were used because two heifers were sick in two different periods for reasons not related to the trial.

Results and Discussion

As the amount of corn gluten feed supplemented was increased, intake of hay (Figure 16), total DM, digestible DM (Table XX) all increased linearly

(P<.01). Total protein intake was in excess of the suggested daily maintenance protein requirement of 460 g (NRC, 1984) on all diets. The adequacy of these protein levels should consider diet quality. Therefore, nitrogen fraction analysis of CGF used in this experiment was examined (Table XXI). It seems that indigestible N indicated by pepsin insoluble N fraction was low compared to the other batches used in the other trials in this thesis. Concomitantly, the N solubility in this batch was much higher than for batches used in this thesis. Because intake was increased by CGF supplementation, this demonstrates that the NRC (1984) estimated need for dietary protein supplementation is too low to maximize intake of prairie hay.

Digestibility of total diet DM, OM, protein, NDF, and ADF all increased linearly (P<.01) as level of CGF supplementation increased (Table XXII). Observed values were higher than expected for ration DM digestibility at all CGF supplement levels (Table XXII, Figure 17) indicating a positive synergistic effect of protein on the digestibility of prairie hay. The magnitude of this response was greatest at the two highest CGF levels. This improvement in digestibility probably was due to feeding the highly digestible fiber together with added nitrogen which provided essential nutrients for the rumen environment.

Observed crude protein digestibilities were also compared to those expected based on the NRC (1978) equation:

$$\text{Digestibility} = (.9\ CP - 3)/CP * 100$$

where CP equals crude protein percent in total dry matter intake observed values slightly greater than expected values which reflect the improvement in CGF supplementation with medium quality hay (Figure 18).

Although ADF and NDF digestibilities were increased with CGF supplementation (Table XXII), lignin disappearance values, which ranged from 13.6 to 3.99%, were not influenced by supplementation. Lignin disappearance was reviewed by Fahey and Jung (1983). They concluded that disappearance of lignin is due to analytical method errors or changes in lignin in the digestive tract rather than true digestion in the rumen.

Rumen fluid pH values were quite similar on all diets (Table XXIII). Ruminal NH_3 concentration 2 h after feeding supplements (Table XXIII) was very low (0.72 mg/dl) on the control diet and linearly increased (P<.01) with supplementation (Figure 19). All NH_3 values with supplemented diets were acceptably high; the results agree with in situ results of DeHaan et al. (1983) which suggest that CGF protein is extensively degraded in the rumen. Rate of passage of the particulate phase expressed as percent/hour (Table XXIII) increased linearly (P<.01) with CGF supplementation. Ruminal DM, ADF and lignin contents were quite similar among treatments (Table XXIV). In contrast, rumen volume was significantly (P<.09) influenced by supplementation (Figure 20). Rumen fill increased with supplementation compared to control diet. However, the rumen volume linearly decreased (P<.04) as level of CGF increased. That could be attributed completely to increases in diet digestibility and removal of the digesta from the rumen (Figure 21).

Ruminal ADF contents were also calculated from rate of passage and ruminal escape of ADF assuming that reactions are first order. Increasing CGF level in the diet reduced calculated ADF in the rumen by 1.6 to 27%. As a fraction of daily ADF intake, increasing protein from CGF reduced ruminal ADF of daily ADF intake due to increases in rates of both digestion and passage.

Total protozoa numbers in ruminal fluid 2 h after feeding supplements increased linearly (P<.08) with increasing CGF levels (Table XXIII). Protozoa are involved with fiber digestion in the rumen (Demeyer, 1981). Why increasing CGF increased the protozoa population in this study is unknown. Perhaps the elevation in hay intake and availability of N increased the protozoa population in the rumen.

Disappearance of cotton thread DM (Table XXVI, Figure 22) from the incubated dacron bags linearly increased ($P<.01$) with CGF supplementation. DM disappearance increased with exposure time. The slope of disappearance, reflecting the digestion rate for cellulose, was increased with CGF supplementation. The intercept values can be used to calculate lag times. Ruminal pH values determined at 0, 2, 4, 6, 9, 12 and 24 h after feeding of the supplement are presented in Table XXVII. There were no significant differences in ruminal pH attributable to supplement level over the 24 h period which indicate that ruminal buffering capacity was not markedly influenced by CGF level.

The beneficial effect of CGF supplementation was evident from the substantial rise in roughage consumption by animals receiving CGF supplements. Intake of prairie hay was increased by 11 to 32% as level of CGF supplement was increased from .58 to 1.74 kg DM/d. Improvements in voluntary intake of low quality forages usually are attributed to an increased rate of forage digestion and passage as a result of supplementation (Ellis, 1978). Consequently, the total dry matter intake and rate of passage were highly correlated ($r = .99$). Guthrie (1984) similarly reported 9 to 45% increases in prairie hay (5.2% CP) with SBM added at levels from 121 to 603 g DM/d. Likewise, Arelovich et al. (1983) reported that supplementation of diets with CSM or 20% CP CSM-wheat increased prairie hay consumption by mature steers by 20 to 23% over the control diet (10.3% CP).

Increasing levels of corn gluten feed in this study greatly enhanced total DM intakes (Table XXI). Intake of DM ranged from 10.0 to 13.0 kg/day when CGF composed 5.8, 10.0 and 13.4% of the total dry matter intake. Similarly, digestible DM intakes were 5.24 6.6 and 7.7 kg/d at these levels. This indicates that digestible energy intake were increased markedly. Metabolizable energy (ME) intakes (calculated as .82 X 4.40 X DEI) were 15.1, 18.9, 23.9 and 27.9 Mcal/d as compared with NRC (1976) estimates of 14.5, 17.9, 21.2, and 24.4 Mcal/day for C, LL, ML, and HL treatments, respectively. These increases reflect greater feed intakes, but the differences frpm NRC values reflect increased diet digestibility with added CGF. Improvements in digestibility often are associated with increases in protein level. This increase is probably due to feeding the highly digestible CGF material; protein and energy both may have limited intake with our low quality forage.

As level of CGF supplementation increased, ruminal ammonia concentration 2 h postfeeding increased. These values support the suggestion of DeHaan, et al. (1983) that protein from CGF is extensively degraded in the rumen. Ammonia levels at the three supplementation treatments tended to increase in proportion to protein levels. Moreover, these NH_3 values were within the range recommendation of Satter and Slyter (1974) needed to maintain the microbial growth in the rumen. The NH_3 level is a precise index of nitrogen status for rumen bacteria (Kropp et al., 1977) and reflect the positive effect of protein supplementation of poor quality forages.

Although the particulate rate of passage values increased linearly (Table XXIII, Figure 23) among treatments, ranging from 1.73 to 2.74 %/h, values were lower than many in the literatures. Fleck et al. (1986) found that rates of passage were 3.7 to 3.9% h for cows supplemented with CGF, SBM or blends when consuming native grass, but as in our study, passage rates were increased by supplementation. They fed Yb labeled CSH, not Yb labeled native grass as we fed. Guthrie (1984) reported that particulate passage rates ranged from 2.1 to 3.5%/h in heifers consuming prairie hay supplemented with graded levels of SBM of 0 to 630 g DM/day. Rate of passage of low or medium quality forages appear, however, to be consistently elevated by supplemental protein, but rates may be influenced by type and level of supplement fed. The increased particulate passage rate is probably due to an increased rate of cellulolysis as reflected by cotton thread disappearance, which in turn helps explain why hay intake increased with added CGF. McCollum and Galyean (1985) reported a 27% increase in prairie hay intake and increased particulate passage rate when steers were supplemented with CSM.

Ruminal digestibilities of DM, OM, ADF, NDF, and total feed protein increased ($P<.01$) by supplementaton compared to unsupplemented diet (Table XXVIII). Although not significant, CGF levels tended to slightly elevate ruminal digestion rate of DM, ADF, NDF, and protein. With all diets, N reaching the duodenum was below intake. This reflects extensive nitrogen degradability of CGF in the rumen. Low duodenal ammonia N concentrations indicate rapid ruminal uptake of NH_3 by rumen bacteria to maintain maximal microbial growth and dry matter digestion which may result in low duodenal NH_3 concentration. Generally, ruminal digestibilities were similar in pattern to total tract digestibilities.

Apparent postruminal digestibilities of DM, OM, ADF, and NDF were less ($P<.01$) for supplemented diets compared to control diet. Whereas, total protein digestibilities were greater for all diets suggesting a net gain of microbial protein travel to the duodenum. Percentage of total digestion occurring in the rumen (Table XXVIII) ranged from 54-107 percent for supplemented diets whereas, those of the control diet showed a lower value.

As CGF level increased in the diet, feed N escaping the rumen increased ($P<.01$) from 17.2 to 60.7% (Table XXVIII) for the C and the HL treatments, respectively. That indicates increasing N escape from the CGF. At the same time, microbial efficiency slightly improved with CGF supplementation. That could be explained by the low levels of NH_3-N in the duodenum in order to maintain maximal microbial growth (Satter and Slyter, 1974; Weakley, 1983).

The results of our study show that CGF as a source of supplemental protein with medium quality prairie hay increases the rate of ruminal fermentation, digestion parameters and forage intake considered in this study. Moreover, CGF appeared to serve as a supplemental energy source to increase total energy intake without depressing fiber digestion. Thus, CGF appears to be a useful supplement for beef heifers receiving prairie hay.

TABLE XVIII

COMPOSITION OF THE SUPPLEMENTS (DM BASIS)

Ingredient	Supplements[a] C	LL	ML	HL
	g/d			
Corn gluten feed		580	1160	1740
Mineral and vitamin mixture[b]	50	50	50	50

[a]C = control; LL = CGF provides low level of supplemental protein; ML = CGF provides medium level of supplemental protein, HL = CGF provides high level of supplemental protein.

[b]Contained: dicalcium Phosphate 42.4%' Kcl 18.1%, trace minerals 27.4% (.25% Mn, .2% Fe, .033% Cu, .0025% Co, .007% I, .005% Zn), Na_2SO_4 11.8%, and vitamin A .5% (220 USP units/g).

TABLE XIX

NUTRIENT COMPOSITION OF PRAIRIE HAY AND SUPPLEMENTS

Item[a]	Prairie Hay	CGF
	%	
Dry Matter	92.56	86.04
Organic Matter	92.40	90.96
Crude Protein	6.65	26.72
Acid Detergent Fiber	45.59	11.96
Nuetral Detergent Fiber	69.40	48.20
Lignin	8.45	1.63

[a]Dry matter basis.

TABLE XX

EFFECTS OF CGF SUPPLEMENTS ON INTAKE BY HEIFERS FED PRAIRIE HAY

Item	Supplement				SE	Orthogonal Comparisons[a]		
	C	LL	ML	HL		S	L	Q
Prairie hay DM								
kg/d	8.2[b]	9.1[c]	10.0[d]	10.8[e]	.15	.0001	.0001	.65
% BW	2.5[b]	2.8[c]	3.1[d]	3.3[e]	.04	.0001	.0001	.65
Total DM								
kg/d	8.6[b]	10.0[c]	11.6[d]	13.0[e]	.14	.0001	.0001	.46
% BW	2.6[b]	3.1[c]	3.6[d]	4.0[e]	.04	.0001	.0001	.69
Total OM								
kg/d	8.0[b]	9.2[c]	10.7[d]	12.0[e]	.144	.0001	.0001	.69
%BW	2.5[b]	2.9[c]	3.3[d]	3.7[e]	.04	.0001	.0001	.69
Digestible DM								
kg/d	4.1[b]	5.2[c]	6.6[d]	7.7[e]	.15	.0001	.0001	.46
Indigestible DM								
kg/d	4.4[b]	4.7[c]	4.9[cd]	5.3[d]	.15	.001	.05	.75
% BW	1.3[b]	1.4[c]	1.5[cd]	1.6[d]	.04	.001	.05	.75
Crude Protein								
g/d	545[b]	636[c]	860[d]	1066[e]	.01	.0001	.0001	.55
% BW	.13[b]	.20[c]	.26[d]	.33[e]	.003	.0001	.0001	.55

TABLE XX (Continued)

Item	C	LL	ML	HL	SE	S	L	Q
	---------Supplement--------					Orthogonal Comparisons[a]		
Protein as a								
% DM	6.3[b]	6.3[c]	7.4[d]	8.2[e]	.01	.0001	.0001	.55
Acid detergent fiber intake								
kg/d	3.6[b]	4.0[b]	4.5[c]	4.9[c]	.07	.0001	.0001	.72
% BW	1.1[b]	1.3[c]	1.4[d]	1.6[e]	.02	.0001	.0001	.72
Neutral detergent fiber intake								
kg/d	5.7[b]	6.5[b]	7.4[c]	8.2[c]	.1	.0001	.0001	.60
% BW	1.8[b]	2.0[b]	2.3[c]	2.6[c]	.03	.0001	.0001	.55

[a]Contrasts included S for supplemented diets vs. control diet; L and Q for linear and quadratic effects of graded levels of CGF.

[bc]Means in same row with different superscripts differ ($P<.05$).

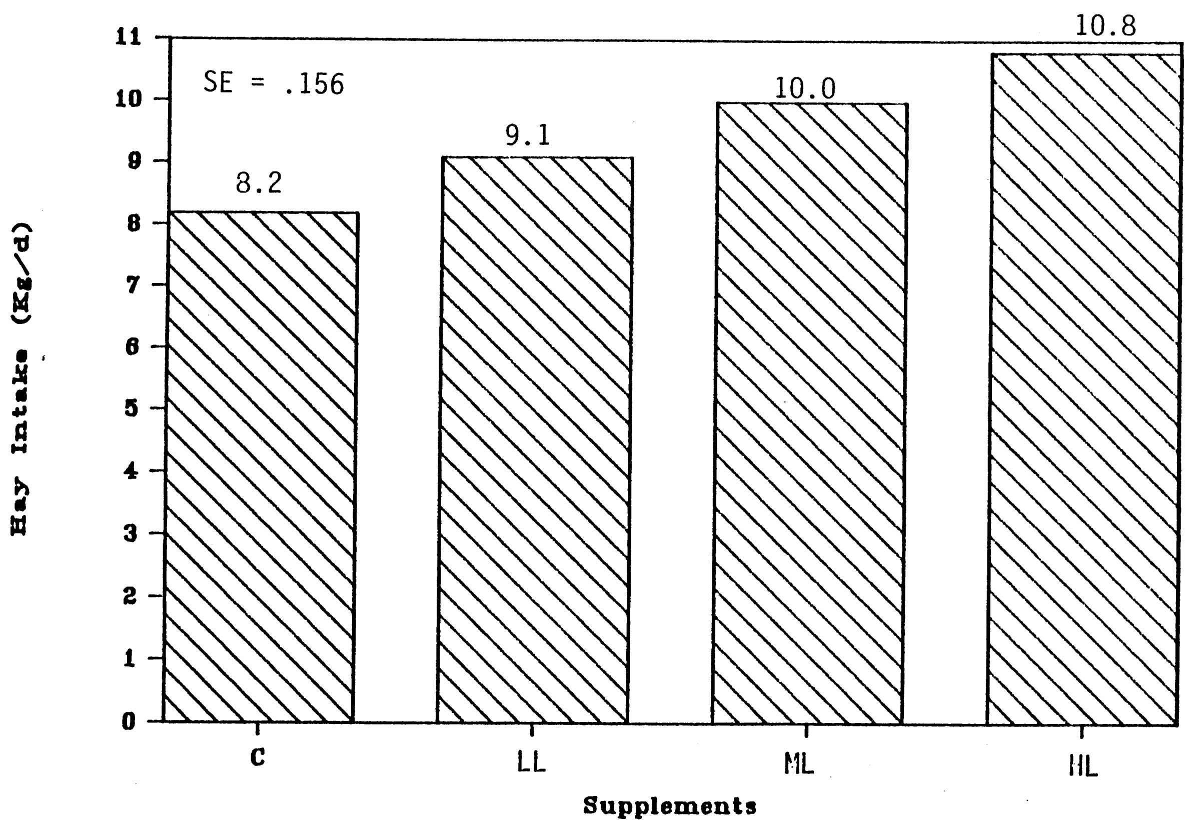


Figure 16. Daily Prairie Hay (DM) Intake by Heifers Fed Graded Levels of CGF

TABLE XXI

NITROGEN FRACTIONS OF CORN GLUTEN FEED

Protein Fractions	CGF
Total N, %	4.2
Ammonia -N[a]	4.1
Pepsin insoluble -N[a]	10.2
Saline soluble -N[a]	52.5
Nonsoluble degradable -N[ab]	37.3

[a]Percent of total N.

[b]Nonsoluble degradable -N was calculated as the difference between total N and the combination of pepsin insoluble -N plus saline soluble -N.

TABLE XXII

EFFECTS OF CORN GLUTEN FEED SUPPLEMENTS ON DIGESTIBILITY BY HEIFERS FED PRAIRIE HAY

	---------Supplement--------					Orthogonal Comparisons[a]		
Component	C	LL	ML	HL	SE	S	L	Q
	-------------% Digestibility-----------							
Total DM								
Observed	48.6[b]	51.9[b]	57.0[c]	59.6[c]	1.29	.0001	.0001	.42
Expected		50.5	51.9	52.9				
Total OM	51.3[b]	54.3[c]	59.4[cd]	62.0[cd]	1.23	.0001	.0001	.39
Crude Protein								
Observed	34.9[b]	42.1[c]	51.0[d]	56.7[e]	1.85	.0001	.0001	.48
Expected	28.7[b]	42.4[c]	49.4[d]	53.4[e]	.74	.0001	.0001	.09
Acid Detergent Fiber	38.2[b]	41.3[b]	47.7[c]	48.9[c]	.180	.007	.004	.24
Neutral Detergent Fiber	46.5[b]	48.9[b]	54.4[c]	56.0[c]	1.40	.0002	.0006	.25
Lignin	-13.6[b]	-.5[b]	.5[c]	3.9[c]	2.57	.74	.63	.85

[a]Contrasts included S for supplemented diets vs. control diet; L and Q for linear and quadratic effects of graded levels of CGF.

[bcde]Means in same row with different superscripts differ (P<.01).

[f]Calculated from NRC (1978).

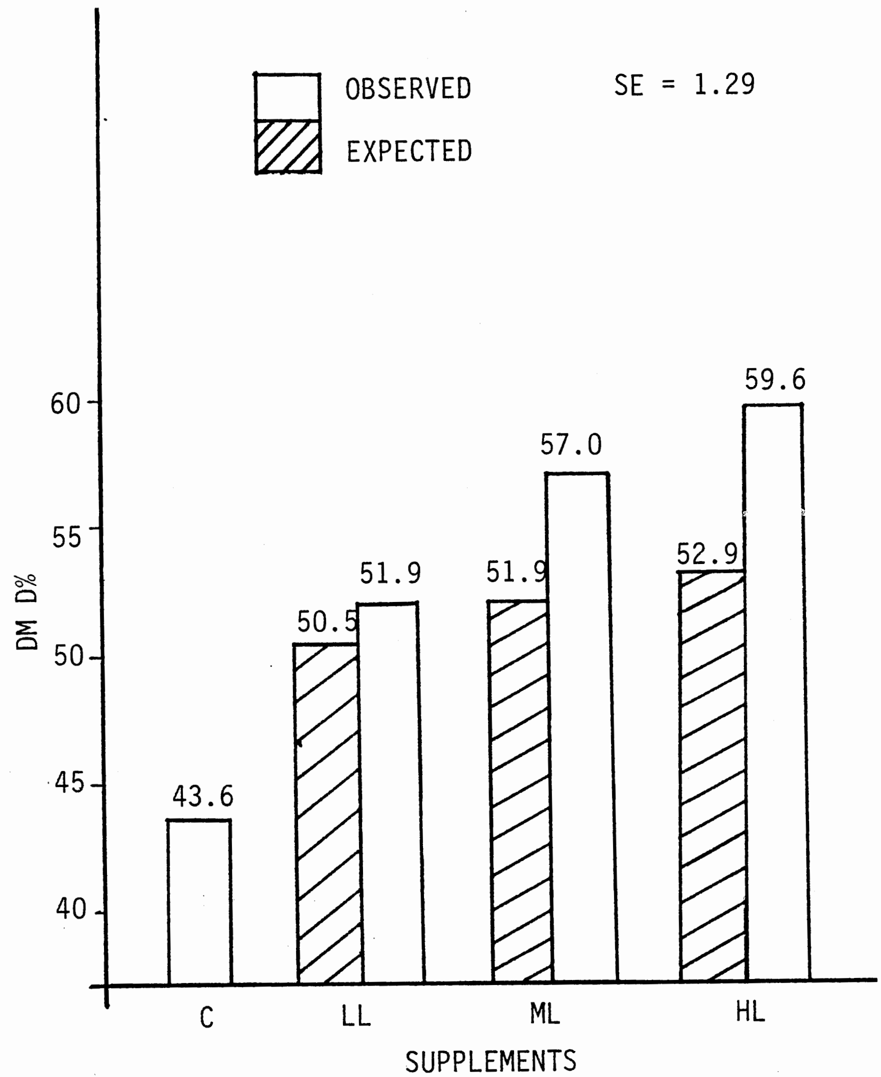


Figure 17. Comparison of Observed vs. Expected Dry Matter Digestibility. Expected Digestibility is Based on Values Obtained from Hay on the C Treatment plus 8% DM Digestibility for the CGF

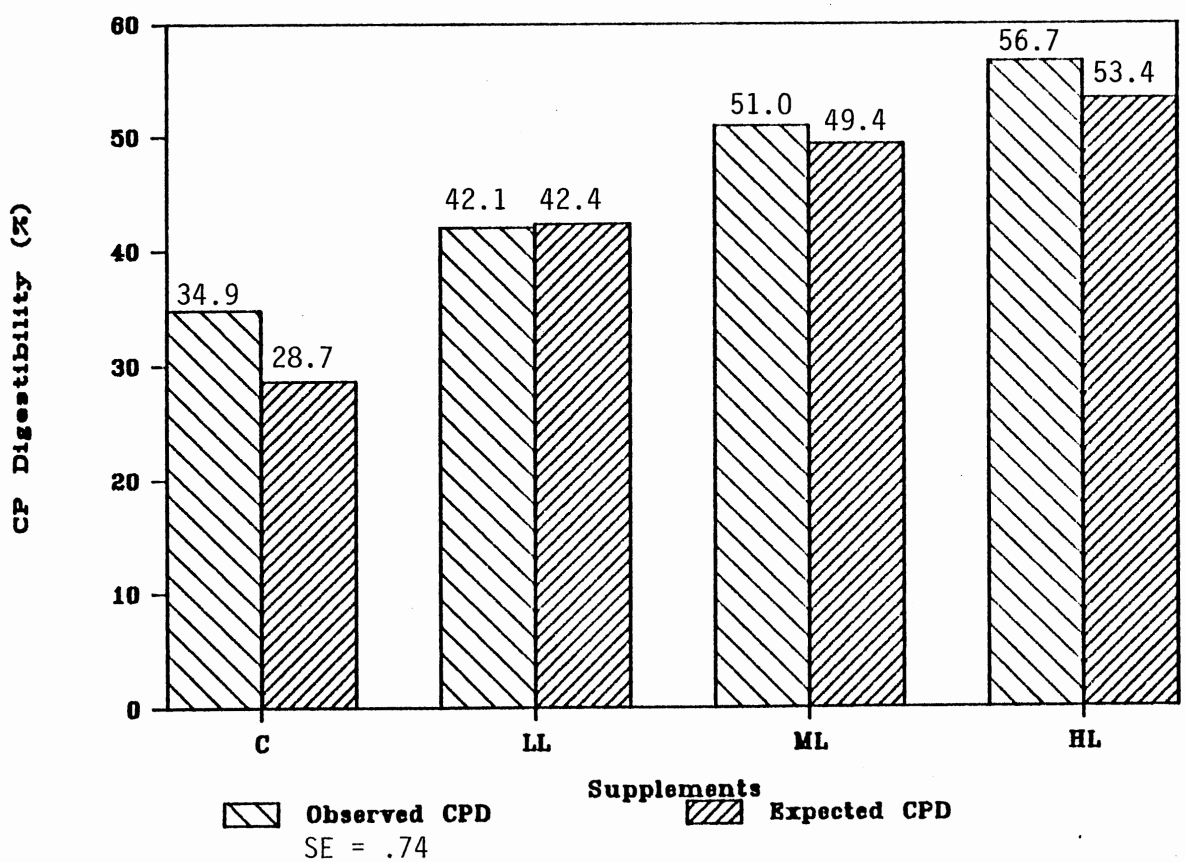


Figure 18. Crude Protein Digestibility (Observed vs. Expected)

TABLE XXIII

RUMINAL MEASUREMENTS OF BEEF HEIFERS FED PRAIRIE HAY WITH VARIOUS AMOUNTS OF SUPPLEMENTAL CGF

Item	Supplement C	LL	ML	HL	SE	Orthogonal Comparisons[a] S	L	Q
Ruminal NH_3 mg/dl	0.7[c]	3.2[d]	4.3[de]	5.8[def]	.19	.0001	.0001	.27
Ruminal fluid pH	7.0[c]	6.9[c]	7.0[c]	6.8[c]	.04	.04	.23	.11
Particulate passage rate/hour	1.73[c]	1.91[c]	2.37[d]	2.74[d]	.19	.001	.003	.79
Protozoa:[b]								
Total	16.3	12.5	17.5	21.0	2.98	.84	.08	.81
Small	12.1	12.3	15.0	15.3	4.81	.72	.65	.81
Large	4.2	.2	2.5	5.8	2.0	.58	.09	.82

[a]Contrasts included S for supplemented vs. control diet; L and Q for linear and quadratic effects of graded levels of CGF.

[b]Means (X 10^{-3}/ml).

[cdef]Means in same row with different superscripts differ (P<.01).

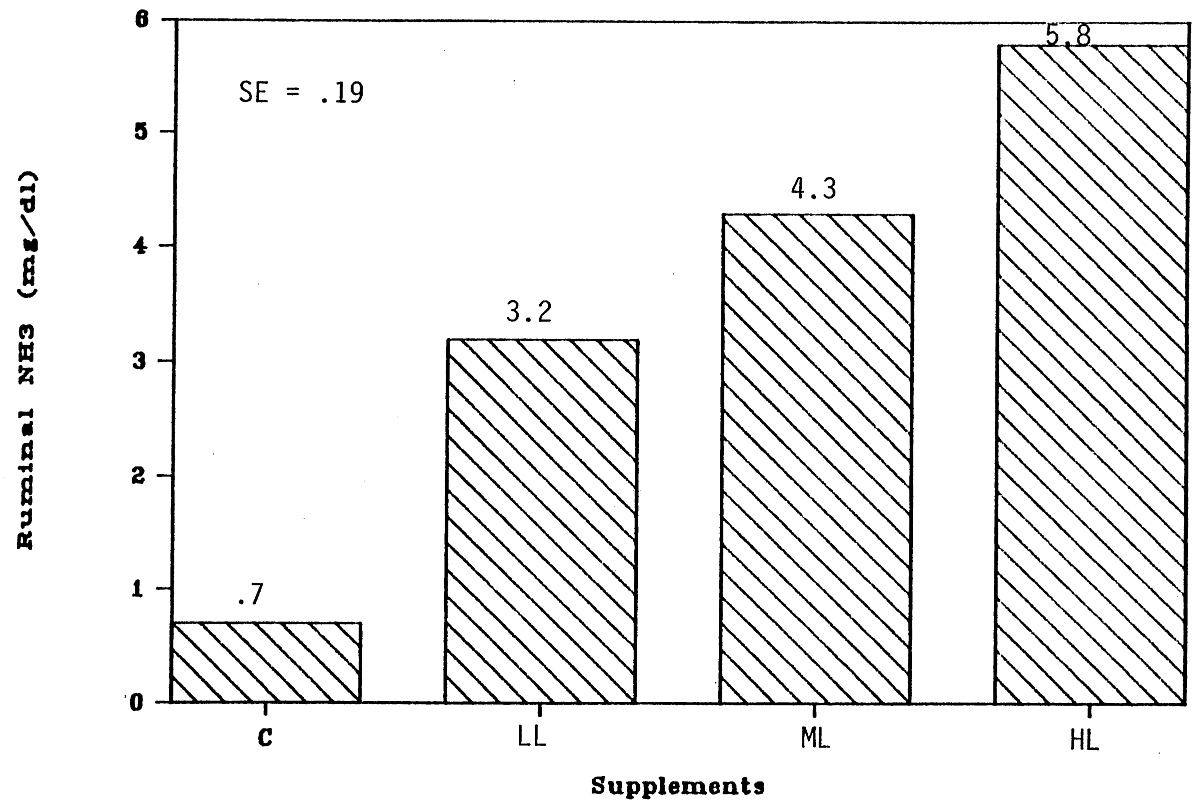


Figure 19. Ruminal Ammonia-N Concentrations (mg/dl) 2-4 h After Feeding Supplements (Trial 3)

TABLE XXIV

RUMINAL CONTENT CHARACTERISTICS

Item	Supplement C	Supplement LL	Supplement ML	Supplement HL	SE	Orthogonal Comparisons[a] S	Orthogonal Comparisons[a] L	Orthogonal Comparisons[a] Q
Ruminal volume[d]								
kg	85.8^{b}	93.9^{c}	89.3^{b}	87.8^{b}	1.72	.09	.04	.40
Ruminal DM								
kg	12.8^{b}	14.3^{c}	13.7^{b}	12.2^{b}	.48	.15	.01	.4
% DM	14.9	15.2	15.3	13.9	.48	.19	.65	.81
%ADF	46.9	45.6	42.2	45.4	.69	.80	.71	.76
% Lignin	5.9	7.2	5.8	6.3	.21	.38	.09	.53

[a]Contrasts included S for supplemented vs. control diet; L and Q for linear and quadratic effects of graded levels of CGF.

[bc]Means in same row with different superscripts differ ($P<.05$).

[d]Measured by evacuating the rumen 5 h after supplement feeding.

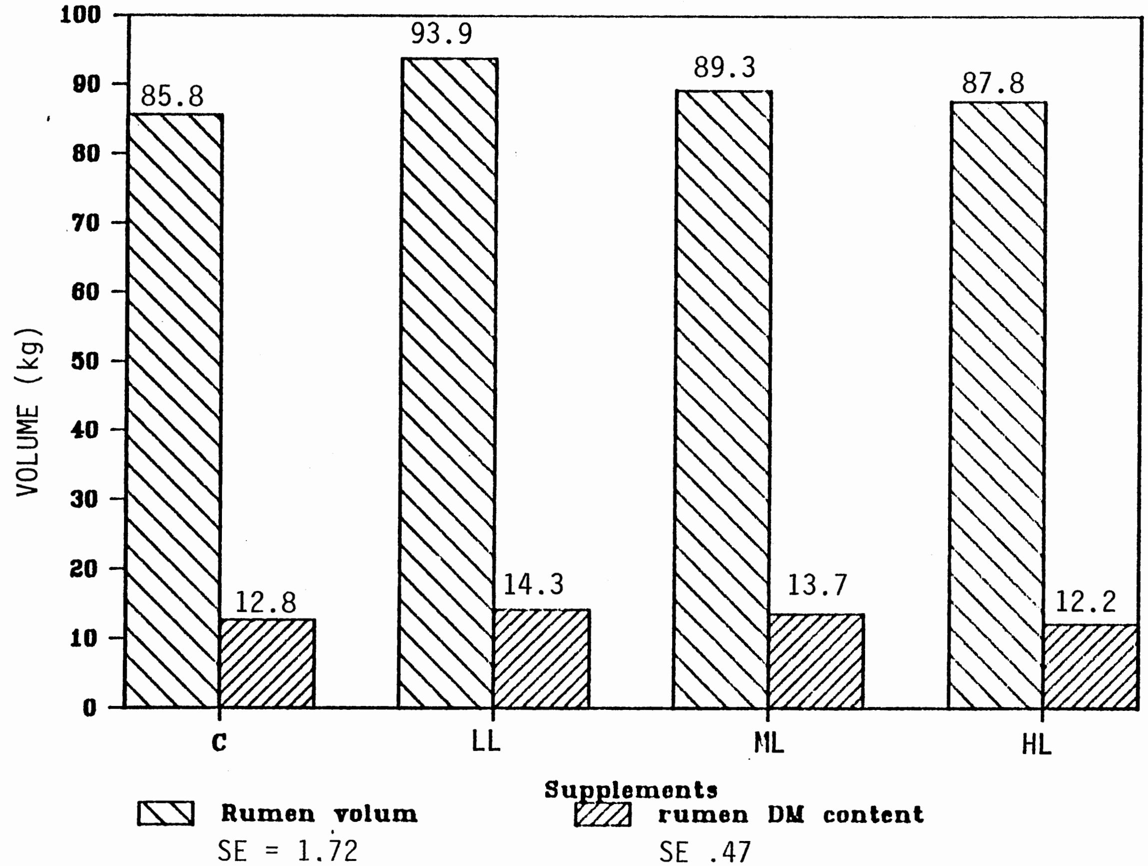


Figure 20. Rumen Volume Measured by Evacuation of the Rumen Contents and Their Related DM Content as Influenced by Feeding Graded Levels of CGF

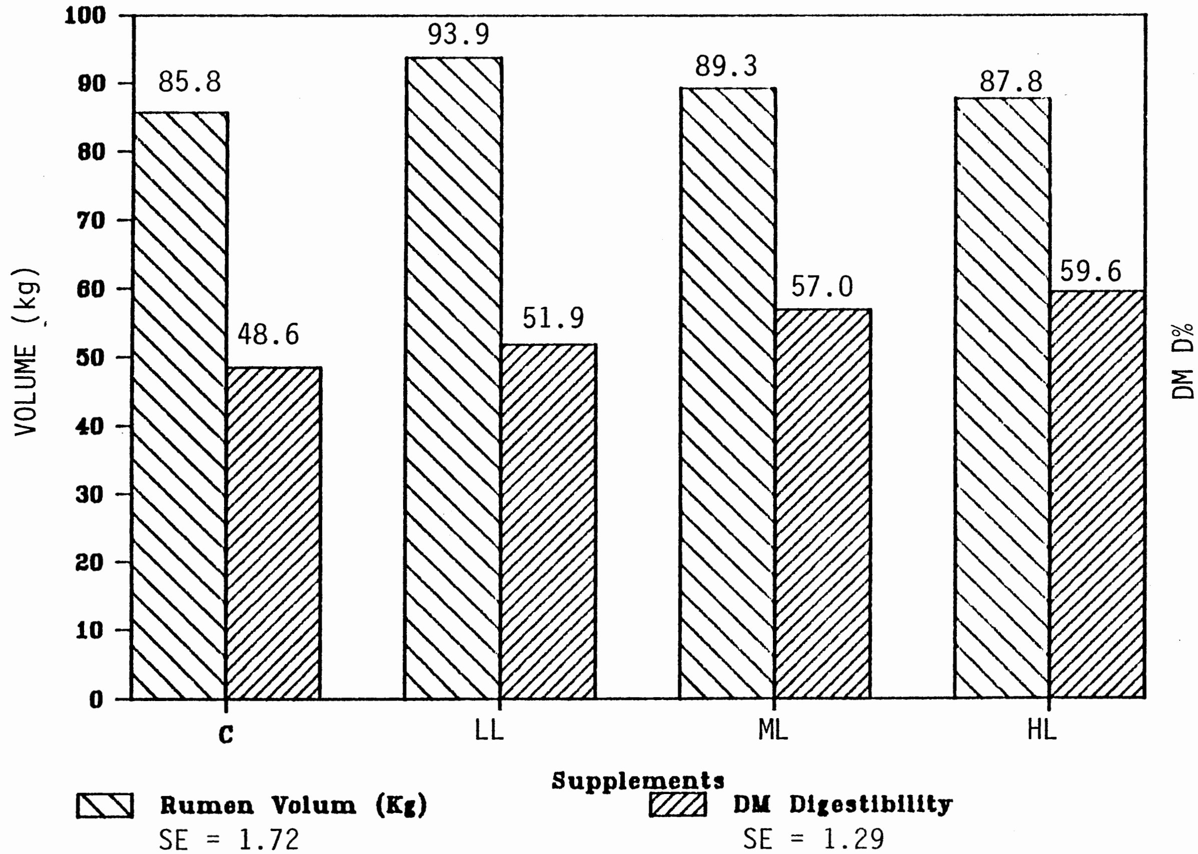


Figure 21. Comparison Between DM Digestibility and Rumen Volume of Heifers Fed Graded Levels of CGF with Medium Quality Prairie Hay

TABLE XXV

RUMINAL DIGESTION PARAMETERS

Item	Supplement				SE	Orthogonal Comparisons[a]		
	C	LL	ML	HL		S	L	Q
Rate of ruminal ADF digestion[b] h^{-1}	5.58[e]	5.73[e] 2%[c]	6.82[f] 22%[c]	7.35[f] 31%[c]	.47	.06	.01	.60
Ruminal ADF[d] g	6485[e]	6379[e] -1.6[c]	4742[f] -26.8[c]	4726[f] -27.1[c]	510	.04	.01	.16
% of daily intake	18.0[e]	16.2[e]	10.4[f]	9.5[f]	1.37	.0004	.0007	.11

[a]Contrasts included S for supplemented vs. control diet; L and Q for linear and quadratic effects of graded levels of CGF.

[b]Calculated assuming that 90% of ADF digestion occurred in the rumen and that rate of passage of all ADF was proportional to particulate rate of passage.

[d]Calculated as hourly ruminal ADF escape [(intake * %ADF) * (1 - .9 ADF digestion)/24] divided by particulate passage rate.

[ef]Means in same row with different superscripts differ (P<.05).

TABLE XXVI

RUMINAL COTTON THREAD DISAPPEARANCE FROM DACRON BAGS FOR BEEF HEIFERS FED PRAIRIE HAY WITH SEVERAL LEVELS OF CGF SUPPLEMENT

Incubation Time	Supplement C	LL	ML	HL	SE	Orthogonal Comparisons[a] S	L	Q
Cotton Disappearance								
24	2.2	4.4	2.9	2.8	1.3	.49	.39	.60
36	6.4	6.8	8.1	11.0	3.92	.65	.44	.83
48	11.3[b]	23.2[d]	19.4[c]	26.9[d]	2.36	.01	.27	.07
72	20.7[b]	33.2[c]	49.5[c]	49.6[c]	6.68	.03	.12	.28
96	36.7[b]	38.2[b]	53.3[b]	76.2[c]	7.53	.09	.01	.62
Slope	.47	.50	.78	1.03	.068	.01	.003	.81
Intercept	-10.5	-6.5	-16.6	-23.6	2.22	.11	.003	.52

[a]Contrasts included S for supplemented vs. control diet; L and Q for linear and quadratic effects of graded levels of CGF.

[bcd]Means in same row with different superscripts differ (P<.01).

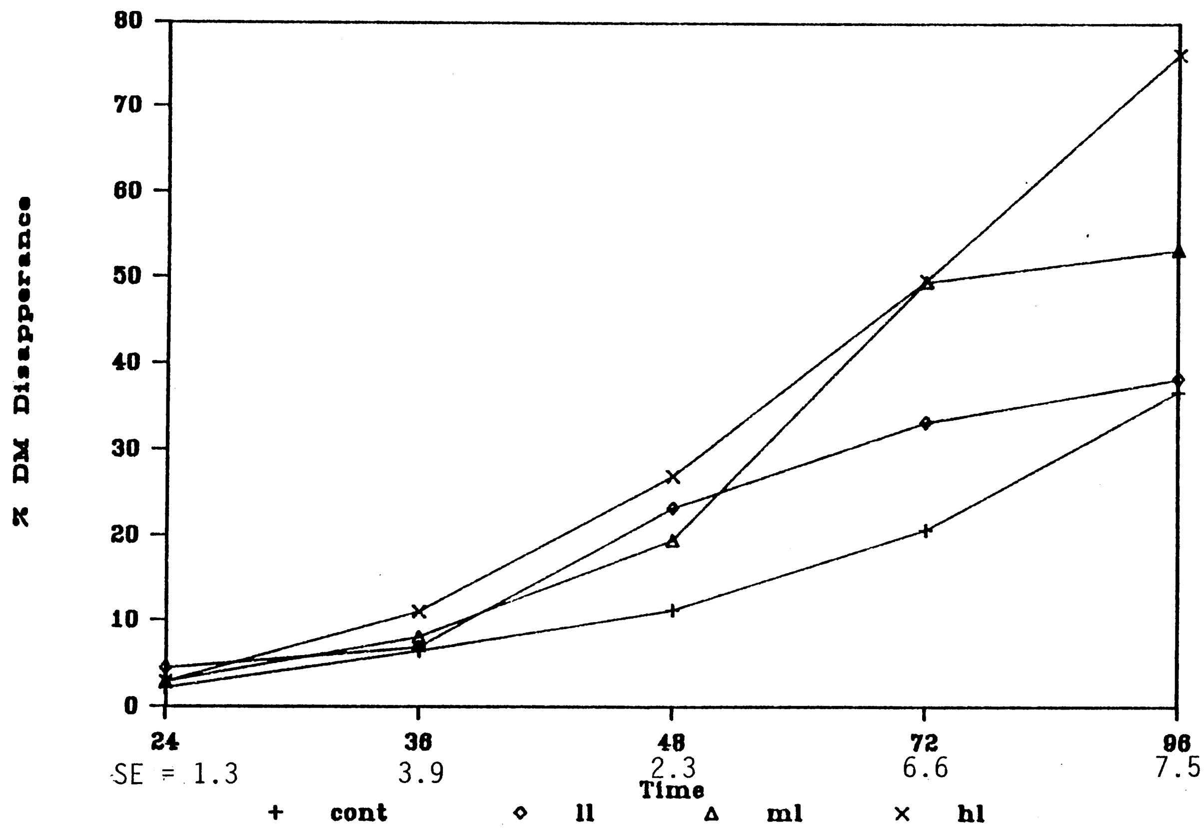


Figure 22. Cotton Thread DM Disappearance

TABLE XXVII

RUMINAL pH IN FISTULATED HEIFERS FED PRAIRIE HAY WITH SEVERAL LEVELS OF CGF SUPPLEMENTS

Item	--------- Supplement --------					Orthogonal Comparisons[a]		
	C	LL	ML	HL	SE	S	L	Q
Ruminal pH								
0	6.80	6.85	6.88	6.97	.111	.49	.46	78
2	6.52	6.68	6.60	6.63	.273	.67	.85	.80
4	6.39	6.50	6.41	6.37	.257	.88	.66	.89
6	6.60	6.49	6.23	6.19	.451	.51	.58	.76
9	6.34	6.54	6.37	6.17	.322	.93	.36	.95
12	6.51	6.64	6.59	6.42	.280	.87	.52	.79
24	6.71	6.76	6.65	6.71	.245	.98	.85	.67

[a]Contrasts included S for supplemented vs. control diet; L and Q for linear and quadratic effects of graded levels of CGF.

TABLE XXVIII

EFFECT OF GRADED LEVELS OF CORN GLUTEN FEED
ON RUMINAL NUTRIENT DIGESTION

Item	----------- Supplement ---------					Orthogonal Comparison[a]		
	C	LL	ML	HL	SE	S	L	Q
Entering the duod (g/day)								
Total dry matter	3353	2314	2705	2725	.375	.15	.43	.64
Total organic matter	2860	1912	2211	2218	.402	.14	.39	.61
Acid detergent fiber	1281	711	872	769	.117	.01	.70	.29
Neutral detergent fiber	1876	1169	1323	1345	.197	.05	.50	.74
Total crude protein	459	392	462	547	.099	.43	.28	.97
Ammonia-N	2.3	1.3	1.9	4.0	.74	.90	.04	.35
Apparent Ruminal Digestibility (%)								
Dry matter	62.5	77.7	77.4	79.4	3.36	.01	.70	.74
Acid detergent fiber	72.8	83.8	81.4	84.9	.935	.01	.39	.03
Neutral detergent fiber	68.4	82.4	82.6	84.0	2.44	.01	.61	.81
Total feed protein	17.2	42.2	48.6	50.2	11.5	.08	.60	.84
Organic matter	65.3	80.5	80.0	81.8	3.37	.01	.76	.73
Apparent Postruminal Digestibility (%)								
Dry matter	51.1	8.9	18.6	27.9	6.42	.01	.07	.97
Organic Matter	50.2	1.2	13.0	22.7	5.71	.01	.03	.84
Total feed protein	72.9	56.6	57.9	68.9	6.51	.19	.20	.48
ADF	51.0	4.1	17.5	7.3	12.6	.04	.85	.39
NDF	54.8	1.9	3.7	16.2	9.88	.01	.31	.61

TABLE XXVIII (Continued)

Item	Supplement C	LL	ML	HL	SE	Orthogonal Comparison[a] S	L	Q
Percentage of Total Digestion Occurring in the Rumen								
Dry matter	77.6	96.8	94.8	94.2	.503	.01	.03	.32
Organic Matter	86.5	107.2	104.6	103.9	.068	.01	.01	.01
Crude protein	22.3	54.9	61.2	59.2	11.8	.05	.78	.74
ADF	85.7	98.2	96.3	99.3	3.57	.03	.81	.52
NDF	81.6	99.6	98.3	97.9	2.28	.01	.56	.83
Ruminal escape feed								
N (%)	17.2	28.4	39.5	60.7	2.59	.0003	.002	.69
Apparent microbial efficiency								
g MP/kg OMF	24.5	24.5	26.3	28.1	1.49	.34	.18	.85
True microbial efficiency								
g MP/kg OM truly fermented	22.8	22.8	23.9	25.0	.097	.34	.18	.85

[a]Contrasts included S for supplemented vs. control diet; L and Q for linear and quadratic effects of graded levels of CGF.

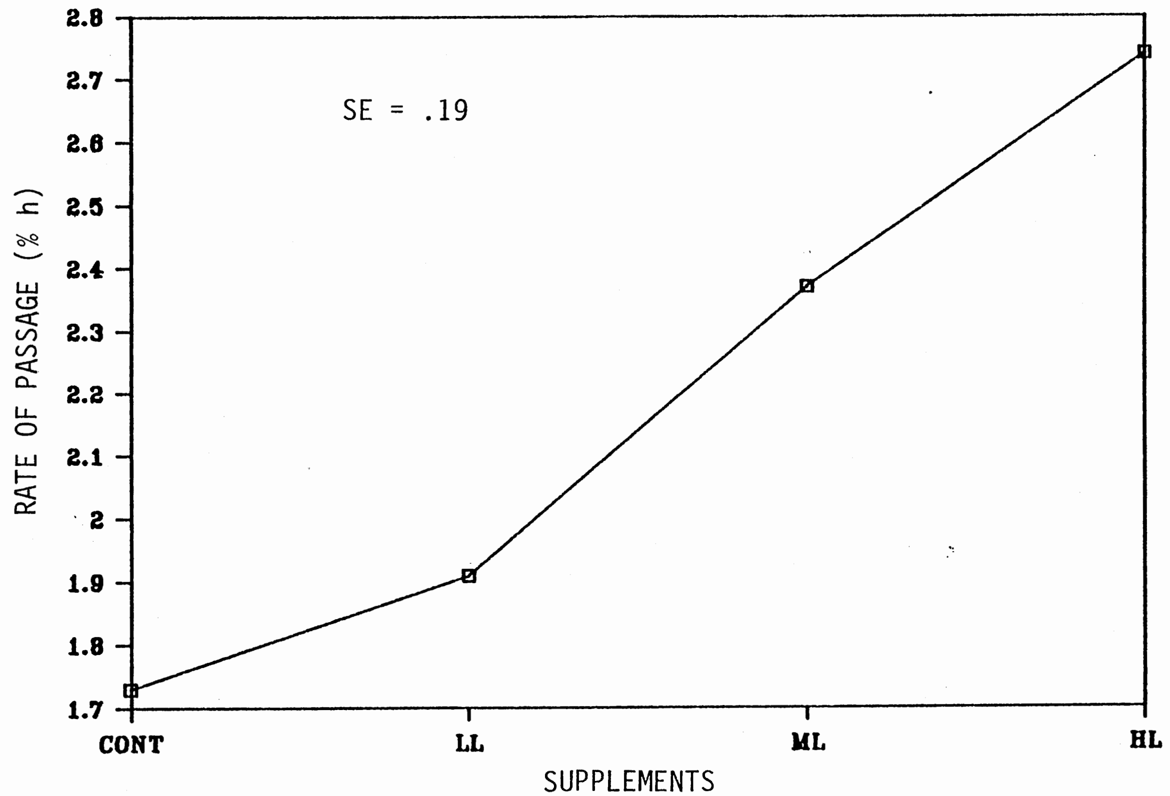


Figure 23. Particulate Rate of Passage (% h) as Increasing Levels of CGF Supplement are Fed with Prairie Hay

CHAPTER VI

SUMMARY AND CONCLUSIONS

Corn gluten feed (CGF), a by-product of the wet milling corn refining industry, is increasing in abundance and availability as a livestock feedstuff. When its price is low enough, corn gluten feed may be a desirable least-cost ingredient in diets for ruminant animals. Most published information about CGF concerns high concentrate finishing diets or comparison with distillers' grains. The traditional method to evaluate protein supplements is to replace a standard protein source like soybean meal (SBM), cottonseed meal (CSM) or urea with isonitrogenous quantities of the test protein and to measure feed intake, digestion parameters and fermentation pattern responses. This study was conducted to evaluate CGF as protein supplement for beef heifers consuming medium quality prairie hay.

In Experiment 1, fifteen heifers were individually fed low quality prairie hay (4.9% CP) and supplements in a triplicated simultaneous 5X5 latin square digestion trial. Prairie hay, cut during the first half of July from a meadow harvested annually, was fed free choice. Treatments were 1) control hay plus minerals and vitamins (Cont.); 2) a soybean meal supplement (.64 kg/d at 49% CP) (SBM); 3) a blend with 2/3 of the supplemented CP from SBM and 1/3 from CGF (.87 kg/d at 39.3% CP) (1/3 CGF); 4) a blend with 1/3 of the protein from SBM and 2/3 from CGF (1.1 kg/d at 28.9% CP) (2/3 CGF); and 5) a CGF supplement (1.4 kg/d oat 23.0% CP) (CGF). Each supplement provided 300 g of supplemental protein per day. Each supplementation program increased ($P<.01$) feed intake and digestibilities of DM, OM, CP, ADF, NDF, cellulose and hemicellulose compared to control. However, replacing SBM by CGF linearly decreased (P<.01) voluntary hay intake and CP digestibility. Likewise, intakes of total DM and digestibilities of DM, OM, CP, ADF, NDF, and cellulose were decreased as CGF replaced SBM. Replacing SBM with CGF decreased (P<.09) ruminal pH from 6.81 to 6.72 but did not depress ADF digestibility. Ruminal ammonia concentration increased as CGF was increased indicating that it was extensively degraded in the rumen. Particulate passage rate was increased (P<.01) by supplementation. Replacing 1/3 to 2/3 of the protein from SBM with CGF protein in a supplement gave intakes and digestibilities equal to that of SBM with medium quality prairie hay.

In a second intake and metabolism trial (Experiment II), CGF was compared with SBM and CSM as a protein supplement for beef heifers consuming medium quality prairie hay (5.2% protein). Twelve heifers, housed in individual pens were used in 3 simultaneous 4X4 latin squares. Prairie hay was available ad libitum. Treatments were: 1) hay plus minerals and vitamin A (C); 2) a SBM supplement (.76 kg/d at 48% CP) (SBM); 3) a cottonseed meal supplement (.85 kg/d at 43% CP) (CSM); and 4) a corn gluten feed supplement (1.74 kg/d at 20.8% CP) (CGF). Each supplement was fed to provide 360 g of supplemental crude protein per day. Prairie hay and total DM intakes were increased (P<.01) by protein supplementation over the control, but there were no significant differences in intake among the three protein supplements. Digestibilities of DM, OM, CP, ADF, NDF, and cellulose were similarly increased (P<.01) by all supplements. Heifers fed CGF had slightly lower intakes and digestibilities than those fed SBM or CSM, but differences were small and not significant. This depression may be due to the higher amount of energy provided by the CGF when fed to supply equal amounts of protein as CSM and SBM. Ruminal pH was not influenced by the protein source. Ruminal-NH_3

concentration was increased (P<.01) by supplementation and was highest (P<.01) with the CGF supplement. Particulate rate of passage was increased (P<.01) with supplementation, but no significant differences were detected among the three protein supplements. This study detected no significant differences in hay intake and digestibilities between CGF and CSM or SBM as a protein supplements when fed with prairie hay diets.

In a metabolism trial, graded levels of CGF (from .58 to 1.74 kg DM/day) were fed with medium quality prairie hay (6.65% CP). Sixteen heifers, including four cannulated (rumen and duodenal) animals, were used in four simultaneous 4X4 latin squares. Heifers had ad libitum access to prairie hay. The treatments were: 1) hay plus minerals and vitamin A (C); 2) a low level (LL) CGF supplement (.58 kg/d at 26.7% CP); 3) a medium level (ML) CGF supplement (1.16 kg/d at 26.7% CP); and 4) a high level (HL) CGF supplement (1.74 kg/d at 26.7% CP). Supplements were fed to provide 150, 300, and 450 g of supplement CP per day on the LL, ML, and HL treatments, respectively. All intake and digestion measurements were linearly increased (P<.01) by added CGF. Hay intakes were increased by 11, 22 and 32 percent on the LL, ML and HL, respectively. DM digestibility increased (P<.01) to 59.6% for the HL compared to 48.6% on the C. Similar linear increase (P<.01) were noted in OM, CP, ADF, and NDF digestibilities. Ruminal pH 2 to 4 h after feeding of supplement was not influenced by supplementation. However, ruminal ammonia concentrations increased linearly (P<.01) as CGF supplementation increased. Ruminal volume was also increased (P<.09) by supplementation. Particulate passage rate ranged from 1.7 to 2.7%/h being linearly increased (P<.01) by supplementation. Ruminal pH recorded every two h was not changed by supplementation, but cotton thread disappearance from dacron bags increased (P<.01) as CGF level increased. These data show a positive effect of CGF as a protein supplement fed with medium quality prairie hay to beef heifers.

In general, CGF is characterized as a protein supplement due to its relatively high protein content (21%). It also is a highly digestible source of energy as reflected by its relatively high digestible NDF and rapid in situ DM disappearance. Blending it with SBM slightly improved hay intake and digestion parameters as compared to feeding CGF as the sole source of supplemental N. Moreover, when compared with SBM or CSM as a sole source of supplemental protein, CGF produced slightly lower hay and energy intakes. When CGF was fed at graded levels, forage intake and digestibility parameters were substantially increased, indicating that CGF can be fed alone as an effective protein and energy supplement for beef heifers consuming medium quality prairie hay.

Although this research provided information on several aspects of CGF utilization, additional research on several points is needed. Different batches of CGF vary in color (from dark brown, coffee smelling to bright yellow); composition and feeding values may differ accordingly. Regarding nitrogen metabolism, ruminal nitrogen escape should be estimated. Standardization of CGF in terms of chemical composition may ensure more consistent digestibility and intake responses which will improve production efficiency of ruminants consuming low or medium quality forage.

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