THE VALUE OF CORN GLUTEN FEED AS A SOURCE OF SUPPLEMENTAL PROTEIN AND ENERGY FOR GRAZING BEEF CATTLE

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TABLE OF CONTENTS

LIST OF TABLES

Table Page

CHAPTER V

CHAPTER I

INTRODUCTION

The ruminant can compete, as a food producing animal, with the non-ruminant because of its ability to utilize fiber. During the life of the ruminant, most of the dry matter (DM) consumed is in the form of forage from pasture, hays, crop residues, or silages. When forages cannot provide sufficient nutrients for the desired growth rate or performance, protein and/or energy concentrates are often added to the diet.

Typical supplements are oilseed meals or 20% protein pellets, depending on producer preference, relative prices of oilseeds and grains, and the availability of forage. When forage is abundant and energy requirements of the animal are relatively low, high protein oilseed meals effectively increase energy intake of grazing ruminants by increasing forage digestibility and intake. When forage is limited or when animal requirements are high (during extreme cold, lactation, or rapid growth), cattle may not be able to efficiently meet their energy requirements from forage supplemented with protein alone. The alternatives in this situation are to feed high quality hay or an energy supplement.

Feeding energy in the form of concentrates often is more economical and preferred because of the expense and labor involved in both harvesting and feeding hay. However, feeding an energy supplement may result in competition between two different rumen microbial populations for limiting nutrients. Amylolytic bacteria digest starch from grain whereas cellulolytic bacteria digest fiber from forage. If a large amount of grain is fed, amylolytic bacteria attack the readily digested starch and proliferate more rapidly than cellulolytic bacteria. This competition can decrease fiber digestion and reduce forage intake. Therefore, even though the energy content of the total diet is increased, the animal eats less forage and the energy intake of the animal remains nearly unchanged.

The energy in an energy/protein supplement can be provided as cereal grains which contain starch, or from milling by-products which contain highly digestible fiber. Replacing grain with a highly digestible fiber is one possible method of alleviating negative effects associated with feeding energy supplements containing starch. Feeding such supplements may allow greater digestion by cellulolytic microorganisms, maintain forage intake, and increase the amount of energy available to the animal.

Grain milling by-products are fed to many livestock species, although ruminants use a greater proportion of these feeds. The by-products of most grain milling

processes are concentrated sources of protein and fiber, or both. The biological value of corn by-products may be poor for non-ruminants yet sufficient for ruminants. The fiber should be more efficiently used by rumen microorganisms than by microbes in the non-ruminant gut. Therefore, supplements containing these highly digestible high-fiber feeds may more efficiently increase total energy intake of grazing cattle than grain supplements.

According to Stadlman (1985), refining is the fastest growing market for corn. This growth has been spurred by the development of two major corn products, high fructose corn syrups (HFCS) and ethanol. The annual U.S. production of HFCS requires almost 400 million bushels of corn while ethanol requires nearly 200 million bushels. The largest single market for HFCS is the soft drink industry. Beverages use 67% of the total HFCS production. The remainder is used in baking, canning, and processed dairy food industries (Stadlman, 1985). The annual production of ethanol, nearly 500 million gallons, is marketed in the form of "gasohol" (10% ethanol and 90% gasoline). According to Stadlman (1985) all U.S. and foreign automobile manufacturers, with the exception of Peugeot, now approve the use of 10% ethanol in their vehicles suggesting that the use of alcohol may become more extensive in the future.

An increase in demand for either or both of these products will require an increase in corn refining which in

turn will increase the quantities of high fiber industrial by-product. Corn gluten feed (CGF) is the corn wet-milling industry's by-product of largest volume. In excess of 270 trailer-truck loads of gluten feed are shipped daily from Iowa alone (Stadlman, 1985). Increased production of CGF has been coupled with a decision by the European Economic Community to limit it's importation. This decision has prompted research in the US to evaluate the potential use of CGF in livestock diets so that proper recommendations can be made to efficiently use CGF domestically.

Available research concerning the use of CGF by ruminants has dealt primarily with high concentrate growing rations in which medium to high quality forage is fed. Limited information exists dealing with the use of these by-products as energy/protein supplements for animals grazing or fed low quality forages. This study will evaluate CGF as a supplement for grazing animals. The study will characterize the protein and fiber constituents and determine their effect on forage intake and digestibility. The study will also determine the effect of CGF as a protein/energy supplement on the performance of growing and mature cattle grazing native range.

CHAPTER II

REVIEW OF LITERATURE

ASSOCIATIVE EFFECTS OF SUPPLEMENTATION

When two or more feedstuffs are fed together, there is seldom a linear response in digestibility and net energy values. This interaction (called an associative effect) will often over- or under-estimate the value of the mixture as compared to those predicted from values for feeds fed individually in separate trials. Associative effects can be either beneficial or detrimental, as illustrated in Figure 1 (Van Soest, 1982). Studying the factors affecting associative interactions among feed mixtures, Rust (1983) suggested that the presence of associative effects depends on the physical and chemical composition of the diet, the proportion of concentrate to roughage, the source of nitrogen (N), the level of intake, and/or the presence of feed additives.

Cattle fed a low quality roughage or grazing dormant range often receive cubed supplements containing a concentrated source of protein and/or energy. Supplements containing oil seed meals contribute much of the protein and some energy, whereas, supplements containing cereal grains

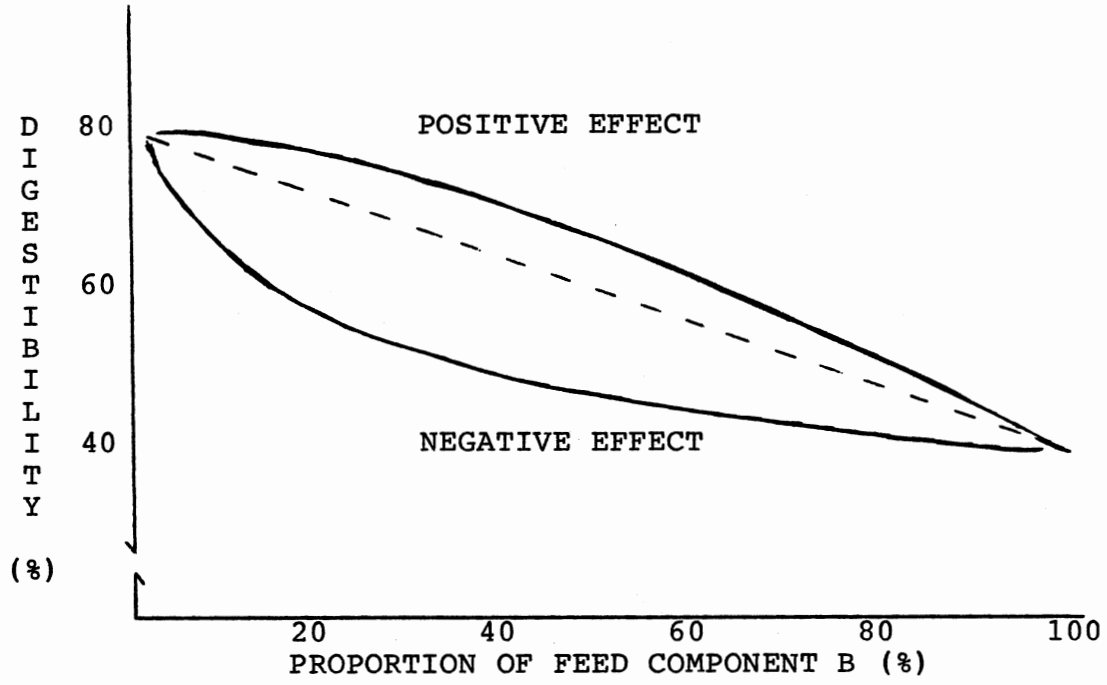

Figure 1. Illustration of the associative effects where poor quality feed B is substituted into a high quality feed A. Dashed line represents expected digestibility if no associative effects occur. Positive and negative effects are denoted by the upper and lower curved lines, respectively. In the case of supplementation of straw with a protein supplement, a positive association may be observed since the addition of an increment of nitrogen allows better utilization of the straw. On the other hand negative associative effects are often observed when high grain diets are diluted by pelleted or finely chopped forage sources (Adopted from Van Soest, 1982).

contribute primarily energy. There may be considerable variation within the feed ingredients of the cube, depending on prices and availability of feedstuffs. Therefore, the starch and protein constituents of a supplement may have opposite effects on fiber digestion.

Positive associative effects of supplementing low quality roughage diets with natural protein or other N sources are well documented (McCollum and Galyean, 1985). Meeting the N needs of ruminal bacteria is essential for rapid rates of fermentation that will increase roughage digestibility, passage rate, forage intake, and subsequently, animal performance. The source of N used in the supplement may be from true protein of plant or dairy by-product origin or from non-protein nitrogen (NPN) such as biuret or urea, depending on the type of diet being supplemented.

Adding an energy source often complicates supplementation of high roughage rations. Adding a large amount of readily available carbohydrate to forage in a ruminant ration usually decreases the digestibility of the fibrous portion of the ration (Mitchell and Hamilton, 1940; Hamilton, 1942; Burroughs et al., 1949). In a comparative slaughter trial, Vance et al., (1972) measured the net energy content of rations containing corn fed alone or with varying proportions of corn silage. The net energy for gain from the corn grain was lower in the corn-corn silage diets

when compared to corn fed alone, while the net energy from the corn silage increased as the increment of corn grain declined. Kroman et al. (1975) fed lambs varying proportions of dehydrated alfalfa and corn (5% increments from 0% to 100% for each ingredient). They found an increase in crude fiber digestibility as the level of corn declined in the diet. Steers fed a 1:2 ratio of corn silage to corn grain had digestion coefficients averaging 11% less than those calculated from the weighted means for the feeds fed individually (Joanning et al., 1981). McDonnell (1982) fed lambs various levels of corn (0, 25, 50, 75 and 100%) in an ensiled corn stover diet and found that neutral detergent fiber (NDF) digestibility increased as level of corn in the diet decreased. Feeding two levels of starch (22.8 and 49.9%) in a 20% CP supplement, Arelovich (1983) found that the high starch level decreased acid detergent fiber (ADF) and cellulose digestibility. A corn-grain, 13% crude protein (CP) supplement fed at the same daily protein level as a 32% CP SBM supplement also depressed cellulose digestibility (Guthrie, 1984). Chase and Hibberd (1985) found similar responses and concluded that feeding more than .91 Kg/d of corn decreases both forage intake and fiber digestibility. The responses in these experiments all reflect negative associative effects.

Researchers have proposed different theories to explain the depression of fiber use in the presence of grain. Common theories according to el-Shazly et al. (1961) are (1)

the production of an inhibitor by starch digesting microorganisms (2) a decrease in pH due to acids produced from starch fermentation and (3) a competition for essential nutrients (such as ammonia) with a preferential proliferation of starch digesting microorganisms.

Starch inhibition of cellulose or fiber digestion has been demonstrated with both in vitro and in vivo studies (Head, 1953; el-Shazly et al., 1961; Mertens and Loften, 1980), yet limited information supports the inhibitor production theory. By reducing the starch level in a continuous culture of rumen contents, Stern et al (1978) noted an increase in ADF digestibility. However, the level of starch needed to depress fiber intake and utilization, or the mechanism by which it occurs, is poorly established.

In support of the pH theory, the number of cellulolytic bacteria and their activity sharply decrease when pH drops below 6.2 (Oorskov, 1982), and at pH 5.5, bacterial growth stops completely (Hungate, 1966). In the rumen, cereal grains ferment faster than roughages; this increases the production of volatile fatty acids (VFA) per unit of feed consumed and decreases rumen pH. The rumen needs more saliva to buffer the declining pH, yet the decreased rumination observed with high concentrated diets results in the production of less saliva (Oorskov, 1982). Amylolytic bacteria, on the other hand, are nearly unaltered between pH of 5.6 and 7.0 (Oorskov, 1982); although, a sudden shift

from a high roughage to a high concentrate diet may promote lactic acid fermentation, a pH decline, and lactic acidosis. Helm el al., (1972) found a reduction in the ratio of acetate to propionate, an increase in lactic acid, and a lower pH when feeding a 40% coastal bermuda grass and a 60% concentrate (mainly reconstituted sorghum grain) diet. In an in vitro study using washed suspensions of rumen microorganisms, Cheng et al. (1955) found that with a pH value lower than 6.4 or higher than 8.0, cellulose digestion decreases. Stewart (1977) studied cellulolytic activity of rumen contents by measuring losses in weight and tensile strength of cotton yarn incubated in rumen contents in the presence of barley at different pH values. Adding barley depressed cellulolysis and the titer of filter paper-degrading bacteria only if the pH was allowed to fall. Adding hydrochloric acid to lower the pH from 7 to 6 almost completely inhibited the digestion of cotton by rumen bacteria. These studies clearly indicate that reductions in rumen pH will cause inactivity and cessation of cellulolytic bacterial growth, resulting in a depression in total fiber digestibility and DM intake.

Evidence also supports the theory that rumen microorganisms preferentially use starch before the microbial population shifts to the degradation of more fibrous feedstuffs. Williams et al., (1953) fed sheep low protein diets (14g CP/d) with varying increments of starch (0, 99, or 149 g/d, representing 0, 27, and 36% of the diet

DM, respectively) and found that the number and type of microorganisms in the rumen decline. Kane et al, (1959) found that adding cornstarch to alfalfa hay diets depresses nitrogen free extract (NFE), protein, and DM digestibility in cattle; however, the effect is removed when an extended adaptation period is allowed. This suggests that dietary starch inhibits the growth of cellulolytic bacteria, and, depending on the amount of starch in the diet, bacterial numbers may return to normal levels after an extended adaptation period.

In an in vitro study, el-Shazly et al. (1961) found that N is the major nutrient involved in the competition between the cellulolytic and amylolytic groups of bacteria. Adding urea to 2:1 and 1:1 hay to corn rations, improved cellulose digestion; however, when the ratio of hay to corn was 1:2, additional N was ineffective. Martin et al. (1981) found when a 25% cornstarch or 80 grams of molasses were fed to sheep consuming 3.6 to 3.9% CP hay, organic matter (OM) digestibility and N retention increased. In the same study, supplemental N gave an additional improvement in OM and cellulose digestibility; however, a high molasses intake (160 grams) depressed voluntary intake of hay. These studies and studies by Williams et al. (1953), el-Shazly et al. (1961); Andrews et al. (1972); and Hennessy et al. (1981) agree that N or protein supplements alleviate some of the inhibitory effects of cellulose digestion associated

with feeding starch or high levels of readily available energy with low quality roughage.

Staples et al. (1982) further demonstrated that factors tending to depress fiber digestion at ad libitum intakes of roughage:concentrate (65:35) diets include a slower DM digestion rate, faster solids passage rate, and a consistently lower rumen pH. Small amounts of soluble carbohydrates can stimulate fiber digestion; however, at higher levels, rumen pH is reduced and fiber digestion declines. In vitro experiments by Mertens and Loften (1980) suggested that starch alters fiber digestion primarily by increasing the digestion lag time. This observation supports the theory that ruminal microorganisms preferentially use starch before the population shifts to degrading the more fibrous feedstuffs. However, a small change in lag time cannot explain the relatively large depression in fiber digestion observed in vivo.

The source of starch was noted to effect intake and ruminal parameters. Varner (1970), Varner and Woods (1975), and Fulton et al. (1979) found feed intake and ruminal pH increase when wheat replaced corn in high concentrate diets. Starch, a reserve polysaccharide in plants, is made up of polymers of glucose and can be in the form of amylose (α 1, 4 linkages) or amylopectin (α1, 4 and α 1, 6 linkages) (Stryer, 1981). Moreover, the relative proportion of amylose to amylopectin, and characteristics of starch

granules in grains, vary within plant species (French, 1973). The effect of the different starch sources and characteristics on forage intake and digestibility are currently not well established.

In summary, N supplements appear to improve the use of low quality feedstuffs by increasing total DM digestibility and intake. The addition of large amounts of starch or soluble carbohydrates often depress fiber digestion and intake. Even with the information available to date, it is difficult to accurately predict the amount of supplemental protein and energy that should be fed with roughages of varying qualities under any given production system. This is especially critical when one considers the variety of protein and energy supplements available.

HIGHLY DIGESTIBLE FIBER SOURCES

The use of high fiber, low starch energy sources instead of cereal grains may alleviate the negative associative effects encountered when feeding cereal grain energy supplements. Cellulolytic bacteria should utilize the highly digestible fiber in the supplement without altering forage digestion or intake. If forage intake and digestibility are not depressed by supplementation, a high fiber supplement would increase the total amount of energy available to the animal. High fiber energy sources are

typically by-products of the corn, wheat, soybean, or sugar beet processing industries.

CORN WET-MILLING PROCESS

The first step in the corn refining process serves to condition the corn kernel by steeping or soaking. Steeping in sulfurous acid is necessary for optimum milling, component separation, and recovery of solubles (Anderson, 1970). This process softens the kernel for grinding, disintegrates the protein that holds the starch granules together, and removes solubles from the germ. The steepwater, containing sulfurous acid water, permits fermentation by lactic acid-producing organisms but forestalls the growth of unwanted bacteria and molds and prevents germination (Corn Industries Research Foundation, 1959). After the steeping process, the steepwater is drawn off and concentrated to a heavy liquid (about 40-50% solids). This concentrated steepwater, containing 41% crude protein on a DM basis, can be sold as condensed fermented corn extractives known as corn steep liquor (Corn Refiners Assn., 1975) or it can be added to the end-products of other steps (corn bran and corn germ meal) to form CGF.

The steeped corn is next milled in a water slurry to remove the germ (oil) portion of the kernel. Corn oil is then extracted from the germ. After drying, the resulting

germ meal can be sold directly as a feed ingredient (Corn Refiners Assn., 1975) or becomes a constituent of CGF.

The degermed corn is next screened for recovery of any starch or protein released during the germ separation process. The remaining fragments are fine milled to separate the starch and gluten from the fiber and hull particles. A wet screening process removes the fibrous portion (corn bran) from the starch granules and protein. Corn bran, containing 11% crude protein, can also be marketed or may be combined with the germ meal and concentrated steepwater to form wet CGF (42% DM). After drying, the product is marketed as dry CGF (91% DM). The crude protein content between batches of CGF can be maintained by adding more or less steepwater (Corn Refiners Assn., 1975).

The starch granules and protein then enter a continuous centrifuge process which separates the suspended starch from the gluten. The lighter gluten fraction passes out in the overflow while the heavier starch suspension leaves in the underflow. To concentrate it, the gluten slurry is again centrifuged, filtered, and dried. The resulting product is called corn gluten meal (CGM) (Corn Refiners Assn., 1975).

The products (% of initial dry solids) obtained from a bushel of corn via the corn wet-milling process are starch (66.2), germ (7.4), gluten feed (19.4), and gluten meal (5.6), leaving 1.2% unrecovered. Starch is used in food,

industrial starch, high fructose corn syrup, conventional corn syrup, dextrose, or is converted to fuel and beverage alcohol. Corn oil is extracted from the germ and used for human consumption, while the gluten feed and gluten meal are used as livestock feeds (Long, 1985).

ALCOHOL FERMENTATION PROCESS

According to Trenkle (1985b) fermentation of the corn kernel converts the starch portion to ethyl alcohol. Distillation removes the alcohol leaving "spent" stillage (5 to 10% DM). This stillage can be further processed into distillers grains (DG), distillers solubles (DS), or distillers grains with solubles (DGS).

Distillers grain, the solid portion of spent stillage, includes fiber, unfermented carbohydrates, and insoluble proteins. Distillers grain is available wet (20 to 25% DM) or dry (94% DM).

Distillers solubles are unfermented soluble nutrients left in liquid after removing DG. The product is marketed at about 93% DM and contains 29.7% CP, 9.25% fat, and 5.0% crude fiber on a DM basis.

Distillers grain with solubles is a combination of DG and DS and is also available wet (5 to 10% DM) or dry (90 to

93% DM). On a DM basis, a typical chemical composition of DGS is 28% CP, 9.5% fat, and 10.7% crude fiber.

CORN REFINING BY-PRODUCTS AND ANIMAL PERFORMANCE

The by-products of largest quantity from the corn wet-milling and corn fermentation processes are CGF, CGM, and DG. Therefore, these feedstuffs will be emphasized in the review of literature.

Corn Gluten Feed.

Corn gluten feed, as stated above, includes the hull of the kernel (corn bran); therefore, it is relatively high in fiber compared with corn grain. The wet form is marketed as a meal while the dry CGF is available ground or pelleted. According to Long (1985), typical contents of crude protein, fat, and crude fiber are 21.0, 3.3, and 8.5% of DM, respectively. National Research Council (1981) reported similar values with the exception of 25% reported for crude protein and described CGF as having a characteristic gluten feed odor (fresh coffee-like, not sour, musty, burnt, or otherwise undesirable), light to brown color, free flowing, and uniform through the lot with respect to composition and grind.

Corn Gluten feed as a protein source: The N in CGF is generally classified as soluble and extensively degraded in

the rumen. Corn gluten feed should not be confused with CGM in which the protein is insoluble and largely escapes the rumen. When characterizing the protein fraction of various protein supplements, Van Soest et al. (1984) reported that the nonprotein nitrogen (NPN) contents were 55 and 13% for CGF and SBM, respectively. The same report suggested that the cell bound, heat denatured, very slowly degradable, or nondegradable protein is very low for CGF (2 to 5%), quite similar to the level in SBM.

Corn gluten feed is approximately two-thirds corn bran (11% CP) and one-third corn steep liquor (41% CP on DM basis), therefore, steep liquor contributes about 65% of the protein to CGF. Corn steep liquor is a concentraded source of highly soluble nutrients, and therefore, adds amino acids, peptides, microbial protein, and soluble protein which are all highly degraded in the rumen.

In an in vitro enzyme assay, DeHaan et al (1983) found that N from CGF is more extensively degraded than N from SBM. The same researchers estimated that CGF fed as a N source to growing steers has a protein value equal to 71% of SBM. Firkins et al. (1984) reported that the rate of in situ N disappearance between 2 and 8 h post feeding was 9.46, 8.93, and 9.97 %/h for wet CGF, dry CGF, and SBM, respectively. A metabolism trial (Firkins et al., 1985) quantified ruminal escape protein values for various by-product feeds. The values were wet CGF, 26%; dry CGF, 14%;

wet DG, 47%; and dry DG, 54%. These studies all indicate that the protein fraction of CGF, though of limited escape value, can furnish the rumen microbial population with N for efficient growth and replication.

Corn Gluten feed as an energy source: The industry often classifies CGF as a protein supplement because it has a relatively high (21%) crude protein content; however, Yen et al. (1974) found CGF has a metabolizable energy (ME) value of 2.77 Kcal/g of DM. This is an acceptable energy source for swine. Corn gluten feed can be substituted for corn up to a dietary level of 30% of a 12% CP fortified corn-SBM ration without reducing performance of finishing swine (Yen et al., 1971). The researchers concluded that any inefficient use of CGF can be attributed to biologically unavailable tryptophan rather than any bulky or unpalatable properties. A N balance study by the same authors indicated that pelleting increases tryptophan availability and improves total diet utilization when fed to swine.

The high energy value of CGF is related to the high digestibilities of both bran and steep liquor. Abe and Horri (1978) reported in vitro cell wall digestibilities for CGF above 80%. DeHaan et. al (1983) also found CGF had rapid (6.2%/h) and extensive rates (87%) of NDF disappearance in vitro. In a metabolism trial, lambs fed a corn silage-based ration had similar fiber digestibilities with wet CGF, dry CGF, and soybean (SBM) supplements

(Firkins et al., 1985). In the same trial lambs receiving wet or dry CGF as 96% of the total ration had NDF digestibilities of 63.5 and 58.2%, respectively, compared to 50.3% for the SBM-corn silage control. Dry CGF diets had lower ADF digestibilities when fed alone or with corn silage then did wet CGF or SBM-corn silage treatments. When replacing corn with CGF at up to 60% of the ration DM for yearling heifers, wet CGF and dry CGF had energy values approximately 90% and 75% that of grain, respectively (Trenkle, 1985a). These studies indicate that CGF fiber is highly digestible and an excellent source of energy. The studies further show that cattle fed 50% or more (DM basis) wet or dry CGF without other sources of roughage have sufficient fiber to avoid digestive problems occasionally associated with feeding high concentrate rations.

To date, most trials with CGF have used growing cattle on common growing rations consisting primarily of good quality forage and greater amounts of concentrates than the amounts fed to cattle maintained predominantly on range. DeHaan et al. (1983) found that finishing lambs consumed more feed, grew faster, and gained more efficiently when dry CGF was substituted for 25 or 50% of a corn silage diet. Substituting corn grain by 25 or 50% CGF, DeHaan et al. (1983) found increased feed intake, only slightly higher gains (8.1%), and reduced efficiency (13.6%). This decreased efficiency may be due to negative associative effects.

In a steer growth trial, Firkins et al. (1985) fed isonitrogenous (11.5% CP) rations of SBM, dry CGF, or wet CGF with corn silage. Average daily gains were 1.24, 1.52, and 1.46 Kg/d for steers receiving supplemental SBM, dry CGF, and wet CGF, respectively, while, feed efficiencies were 7.73, 6.86, and 6.52. In a concurrent finishing trial, diets of 37.3% cracked corn and either 50% dry CGF or 50% wet CGF were compared to a control diet of 7.8% SBM and 80.5% cracked corn. The average daily gains were similar (1.33, 1.35, and 1.38 Kg/d for SBM, dry CGF, and wet CGF, respectively); while, efficiency of feed use poorest with dry CGF (6.13, 7.01, and 6.37 feed/gain for SBM, dry CGF, and wet CGF, respectively).

Studies by Berger (1985) demonstrated that CGF could be substituted in high energy finishing rations without reducing performance. Trenkle (1985a) substituted CGF for both corn and roughage at levels of 0, 30, 50, or 70% of the ration DM. Steer average daily gains were 1.30, 1.52, 1.51, and 1.42 kg/d while respective feed efficiencies were 7.15, 6.40, 6.21, and 6.20. Feed intakes were 9.27, 9.77, 9.50, and 8.82 kg/d with the 0, 30, 50, and 70% CGF substitution treatments, respectively. Compared with animals receiving no CGF, steers at the 30 and 50% levels ate more feed, gained faster, and were more efficient. Although feed intake was reduced at the 70% level, performance remained acceptable.

In a growth trial, Cordes et al. (1986) fed heifers fescue hay supplemented with 1.8 kg of dry CGF, corn plus urea, or a 1:1 mixture of CGF and corn plus urea. Average daily gains for the 86 d trial were greater for heifers fed CGF and CGF/corn plus urea blend (.50 and .54 kg/d) than for heifers fed corn plus urea supplement (.34 kg/d). In a subsequent trial, heifers supplemented with 2.7 kg/d of corn/SBM or CGF had similar rates of gain (.70 kg/d).

In summary, protein efficiency for CGF when fed to growing steers is slightly lower (71%) than that of SBM. This is consistent its faster rate of ruminal protein degradation. Soybean meal should contribute more undegraded protein to the small intestine or may release N in the rumen over a longer period for greater microbial efficiency than will CGF. Low true protein content and rapid ruminal destruction of crude protein from CGF limit its usefulness as a bypass protein source for young ruminants. Although, it appears to be very acceptable source of N for growing and finishing ruminants in a variety of diets.

Rapid and extensive degradation of fiber in CGF, potentially avoiding reduction in fiber digestion of the forage, makes CGF a promising energy/protein supplement for high roughage diets. Replacing conventional protein supplements (oil seed meals) with CGF therefore may increase the total energy intake of ruminants consuming forage, and consequently, improve performance.

Corn Gluten Meal

Corn gluten meal consists primarily of the insoluble protein (zein) from the corn kernel plus minimal quantities of starch and fibrous materials. It is generally dried, ground, and sold as a meal containing 90 to 93% DM. Its typical chemical composition is 60% CP, 2.5% fat, and 10% crude fiber (Long, 1985).

Zein is only slightly soluble in rumen fluid and resists microbial proteolysis (McDonald, 1952); therefore, a substantial amount of the protein from CGM escapes microbial degradation in the rumen (Ely et al., 1967). The percentage of protein from CGM which escapes ruminal destruction and reaches the small intestine for enzymatic digestion has been estimated at 62% (Waller, 1978), 46% (Zinn et al., 1981), and 57% (Stern et al., 1983). In an in vitro study, Little et al. (1963) found that only 13% of the total N in CGM was soluble in rumen fluid. Adding urea to cellulose improved cellulose digestibility more ($P<.05$) than adding CGM alone. This large response to urea indicates that CGM alone does not provide enough ammonia in the rumen for optimum microbial growth and activity. However, feeding urea with CGM will support cattle growth equal to supplementing with SBM alone (Peterson, 1977; Peterson and Klopfenstein, 1977).

As 45 to 65% of the protein from CGM reaches the lower digestive tract unchanged, its quality or biological value

is important. Relative to animals requirements, lysine and tryptophan are both low in CGM (Reiners et al., 1973). Combinations of natural proteins help balance the amino acid pattern and have complimentary effects. When CGM plus urea was fed to growing steers in combination with SBM, no complimentary effect on performance was apparent (Peterson, 1977; Peterson and Klopfenstein, 1977). However, Rock et al. (1983) found that feeding dehydrated alfalfa and CGM (both slowly degradable protein sources) improved the performance of steers above the average of the two sources fed individually ($P<.05$). Steers fed combinations of 30% CGM, 30% blood meal and 40% urea also performed slightly better than steers fed the 40% urea plus these natural protein sources individually (Merchen et al., 1978). DeHaan et al. (1982) found that growing calves receiving 50% of their dietary CP from CGM and 50% from urea had similar daily gains and feed efficiencies as control calves receiving 50% SBM and 50% urea indicating that its value is equal to SBM when fed in combination with urea.

These studies indicate that CGM is a highly insoluble source of protein which extensively escapes degradation in the rumen. When fed as the only protein source, however, CGM is inferior to SBM due to insufficient release of ammonia in the rumen and/or its poor amino acid balance. Corn gluten meal may be more useful in growing rations if fed with other slowly degraded protein sources to correct amino acid deficiencies. Because CGM may not release enough

ammonia in the rumen to support normal microbial activity, it is ineffective as the sole source of protein in high roughage diets.

Distillers Grain

Distillers grain is the largest component by-product of the alcohol fermentation process. Distillers grain consists of the solids or unfermented carbohydrates, fiber, and insoluble proteins which remain after the corn kernel is ground, soaked and fermented, and the alcohol is removed. Distillers grain is marketed wet (20 to 25% DM) or dry (90 to 94% DM) and has a typical chemical composition of 29.5% CP, 9.8% fat, and 12.1% crude fiber (Trenkle, 1985b). Distillers grain contains protein insoluble during the alcohol fermentation process; therefore, some DG protein also may by-pass ruminal fermentation. The portion of protein which is soluble in the rumen is rapidly and extensively degraded, while the portion that by-passes the rumen due to insolubility may also resist digestion in the small intestine (Van Soest et al., 1984).

DeHaan et al. (1982) found lambs fed DG gained faster and more efficiently than lambs supplemented with SBM. Daily gains were .073 and .082 Kg/d, feed efficiencies were 8.67 and 8.01 and protein efficiencies of .83 and 1.06% for lambs receiving mixtures of SBM plus urea or dry DG plus urea, respectively. These protein efficiencies were calculated by dividing the supplemental natural protein

intake by gain above the 100% urea control. Growing calves receiving wet DG, fed as is or ensiled, performed better than calves receiving dry DG. Assigning SBM an average protein efficiency value of 100%, the authors estimated that protein efficiency values were 200 and 214% for dry DG and wet DG, respectively, when limit fed to growing calves in roughage-based diets. Lambs fed wet DG and dry DG had similar apparent N digestibilities (80.5 and 80.8%, respectively) but dry DG had slightly higher ADF and NDF digestibilities (Firkins et al., 1985). In a growing trial, steers fed supplemental dry DG gained faster and more efficiently than steers supplemented with SBM.

The results of these trials indicate that dry DG will produce performance comparable to that from wet DG. Furthermore, dry or wet DG may be included at 50% of a ruminant finishing diet without depressing performance. Research with low quality high roughage diets is needed to determine how effective DG is as a protein/energy supplement for grazing or forage-fed ruminants.

WHEAT BY-PRODUCTS AND ANIMAL PERFORMANCE

The wheat milling process, designed to remove flour, begins with the removal of all foreign matter by an air-flow and screening process. The cleaned wheat is then soaked, or tempered, similar to the corn milling process. Tempering

will condition the endosperm so that the floury particles break free during milling. The cleaned, tempered grain then enters a repeated process of grinding, sifting, and purifying until the maximum amount of flour is removed (Millfeed, 1972). The by-products in largest quantity from wheat milling are wheat bran (WB) and wheat middlings (WM).

Wheat Bran

Wheat bran is a mixture of the course outer covering of the wheat kernel, flour, and some finely ground nonwheat material. The appearance of bran is that of a flaky brown material lightly dusted with endosperm particles (Millfeed, 1972). Making up 50% of the total wheat by-products, the proximate analysis of WB is 13% CP, 4.4% fat, and 11.3% crude fiber (NRC, 1984). Wheat bran is known for its moderate level of protein, high phosphorus content, and bulky, laxative characteristics.

Wheat Middlings

Wheat middlings come from the layer of the wheat kernel just inside the outer bran covering plus endosperm particles, bran particles, ground weed seeds, and other nonwheat materials. The appearance is that of a brownish finely ground meal. Approximately 45% of total wheat by-products are WM. However, the proportion of WM will increase to 98 or 99% of the total if one adds finely ground bran and offal (the "tail of the mill"). Wheat middlings

have a chemical composition of 18.4% CP, 4.9% fat, and 8.2% crude fiber (NRC, 1984).

Though WM have been used in both dairy and beef rations, little documented research has evaluated it. The fiber is highly digestible, therefore WM is also a potential energy and protein supplement for cattle consuming low quality roughage. Morrison (1956) suggested that WM should not be fed in excess of one third of the concentrate in the ration. Amounts exceeding one third were expected to reduce feed intake and, subsequently, performance. These reductions disappear when WM are pelleted or when molasses is added.

Van Horn (1982) reported that WM when fed to dairy cows at levels as high as 45% of the concentrate had no deleterious effect on milk yield, feed intake, or milk fat percentage. Acedo (1983) fed concentrates containing 40% WM and 60% WM to dairy cows. At 40%, intake and milk production were maintained, with 60% WM, intake was not changed but milk yield declined. The authors concluded that WM could be fed up to 40% of the concentrate without reducing milk production. These studies all show WM is useful as a portion of the dairy cow diet. Research is still needed to characterize the fiber in WM and determine its value as a protein/energy supplement for beef cattle.

OTHER HIGHLY DIGESTIBLE FIBER SOURCES

Soybean Hulls

Soybean hulls (SH) are a high fiber by-product of soybean meal production. The chemical composition of whole soybean hulls according to McDonnell et al. (1982) is 73% NDF, 50% ADF, 3% lignin, and 9% CP. McDonnell et al. (1982) reported that ground SH produced weight gain equal to corn when fed to steers at 12.5, 25, or 50% of a basal ration of corn stalklage, ground corn cobs, and brome hay (1:1:1). The ME of SH is considerably lower than corn (1.63 vs 3.29 Mcal/kg), therefore the additional performance is suspected to be due to positive associative effects on fiber digestion. Dry matter intake was slightly higher for steers fed SH; therefore, feed efficiency was slightly poorer.

Johnson et al. (1962) found that soybean flakes had an energy value equal to ground ear corn when the flakes replaced corn in a meadowcrop silage and hay wintering ration for heifers. Quicke et al. (1959) using in vitro and in vivo techniques showed that the cellulose in soybran flakes are highly digestible (86-90%) by rumen microbes. However, when fed as the sole energy source, in vivo digestibility coefficients of only 50-60% were observed. Apparently, rate of passage of soybran flakes fed as a complete diet was very rapid and were laxative.

Sudweeks (1977) compared SH and corn fed at levels of 10, 40, or 70% of a corn silage, sorghum silage, or bermuda grass hay diet. Soybean hulls had equal DM digestibility values to corn at all levels. When whole, ground, or pelleted SH replaced corn at 25 and 50% in a corn stalklage diet fed to lambs, fiber digestibility increased (McDonnell et al., 1982). The authors noted that in vitro DM disappearance for corn was 95% compared to 78% for whole or ground SH. Whole SH remained in the rumen longer than ground or pelleted hulls which should increase the time for digestion.

Beet Pulp

Beet pulp is the residue remaining after extraction of the sugar from sugar beets. The chemical composition of beet pulp according to Bhattacharya and Sleiman (1977) is 11% CP, 22% crude fiber, 2.8% lignin, and 3% sucrose. When beet pulp replaced 50, 75, or 100% of the corn in a 60% corn, 23% wheat bran, and 9% alfalfa diet, crude fiber digestibility increased as level of beet pulp increased. Metabolizable energy of the ration did not change due to addition of beet pulp. Therefore, when incorporated up to 60% in a dairy ration, the authors reported that beet pulp was equal to corn or barley in promoting milk production.

Wallenius (1977) reported no difference in milk yield, fat percent, or body weight changes when 50% of the concentrate was replaced with pelleted beet pulp in dairy

rations. Bhattacharya and Lubbadah (1977) fed rumen fistulated steers diets containing approximately 26% alfalfa hay and 74% concentrate with beet pulp replacing corn at 50, 75, and 100% of the concentrate. Total VFA concentration increased significantly in the rumen fluid as the proportion of beet pulp increased. This may be due to an increase in digested fermentable substrate from the beet pulp diets.

Beet pulp is lower in protein and higher in fiber than grain milling by-products. Although limited, the information suggests that the fiber is highly digestible; therefore, beet pulp may be effectively used as an energy source for ruminants.

By-product compositions by different references.[ab]

Feedstuff	Composition							
	TDN	CP	CF	EE	ADF	NDF	LIG	ASH
Beet pulp, dehy.:								
A	74	9.7	19.8	.6	33	54	2.0	5.4
B	72	9.6	20.1	.6				5.3
C	78	8.0	22.0	.7	34			3.9
D	74	7.7		.6	33	54	2.0	5.0
Corn bran:								
B	77	9.1	11	5.1				2.2
D	83	11.0		10.3	16	60	1.0	5.0
Corn gluten feed:								
A	83	25.6	9.7	2.4				7.5
B	74	28.6	8.1	2.9				7.3
C	82	27.5	8.0	2.8	10			8.6
D	83	25.6		7.5	12	45		5.0
Corn gluten meal:								
A	89	67.2	2.2	2.4	5	14	1.0	1.8
B	83	42.9	5.1	2.6				3.6
C	87	48.0	4.2	2.4	5			3.9
D	84	46.8		2.4	9	37	1.0	3.0
Distillers grains:								
A	86	27.9	12.1	9.8		40		2.4
B	84	29.7	13.4	9.9				2.4
C	84	29.5	13.0	9.9	20			2.7
D	86	22.0		9.8	17	50		2.0
Distillers grains w/solubles:								
A	88	27.1	9.1	9.4	17	40	4.0	4.4
B	87	29.2	9.8	11.2				5.0
D	88	24.0		10.3	16	44	4.0	5.0
Distillers solubles:								
A	88	29.7	5.0	9.2	7	23	1.0	7.8
B	86	31.5	3.8	10.0				8.0
C	88	28.9	4.0	5.7	6			7.2
Soybean hulls:								
A	77	12.1	40.1	2.1	50	67	2.0	5.1
B	64	12.4	36.1	2.8				4.2
C	64	12.4	36.1	2.8	45			4.2
D	80	12.1		2.1	50	67	2.0	5.0
Wheat bran:								
A	70	17.1	11.3	4.4	15	51	3.0	6.9
B	70	17.8	9.7	5.0				6.7
C	70	18.0	11.0	5.0	14			6.8
D	78	17.1		4.4	15	51	3.0	7.0
Wheat middlings:								
A	69	18.4	8.2	4.9				5.2
B	71	19.6	7.3	5.4				4.8
C	83	19.1	8.9	5.7	11			4.8

[a]References: A = US-CTFC, 1982.
B = NRC. Atlas of Nutritional Data, 1972.
C = WREP, 1980.
D = Van Soest et al., 1984.

[b]Blanks represent available data.

SUMMARY OF LITERATURE REVIEWED

Available research clearly demonstrates that protein supplements will increase the value of low quality forage by increasing digestibility, rate of passage, and intake. This in turn increases animal performance. The data also indicate that energy supplements containing large amounts of starch or soluble carbohydrates, if fed in sufficient amounts, will reduce forage digestibility and intake. If forage is available and the energy supplement reduces forage intake, such a supplement is substituting for forage and is not supplementing the diet. This results in an expensive supplement program and inefficient use of range or harvested forage. One solution to the negative effects associated with feeding high starch energy supplements is to feed an energy source that is low in starch, does not compete with forage fiber digestion, and is high in digestible energy.

High fiber by-products of the various grain milling processes possess the characteristics needed to provide both supplemental protein and energy without interfering with digestion of forage. The available data on CGF indicates that the protein is very soluble and capable of providing the rumen microbial population with adequate N for efficient growth and replication. The excellent animal performance due to positive associative effects of high fiber feeds on the digestion of dietary forage has prompted researchers to give CGF an energy value nearly equal to corn.

Available performance data on CGF, consisting primarily of growing trials in which higher levels of concentrate and higher quality forage is fed, is very positive. The fiber in CGF is suspected to be degraded by cellulolytic bacteria which also degrade fiber of forage origin. Therefore, competition between microbial populations may be avoided when CGF is fed as a supplement for low- to medium-quality high- forage diets. Corn gluten feed is also available in large quantities and, at times, competes in price with alternative supplement feeds.

Research data are more limited for high fiber by-products produced by the wheat, soybean, and beet pulp industries. Although, the available data are promising, more research with different types of livestock is needed. It is important to bear in mind that these are all by-products for which there is no close regulation of composition. Hence, variation would be expected to occur between or even within processing plants.

The following trials were designed to evaluate CGF as a protein/energy supplement for beef cattle consuming medium to low quality forage. Effect of CGF on ruminal parameters, forage intake, and fiber digestion of cows fed low quality hay were measured. The study included performance trials with heifers and mature beef cows supplemented with CGF while grazing native range. In addition, samples of CGF obtained from different processing plants were characterized

for chemical and nutrient composition and compared among manufacturing plants to assess product variability.

CHAPTER III

EFFECTS OF CORN GLUTEN FEED ON FORAGE INTAKE, DIGESTIBILITY, AND RUMINAL PARAMETERS OF CATTLE FED NATIVE GRASS HAY[1]

Abstract

Thirty-two beef cows (467 kg) were individually fed native grass hay and supplement for two 14 d periods in each of 2 yr. Supplement treatments and amounts fed (kg/d) were negative control (NC) 0; or equal amounts of protein from soybean meal (SBM), .7; a blend of soybean meal and corn gluten feed (SBM/CGF), 1.0; or corn gluten feed (CGF), 1.6. Cows received supplement at 0645, and had ad libitum access to native grass hay from 0700 to 1130 and 1530 to 2000. Replacing SBM with CGF decreased ($P<.01$) the molar proportion of acetate, and increased proportions of propionate and butyrate 4 h after the supplements were fed. Cows fed SBM consumed more hay and water ($P<.01$), had higher ADF ($P<.05$) and DM ($P<.01$) digestibilities and greater forage digestibility ($P<.05$) than the negative control cows. Voluntary intakes of hay were similar for the SBM and SBM/CGF treatments (1.75 and 1.73% of body weight, respectively), but decreased ($P<.01$) to 1.62% when CGF totally

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replaced SBM. Hay DM, total DM, and ADF digestibilities were not significantly affected by type of supplement. Forage intake declined when CGF was fed as the sole source of supplemental protein as compared to the SBM control though energy intakes were similar due to the greater amount of supplement fed. Calculated daily intakes of ME (Mcal) were 12, 17, 18, and 17 for NC, SBM, SBM/CGF, and CGF, respectively due primarily to changes in diet digestibility. Daily indigestible dry matter intake ranged from .87 to .93% of body weight and did not differ among diets. Cows receiving CGF had increased ADF digestion and tended to consume more hay than unsupplemented cows, indicating that CGF is an acceptable protein/energy supplement for beef cows consuming low quality forage.

Introduction

The positive associative effects of supplementing low quality roughage diets with protein are well documented (McCollum and Galyean, 1985). However, feeding energy in the form of readily available carbohydrate usually decreases forage intake and fiber digestibility (Arelovich, 1983; Guthrie, 1984; Chase and Hibberd, 1985). The use of low-starch feedstuffs that are high in digestible fiber as well as energy may alleviate the negative effects of cereal grain based supplements on forage intake and digestibility.

Corn gluten feed (CGF), a by-product of the corn milling industry, is the portion of the corn kernel that remains after removal of the germ, starch, and gluten. Corn gluten feed is commonly marketed at 21%

crude protein and 8.5% crude fiber, (Corn Refiners Assn., 1975). Its medium protein content and highly digestible fiber should make it useful as a protein/energy supplement. Abe and Horii (1978) reported that in vitro cell wall digestibilities of CGF were above 80%. In vitro neutral detergent fiber (NDF) disappearance of CGF was rapid and extensive while the protein of CGF was more extensively degraded than SBM (DeHaan et al., 1983). This contrasts with low ruminal destruction of protein from corn gluten meal, a product obtained at a different step in the wet-milling process. Similar fiber and N digestibilities for lamb diets supplemented with wet CGF, dry CGF, and SBM indicate that CGF could furnish the rumen with N for microbial growth (Firkins et al., 1985). This study was conducted to evaluate CGF as a protein/energy supplement for beef cows consuming low-quality forage.

Materials and Methods

Thirty-two nonlactating Hereford and Hereford x Angus cows (467 kg mean weight) were individually fed mature native grass hay plus supplement for two 14 d periods in each of 2 yr for a total of 32 measurements on each of four treatments. In period 1 of each yr, cows were randomly allotted within breed, body weight and condition, and pregnancy status to four treatment groups. In period 2, cows were reallotted by the above criteria plus previous treatment. Treatments were negative control (no supplement; NC); positive control, in which all the supplemental protein was supplied from soybean meal (SBM); a SBM and CGF blend, in which half of the supplemental protein was replaced by CGF (SBM/CGF); and CGF, in which all the supplemental protein was

supplied from CGF. Amounts of feed and supplement compositions are presented in Table 1. Cows were housed individually with ad libitum access to native tall grass hay for 9 h/d (0700 to 1130; 1530 to 2000), and to water plus minerals for 15 h/d (1130 to 1530; 2000 to 0700). The late-summer harvested hay was not ground or chopped prior to feeding. The pelleted (4.8 mm) supplements were fed once daily at 0700 and provided equal amounts of supplemental crude protein.

Voluntary intake of hay was measured directly for 6 d following an 8 d adjustment to supplements. Fecal output was estimated using ytterbium (Yb) as an indigestible marker. Cottonseed hulls were labeled with Yb (Teeter et al., 1984) and 130 g containing 462 mg of Yb were fed with the supplements once per d (0645) from d 5 through 14 of each period. To reduce the effects of diurnal variation, fecal grab samples taken on d 13 and 14 of the trial were obtained every 8 h during the 48 h sampling period. Fecal samples were composited, thoroughly mixed, subsampled, and frozen in plastic bags for laboratory analysis. Total feces were collected for a 48 h period from two animals per treatment to determine marker recovery. Water consumption was measured for 48 h on d 13 and 14 of each period. Fecal grab samples were obtained at 0800 on d 1, 2, and 3 after terminating Yb dosing in year II to estimate particulate passage rate based on the decline in Yb concentrations of fecal DM.

In year II, rumen fluid samples were obtained via stomach tube at 4 and 24 h after the protein supplement was fed. To minimize interruption of hay intake, the 4 h sample was taken at 1100 on d 8 whereas the 24 h sample was obtained at 0700 on d 14. Ruminal fluid pH

was determined immediately after sampling using a Model 125 Corning pH meter fitted with a combination electrode. Samples were acidified with 20% sulfuric acid (1 ml/100 ml of rumen fluid) and refrigerated for later laboratory analysis. One ml of the rumen fluid taken at 0700 on d 14 during period 2 of year II was preserved with 9 ml of saline formalin solution as described by Goetsch and Galyean (1982) and stored for subsequent enumeration of protozoa using a Levy-Hausser counting chamber. One drop (approximately .05 ml) of the 1:10 dilution of rumen fluid was added to each chamber and large and small protozoa were counted at a 10 x magnification. Duplicate counts were averaged and expressed as number of small, large, and total protozoa per ml of rumen fluid.

Hay and supplement samples were prepared for analysis by drying at 50C for 48 h followed by air-equilibration for at least 12 h. Samples were then ground through a 2 mm screen to achieve a uniform particle size and analyzed for crude protein (CP) using the macro-Kjeldahl procedure (AOAC, 1975), and neutral detergent fiber (NDF), acid detergent fiber (ADF), cellulose, lignin, and ash as outlined by Goering and Van Soest (1975). Fecal ADF was determined by the same procedure while fecal Yb concentrations were determined by atomic absorption spectrometry after extraction with EDTA (Hart and Polan, 1984). Standards for Yb analysis were prepared in an EDTA solution extracted from 0 h fecal samples.

Ruminal fluid samples, analyzed within 30 d of collection, were centrifuged at 10,000 x g for 15 min. The supernatant fraction was analyzed for ammonia by the phenol-hypochlorite procedure (Broderick and

Kang, 1980). Five ml of the supernatant fluid was added to 1 ml of 25% meta-phosphoric acid containing 2.75 g/liter of an internal standard, 2-ethyl butyric acid. Samples were again centrifuged at 25,000 x g for 20 min and volatile fatty acids (VFA) were determined by gas chromatography (Erwin et al., 1961).

Fecal output, as measured by total collection for eight cows per period, was 115% (SE of the mean = .05) of fecal output estimates based on the Yb marker; hence, estimates of fecal output calculated from Yb dilution were used in subsequent calculations. Fecal DM output from hay alone was calculated as total fecal output minus feces derived from supplements assuming that the digestibility of each supplement was 80%, based on literature values for CGF (Firkins et al., 1985) and SBM (Weakley, 1983). Digestibility of hay for each cow in each period was calculated from measured intake of hay and fecal output calculated to be of hay origin. Digestibility of ADF was calculated from total ADF intake (Table 2) and total ADF output in feces without adjustment for indigestible ADF from the supplement. Particulate passage rate was estimated by regressing the natural logarithm of fecal Yb concentration against time after withdrawal of Yb from the diet. Therefore, the estimate is for the slower ruminal pool. Estimation of the rapid ruminal passage pool, attributable to mixing, a secondary pool, or time delay, was not attempted.

Data were initially subjected to least squares analysis of variance with a statistical model which included cow, cow weight, breed, pregnancy status, treatment, period, yr, cow (within yr), and all possible two and three way interactions. No treatment by yr interaction

was detected; hence, data were pooled across yr for analysis. Variables failing to significantly (P>.20) effect the dependent variables were excluded from the model. The final model for each variable included treatment, period, yr, initial weight, breed, pregnancy status, period x yr, and cow (within yr). The least significant difference technique was used to separate means for characteristics in which treatment differences were significant (P<.05).

Results and Discussion

Rumen fluid pH values were quite similar among treatments both at 4 and 24 h after feeding supplements (Table 3). Failure of supplements to depress ruminal pH contrasts with results from some trials using high-starch supplements (Chase and Hibberd, 1985) and is probably due to the slower rate of fermentation of a more fibrous supplement (CGF). Corn bran fed at 25% of DM with a corn cob plus alfalfa haylage ration reduced pH only slightly and did not alter fiber digestion (Klopfenstein et al., 1985). At 50% of the diet, they noted that corn bran reduced ruminal pH and total tract fiber digestion but to a lesser degree than when corn was fed. This suggests that high fiber supplements can be fed in greater amounts than grain without depressing ruminal pH to levels which reduce rate and extent of fiber digestion.

Ruminal ammonia levels 4 h after the supplement was fed were lowest for unsupplemented cows and highest for cows receiving CGF (Table 3). This is in agreement with in situ results of DeHaan et al. (1983) whose results suggest that protein from CGF is extensively

degraded in the rumen. Ammonia levels 4 h after supplementation tended to be lower with SBM than CGF supplements. Ammonia levels with the SBM/CGF blend were significantly lower than with CGF alone. Such a blend of SBM and CGF would not be expected to produce lower ammonia values than the average of each fed alone. Twenty-four h after supplement feeding, ammonia levels remained higher ($P<.01$) for cows receiving supplement than for the unsupplemented NC treatment group. Ruminal ammonia levels at 24 h were higher ($P<.01$) for SBM than CGF with SBM/CGF being intermediate. The 24 h data indicate that SBM may maintain a higher rumen ammonia concentration than CGF. McCollum and Galyean (1985) reported that ruminal ammonia concentrations were 8.6 and 6.2 mg/dl at 3 and 6 h respectively, after feeding .8 kg/d cottonseed meal to steers consuming prairie hay. Satter and Slyter (1974) suggested that ammonia concentrations of 5 mg/dl are adequate for maximal microbial growth in situ. In contrast, Weakley (1983) and Erdman (1986) have concluded that higher ruminal ammonia levels can increase the extent of digestion of organic matter in the rumen. Ammonia levels in all treatments, especially the NC, may have limited both microbial protein yield and extent of ruminal fermentation.

Total VFA concentrations in ruminal fluid of cows fed SBM tended to be higher ($P<.17$) at 4 h after supplement feeding than for unsupplemented NC cows (Table 3). The molar proportions of acetate, propionate, and butyrate were similar for the NC and SBM treatments. This agrees with results of studies reported by Topps et al. (1965) and Wagner et al. (1983) in which protein supplements were fed to beef cattle grazing dormant native range. However, replacing SBM by CGF decreased ($P<.01$) the molar proportion of acetate and increased ($P<.01$)

the proportions of propionate and butyrate. A similar response was observed with CGF supplements fed to gestating beef cows grazing dormant winter range (Fleck and Lusby, 1986). In a study with lambs, Firkins et al. (1985) reported similar changes in acetate and propionate when CGF was increased from 35 to 70% of the diet. If increased ruminal concentrations of propionate and butyrate reflect increases in their ruminal production rates, CGF supplementation may increase efficiency of utilization of dietary energy and decrease loss of energy as methane from the rumen. At 24 h after feeding supplements, total volatile fatty acid (VFA) concentrations and molar proportions of acetate, propionate, and butyrate were similar among all treatments.

The number of small and large protozoa in ruminal samples tended to decrease ($P<.15$) as CGF was substituted for SBM (Table 3). Numbers of protozoa and bacteria are usually inversely related (Rowe, 1985) suggesting an active competition between these microbes for energy and/or nitrogen. Fiber digestion studies by Demeyer (1981) suggest that protozoa are responsible for a substantial amount of ruminal fiber digestion. The contribution of protozoa to the animal's nitrogen status remains questionable. Leng (1976) suggested that the low yields of protozoa from the rumen reduce the total amount of microbial protein available to the host animal and may limit productivity of ruminants fed low protein diets. If the observed protozoal numbers reflect reductions in the total ruminal mass of protozoa, substitution of CGF for SBM may reduce nutrient competition between these two groups of microbes and increase bacterial yield and ruminal protein output.

Intakes, digestibilities, and particulate passage rates are presented in Table 4. Compared with cows fed no supplemental protein, cows fed SBM consumed more ($P<.01$) hay and had higher digestibilities for hay DM ($P<.05$), ADF ($P<.05$), and total DM ($P<.01$). This demonstrates a need for dietary protein supplementation. Cows fed CGF tended ($P<.22$) to consume more hay than unsupplemented cows but less than SBM-fed cows. Feeding the blend of SBM/CGF resulted in a hay intake similar to that of SBM-fed cows and greater than that of unsupplemented cows ($P<.01$). Forage DM digestibility was increased by feeding SBM/CGF ($P<.05$) and was slightly increased by feeding SBM or CGF as compared to no supplement. Digestibility of ADF was increased ($P<.05$) in all supplement treatment groups. Total diet DM digestibility was greater ($P<.01$) for supplemented than unsupplemented cows. To determine if all of the intake response could be attributed to increased diet and forage digestibility, daily intakes of indigestible DM and ADF (table 4) were calculated. Intakes of indigestible DM and ADF were not altered by protein supplementation suggesting that ruminal or gut fill of indigestible material probably limited intake of all diets. Therefore, intake increases can be attributed completely to increases in diet digestibility. Why substitution of CGF for SBM decreased intake and forage digestibility is unknown; perhaps the presence or rate of ruminal release of some protein constituent limited ruminal digestion. The slightly greater ($P<.16$) total DM digestibility observed from replacement of SBM by CGF presumably is the result of feeding a larger amount of a highly digestible material. Water intake was higher ($P<.01$) for cows fed protein supplement. This is probably due to greater forage intakes and fluid excretion in feces and urine. Water intake was no

different between cows receiving supplements. Rate of passage for Yb ranged from 3.74 to 3.91 %/h and were not affected by treatment.

Adverse associative effects of feeding grain supplements with low quality roughages have recently been reported. Merrill and Klopfenstein (1985) reported that feeding 51% corn to lambs grazing summer bromegrass or cornstalks reduced fiber digestion while soybean hulls had no detrimental effect on either forage intake or neutral detergent fiber digestibility. When corn bran and corn grain were included in the ration at a level of 25% of diet DM and compared as energy supplements, corn supplementation reduced fiber digestion (-14%) while corn bran did not (Klopfenstein et al., 1985). At a level of 50%, corn bran reduced fiber digestion by only 7%. These reports and the results of this study in which CGF provided 16.5% of the diet DM, suggest that one can supplement forage diets with much higher levels of high fiber feeds than grains before drastically reducing fiber digestion or forage intake. This is particularly true if the fiber fraction of the high fiber supplement is highly digestible.

The slightly lowered digestibility and lower forage intake observed when CGF was fed as the sole source of supplemental protein was offset by the increased supply of energy when CGF was fed at levels to supply equivalent amounts of protein as SBM. Using digestible DM as an estimate of dietary TDN and converting TDN to metabolizable energy based on NRC, (1984) equations, metabolizable energy intakes (Mcal/d) were 12.3, 16.9, 18.4, and 17.5 for the NC, SBM, SBM/CGF, and CGF treatment groups, respectively. These relative differences in ME intakes mirror performance differences observed in performance trials. Heifers grazing

summer range and fed these same supplements for 84 d gained 39, 53, 63, and 63 kg/head, respectively (Fleck and Lusby, 1987), while gestating beef cows grazing dormant winter range for an average of 116 days had weight changes of -35, -11, +1.27, and +.45 kg/head, respectively (Fleck and Lusby, 1986).

The results of this trial suggest that when fed as a source of supplemental protein, CGF can alter ruminal fermentation and increase ADF digestion. In addition, CGF fed as a protein/energy supplement to beef cows consuming low quality forage can increase the cows total energy intake. Adding SBM to CGF appeared to improve the utilization of CGF which suggests that some combination of CGF and SBM may be a more useful supplement than CGF alone.

Table 1. Supplement composition and amounts fed (DM basis).[a]

	SBM	SBM/CGF	CGF
Ingredients, %:			
Soybean meal	93.1	32.3	0.0
Corn gluten feed	0.0	62.6	96.38
Molasses	3.6	3.6	3.6
Dicalcium phosphate	3.2	1.4	0.0
Vitamin A premix	0.07	0.05	0.04
Year I			
Amount fed Kg/d,	.68	1.09	1.57
Supplied per day:			
Crude protein, kg	.28	.28	.28
TDN, kg	.51	.81	1.16
Calcium, g	6.66	6.76	5.34
Phosphorus, g	8.30	10.25	11.15
Potassium, g	12.72	11.77	10.36
Year II			
Amount fed Kg/d,	.71	.93	1.42
Supplied per day:			
Crude protein, kg	.26	.26	.26
TDN, kg	.53	.69	1.05
Calcium, g	6.96	5.77	4.83
Phosphorus, g	8.66	8.74	10.08
Potassium, g	13.28	10.04	9.37

[a]Calculated nutrient values.

Table 2. Chemical composition of hay and supplements (DM basis).

Item[a]	Forage	Supplement		
		SBM	SBM/CGF	CGF
Year I				
Dry matter	94.40	90.13	90.87	89.92
Ash	4.30	.25	.50	1.10
Crude protein	4.82	42.91	25.10	18.78
Neutral detergent fiber	69.01	20.75	42.27	51.32
Acid detergent fiber	43.71	10.47	11.00	10.61
Cellulose	31.20	8.56	9.12	8.69
Lignin	8.20	1.70	1.39	1.32
Year II				
Dry matter	92.30	89.70	88.08	88.80
Ash	3.40	.11	.65	1.05
Crude protein	5.26	36.00	27.70	20.90
Neutral detergent fiber	76.02	22.74	40.02	49.52
Acid detergent fiber	45.45	11.38	10.37	10.40
Cellulose	33.93	9.56	8.24	8.50
Lignin	8.12	1.68	1.32	1.27

[a]Percent of dry matter.

Table 3. Ruminal pH, ammonia, volatile fatty acid (VFA), and protozoa concentration, at 4 and 24 h after feeding supplement.

	Treatment[d]				
	NC	SBM	SBM/CGF	CGF	SE
No. Cows	16	16	16	16	
Rumen fluid pH:					
4 h	6.8	6.9	6.8	6.8	.13
24 h	7.1	7.1	7.1	7.0	.13
Rumen ammonia, mg/dl:					
4 h	.5[a]	4.1[bc]	2.4[ab]	5.8[c]	1.62
24 h	1.2[a]	4.2[d]	3.3[c]	2.3[b]	.65
VFA, 4 h:					
Total µmoles/ml	123.0	134.3	126.3	127.9	14.72
Acetate, %	80.2[a]	79.7[ab]	78.6[b]	76.7[c]	.92
Propionate, %	11.7[a]	11.6[a]	12.4[ab]	13.00[b]	.70
Butyrate, %	8.1[a]	8.7[b]	9.0[bc]	10.3[c]	.74
VFA, 24 h:					
Total µmoles/ml	97.3	96.1	92.9	95.5	12.57
Acetate, %	81.9	81.9	81.6	81.8	.89
Propionate, %	9.8	10.1	10.0	10.1	.57
Butyrate, %	8.3	7.9	8.4	8.1	.66
Protozoa:[e]					
Small	14.4	26.2	22.2	17.4	4.2
Large	8.0	14.5	9.6	5.7	2.4
Total	22.4	40.7	31.8	23.1	5.5

[abc]Means in same row with different superscripts differ P<.05.
[d]Least squares means.
[e]Least squares means (X 10^{-3}/ml) based on 8 cows per treatment.

Table 4. Voluntary forage intake, water intake, forage digestibility, and ytterbium passage rate (DM basis).

	Treatment[c]				
	NC	SBM	SBM/CGF	CGF	SE
No. Cows	32	32	32	32	
Cow wt., kg	466	467	466	470	
Hay DM intake:					
% of body wt.	1.56[a]	1.75[b]	1.73[b]	1.62[a]	.07
Water intake:					
% of body wt.	4.35[a]	5.83[b]	5.20[b]	5.48[b]	.49
Digestibility:					
Hay DM, %	45.87[a]	50.21[ab]	52.81[b]	48.90[ab]	3.56
ADF, %	41.06[a]	46.98[b]	50.32[b]	47.34[b]	3.84
Total DM, %	46.68[a]	52.78[b]	55.96[b]	53.53[b]	3.34
Digestible intake:					
Forage, % of BW	.69[a]	.86[b]	.89[b]	.76[a]	.075
Total, % of BW	.69[a]	.98[b]	1.06[b]	1.01[b]	.075
Total ME, Mcal/kg MBS	.12[a]	.16[b]	.18[b]	.17[b]	.012
Indigestible intake:					
DM, % of body wt.	.87	.93	.88	.92	.055
ADF, % of body wt.	.42	.43	.41	.40	.027
Particulate passage rate, %/h[e]	3.79	3.74	3.91	3.85	.6

[ab]Means in same row with different superscripts differ P<.05.
[c]Least squares means.
[d]ME = .82 (DDMI * 4.4 Mcal/kg) / cow weight$^{.75}$.
[e]16 animals per treatment.

CHAPTER IV

THE VALUE OF CORN GLUTEN FEED AS A SUPPLEMENT FOR BEEF CATTLE GRAZING NATIVE RANGE[1]

Abstract

Corn gluten feed was evaluated as a supplement for beef cows grazing native range in winter and for heifers grazing the same pastures in summer. In two replications, a total of 142 mature Hereford cows bred to calve in March and April were divided into four treatments. Treatments and daily feed levels (kg/head) from November to January 30 were negative control, .5 soybean meal (NC); positive control, .9 soybean meal (SBM); 1.4 kg/d of 1:2 ratio of soybean meal and corn gluten feed (SBM/CGF); and 2.0 corn gluten feed (CGF). Supplementation began in mid-November and ended as each cow calved. On d 75 (January 30) of the trial, supplement levels were adjusted based on weight changes of negative and positive control cows. All supplement levels were increased by 50% in 1985, and reduced by 33% in 1986. Supplements were prorated and individually fed 6 d per wk. Ruminal pH was lowered ($P<.01$) at 4 h after feeding CGF supplement. Ruminal ammonia was higher ($P<.01$) at 4 h after feeding SBM. At both 1 and 4 h after feeding supplements, the proportion of acetate was decreased ($P<.01$) but

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propionate and butyrate were increased (P<.01) in cows fed CGF. NC cows lost more weight and body condition (P<.01) than SBM cows, while SBM/CGF and CGF cows maintained body weight and condition similar to cows receiving SBM. Forty-three Hereford and Hereford X Angus heifers in 1985 and 48 in 1986 were similarly fed 5 d each wk from July 16 to October 8 at daily rates of 0, .55, .86, and 1.27 kg/head for NC, SBM, SBM/CGF, and CGF treatments respectively. Heifers receiving SBM gained more weight (P<.01) than unsupplemented NC heifers while heifers fed SBM/CGF and CGF gained more weight (P<.01) than heifers fed SBM. Corn gluten feed appears to be an effective energy and protein supplement for beef cows consuming winter native range and for heifers grazing mid- to late-summer range. The similar or superior performance observed in the SBM/CGF treatment as compared to the CGF treatment suggests that the utilization of CGF as a supplement was improved when SBM provided half of supplemental protein.

Introduction

When native range fails to provide sufficient energy and protein for adequate animal performance, concentrates are often fed. The positive effect of supplementing low quality roughage diets with protein is well documented (McCollum and Galyean, 1985), while feeding energy in the form of readily available carbohydrates tends to decrease forage intake and fiber utilization (Arelovich, 1983; Guthrie, 1984; Chase and Hibberd, 1985). Recent research (Green et al., 1987) has shown that feeding supplements that are high in digestible fiber may avoid the negative effects encountered when feeding grain-based supplements.

Corn industry by-products have become more available and, at times, compete with cereal grains and oilseed meals as sources of energy and protein. Corn gluten feed (CGF), a product of the wet corn milling industry marketed at 21% crude protein and 8.5% fiber, is the portion of the kernel that remains after removing the starch, gluten, and germ. The protein content and highly digestible fiber makes CGF a potentially acceptable source of supplemental protein and energy. Replacing soybean meal (SBM) with CGF, Firkins et al. (1985) reported that CGF can be fed at levels of at least 50% of the diet dry matter (DM) and maintain performance comparable to steers fed corn-SBM diets. As a source of energy, replacing corn with CGF up to 60% of the ration DM, CGF had an equivalent energy value approximately 75% that of corn (Trenkle, 1986). Supplementing hay diets with CGF increased DM intake and digestibility compared to a corn plus urea supplement (Cordes, 1986). In a subsequent growth trial, grazing heifers fed CGF as a supplement gained faster than heifers fed corn plus urea, but similarly to heifers fed a corn plus SBM supplement. The data suggest that dry CGF may be used as a supplement to positively affect fiber digestion, forage intake, and animal performance. The following studies were conducted to evaluate CGF as a protein and energy supplement for beef cattle grazing medium quality native range in mid- to late-summer or low quality dormant native range in winter.

Materials and Methods

Trial 1. In each of 2 yr, 72 mature Hereford cows bred to calve in March and April were blocked by age, weight, body condition, and

expected calving dates and allotted to four supplement treatment groups. Treatments, presented in Table 1 and 2, were negative control, a low level of soybean meal supplement (NC); and three treatments of equal daily supplemental protein made up of soybean meal (SBM), soybean meal plus corn gluten feed in which each provided half the protein (SBM/CGF), or corn gluten feed (CGF). Supplementation began mid-November and terminated as each cow calved. On January 30th, supplement levels were adjusted based on observed weight change differences between positive and negative controls. All supplements were increased 50% in 1985 but were decreased 33% in 1986 because of mild winter conditions (Table 2). All cows grazed as a group on native tallgrass range. Cows were gathered 6 d per wk and individually fed their respective supplements in covered stalls. Daily feeding rates were prorated for a 6 d/wk feeding schedule.

Cane molasses was added to aid pelleting and supplements were balanced to provide equal daily amounts of calcium, phosphorus, potassium, and vitamin A. A mineral mix containing 55% dicalcium phosphate and 45% salt was provided free choice in the pasture. Grass hay was fed only when snow or ice covered the ground and when extreme cold (below -12C windchill) was encountered.

Cow weights and body condition scores (score of 1 = very thin to 9 = very fat) were taken after 16 h (overnight) withdrawal from feed and water at 28 d intervals until cows neared calving at which time measurements were taken every 14 d. As cows calved, they were removed from the trial and the 14 d record nearest to calving was used as the final measurement. After calving all cows were maintained on native

range until weaning. Calf birth date and weight, sex, and weaning weight were recorded. Calf weaning weights were adjusted to 205 d equivalents using standard adjustments suggested by Beef Improvement Federation Guidelines (Hubbard, 1981). Cows were bred by natural service and pregnancy was determined by rectal palpation in mid-October. Cow fall weight and body condition were recorded at weaning (October 16).

On d 114 of the 1985 trial (March 12), rumen fluid samples were obtained via stomach tube at 1 and 4 h after feeding supplement from 32 randomly selected cows. Fluid pH was recorded immediately using a Model 125 Corning combination electrode. Samples were acidified with 20% sulfuric acid (1 ml/100 ml of fluid) and refrigerated for laboratory analysis. Rumen fluid was analyzed for ammonia concentration by the phenol-hypochlorite procedure (Broderick and Kang, 1980)) and for volatile fatty acid (VFA) concentration by gas chromatography (Erwin et al., 1961).

Trial 2. Forty-three Hereford and Hereford X Angus heifers in 1985 and 48 in 1986 (308 kg and 16 mo old) were allotted by breed and weight to the four supplement treatments described for Trial 1. Supplement amounts are presented in Table 2. The treatment period began July 16 and ended October 8. All heifers grazed as a group on native tall grass range and were individually fed their respective supplements prorated for a 5 d per wk feeding schedule. Heifers were weighed at 28 d intervals after 16 h withdrawal from feed and water. A mineral mix containing 55% dicalcium phosphate and 45% salt was provided free choice to all heifers.

Data from both trials were pooled over years and subjected to least squares analysis of variance. Variables failing to effect (P>.20) the dependent variables were excluded from the model. The final statistical model for each dependent variable in Trial 1 included treatment, starting weight, initial body condition, cow age, yr, and yr x treatment. The final statistical model for Trial 2 included treatment, initial weight, yr, and yr x treatment. The least significant difference technique was used to separate means for characteristics in which treatment differences were significant (P<.05).

Results and Discussion

Trial 1. Rumen fluid pH was similar among treatments 1 h after feeding supplements (Table 3). At 4 h after feeding supplement, pH was lower (P<.01) when CGF was the sole source of supplemental protein. Assuming that cows fed CGF supplement were consuming about 9 kg/day of total diet, CGF would have represented 36% of the total DM intake. Klopfenstein et al. (1985) reported that corn bran fed at 25% of a 2:1 corn cob-alfalfa ration lowered ruminal pH, although fiber digestion was not altered. This suggests that fibrous feeds containing readily digestible fiber may be fed at relatively high levels to increase the energy status of the diet without lowering pH to levels which would reduce fiber digestion and intake.

Rumen ammonia levels at 1 h after feeding supplement tended (P<.07) to be higher for the SBM and SBM/CGF treatments (Table 3). At 4 h post supplementation, rumen ammonia was higher (P<.05) for SBM cows

but not different among other treatments. Satter and Slyter (1974) suggested that microbial growth in situ is maximum when ammonia concentrations exceed 5 mg/dl but Weakley (1983) and Erdman (1986) concluded that higher ruminal ammonia levels can increase the extent of digestion of organic matter in the rumen. The relatively high ammonia levels observed in this study suggest that adequate nitrogen existed for microbial growth and replication.

Total VFA concentrations were similar among treatment groups at 1 and 4 h after feeding supplement (Table 4). However at both collection periods, when SBM was replaced by CGF, the molar proportion of acetate decreased ($P<.01$) and the proportion of propionate and butyrate increased ($P<.01$). The same response was observed in an intake and metabolism trial in which mature beef cows were fed the same supplement treatmentss while consuming mature native grass hay (Fleck et al., 1987). In a lamb study, Firkins et al. (1985) also reported linear decreases in the molar proportion of acetate and increases in propionate at 3, 6, and 9 h postfeeding as CGF was increased from 35 to 70% of the diet. If the observed increased ruminal VFA concentrations reflect increased ruminal production of propionate and butyrate, CGF supplementation may increase efficiency of utilization of dietary energy and decrease loss of energy as methane from the rumen.

Cow body weight and condition loss was greater ($P<.01$) for the NC treatment group than the SBM positive control, demonstrating that a protein and/or energy deficiency existed (Table 5). Replacing half of the supplemental protein with CGF (SBM/CGF) or all of the supplemental protein (CGF), maintained body weight and condition similar to the SBM

treatment group. Initial fall body weights of the SBM, SBM/CGF, and CGF treatment groups were maintained through the winter period, while fall body condition decreased an average of .37 units. Precalving cow weight were similar between the CGF treatment group and the SBM/CGF group in which 30% less total supplement was fed. This suggests that CGF may lack one or more protein constituents that are supplied by the addition of SBM. The total protein requirement may also have been increased due to a larger amount of energy provided by CGF compared to SBM/CGF. Although CGF slightly reduced forage intake and digestibility, Fleck et al. (1987) found that daily metabolizable energy (ME) intakes were similar among cows fed native grass hay and supplemented with SBM, SBM/CGF or CGF because of the larger amount of CGF fed. Cow weights and body condition scores at fall weaning were similar for all treatment groups.

Cow conception rates and calf performance are presented in Table 5. The percent of cows conceiving within the breeding season tended to be lower for the NC treatment group compared to cows supplemented with SBM, SBM/CGF, and CGF precalving (72 vs 79, 83, 84%, respectively). Calf birth weights and average daily gain to weaning tended to be lower for calves whose dams were in the NC treatment group precalving than for calves in other treatment groups. Treatment differences for weaning weight approached significance ($P<.08$) because of the combination of heavier birth weights and higher daily gains to weaning for groups whose dams had been supplemented with SBM, SBM/CGF, or CGF. Calf performance was similar for calves of dams fed SBM, SBM/CGF, and CGF precalving.

Trial 2. Heifers grazing native range in mid- to late-summer and supplemented with SBM gained more weight (P<.01) than unsupplemented heifers, demonstrating that nutrient availability was limiting performance (Table 6). The increased gain from feeding a small amount of SBM supplement probably was the result of increased fiber digestibility and forage intake. When CGF was fed with SBM or as the sole source of supplement, heifers had greater (P<.01) weight gains than the SBM-fed heifers. Supplement conversions were 3.23, 2.97, and 4.70 kg of supplement per kg of added gain for the SBM, SBM/CGF, and CGF treatments, respectively. This strongly suggest that all supplements, especially SBM and SBM/CGF, were positively affecting forage digestibility and intake. The consumption of higher levels of supplemental energy from CGF or SBM/CGF under these circumstances would be expected to efficiently increase the total energy intake of the grazing animal.

Heifers and cows fed SBM/CGF supplement while grazing late summer range and dormant winter range, respectively, performed similarly, on 30% less supplement, to the CGF groups. This response supports the concept that CGF was more efficiently utilized when SBM was added to the supplement.

These trials show that CGF can be fed alone or with soybean meal as an effective energy and protein supplement for beef cattle consuming medium quality forage in mid- to late-summer or low quality dormant native forage in winter. The trials also demonstrate that the addition of SBM to CGF improves the utilization of CGF as a protein and/or energy supplement. Whether the arbitrary blend of 1/3 SBM to 2/3 CGF so that

each provides half of supplemental protein is optimal, is not known. Further research might show that smaller amounts of SBM or other protein sources may be adequate for improving the utilization of CGF as a protein and/or energy supplement.

Table 1. Composition of supplement used in Trials 1 and 2.

	Treatment			
	NC[a]	SBM	SBM/CGF	CGF
Ingredients, %:				
Soybean meal	84.7	93.1	32.3	.0
Corn gluten feed	.0	.0	62.7	96.4
Molasses	3.6	3.6	3.6	3.6
Dicalcium Phosphate	9.3	13.2	1.4	.0
Potassium chloride	2.26	.0	.0	.0
Vitamin A premix	.15	.07	.05	.04

[a]NC supplement applies only to Trial 1 - NC in Trial 2 received no supplement.

Table 2. Supplement treatments and amounts fed in Trial 1 and 2 (DM basis).

	Treatment			
	NC	SBM	SBM/CGF	CGF
Trial 1.				
Year I, kg/day:				
11/20/84 to 1/29/85	.50	.91	1.45	2.09
1/30/85 to 3/26/85	.73	1.36	2.18	3.14
Average crude protein	.23	.45	.45	.45
Average TDN	.41	.86	1.32	1.95
Year II, kg/day:				
11/20/85 to 1/29/86	.50	.95	1.41	2.00
1/30/85 to 3/4/86	.35	.64	.95	1.32
Average crude protein	.16	.32	.32	.32
Average TDN	.28	.59	.86	1.14
Trial 2.				
Supplement, kg/day	0.0	.55	.86	1.27
Crude protein	0.0	.23	.23	.23
TDN	0.0	.41	.64	.94

Table 3. Ruminal pH and ammonia concentration at 1 and 4 h post supplementation.

	Treatment[d]				
	NC	SBM	SBM/CGF	CGF	SE
No. Cows Sampled	8	7	6	11	
Rumen pH:					
1 h	7.5[a]	7.3[a]	7.2[b]	7.0[c]	.08
4 h	7.5[a]	7.4[a]	7.2[b]	6.8[c]	.09
Rumen ammonia, mg/dl:					
1 h	13.7[b]	18.8[a]	17.5[b]	13.7[b]	2.10
4 h	14.5[b]	20.9[a]	14.8[b]	10.9[b]	1.90

[abc]Means in same row with different superscripts differ (P<.05).
[d]Least squares means.

Table 4. Ruminal VFA concentration at 1 and 4 h post supplementation.

	Treatment[d]				
	NC	SBM	SBM/CGF	CGF	SE
No. Cows Sampled	8	7	6	11	
One Hour					
Total VFA (µmoles/ml)	55.2_{a}	63.6_{ab}	60.1_{b}	59.6_{c}	5.46
Acetate, %	75.5_{b}	72.1_{b}	69.7_{b}	64.0_{a}	1.45
Propionate, %	13.5_{b}	15.5_{b}	17.0_{a}	22.8a	1.14
Butyrate, %	6.9_{b}	7.5_{b}	9.2_{a}	9.8a	.56
Four Hour.					
Total VFA (µmoles/ml)	57.7_{a}	66.5_{ab}	60.6_{b}	70.7_{c}	6.52
Acetate, %	71.8_{a}	67.9_{ab}	66.8_{b}	60.7_{c}	1.43
Propionate, %	17.5_{b}	17.7_{b}	18.3_{b}	24.5_{a}	1.00
Butyrate, %	6.3_{c}	8.3_{bc}	10.3_{ab}	11.3_{a}	.71

[abc]Means in same row with different superscripts differ (P<.05).
[d]Least squares means.

Table 5. Effects of supplements containing soybean meal (SBM) or corn gluten feed (CGF) on cow and calf performance. Trial 1.

	Treatment[c]				
	NC	SBM	SBM/CGF	CGF	SE
No. Cows	36	35	36	35	
Precalving performance					
Initial weight, kg	462	460	465	463	8.8
Weight change, kg	-26.7[a]	1.5[b]	0.0[b]	1.4[b]	7.13
Initial condition[d]	5.6	5.5	5.6	5.6	.10
Condition change	-.87[a]	-.46[b]	-.46[b]	-.33[b]	.08
Rebreeding performance					
No. Cows Exposed	36	33	36	32	
Conception rate, %	72	79	83	84	
Calf performance, kg					
Birth	34.4	35.7	36.3	36.4	1.04
Weaning[e]	167	188	181	180	7.0
Daily gain	.62	.71	.68	.68	.04

[ab]Means in same row with different superscripts differ (P<.05).
[c]Least squares means.
[d]Condition scoring system used was 1 through 9 (1=very thin, 9=very fat).
[e]Calf weaning weights adjusted for sex, age of calf, and age of cow.

Table 6. Performance of grazing heifers fed supplements containing soybean meal (SBM) or corn gluten feed (CGF), Trial 2.

	Treatment[d]				
	NC	SBM	SBM/CGF	CGF	SE
No. Heifers	22	23	23	23	
Initial weight, kg	304[c]	303[b]	303[a]	303[a]	
Weight gain, kg	39[c]	53[b]	63[a]	62[a]	2.23
Daily gain, kg	.46[c]	.63[b]	.75[a]	.74[a]	
Kg of supplement per kg of added gain		3.23	2.97	4.70	

[abc]Means in same row with different superscripts differ (P<.05).
[d]Least squares means.

CHAPTER V

CHARACTERIZATION AND COMPARISON OF CORN GLUTEN FEED FROM SIX MIDWEST CORN PROCESSING PLANTS[1]

Abstract

Twenty-one corn gluten feed (CGF) samples obtained from six Midwestern Manufacturing plants were analyzed chemically and in an in situ digestion trial to characterize CGF and to assess variation among sources. Starch content (12.2%) and pH (4.1) were similar among sources, while ether extract (EE) varied ($P<.001$) from 2.1 to 7.2%. Neutral detergent fiber (NDF) was higher ($P.01$) for samples from one plant (54.2 vs 50.1%) and acid detergent fiber (ADF) was higher ($P<.05$) for one plant (12.4 vs 11.1%) compared to the average of all samples. The percent lignin (LIG) ranged ($P<.05$) from 1.44 to 2.02%, and cellulose (CELL) from 7.3 to 9.9% ($P<.01$). Free ammonia N (2.9% of total N) was similar for samples from all plant while nondigestible nitrogen (NDN) ranged ($P<.001$) from 7.7 to 20.0% of total N. Sodium chloride soluble N (SN) was higher ($P<.001$) for one plant than for others (60.7 vs 42.2%). Total N was lower ($P<.05$)

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[1]Journal Article No. of the Oklahoma Agricultural Experiment Station.

for samples from one plant (2.5%) compared to others (3.2%). Corn gluten feed DM and OM disappearance after 24 h of in situ incubation in the rumen ranged ($P<.05$) from 67.7 to 79.7% and 64.7 to 79.3%, respectively. In situ N disappearance after 0, 12, and 24 h averaged 48.6, 53.5, and 72.0%, respectively. Regressing laboratory values on in situ results, extent of DM digestion was best described ($P<.01$; $R2=.65$) by OM and N (negative βs) and EE, LIG, and SN (positive βs). Extent of N disappearance rate was best described ($P<.01$; $R2=.53$) by OM and CELL (negative βs) and NDF, LIG, N, and SN (positive βs). Ether extract was the most variable energy component while SN and NDN were the most variable N components of CGF samples. Corn gluten feed was rapidly and extensively degraded in the rumen.

Introduction

Corn refining by the wet-milling process has steadily increased in recent years with 10 major companies grinding about 77 percent of all corn used in the food, seed, and industrial use category (Livezey, 1985). Primary products are corn sweeteners, corn starch, and alcohol, although 25 to 30% of the output is by-product feed (Brenner, 1978).

The refining process begins by steeping the kernel in a sulfur dioxide solution to soften the grain. After steeping, soluble nutrients are drawn off and concentrated to form corn steep liquor. Corn oil is removed from the

germ leaving corn germ meal. A screening process removes the bran and the remainder is centrifuged to separate the starch from the gluten. Starch is sold or is converted to sweeteners or alcohol while the gluten is marketed as corn gluten meal (CGM). End products of initial steps include steep liquor, germ meal, and bran. They can be marketed individually or combined to form corn gluten feed (CGF; CIRF, 1959). Corn gluten feed is the highest volume feed ingredient (13 kg per bushel of corn processed) of the wet-milling process and contains an average of 21% protein, 8.5% fiber, 3.3% crude fat, and 82% TDN (Reiners et al., 1985). The CGF product should not be confused with CGM which is insoluble protein obtained in the centrifugation step (Van Soest et al., 1984).

Corn gluten feed has been fed to many types of beef cattle with considerable success (Green et al., 1987). But because it is a by-product, its nutritional consistency is of concern. The objective of this study was to characterize the nutritional components of dry CGF and to determine the degree of variation among CGF samples obtained from different sources.

Materials and Methods

Twenty-one samples of dry CGF were obtained from six corn wet-milling plants (a minimum of three samples per

plant) located throughout the Midwest. Samples arrived in either meal or pelleted form and were ground to a uniform particle size using a Wiley Mill equipped with a 0.05 mm screen for the laboratory experiment and 2.0 mm screen for the in situ digestion experiment.

Laboratory Experiment. Samples were analyzed for crude protein (CP) by Kjeldahl total N determination and for free ammonia nitrogen (AN) by magnesium oxide distillation (AOAC, 1975). The soluble nitrogen (SN) fraction was determined by incubating samples in .15N NaCl (Waldo and Goering, 1979) while nondigestible nitrogen (NDN) was determined by the pepsin insoluble N procedure (AOAC, 1975). The nonsoluble but digestible nitrogen (NSDN) fraction was calculated as the difference between total N and the combination of SN plus NDN.

Dry matter (DM) was determined by drying 2 g samples for 48 h at 100C. Organic matter (OM) was determined by ashing 2 g samples at 500C for 8 h and subtracting the ash from DM. To estimate the acidity of the sample, one part CGF was diluted with four parts deionized water. The mixture was placed in a shaker for 1 h, refrigerated 18 h, and again shaken for 1 h. The mixture was then filtered through #4 filter paper and the pH of the aliquot was measured with an Ion/pH 9000 Sargent-Welch pH meter. Crude fat content (EE) was estimated by extracting samples with ethyl ether for 48 h using a Soxhlet apparatus.

The amount of starch (S) remaining in the CGF samples was determined by the enzymatic procedure described by MacRae and Armstrong (1968). The fibrous fractions of CGF were determined by analyzing samples for acid detergent fiber (ADF), permanganate lignin (LIG), and neutral detergent fiber (NDF; Goering and Van Soest, 1970). Cellulose (CELL) was calculated as the difference between ADF and LIG. A single sample of soybean meal (SBM) was included in the study as a standard for comparison. All samples were analyzed in duplicate.

All CGF samples were subjectively scored for color, odor, and texture using five evaluators. The color scale was 1=bright yellow, 2=dark yellow, 3=tannish brown, 4=camel brown, and 5=dark brown. The odor scale was 1=sweet corn smell, 2=neutral corn smell, 3=sour corn smell, and 4=burnt; while the texture scale was 1=fine meal, 2=medium coarse meal, 3=coarse meal, 4=soft pellet, and 5=firm pellet.

In Situ Experiment. Two mature beef cows each fitted with large rumen cannula had free access to winter-harvested native grass hay and were fed 2.2 kg of CGF per d. Corn gluten feed samples (2.5 g) were placed in quadruplicate dacron bags and washed to determine 0 h disappearance, or incubated in the rumen (2 bags of each sample/cow) for 12 or 24 h. After removal from the rumen, bags were thoroughly washed and dried at 100C for 24 h. The extent of DM disappearance (DMD) at 0, 12, or 24 h was calculated as the

difference between initial DM and residual DM. Two bags of each sample were then analyzed for N by the Kjeldahl procedure (AOAC, 1975) while the remaining two were ashed at 500C for 6 h to determine residual OM. As with DMD, nitrogen disappearance (ND) and organic matter disappearance (OMD) at 0, 12 and 24 h were calculated as the difference between initial and final contents. Rates of in situ DM, OM, and N disappearance were calculated as the slopes obtained by regressing the natural logarithm of the percentage of residual DM, OM, or N against incubation time.

The averaged laboratory values of all CGF samples were subjected to least squares analysis of variance and covariance with processing plant as the independent variable. Residual sums of squares and cross products were used to estimate correlations among the dependent variables. Duncan's multiple range test was used to separate means for characteristics in which the F-test for processing plant was significant ($P<.05$). Stepwise regression (Draper and Smith, 1966) was used to describe rate and extent of DM, OM, and N disappearance with the eleven laboratory chemical composition values serving as independent variables. Variables were included in the model only if the R^2 value was increased at least 2% by the addition of each variable and if the error mean square was decreased. The best models and standard errors (Sy.x; mean square error.5; Draper and Smith, 1966) are reported.

Results and Discussion

Laboratory Experiment. Least squares means of the chemical composition and subjective measurements on CGF samples are presented in Table 1. Dry CGF is typically marketed at 90 to 92% dry matter (DM) (Trenkle, 1985b). The average DM content of all samples analyzed in this study was 90% but DM values among plants varied ($P<.001$), ranging from 85.4 to 94.9%. Ash varied ($P<.05$) less, ranging from 5.1 to 7.9%, in comparison to 5% reported by Van Soest (1984). The average DM and ash content for all CGF samples were similar to the SBM comparison sample (90.0 vs 89.5% for DM and 6.2 vs 7.8% for ash, respectively). Sample pH did not differ among CGF sources but CGF was considerably more acidic then SBM (4.1 vs 6.2, respectively). Sulphurous acid solution, which is employed in the initial soaking step and added back to corn bran in the form of corn steep liquor, probably accounts for the lower pH of CGF.

Starch content varied slightly among processing plants ($P<.16$) with values ranging from 9.7% to 14.5%. The starch content for all CGF samples was considerably higher than that of SBM (12.2 vs 4.0%). Fat content, as determined by ether extraction, varied ($P<.001$) from 2.1 to 7.2%. Addition of different amounts of corn germ meal to CGF could easily account for this range of EE as raw corn germ meal contains nearly 10% EE (NRC, 1972). The guaranteed minimum

fat content is 1.0% while the typical range is 1.4 to 3.5% (CRAI, 1982). The average EE for all CGF samples was higher than SBM (5.0 vs 2.0%) and higher than expected from tabular values for CGF (2.4%; NRC, 1984). Van Soest et al. (1984) also noted a high (7.5%) EE level in CGF.

Corn gluten feed is highly fibrous as reflected by the high NDF (50.1%) content of all samples while SBM, by comparison, averaged only 15.9%. These values are slightly above the 45 and 14% NDF values for CGF and SBM reported by Van Soest et al. (1984). The NDF content varied ($P<.01$) among processing plants with values ranging from 47.8 to 54.2%. Although the percent ADF varied ($P<.05$) from 10.2 to 12.4%, the average ADF content for all CGF samples was similar to that of SBM (11.1 vs 11.2%, respectively). Acid detergent fiber values for CGF and SBM cited by Van Soest et al. (1984) were 12 and 10%, respectively. Permanganate lignin content varied ($P<.05$) among plants and ranged from 1.44 to 2.02% with the average being greater than for SBM (1.70 vs 1.09%). Lignin contents of both CGF and SBM were 1% according to Van Soest et al. (1984). Cellulose content varied ($P<.01$) from 7.3 to 9.9% among plants, while the average CELL content of CGF and SBM were both 8.6%. Within the energy components, our data indicates that CGF has about three times as much S and NDF as does SBM, while the most variable component among CGF samples was EE.

All CGF samples, except those from Plant D, had a N content near 3.2% which calculates to a crude protein (CP) content near 20%. Samples from Plant D were lower ($P<.05$) in N (2.5%). According to CRAI (1982), protein content of CGF ranges from 21.0 to 25.4% with a guaranteed minimum of 21%. The measured protein values are all considerably lower than the NRC (1972; 1982) means (28.6 and 25.6% CP) as well as the 22% and 25.6% values cited by Van Soest et al. (1984). Based on these results, protein content should be checked when CGF is to be used as a protein source.

Ammonia N fractions were similar among CGF samples but higher than for SBM (2.92 vs 1.0% of total N). Soluble N content was similar (approximately 35%) for all plants except Plant F (61%; $P<.01$). Soluble N content for all CGF samples averaged 42.2% while SBM, by comparison, was 16.0% of total N. The high level of SN observed in CGF is probably due to addition of corn steep liquor which is high in soluble nutrients. Van Soest et al. (1984) reported that nonprotein N as a fraction of total N was 55 and 13% for CGF and SBM, respectively. Nondigestible N, as predicted from pepsin insoluble N, was inversely related to NaCl soluble N and highly variable ($P<.001$) among plants. Sample NDN ranged from 7.7% of total N for Plant F to 20.0% for Plant D. Samples from Plant D were also dark brown and had a roasted coffee-like smell. Color was positively ($P<.05$) correlated (correlation coefficient = .48) with the NDN content of the sample. This would indicate that in extreme

cases, the dark color and burnt smell may reflect heat damage of the protein. In a recent study (Oliveros et al., 1987) in which corn bran was mixed with two sources of corn steep liquor (one of which was dark brown) and dried at 60 or 90C, DM digestibility of the dark brown gluten feed was decreased ($P<.001$) as drying temperature was increased. This may suggest heat damage of protein can occur either when the steep solution is condensed to form corn steep liquor or later when wet CGF is dried to form dry CGF.

Nitrogen that is nonsoluble in NaCl but digestible (NSDN) was calculated by subtracting SN and NDN from total N. Due to the high level of SN observed in samples from Plant F, it had the lowest NSDN (31.7% of total N). Values varied ($P<.01$) from 31.7 to 54.0% of total N and averaged 44.7%. The NSDN value of SBM was 77.0% due to its smaller SN fraction. Insoluble protein minus NDF-bound protein, another index of digestible ruminal escape protein, was reported to be 37 and 71% for CGF and SBM, respectively (Van Soest et al., 1984).

The high SN levels of CGF observed in this study suggests that the N from CGF should be more extensively degraded in the rumen than SBM. Based on NDN, total tract digestibility of N from CGF, should be similar to SBM. The N data also suggests that there is greater variation in the protein fraction of CGF than in its energy fraction, especially in NaCl soluble and pepsin insoluble N estimates.

These may reflect the amount of steep water added and the extent of heat damage.

In Situ Experiment. The extent of in situ DM, OM, and N disappearance after 0, 12, and 24 h of incubating CGF in the rumen are presented in Table 2. The 0 h DM disappearance, or disappearance due solely to washout, did not differ among samples. The DM washout for CGF (34.6%) was only slightly greater than for SBM (29.0%). Disappearance of DM after 12 h of incubation in the rumen varied ($P<.05$) from 48.0 to 57.7%. The average DM disappearance for CGF (52.3%) was slightly lower than for SBM (58%). The extent of DM disappearance after 24 h varied ($P<.01$) from 67.7% for Plant A to 79.7% for Plant D. The extent of DM disappearance after 24 h averaged 73.2% for all samples indicating that CGF is extensively digested in the rumen. The greater extent of disappearance observed for SBM than CGF (83.0 vs 73.2%) at 24 h suggests that extent of ruminal DM digestion of SBM is more complete than for CGF, probably due to the greater amount of fibrous material in CGF.

The disappearance of OM due to washout was not different among CGF from the various plants but was greater for CGF than SBM (30.3 vs 23%). The extent of OM disappearance after 12 h of incubation paralleled DM disappearance being higher for SBM than for CGF (56.0 vs 48.2%). After 24 h, the variability in OM disappearance was

similar to that for DM. Plant D again had the greatest ($P<.01$) extent of OM disappearance (79.3%) which was similar to the value for SBM (80.0%).

The extent of N disappearance at 0 h due to washout was not different among plants and averaged 48.6% compared with only 2.0% for SBM. The large washout of N may be the reason why OM and DM disappearance at 0 h was high relative to SBM. Disappearance of N from CGF due to washout is partially attributable to the high soluble N from the corn steep liquor as detected by NaCl soluble and free ammonia N. After 12 h of incubation, N disappearance of CGF samples averaged 53.5% with no differences among samples from different plants. Nitrogen disappearances for CGF and SBM were 53.5 vs 30.0% after 12 h and 72.02 vs 63.0% after 24 h of ruminal incubation, respectively. The extent of N disappearance was highly ($P<.01$) correlated with SN (correlation coefficient = .76). The results suggest that less time is required for ruminal release of N from CGF than from SBM. This is in agreement with in situ results of DeHaan et al. (1983) who suggested that protein from CGF is extensively and rapidly degraded in the rumen. Though pepsin insoluble N values in samples from Plant D were greater than values from other plants (20.0 vs 7.7%), these samples had similar rates of DM, OM, or N disappearance. This could mean that differences were too small to be detected or that pepsin insoluble N disappeared from the dacron bags.

Results of the in situ trial indicate that OM or DM disappearance after 12 or 24 h of incubation varies among CGF samples and is slightly less than OM or DM disappearances for SBM. Extent of N disappearance did not vary among CGF samples but was greater than N disappearance values for SBM. Results indicate that CGF nitrogen is readily and extensively degraded in the rumen.

Stepwise regression models developed to describe ruminal disappearances in situ are presented in table 3. Five variables were included in the best model (R2 = .6464) describing extent of in situ DMD. The model included EE, LIG, and SN, all of which were positively related while OM (ash was lost more extensively than OM) and total N being negatively related. The CGF samples which were low in total N were high in pepsin insoluble or nondigestible N. This could explain the negative effect of total N on DMD.

Three variables proved to be related to rate of DM disappearance (R2 = .6033). These variables were EE, ADF, and NDN, all of which retarded rate of digestion. The variables found to describe the extent and rate of DMD were similar to those selected to for OMD, and therefore those variables are not reported separately.

The extent of CGF nitrogen disappearance (END) in situ was best described by a six variable equation (R2 = .53). Organic matter and CELL amounts had negative effects whereas NDF, LIG, N, and SN contents had positive effects on extent

of N disappearance. The presence of CELL probably retarded particle washout whereas washout may have been increased by ash and certain other components.

Rate of nitrogen disappearance (RND) was best described by seven factors (R2 = .6002). The model included S, ADF, CELL, all of which reduced the rate of N disappearance, and LIG, NDN, N and SN which increased the rate at which N disappeared in situ. Some of these variables might relate to microbial attachment or type but others could alter particle size reduction and washout, as well.

In comparison to SBM, CGF was similar in the percentage of DM, OM, ADF, LIG, and CELL; higher in S, EE, NDF, AN, SN, and NDN; and lower in pH. Among CGF samples, EE was most variable energy component while pepsin insoluble N and NaCl soluble N were the most variable N components. Extents of in situ DM and OM disappearance from CGF were slightly lower than from SBM and varied among CGF sources. Extent of in situ N disappearance did not differ among plants but exceeded that of SBM. The percent EE, OM, LIG, N, and SN were the variables that best described extent of ruminal DM disappearance while the percent OM, NDF, LIG, CELL, N, and SN were the variables which best described the extent of ruminal N disappearance. Darker colors of CGF samples were associated with increased levels of nondigestible nitrogen.

Table 1. Chemical composition and subjective scores of corn gluten feed (CGF) samples obtained from six processing plants.

		Processing Plant							
	SBMe	A	B	C	D	E	F	Meanf	SE
No. Samples	1	6	3	3	3	3	3		
Chemical composition:[h]									
DM[i]	89.5	89.3[b]	95.6[a]	89.7[b]	89.9[b]	91.1[b]	85.4[c]	90.0	.80
OM[i]	92.2	92.7[b]	94.9[a]	94.0[ab]	92.1[b]	93.1[ab]	93.8[ab]	93.4	.51
pH	6.2	4.0	4.2	4.1	3.9	4.4	4.0	4.1	.12
Energy factors:									
S[i]	4.0	12.9[a]	11.7[a]	11.5[a]	13.0[a]	14.5[a]	9.7[b]	12.2	1.51
EE[i]	2.0	2.1[c]	3.0[c]	7.2[a]	5.2[b]	5.2[b]	6.1[ab]	5.0	.47
NDF[i]	15.9	50.4[b]	54.2[a]	48.3[b]	47.8[b]	48.7[b]	51.3[ab]	50.1	.94
ADF[i]	11.2	11.0[ab]	11.0[ab]	10.2[b]	12.4[a]	11.3[ab]	10.8[b]	11.1	.37
LIG[i]	1.09	1.44[b]	2.02[a]	1.86[ab]	1.54[ab]	1.84[ab]	1.50[ab]	1.70	.14
CELL[i]	8.6	8.4b[c]	9.9[a]	8.3[bc]	7.8b[c]	7.3[c]	9.9[a]	8.6	.33
Protein factors:									
AN[j]	1.00	2.83	3.00	2.33	3.33	3.00	3.00	2.92	.208
NDN[j]	7.0	13.0[bc]	15.7[b]	10.7[cd]	20.0[a]	12.3[bc]	7.7[d]	13.2	1.14
SN[j]	16.0	39.2[b]	43.3[b]	40.0[b]	36.3[b]	33.7[b]	60.7[a]	42.2	3.55
NSDN[j]	77.0	47.8[ab]	41.0[bc]	49.7[ab]	43.7[ab]	54.0[a]	31.7[c]	44.7	3.20
TN[i]	7.15	3.14[a]	3.39[a]	3.21[a]	2.50[b]	3.07[a]	3.22[a]	3.09	.14
CP[i]	45.0	19.5[a]	21.0[a]	20.0[a]	15.7[b]	19.3[a]	20.0[a]	19.3	.90
Subjective scores:[g]									
Color		2	2	3	5	3	2		
Odor		1	2	2	4	2	2		
Texture		1	1	3	5	1	5		

[abcd] Means in the same row with different superscripts differ (P<.05).
[e] Soybean meal was included only as a reference.
[f] Mean composition of all CGF samples.
[g] Color: 1=bright yellow, 2=dark yellow, 3=tannish brown, 4=camel brown, 5=dark brown. Odor: 1=sweet corn smell, 2=neutral, 3=sour, 4=roast coffee. Texture: 1=fine meal, 2=medium coarse meal, 3=coarse meal, 4=soft pellet, 5=firm pellet.
[h] DM=dry matter, OM=organic matter, S=starch, EE=ether extract, NDF=neutral detergent fiber, ADF=acid detergent fiber, LIG=lignin, CELL=cellulose, AN= ammonia nitrogen, NDN=pepsin insoluble nitrogen, SN= NaCl soluble nitrogen, NSDN=nonsoluble but degradable nitrogen, TN=total nitrogen, and CP=crude protein.
[i] percent of DM.
[j] percent of total N.

Table 2. Corn gluten feed (CGF) extent of in situ dry matter (DM), organic matter (OM), and nitrogen (N) disappearance in cows consuming low quality native grass hay and supplemented with 2.2 kg of CGF per day.

		Processing Plant							
	SBM[e]	A	B	C	D	E	F	Mean[f]	SE
No. samples	1	6	3	3	3	3	3		
DM disappearance, % of DM									
0 h	29.0	32.2$_{b}$	33.3$_{b}$	34.7$_{ab}$	38.3$_{a}$	32.3$_{ab}$	37.0$_{ab}$	34.5	1.89
12 h	58.0	49.2^{d}	48.0^{cd}	53.3^{bcd}	57.7^{a}	52.3^{abc}	53.3^{ab}	52.3	1.75
24 h	83.0	67.7^{d}	69.0^{cd}	72.3^{bcd}	79.7^{a}	74.7^{abc}	76.0^{ab}	73.2	1.80
OM disappearance, % of DM									
0 h	23.0	27.2$_{b}$	30.3$_{b}$	30.3$_{ab}$	33.0$_{a}$	28.0$_{ab}$	32.7$_{ab}$	30.3	1.80
12 h	56.0	45.5^{b}	44.7^{b}	49.0^{ab}	52.7^{a}	47.3^{ab}	50.0^{ab}	48.2	1.66
24 h	80.0	64.7^{c}	67.7^{cd}	71.0^{bc}	79.3^{a}	73.0^{bc}	74.3^{ab}	71.7	1.67
N disappearance, % of DM									
0 h	2.0	51.0	48.3	45.0	43.3	48.0	56.3	48.6	2.95
12 h	30.0	55.2	54.7	56.3	48.3	48.7	57.7	53.5	3.81
24 h	63.0	69.7	71.7	69.7	71.3	75.0	74.7	72.0	3.55

~~abcd~~Means in the same row with different superscripts differ (P<.05).
[e]Soybean meal was included only as a reference.
[f]Mean value of all CGF samples.

Table 3. Equations describing rate and extent of CGF dry matter (DM) and nitrogen (N) disappearance in situ.[a]

Equation[bc]	R2	Sy.x
Dry matter:		
EDMD=304.06-2.51(OM)+.97(EE)+6.26(LIG)-7.14(N)+.24(SN)	.6464	3.58
RDMD=.81-.28(EE)-.23(ADF)-.05(NDN)	.6706	.401
Nitrogen:		
END=223.90-2.11(OM)+.75(NDF)+7.25(LIG) -4.36(CELL)+4.23(N)+.46(SN)	.5306	4.93
RND=-7.94+.14(S)+.37(ADF)-1.42(LIG)+1.15(CELL) -.80(N)-.15(NDN)-.09(SN)	.6002	.844

[a]Only models in which the addition of each variable increased R2 by >2% were and reduced mean square error were included.
[b]n=21.
[c]EDMD=extent of DM disappearance, %; RDMD=rate of DM disappearance, %/h; END=extent of N disappearance, %; RND=rate of N disappearance, %/h; EE=ether extract, %; OM=organic matter, %; ADF=acid detergent fiber, %; LIG=lignin, %; N=total nitrogen, %; SN=NaCl soluble nitrogen, % of N; NDN=pepsin insoluble nitrogen, % of N; NDF=neutral detergent fiber, %; CELL=cellulose, %; and S=starch, %.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Corn gluten feed (CGF), a by-product of the wet-milling corn refining industry used as livestock feed, is often available in large amounts. When prices are favorable, livestock producers may consider CGF as an alternative feedstuff. Research with CGF prior to this study had been conducted with growing cattle and sheep in which CGF was used in higher concentrate rations or to supplement high quality forage. In this study three experiments were conducted to determine the potential of CGF as a protein and energy supplement for beef cattle consuming low quality forage.

In an intake and metabolism trial (Experiment I) thirty-two beef cows were individually fed native grass hay and supplement for two 14 d periods in each of two yr. Supplement treatments and amounts fed (kg/d) were negative control (NC), 0; or equal amounts of protein from soybean meal (SBM), .7; a blend of soybean meal and corn gluten feed (SBM/CGF), 1.0; or corn gluten feed (CGF) 1.6. Cows received supplement at 0645, and had ad libitum access to native grass hay from 0700 to 1130 and from 1530 to 2000.

Replacing SBM with CGF decreased (P<.01) the molar proportion of acetate and increased propionate and butyrate proportions 4 h after supplement was fed. Voluntary hay intakes were similar for SBM and SBM/CGF treatments (1.75 and 1.73% of body weight, respectively), but was reduced (P<.01) to 1.62 when SBM was totally replaced by CGF. Forage, acid detergent fiber (ADF), and total dry matter (DM) digestibilities were similar for the SBM, SBM/CGF, and CGF treatments. Forage intake declined when CGF was fed as the sole source of supplemental protein as compared to the SBM control though energy intakes were similar due to a greater amount of supplement fed. The calculated ME (Mcal/d) intakes were 12, 17, 18, and 17 for NC, SBM, SBM/CGF, and CGF, respectively due primarily to changes in diet digestibility. Daily indigestible DM intake ranged from .87 to .93% of body weight and did not differ among treatments. The increased diet DM and ADF digestibility, and the slight increase in forage intake with CGF indicates that CGF is an acceptable protein/energy supplement for beef cows consuming low quality forage.

In performance trials (Experiment II) CGF was evaluated as a protein and energy supplement for mature beef cows grazing native range in winter and for growing heifers grazing native range in summer. In 1985 and 1986, 72 mature Hereford cows bred to calve in March and April were divided into four supplement treatment groups. Treatments and daily feed levels (kg/head) from November to January 30 were NC,

.5; SBM, .9; SBM/CGF 1.4; and CGF, 2.0 (the latter three contained equal amounts of CP). Supplementation began in mid-November and ended as each cow calved. On d 75 (January 30) of the trial, supplement levels were adjusted based on weight changes of negative and positive control cows. All supplement levels were increased by 50% in 1985, and were reduced by 33% in 1986. Supplements were prorated and individually fed 6 d per wk.

Ruminal pH was lowered ($P<.01$) at 4 h after feeding SBM/CGF or CGF supplement as compared to NC (7.2, 6.8, and 7.5, respectively). At both 1 and 4 h after feeding supplements, the ruminal proportion of acetate was reduced ($P<.01$) while propionate and butyrate were increased ($P<.01$) in cows fed CGF. This is consistent with responses observed in Experiment I. Negative control-cows lost more weight ($P<.01$) than cows fed SBM, while SBM/CGF- and CGF-cows maintained body weight similar to cows receiving SBM (-26.7, 1.5, 0.0, and 1.4 kg for NC, SBM, SBM/CGF, and CGF, respectively).

Forty-three Hereford and Hereford X Angus heifers in 1985 and 48 heifers in 1986 were similarly fed 5 d each wk from July 16 to October 8 at daily rates of 0, .55, .86, and 1.27 kg/head for NC, SBM, SBM/CGF, and CGF treatments respectively (the latter three contained equal amounts of CP). Heifers receiving the SBM treatment gained more weight ($P<.01$) than unsupplemented NC heifers, while heifers fed

SBM/CGF or CGF gained more weight (P<.01) than heifers receiving SBM (39, 53, 63, and 62 kg for NC, SBM, SBM/CGF, and CGF, respectively).

The SBM/CGF treatment in both performance trials responded similarly to the CGF treatment with approximately 30% less supplement, indicating that the utilization of CGF as a supplement is improved when SBM provided half of the supplemental protein. The performance data also suggest that CGF is an effective energy and protein supplement for beef cows consuming winter native range and for heifers grazing mid- to late-summer range.

Experiment III was conducted to characterize the chemical and physical components of CGF and to determine the degree of variability in CGF obtained from different sources. Twenty-one samples of CGF were obtained from six Midwest corn wet-milling plants and exposed to laboratory analysis and an in situ digestion trial. A single sample of SBM was included only as a reference of comparison.

Organic matter (OM) varied only slightly among plants with values ranging from 92.1 to 94.9% of DM. The average of 93.4% OM is similar to the 92.2% determined for SBM. Starch (S) content did not differ among plants but was substantially higher than in SBM (12.2 versus 4.0%). Ether Extract (EE) appeared to be the most variable energy component (ranging from 3.0 to 7.2%). The average EE of 5.0% is considerably higher than the 2.0% determined for

SBM. The pH of CGF did not differ among plants but was consistently more acidic than SBM (4.1 versus 6.2).

Neutral detergent fiber (NDF) was higher (P<.01) for one than the other plants. The average NDF (50.1%) is much higher than for SBM (15.9%). Acid detergent fiber (ADF) was higher (P<.01) for one plant but similar for other plants and similar to SBM (11.1% versus 11.2%). The percent lignin (LIG) was higher (P<.01) for one plant B but similar for other plants; LIG content was 1.70 and 1.09% for CGF and SBM, respectively. Cellulose (CELL) content ranged from 7.3 to 9.9% among plants though the average of 8.6% was the same as the CELL content of SBM.

Free ammonia nitrogen (AN) for CGF was 2.92% of total N and similar among plants compared to 1.0% for SBM. Pepsin insoluble N or nondigestible nitrogen (NDN) was variable (P<.01) among plants ranging from 7.7 to 20.0% with the average being considerably higher than for SBM (13.2 versus 7.0% of total N). One plant had a higher (P<.01) NaCl soluble nitrogen (SN) content (60.7%) but all other plants were similar. Corn gluten feed is much higher in SN than SBM (42.2 versus 16.0%). All plants were near the 3.5% guaranteed N content except one plant which was considerably lower (2.5%).

Corn gluten feed DM disappearance after 24 h of in situ incubation in the rumen was variable (P<.01) among plants ranging from 67.7 to 79.7% and lower than SBM (83.0%). In

situ OM disappearance followed the same trend with CGF again being lower than SBM (71.7 versus 80.0%). In situ N disappearance after 0, 12, or 24 h did not differ among plants. The 0, 12, and 24 h values were 48.65%, 53.48%, and 72.02% for CGF versus 2.0%, 30.0%, and 63.0% for SBM.

The results of Experiment III suggest that while CGF is similar to SBM in DM, OM, ADF, LIG, and CELL, CGF; higher in S, EE, NDF, AN, SN, and NDN; and lower in pH. Ether extract was the most variable energy component among different sources of CGF while SN and NDN were the most variable N components.

In summary CGF is a highly digestible source of energy due to the highly digestible nature of its fiber. Protein in CGF is a readily available in the rumen due to its high solubility as reflected by its high SN content and the high and rapid rate of in situ N disappearance.

Feeding CGF as the sole source of supplemental N slightly reduced hay intake, possibly due to the larger volume of feed being fed. As more supplemental feed was consumed without dirasically depressing diet digestibility, the total amount of energy available to the cow was similar to that of cows supplemented with SBM. Performance data suggest that CGF can be fed alone or with SBM as a protein and energy supplement for beef cattle consuming medium to low quality forage. However, the consistent and similar performance of cows fed SBM/CGF and CGF, even though SBM/CGF

cows received 30% less total feed, suggests that CGF may lack protein components which are corrected by adding SBM. An arbitrary blend of 1:2 SBM to CGF was selected in this study so that each provided half of the supplemental protein. Additional research may show that a smaller amount of SBM or other protein source may be adequate to improve the utilization of CGF as a energy and protein supplement for beef cattle consuming average to low quality forage.

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