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Alfalfa Products as Roughage and Protein Sources for Corn and Corn Stover Beef Diets

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ALFALFA PRODUCTS AS ROUGHAGE AND PROTEIN SOURCES FOR CORN AND CORN STOVER BEEF DIETS

BY

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ALFALFA PRODUCTS AS ROUGHAGE AND PROTEIN SOURCES

FOR CORN AND CORN STOVER BEEF DIETS

This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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INTRODUCTION

New feeds are continually being developed, especially from by-products of an industrial process which produces a product already in demand. For example, soybean oil meal was initially a by-product of an extraction process for soybean oil, a product in great demand at the time as the base material of paints. As the demand for the oil subsided, the by-product, soybean oil meal, assumed the major role as a protein supplement for livestock. Alfalfa, on the other hand, has always been an important feedstuff, as well as many of its related products such as alfalfa leaf meal and dehydrated alfalfa. The continuous demand for high quality protein sources in human and animal diets has caused an intensive search for protein from many plant sources, including alfalfa. It has been found that, if the soluble alfalfa leaf proteins are removed (Pro-Xan process) for use in poultry diets or for preparation of milk replacers, a rather high protein by-product still remains. This by-product, press cake, could be a valuable feed supplement for lower grade feedstuffs. An explanation of this protein extraction process may be helpful in estimating the feeding value of the alfalfa plant components.

Pro-Xan is a leaf protein concentrate extracted from freshly cut alfalfa. Figure 1 outlines the steps involved in the Pro-Xan process. In this process, the material is macerated and compressed to remove the soluble (green) juices. The fibrous by-product is termed "press cake." The soluble (green) juices undergo further processing to remove the high protein fraction, Pro-Xan. The remaining (brown) juices may

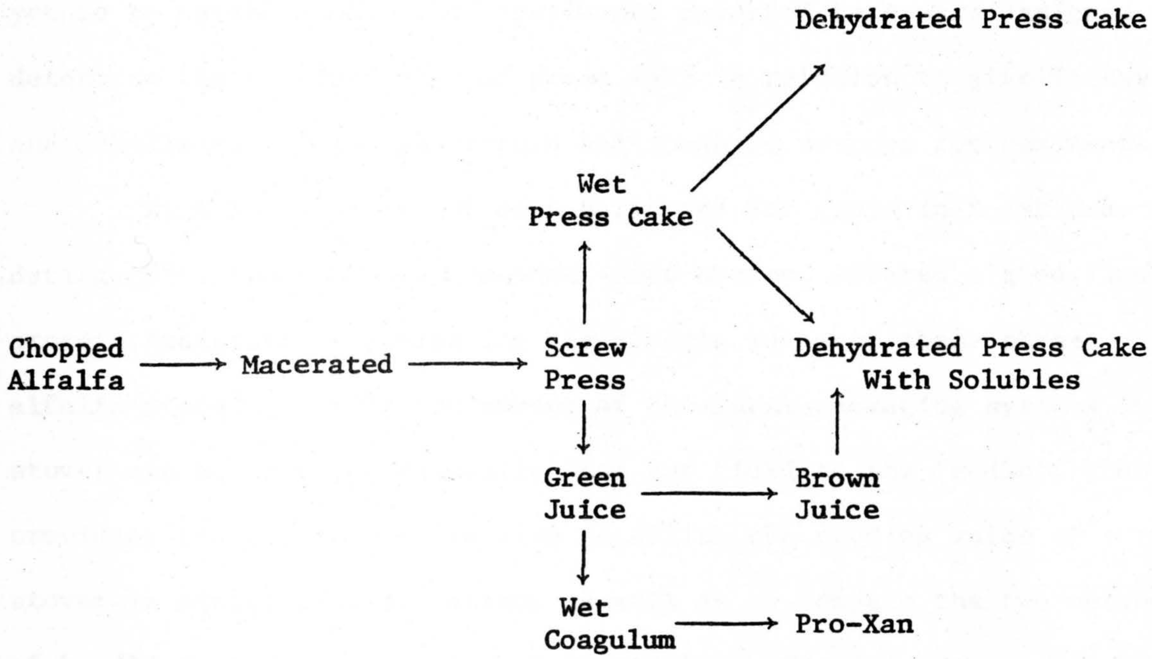


Figure 1. Outline of Pro-Xan extraction process.

or may not be added back into the press cake fraction. The Pro-Xan fraction contains the high protein, high xanthophyll portions that are desirable in poultry rations or as milk replacer proteins. The more fibrous by-product, press cake, might be a suitable feedstuff for ruminants, either as a roughage source or as a low level protein source.

Numerous studies have already been conducted on the benefits of the Pro-Xan fraction. Enochian _et al_. (1980), for example, found that the xanthophyll from Pro-Xan was utilized 1.7 times more efficiently in poultry rations than the xanthophyll found in dehydrated alfalfa and contained a more soluble protein content. Pro-Xan then is the primary commercial product of demand in the existing market.

Press cake, the by-product of the Pro-Xan process, has been studied very little and has no established market as the feed value has yet to be established. The experiments reported here were designed to determine the feeding value of press cake in relation to alfalfa hay and dehydrated alfalfa as protein and roughage sources for ruminants.

With 1,153,395 ha of corn harvested for grain in South Dakota during 1979, the corn crop residue, corn stover, offered a good, low protein feedstuff for comparing the protein value of these three alfalfa products. With the advent of the large packaging systems, corn stover can be transported easily from the field to the feedlot, thus providing the opportunity to also establish the feeding value of corn stover in winter growing rations as well as to compare the two methods of handling corn stover, stacked or ensiled. Growing steers were utilized in this experiment, as their requirements for protein were much higher than with animals in later stages of growth.

When feeding high-concentrate rations, as in the second experiment, the roughage portion need not be of high quality, since the digestibility of fiber decreases rapidly as the concentrate portion of the diet exceeds 30%. This provides an opportunity to use a variety of fibrous materials to replace more expensive choices of roughages such as dehydrated alfalfa or high-quality alfalfa hay as long as the protein values are similar. Because corn is normally considered adequate in protein for finishing steers, the protein content of the alfalfa products was not as critical to this experiment as the roughage additions.

From the analysis of the press cake product, it would appear that its use as a feedstuff would be quite similar to the parent material, alfalfa hay, depending upon animal response. In this study, press cake was compared to dehydrated alfalfa and alfalfa hay.

REVIEW OF LITERATURE

Protein Supplementation to Corn Stover in Beef Growing Diets

Need for Protein Supplementation. Limited research has been reported on the feeding value of corn stover in beef cattle rations. Most of the research reported has been conducted with maintenance rations for gestating beef cows. Methods of utilizing corn stover as a feedstuff include direct field grazing or feedlot feeding. Feedlot feeding requires that the material be transported as stacks or ensiled prior to feedlot use.

Henderson (1973) stated that grazing is the cheapest method of utilizing crop residues, but additional feeds may be needed for times when grazing is undesirable or not possible. When considering how to utilize crop residues, it is important to evaluate equipment costs, labor costs and the fertilizer value of the crop residue. The most profitable operation does not necessarily make complete use of the crop residue. Cornstalks left in the field (2.5 MT of No. 2 corn per ha) contain 25.5 kg nitrogen, 1.4 kg phosphorus, 12.3 kg potassium and 7.7 kg calcium. Cornstalks also provide organic matter for the soil.

In grazing studies conducted from 1966 to 1971, Vetter and Ayres (1973) found that mature beef cows could be wintered on .81 ha of cornstalks (2.5 MT of No. 2 corn per ha) for 100 to 110 days under open winter conditions (less than 7.6 cm snow). Supplementing corn stover grazing with corn or hay did not greatly improve weight gains, as the daily energy supplementation discouraged grazing. In one trial, Vetter and co-worker found that providing a free-choice urea supplement increased gains in the initial period (grazing alone). However, in the second period (grazing plus husklage dumps), the urea added no benefit, suggesting that the corn lost during harvest provided enough additional energy for the urea to be utilized more efficiently during the first growing period. Intake of the urea-based supplement averaged .91 kg per day for the entire trial with overall utilization of the nonprotein nitrogen very low. Comparisons among years were difficult to make due to the different field losses, yields and weather conditions.

Ritter and Vetter (1976) compared three different liquid non-protein nitrogen (urea) supplement levels (25%, 32% and 35%) when feeding beef cows stacked corn stover in the field and under drylot conditions. No significant differences in weight gains were noted among supplemental treatments. Stover stack wastage was estimated at 25 to 30%. Vetter (1977) found that stack grazing allowed cows greater opportunity for selection, resulting in improved performance over that of cows under drylot conditions. Addition of nonprotein nitrogen liquid supplement directly to the stack provided for uniform consumption. Weber and Vetter (1973) fed low protein diets (4.7%) to gestating and lactating beef cows. There was no effect on calf birth weights. However, the consequent weight loss of the cows did limit milk production during lactation. Weber and Vetter (1974) reported interesting results in cows fed variable nitrogen levels. The percentages of total protein in the first trial were 3.1, 6.4, 11.8 and 11.9 during gestation and 7.9, 10.9, 13.1 and 13.2 during lactation for the low protein, adequate protein, high urea and high preformed protein treatments, respectively. The second year required a slight adjustment to reduce intake problems. Based on the amount of dietary nitrogen consumed, the cows fed high urea and high preformed protein would have been expected to produce comparable gains. However, the high urea-fed cows gained comparably to the cows fed adequate protein. Thus, the high urea-fed cows received very little advantage by consuming the additional urea. Insufficient protein resulted in decreased appetite, weight loss and milk production. Calf birth weights were not affected by the level of protein fed to the dam. High urea tended to adversely affect ration palatability. The protein quality and quantity also tended to adversely affect the low protein and high urea-fed cows' ability to rebreed, emphasizing the necessity for defining and administering an optimum plane of nutrition.

In comparing corn stover silage, corn stover silage plus urea and corn silage (Colenbrander et al., 1971), the urea-treated corn stover (42% at .5% on a wet basis) had a protein value similar to that of corn silage. The addition of urea did improve feed efficiency, although not as effectively as the corn silage. Overall, the corn stover had an atypical fermentation when compared to corn silage as characterized by a higher pH, lower titratable acidity and less lactic acid production. The fermentation deviated even more from that of corn silage when urea was added. Colenbrander and co-workers found that growing Holstein heifers could consume enough corn stover silage as the primary energy source for maintenance and .50 kg daily gain. Vetter and Ayres (1973) also ensiled corn stover using a Beefmaker (a machine developed by Iowa State University to harvest the whole plant in one operation, separating the forage from the grain). Vetter and Ayres (1973) stated that stalkage to be ensiled should be harvested immediately after combining to prevent further drying. It should be chopped fine, stored rapidly and packed for 2 to 3 days after filling. The forage should not be less than 40% moisture. Results of Vetter and Ayres' study showed a slight advantage in animal gains by ensiling over stacking. However, husklage dumps appeared to be better than either the stacks or ensilage.

Strohbehn and Ayres (1976) reported that the nutritive value of corn varies greatly depending upon the amount of husks, leaves and stalks. TDN is quite variable. When feeding corn stover, up to 30% of the crude protein is undigestible. Overall, crude protein is extremely low at 4 to 5%. Vitamin A and phosphorus supplementation is also necessary. The palatability of corn stover varies tremendously, depending upon the leaf and husk content, stack heating, dirt contamination and mold formation. Brackelsburg et al. (1977) found a significant 8.9% reduction in stover refusal with beef cows after tub-grinding the stacked stover. Oh et al. (1971) reported that alfalfa had a higher relative feeding value, with both rice straw and barley straw lower than pelleted cornstalks.

Ward (1973) summarized the results of feeding crop residues at the 1973 Nebraska Crop Residue Symposium. Crop residues have enough energy for mature gestating cows, but productivity as growth or milk production requires additional energy. Protein is also too low (4.5 to 5.0%) to support growth or milk production. Preformed proteins appear to produce greater winter gains than urea. As noted previously, corn stover is deficient in vitamin A and phosphorus. Calcium may also be deficient for lactating cow rations. Ward also noted that producers should not overlook the possibility of feeding high quality grass or legume hay to meet both the additional protein and energy requirements.

It therefore seems possible that corn stover could be a viable feedstuff for ruminants if supplemented with the proper minerals, vitamins and protein. Utilization of corn stover as a feedstuff is obviously dependent upon the economics of each individual situation. If it is economical to feed corn stover, then it is also necessary to find a suitable supplement to alleviate the corn stover deficiencies.

Alfalfa Products as Protein Sources. Alfalfa may be utilized in several forms or products. For the purpose of this discussion, only three of these products, alfalfa hay, dehydrated alfalfa and alfalfa press cake, will be considered in detail. These three alfalfa products may have several different quality types and forms that need to be considered when feeding them as a protein supplement.

It has long been established that alfalfa hay is a suitable protein supplement for ruminants. Shrewsburg et al. (1943) noted the excellent vitamin and protein properties of alfalfa. However, alfalfa has exhibited other favorable characteristics which may deem it a more desirable ruminant protein supplement than even the high protein meal supplements.

Block and Weiss (1956) found that the solubility and amino acid contents of the protein contained in soybean meal and alfalfa were not significantly different. However, Tagari (1969) found protein from alfalfa hay to be utilized more efficiently than the protein from soybean meal when feeding the two protein supplements as the sole source of protein in high-roughage sheep diets. This superiority of alfalfa hay over soybean meal was supported by blood urea concentrations, amino acids and medium chain fatty acids of the rumen liquor. Generally, when blood urea concentrations are lower, the protein is used more efficiently. The alfalfa hay, following this pattern, exhibited lower blood urea concentrations than the soybean meal diets. It has also been thought that rumen NH_3 can be utilized in protein synthesis. Therefore, higher concentrations of rumen NH_3 may result in more efficient nitrogen utilization. The alfalfa hay also exhibited a higher rumen NH_3 than the soybean meal diet. In addition, the alfalfa showed enhanced dehydrogenase activity of the rumen liquor, indicating greater rumen microbial activity and thus greater ability to synthesize protein.

Tagari's work suggested that the solubility of the protein source may not be as important in this case, as the proteins of alfalfa hay and soybean meal had similar solubilities. In analyzing the two protein sources, the greatest difference was found to be in the nonprotein nitrogen concentration (alfalfa hay, 25.5%, and soybean meal, 1.5%). Nonprotein nitrogen concentrations of the alfalfa resulted in greater ruminant synthesis of particularly high amounts of proline, alanine, valine and serine. This may have stimulated the greater metabolic activity of the rumen microorganisms, ultimately resulting in increased protein synthesis. Some of the same amino acids found in high quantity in Tagari's experiments were shown to form valeric acid (Johnson et al., 1957), and valeric and caproic acids have been shown to be stimulatory factors of microbial activity in the rumen.

Numerous studies have recognized the improved performance resulting from the feeding of dehydrated alfalfa in poor quality, high-roughage diets. The reasoning, however, as to how the dehydrated alfalfa improved these diets is still not altogether clear.

Bentley et al. (1952) attributed the increased average daily gain noted with the dehydrated alfalfa supplemented diets over the soybean meal diets to the difference in their mineral content. Gossett and Riggs (1956) attributed the improved performance to higher blood plasma carotene levels in the dehydrated alfalfa diets. Cheng et al. (1953) and Bickoff et al. (1960) suggested that the estrogens within the alfalfa may have resulted in the increased production. Perhaps the difference in production with the dehydrated alfalfa was due to a non-protein nitrogen content which produced desirable amino acids as suggested in Tagari's work. However, the dehydrated alfalfa has given greater improvement in performance than even alfalfa hay in these low quality diets. With this in mind, Pfander (1977) tried to explain the improvements noted with the dehydrated alfalfa in another manner. As a result of 128 individual, 5-week evaluations of sheep fed prairie hay and dehydrated alfalfa, Pfander found that the addition of 100 g of pelleted dehydrated alfalfa increased intake by 11.4% by improving the protein economy of the animal. Average daily gains were also positively influenced. An addition of 6 to 12% dehydrated alfalfa improved the protein deposition in the lambs, suggesting that the improved performance of the dehydrated alfalfa in high-roughage diets may be due to some rumen by-pass characteristics of the protein. The overall benefit of these alfalfa products may be a combination of all of the factors mentioned or an unknown factor.

The last alfalfa product to be discussed that may have potential as a protein supplement is actually a by-product called "press cake." Alfalfa press cake, as mentioned in the introduction, is the more fibrous fraction remaining after removing part of the high quality, leaf proteins. Several studies have been conducted on the Pro-Xan (leaf protein concentration fraction) in poultry rations. Very little research, however, has been conducted on the feeding value of alfalfa press cake in ruminant diets.

Raymond and Harris (1957) were some of the first to work with the fibrous residues from leaf protein extractions. Their results showed alfalfa press cake to be equivalent to medium quality hay with respect to digestibility. Since the extraction process was costly, however, little additional research was devoted to the press cake product until the mid-1970's. Improved extraction procedures have now made the process more economical and have called for additional information on the product.

Russell *et al.* (1978) fed pressed alfalfa silage to dairy cattle and found a slight decrease in dry matter intake, milk production and milk fat content with the press cake silage over the field-wilted alfalfa silage. However, digestibilities were very similar, probably due to the comminution of the press cake product. The press cake silage had higher acetic, butyric and nonprotein nitrogen contents but a lower lactic acid content than the wilted alfalfa silage. Rumen NH_3 was also lower with the press cake silage.

Kohler *et al.* (1979) and Greenhalgh and Reid (1975) both noted that digestibility of the processed and unprocessed alfalfa products was similar, concluding that the detrimental effects of removing solubles from forages were counterbalanced by the beneficial effects of comminution.

The protein value of the press cake products varies depending upon the quality of the raw material, the amount of protein extracted as Pro-Xan and whether or not the "brown juices" are added back to the press cake (Brown juices are the residual juices remaining after the protein is coagulated and removed.). Kohler *et al.* (1979) found that the press cake without juice added back ranged from 10.3 to 16.6% protein, depending upon the amount of Pro-Xan removed, whereas, with the "brown juice" added back, the protein ranged from 12.6 to 17.5%. Crude protein digestibility in lambs was 69.3% with low extraction press cake, 58.3% with high extraction press cake and 61.1% with high extraction press cake, brown juice added back, compared to 70.9% with straight alfalfa, thus exhibiting the need for the solubles to be added back under high extraction processes.

More recently Merrill et al. (1981) studied alfalfa press cake for growing calves fed corn silage and corn cobs (2:1 ratio) to which urea; soybean meal; press cake; press cake with brown juice; press cake, brown juice and Pro-Xan or dehydrated alfalfa were added. Protein efficiencies of all the alfalfa products were considered higher than that for soybean meal, indicating that the alfalfa products had a "higher by-pass protein" which was utilized more efficiently than the soybean meal protein. Of all the protein supplements, the press cake with brown juice produced the highest average daily gain.

Merrill et al. (1981) showed that gains of steers fed corn silage supplemented with alfalfa press cake were similar to those of steers fed growing diets supplemented with dehydrated alfalfa and much higher than those supplemented with soybean meal or urea. The brown juice when added back appeared to improve efficiency beyond the by-pass qualities, as the brown juice supposedly had no by-pass protein left within it.

In retrospect, results from these alfalfa studies indicated that all three alfalfa products (alfalfa hay, dehydrated alfalfa and alfalfa press cake) should show benefits in low quality roughage diets such as corn stover over those for soybean meal or nonprotein nitrogen sources. Results also seem to indicate that the brown juice added back into the press cake would be a more favorable feedstuff in comparing the three alfalfa products.

Roughage Supplementation to All-corn Beef Finishing Diets

Need for Roughage Supplementation. There are several physiological problems that evolve in the feeding of all-concentrate diets to ruminants. All-concentrate diets can be fed to ruminants with good management and proper nutrition. However, the incidence of certain physiological problems in the animal increased with the feeding of all-concentrate diets (Hungate *et al.*, 1952; McGinty, 1963; Tremore *et al.*, 1968; McCartor *et al.*, 1972). These problems affect the animal's overall performance.

Hungate *et al.* (1952) found that an excess of grain or glucose in the rumen greatly decreased cellulytic bacteria and killed all protozoa. However, the number of gram-positive bacteria increased. This increase resulted in an accumulation of nonvolatile fatty acids, especially lactic acid, with diminished volatile fatty acids. This accumulation of acid has been termed rumen acidosis or rumen impaction.

According to Jensen and Macky (1965), rumen acidosis may partially or completely suppress rumen motility. The papillae may become swollen, with decreased absorption across the rumen epithelium. Extreme acidosis could result in necrosis of the epithelium (rumen parakeratosis), enabling *Spherophorus necrophorus* to enter the blood stream causing liver abscesses. Acidosis also causes increased heart and respiratory rates along with loss of appetite and extreme diarrhea. In terminal stages, the animal develops subnormal temperatures, low blood pressure and is extremely weak. If the animal survives, its performance is usually extremely poor.

Approximately 74% of steers fed all-concentrate diets have abscessed livers according to McGinty (1963). Burkhardt (1971) stated that not only do liver abscesses decrease performance but they also result in a great loss to the industry. An estimated 9.6% of all cattle slaughtered at inspected plants have their livers condemned.

McCartor et al. (1972) fed various roughages in all-concentrate diets. The concentrate diet (grain sorghum) resulted in liver abscesses in 40% of the animals fed. No abscesses were reported with the addition of 10% hulls. Protozoa were absent in one-half of the rumen samples taken with the all-concentrate diets.

Welch and Smith (1969) found that decreasing the roughage level decreased rumination time, which resulted in decreased salivary flow. This decrease in salivary flow ultimately decreased the saliva buffering capability in the rumen.

It has been suggested that feeding buffers would alleviate the acidosis problem. Tremore et al. (1968) found that feeding buffers and even intraruminal infusion did not completely prevent the decreased performance of the animals, suggesting that the disturbances caused by high-concentrate diets may be due to other factors acting separately or in combination with the high ruminal acidity.

Luther and Trenkle (1963) fed lambs diets containing 20:80 and 80:20% concentrate to roughage ratios. Results of rumen fluid studies showed a lower pH, narrower acetate:propionate ratios and a lower total volatile fatty acid content in the 80% concentrate diet as compared to the 20% concentrate diet.

Oltjen et al. (1971) also found the VFA concentration to be higher in low roughage-high concentrate diets than in all-concentrate diets. Oltjen also noted a dramatic increase in the numbers of bacteria to protozoa in the rumen.

Haskins et al. (1969) found that the addition of roughage to the diet enhances the integrity of the rumen papillae, possibly by cleaning the papillae to allow greater absorption. Therefore, by increasing the absorption and having a higher concentration of VFAs, the animal's efficiency in the utilization of the high-concentrate feedstuff may be increased.

Even if the animals had shown decreased weight gains and lowered feed efficiency, the decrease in management difficulties by adding low levels of roughage is worth consideration. Roughage sources are generally cheaper than concentrates and, if the roughage can be utilized as well as the concentrate, the economics of feeding the roughage also warrant the addition. There is still the problem of the source of roughage and the amount of roughage that can be included in the diet before the performance is decreased.

White et al. (1971) fed several roughage sources, including polyethelene chips, and found that it was not just the roughage alone, as the source may affect the performance as well. Polyethelene chips did not increase the digestibility of the concentrate, but rather the chips merely diluted the nutrients within the diet, although, if this dilution was accounted for, digestibility of the concentrate may have been increased. White concluded that the roughage source had the greatest influence on the energy digestibility.

The level of roughage has been investigated by several researchers in an attempt to determine the most advantageous use of roughages. Davis et al. (1963) found that a 7.0% fiber diet exhibited a 27% increase in consumption over a 2.6% fiber diet. Several experiments have been conducted on the level of roughage to be included in these high-concentrate rations (Dowe et al., 1955; Richardson et al., 1961; Embry and Fredrikson, 1969; Embry et al., 1969a,b). From these studies, it would appear that levels beyond 15 to 20% of the ration decrease the performance of finishing steers. Likewise, levels below 5% increase the incidence of digestive disturbances and decrease performance. No set ration has been determined as it appears to depend upon the maturity, form and kind of roughage used. Chalupa and McCullough (1967) gave a very generalized report on the nutritional evaluation of forage crops. This report emphasized the effect of physical form, mechanical processing and maturity of the forage on the digestibility and utilization of that forage.

Alfalfa Products as Roughage Sources for Ruminants. Alfalfa products have long been utilized in high-concentrate rations as roughage sources. The popularity of alfalfa is not only due to its availability but also because of its excellent vitamin and protein qualities as previously mentioned. With all of these properties combined, alfalfa offers an excellent choice for the beef producer.

Richardson *et al.* (1961) studied various levels of alfalfa hay in all-concentrate diets (corn and grain sorghum). In these studies, the diets consisted of roughage to concentrate ratios of 1:1, 1:3, 1:5 and a changing ratio alternating the above ratios every 28 days. The 1:5 diet produced the best gains. The 1:3 diet resulted in the best crude fiber digestibility and carcass traits. TDN digestibility was improved with the 1:3 and 1:5 diets over the 1:1 diet. Protein digestibility was not affected.

Embry *et al.* (1969a) fed alfalfa hay with 0, 20, 40 and 60% corn and found the greatest improvement in performance between 0 and 20% alfalfa. Embry also stated that the efficiency of roughage utilization and economy of various roughage levels depended upon the weight, degree of fatness and the production rate desired. Embry and Fredrikson (1969) found that roughages, 3 to 10% of the air-dry diet, improved gains, reduced the incidence of liver abscesses and lessened management problems in comparison to all-concentrate diets. Higher alfalfa levels lowered the additional protein supplementation required but also lowered the overall efficiency of the diet. Embry *et al.* (1969b) fed .91 kg of different forms of dehydrated alfalfa (approximately 9% of the diet) to steers and found that all forms increased gain and intake over the all-concentrate diet, with 7.6% more gain with the pelleted dehydrated alfalfa. Cattle fed all-concentrate diets exhibited less marbling and fat covering and graded lower than those receiving the .91 kg of dehydrated alfalfa. From these results, it can be concluded that the alfalfa hay and dehydrated alfalfa could make good roughage sources for high-concentrate rations at levels of 5 to 10% of the diet.

Alfalfa press cake has been studied as a protein source for ruminants. However, very little research has been conducted on the fiber value of the alfalfa press cake. Kohler et al. (1979) found that the fiber content of the press cake varied from 36.2 to 41.5% without the brown juices added back. The range depended upon the amount of Pro-Xan protein removed. These fiber contents suggest that a lower amount of press cake than the alfalfa products may be needed to supply the necessary roughage for high-concentrate diets. Research studies with cattle growing rations (Greenhalgh and Reid, 1975; Russell et al., 1978; Kohler et al., 1979) determined that this protein source did not have a significant effect on fiber digestibility of the diet. Research data on press cake in finishing diets are lacking and the effect could be much different.

Closing Statements Leading to Research Problem

Although wintering stock cows are sometimes maintained on corn stover alone, previous studies indicate a deficiency of protein, vitamin A (carotene), phosphorus and possibly calcium for any type of feeding regime other than possibly maintenance. Supplementation of even wintering animals may be necessary, depending upon winter conditions or previous feeding. Since this study was concerned with growing animals fed corn stover, it became necessary to use supplements to correct deficiencies at the least possible cost. Alfalfa hay or its products have been a choice for such supplementation. Mid-bloom alfalfa hay (NRC, 1976) has a fairly good protein value (17.1%), a very good carotene level (127.2 mg per kg), a much higher calcium level (.23%) plus a higher TDN value (55%) than corn stover. Dehydrated alfalfa, 17% protein type, has an even higher amount of these nutrients, with alfalfa press cake (Kohler et al., 1979) somewhere in between the alfalfa and the dehydrated alfalfa. Obviously, a mineral and vitamin deficiency could be balanced with a free-choice supplement mix. Alfalfa was the logical choice of feedstuff to alleviate the stover deficiencies in feeding growing steers, since alfalfa should meet these mineral and vitamin needs without additional supplementation when balanced for protein. It should also be considered that the protein contained in alfalfa has been shown to be utilized more efficiently than the protein contained in soybean meal.

When feeding finishing steers, roughage fed in conjunction with high-concentrate diets shorten the adaptation period, decreased management problems while providing for maximum efficiency and growth. Traditional alfalfa products can supply the roughage needed to meet this requirement. However, lower quality materials could probably serve the same purpose more economically. Corn alone may have an adequate supply of protein. However, corn varies greatly in its protein content. Thus, any roughage source added to the corn diet may have to contribute some additional protein in marginal cases.

Whether the press cake product can produce gains as efficiently as alfalfa may determine the product's acceptability. It should be an objective of this study to determine if the press cake can give the same improvements noted with dehydrated alfalfa and alfalfa hay and if the press cake is palatable. In addition, this study will offer the opportunity to look at the feeding of high-corn diets and to compare them to corn diets with low roughage additions. Thus, several factors may be observed with the completion of this study.

EXPERIMENT I

General

Experiment I was conducted in the fall of 1979 and the spring of 1980. A feeding trial complemented with two 5-day total collection digestion nitrogen balance trials were conducted with growing steers to evaluate the protein value of three alfalfa products, alfalfa hay, dehydrated alfalfa and alfalfa press cake (with solubles added) in ground corn stover and corn stover silage based diets. The digestion trial rations were similar in composition to the feedlot rations. All trials were conducted in a completely randomized design.

Experimental Procedures

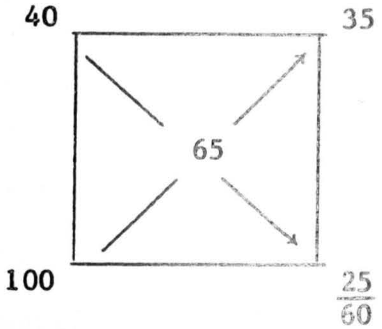
Feeds Used in Feedlot and Digestion Trials. Cornstalks were gathered into windrows in late October and early November, 1979, with a 12 E Ford rotary scythe. The corn stover was either chopped with a silage cutter equipped with a forage head or stacked with a Model 3600 Hesston stacker. The material was then transported to the Beef Cattle and Sheep Nutrition Unit, South Dakota State University.

Twenty loads of chopped corn stover were elevated into a 7.6 x 15.2 meter concrete bunker silo. Each load contained approximately 2.3 metric tons of chopped corn stover with a dry matter content of 32.5%. Each load was sampled individually, with a composite of all loads retained for analysis (table 1). Reconstitution with water was necessary to obtain a more ideal silage moisture level. The water additions were made while the stover was elevated into the bunker with

TABLE 1. INITIAL FEED COMPOSITION FOR RATION FORMULATION

Analysis	Chopped stover before reconstitution, %	Hesston stover stacks %	Alfalfa hay %	Dehydrated alfalfa %	Alfalfa press cake with solubles %
NRC Feed Reference No.	1-02-776	1-02-776	1-00-063	1-00-023	--
Moisture	65.7	73.6	90.9	92.62	93.9
Crude protein, dry matter basis	4.17	4.38	17.47	19.19	17.24
Crude fiber, dry matter basis	40.18	32.89	36.81	21.38	24.29
Ether extract, dry matter basis	.73	1.32	1.60	4.41	2.77
Ash, dry matter basis	5.84	12.12	8.93	12.88	12.30
Nitrogen-free extract, dry matter basis	49.08	49.29	35.19	42.14	43.40

a 2.5-cm pipe perforated with twelve .6-cm holes. A modification of the Pierson square method of balancing rations was utilized to calculate the desired quantity of water needed in the moisture reconstitution process (figure 2). The water was metered on as the chopped stover was elevated into the bunker silo.



$$\frac{35}{60} \times 1000 \text{ kg} = 583.3$$

$$\frac{25}{60} \times 1000 \text{ kg} = 416.7$$

$$\frac{416.7 \text{ kg}}{\text{MT}} \times \frac{1 \text{ cubic meter}}{1013 \text{ kg}} = .41 \text{ cubic meter water/MT}$$

Figure 2. Water reconstitution calculations for corn stover silage using a modified Pierson square.

It was found that the quantity of water added during delivery (.22 cubic meter/metric ton) was insufficient to reach the desired moisture content, 65%. An oscillating garden sprinkler was employed at the end of each day to reach the additional quantity of water needed. Since it was difficult to distribute the water evenly throughout the bunker by these methods, sampling was delayed to allow for moisture equilibrium to occur within the bunker. The material was continuously packed while the bunker was being filled as well as after filling was completed. Upon completion of filling, 2 1/2 days, the bunker was covered with a 6-mil, black polyethelene tarp with several used tires placed on the top of the tarp to hold it in place. The bunker silo remained covered until feeding began with the feedlot and digestion trials.

During this same period, 21 Hesston stover stacks were also delivered to the Beef Cattle and Sheep Nutrition Unit. Grab-samples were taken at random from all sides of the stacks by reaching approximately 1/3 to 1/2 meter into the stacks. Moisture determinations were made on all samples. Composites were then made from these samples for chemical analysis (table 1). The stover stacks were ground as needed during the feedlot trial in a tub grinder, approximately seven stacks per grinding, and stored under a metal hay shed. The particle size was approximately 1 to 2 cm in diameter.

Baled, medium quality alfalfa hay was ground and stored under the metal hay shed for weather protection. Commercially prepared and bagged dehydrated alfalfa meal was purchased through the university feed mill. The alfalfa press cake (with solubles added) was pelleted and shipped from Sterling, Colorado[1]. All alfalfa products were analyzed prior to ration formulation (table 1).

Throughout the feedlot study, corn stover silage samples were collected at various times from the face of the exposed bunker stover silage. Ground corn stover samples were also collected regularly throughout the trial. Due to the variable amounts of feed refused, orts were collected at the end of each weigh period and after measurable

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[1]Pro-Xan is a commercial product marketed by Valley Dehydrators, Sterling, Colorado. Press cake is the by-product of that Pro-Xan process.

amounts of precipitation. These orts were then subtracted from the stover on a dry basis to obtain the animal intake. Chemical analyses of all feeds, orts, feces and urines collected during the feedlot and digestion trials were conducted using AOAC methods (1975). Digestion trial samples were bombed for gross energy in a Parr oxygen bomb calorimeter. Moisture contents of the orts, feeds and feces samples were determined by oven drying for 72 hr at 70 C. Moisture content of the corn stover silage was also determined by toluene distillation (Dewar and McDonald, 1961). In addition, corn stover silage samples were analyzed for lactic acid (Barker and Summerson, 1941) and volatile fatty acid (VFA) contents (Baumgardt, 1964). In order to determine the dry matter (toluene), lactic acid and VFA contents, a deproteinized extract had to be prepared. Twenty-five g of wet silage in 225 ml of water were homogenized in a blender and filtered. A 1 to 10 ratio of meta phosphoric acid to extract was prepared to deproteinize the extract. Samples were frozen until needed. Lactic acid content was determined by the use of a standard curve with lithium lactate as the standard. VFA contents were measured by injection of microliter quantities of extract into a Varian 1800 series gas chromatograph with a .3 cm by 1.8 m stainless steel column (neopentyl glycol succinate with 2% phosphoric acid on chromasorb PAW) with acod pm a 60/80 mesh. VFA contents were then determined by standard curves previously established for the individual VFAs.

Feedlot Trial. Seventy-two Angus x Hereford crossbred cattle were purchased for a 2 x 3 factorially designed feedlot experiment, in which the two stover feedstuffs, corn stover silage and ground corn stover, were compared to each of the three alfalfa products, alfalfa hay, dehydrated alfalfa and alfalfa press cake (figure 3).

		Alfalfa hay	Dehydrated alfalfa	Alfalfa press cake	
Feedlot trial	Corn stover silage				Digestion trial I
	Ground corn stover				Digestion trial II

Figure 3. Design of experiment I.

The steers averaged 260 kg and were allotted to 12 pens with two replications per treatment and six steers per replication. All animals were ear tagged, implanted with Ralgro, vaccinated for blackleg and poured with Warbex. The animals were then allowed a 2-week adaptation period (rations are listed in table 2). All animals received trace mineral salt on a free-choice basis for the duration of the experiment. Shrunk weights were taken at the beginning and at the end of the experiment. Filled weights were taken at 0, 27, 55, 83 and 101 days into the feedlot trial. Feed intake, average daily gain and feed efficiency values were calculated and subjected to least squares analysis. Any significant differences were then subjected to Duncan's new multiple range test (Steel and Torrie, 1960).

TABLE 2. PERCENTAGE COMPOSITION OF FEEDLOT AND DIGESTION TRIAL RATIONS ON A DRY BASIS[a]

Feedstuff	Percent of ration	Crude protein, %[b]
Corn stover silage	48	2.0
Alfalfa hay	52	9.1
	100	11.1
Corn stover silage	54	2.3
Dehydrated alfalfa	46	8.8
	100	11.1
Corn stover silage	47	2.0
Alfalfa press cake	53	9.1
	100	11.1
Ground corn stover	48	2.1
Alfalfa hay	52	9.1
	100	11.2
Ground corn stover	54	2.4
Dehydrated alfalfa	46	8.8
	100	11.2
Ground corn stover	47	2.1
Alfalfa press cake	53	9.1
	100	11.2

[a] All rations were adequate in calcium, phosphorus and vitamin A (carotene). Trace mineral salt was provided on a free-choice basis for all feedlot animals.

[b] Calculated values.

Digestion-Metabolism Trials. Total collection digestion-metabolism trials were conducted with the same rations utilized in the feedlot study (table 2). However, the digestion-metabolism trials were conducted separately for the corn stover silage and the corn stover rations (see figure 3). Twelve Simmental x Hereford steers were weighed and allotted to the three stover-alfalfa treatments with four steers per treatment. The steers were allowed 3 weeks to adjust to the diets. Maximum feed intake was established during the initial adjustment period. The steers were then reweighed and placed in the digestion crates and allowed 4 days to adapt to the crates. The steers were fed twice daily while in the crates with orts weighed daily. Collection vessels were positioned on the morning of the first collection day. Twenty ml of 50:50 HCl were pipetted daily into each urine vessel throughout the entire collection period as a preservative for the urine. Fecal collections were taken in the morning for each of the 5 collection days. Urine collections were made each evening, with the final collection taken the morning of the last fecal collection. Ten percent aliquots were saved from all fecal and urine collections with a composite made for each animal. Representative samples of feeds and orts were also collected daily and composited for chemical analyses. Similar procedures were then followed for the second digestion-metabolism trial.

Chemical analyses for total nitrogen, ash, moisture and gross energy were determined on all feed, orts and feces. Total nitrogen was determined for the urine samples. Dry matter, organic matter, crude protein and energy digestibilities and nitrogen retention values were computed.

All digestion trial data were subjected to least squares analysis. Any data exhibiting significant differences in the least squares analysis were subjected to Duncan's new multiple range test (Steel and Torrie, 1960).

Results and Discussion

Feeds Used in the Feedlot and Digestion Trials. Table 3 lists a summary of the ten daily composite samples taken as the corn stover silage was removed from the bunker silo at various times throughout the trial. The moisture content of the corn stover silage tended to decrease (approximately 10%) as the feedlot trial progressed, with an average oven-dry matter of 46.8%. Ash content also tended to decrease as the trial progressed, with an average ash content of 7.2% on a dry basis. Crude protein, on the other hand, varied irregularly throughout the trial with an average protein content of 5.5% on a dry basis. Lactic acid content of the stover silage averaged 2.13% on a dry basis. However, during the first month of feeding the stover silage, the lactic acid content was very low. The volatile fatty acids were in a desirable range, equivalent to medium quality corn silage, with a higher amount of acetic acid, negligible amounts of butyric acid and with propionic acid intermediate. Titratable acidity was at 6.2%. It should be noted that the stover silage samples were collected during feeding from the face on the bunker stover material. Thus, the sample analyses shown in table 3 would vary due to time and location within the bunker.

As the stover silage was removed and fed, two layers of mold corresponding to the levels at which the oscillating garden sprinkler was employed were also noted. The moisture added by the garden sprinkler did not appear to penetrate very far into the chopped stover to aid in achieving the desired moisture content. This resulted in the

TABLE 3. PROFILE OF DAILY COMPOSITE SAMPLES OF CORN STOVER SILAGE TAKEN AT VARIOUS TIMES THROUGHOUT THE FEEDLOT TRIAL ON A DRY MATTER (DM) BASIS

Date	Oven dry matter %	Toluene dry matter %	Ash % DM	Crude protein[a] % DM	Ammonia nitrogen % DM	Lactic acid % DM	Total VFA: Acetic % DM	Total VFA: Propionic % DM	Total VFA: Butyric % DM	Titratable acidity
1/18/80	39.7	37.9	7.9	5.6	.017	.57	1.89	.67	--	--
1/23/80	42.2	41.6	7.6	5.6	.107	.20	1.47	.80	--	.35
1/28/80	39.5	40.3	7.6	5.5	.018	.67	1.93	.57	trace	3.50
2/1/80	43.3	42.3	6.9	5.7	.026	2.08	3.83	1.09	trace	6.60
2/18/80	47.0	47.8	7.0	5.1	.027	3.81	2.03	.24	.02	8.43
3/19/80	46.0	47.3	7.0	5.0	.023	2.02	1.27	.24	trace	4.15
4/19/80	57.5	56.5	6.8	6.0	.043	3.76	3.55	1.34	.02	10.19
5/19/80	51.0	52.9	6.5	5.3	.039	2.81	1.61	.51	trace	12.43
6/6/80	51.9	52.8	7.2	5.6	.028	1.73	1.06	.34	--	3.66
7/3/80	50.4	50.7	7.0	5.3	.043	3.61	2.06	.66	.04	12.73
Average	46.8	47.0	7.2	5.5	.028	2.13	2.07	.65	.01	6.20

[a] Crude protein = total nitrogen x 6.25.

two layers of mold. However, moisture content of the reconstituted stover was adequate for fermentation to occur.

The average composition of all feeds used in the feedlot and digestion trials are listed in table 4. Although crude protein values were very similar between the ground corn stover and the corn stover silage, the ash content of the ground corn stover was nearly twice as high as that for the stover silage in the feedlot trial. Even in the digestion trials, the ash content of the ground stover was notably higher than with the corn stover silage. This increased ash content was probably due to higher amounts of soil picked up in the grinding and feeding of the stover stacks. The corn stover silage was stored on a concrete floor, whereas the stover stacks were stored directly on the ground and after grinding on a gravel base. Thus, the opportunity for higher contamination of the stover stacks with soil during grinding and feeding was much greater than with the stover silage.

The high initial moisture content (26.36%) of the stover stacks contributed to some spoilage and caused the material to heat after grinding. Spoilage also increased toward spring in both the ground stover stacks and the corn stover silage.

The alfalfa press cake and the alfalfa hay had very similar protein values in the initial analysis for ration formulation (17.47 and 17.24%, respectively), while the value for dehydrated alfalfa was slightly higher at 19.19% (table 1). Similar protein contents were noted for the three alfalfa products in the feedlot study (table 4). However, the press cake had a lower protein content when analyzed

TABLE 4. CHEMICAL COMPOSITION OF FEEDS ON A DRY BASIS

Item	Stover silage %	Ground stover %	Alfalfa hay %	Dehy-drated alfalfa %	Alfalfa press cake %
NRC Reference No.	1-02-776	1-02-776	1-00-063	1-00-023	--
Feedlot Trial (3/14-6/24/81)					
Dry matter	46.85	73.64	89.06	93.17	94.25
Crude protein[a]	4.85	4.39	17.55	20.03	16.94
Ash	8.31	16.44	9.75	12.19	12.50
Digestion Trial (2/15-2/20/81)					
Dry matter	46.04	--	86.25	94.93	94.62
Crude protein	4.81	--	17.63	19.19	15.19
Ash	8.22	--	10.56	10.74	12.55
Gross energy, Kcal/g	4.08	--	4.24	4.46	4.15
Digestion Trial (3/24-3/29/81)					
Dry matter	--	64.74	86.94	91.96	94.24
Crude protein	--	4.41	20.88	23.38	15.88
Ash	--	10.55	10.62	12.96	12.65
Gross energy, Kcal/g	--	3.80	4.06	4.23	4.17

[a] Crude protein = total nitrogen x 6.25.

in the digestion trials. Also, the alfalfa hay and the dehydrated alfalfa exhibited an even higher protein content in the digestion trial.

Feedlot Trial. Results of the feedlot study are listed in table 5. In viewing the stover differences irregardless of the alfalfa supplement (table 6), the steers fed the ground corn stover diets had slightly higher average daily gains but higher feed requirements than those steers fed the corn stover silage diets. Steers on the ground corn stover diets also had increased feed intake over the steers on the

TABLE 5. OVERALL FEEDLOT PERFORMANCE OF STEERS FED ALFALFA-STOVER DIETS (MARCH 14-JUNE 23, 1980--101 DAYS)

Item	Alfalfa press cake		Alfalfa hay		Dehydrated alfalfa	
	Stover silage	Ground stover	Stover silage	Ground stover	Stover silage	Ground stover
Number of animals	12	12	12	12	12	12
Initial shrunk weight, kg	259	263	255	257	262	251
Final shrunk weight, kg	295	305	287	284	300	300
Avg daily intake (DM), kg	5.9	6.5	5.9	6.6	6.2	7.6
Avg daily gain (shrunk), kg	.36	.40	.30	.27	.37	.43
Feed/kg gain (shrunk), kg	16.2	16.2	19.7	24.3	16.7	17.7

TABLE 6. FEEDLOT PERFORMANCE OF CORN STOVER-BASED DIETS IRREGARDLESS OF ALFALFA SUPPLEMENT

Item	Average of all stover silage	Average of all ground stover	$S\bar{x}$
Number of animals	36	36	--
Initial shrunk weight, kg	259	257	--
Final shrunk weight, kg	294	296	--
Avg daily intake (DM), kg	6.0	6.9	±.032
Avg daily gain (shrunk), kg	.34	.37	±.043
Feed/kg gain (shrunk), kg	17.5	19.4	±.660

corn stover silage diets. Overall, however, there were no significant differences between the corn stover and corn stover silage fed steers.

As there were no interactions between the stover treatments, the alfalfa supplements could be compared (table 7). Average daily gain was improved significantly ($P<.05$) with steers fed the dehydrated alfalfa and the alfalfa press cake diets over that for steers fed the alfalfa hay diets. Although not significant, the steers on the dehydrated alfalfa diets exhibited slightly higher average daily gains than those steers fed the alfalfa press cake. However, the steers fed the alfalfa press cake diets had lower feed requirements than those steers fed the dehydrated alfalfa diets. Daily intake was highest for the steers on the dehydrated alfalfa diets (6.9 kg), followed in order by the steers fed the alfalfa hay (6.3 kg) and alfalfa press cake (6.2 kg) diets.

TABLE 7. FEEDLOT PERFORMANCE OF THE ALFALFA-SUPPLEMENTED DIETS IRREGARDLESS OF STOVER TREATMENTS

Item	Alfalfa press cake	Alfalfa hay	Dehydrated alfalfa	$S\bar{x}$
Number of animals	24	24	24	--
Initial shrunk weight, kg	261	256	256	--
Final shrunk weight, kg	300	286	300	--
Avg daily intake (DM), kg	6.2	6.3	6.9	±.766
Avg daily gain (shrunk), kg	.38[a]	.29[b]	.40[a]	±.035
Feed/kg gain (shrunk), kg	16.2	22.0	17.0	±3.907

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

The results of this trial concur with results observed by other workers (Bentley 1956; Gossett, 1956; Cheng, 1953; Bickoff, 1960; Pfander, 1977) in showing improved gains for low quality, high roughage feeds with dehydrated alfalfa supplementation to the diet. The improved steer performance when feeding the dehydrated alfalfa supplemented diets was significantly higher (P<.05) than that for steers fed the alfalfa hay supplemented diets. Alfalfa press cake was shown to give similar responses in gain and feed efficiency when compared to the dehydrated alfalfa in low quality, high roughage corn stover diets. Therefore, it can be concluded that the alfalfa press cake would make a more desirable substitute for dehydrated alfalfa in high-roughage growing diets than alfalfa hay. There also appears to be no significant advantage for either gain or feed efficiency when using corn stover silage or ground corn stover for growing steers.

<u>Digestion-Metabolism Trials</u>. In experiment I, a digestion trial was conducted on the three alfalfa products tested in corn stover silage-based diets (table 8). Alfalfa hay diets exhibited significantly higher dry matter (DM) digestibility and organic matter digestibility than the other two alfalfa diets, corresponding to the decreased DM intake. Crude protein digestibility of all alfalfa diets tested was significantly different, with alfalfa hay diets the highest (66.93%), dehydrated alfalfa diets intermediate (59.95%) and alfalfa press cake the lowest (52.78%). Digestible energy followed the same trend. However, only the alfalfa hay diets and the alfalfa press cake diets were significantly different ($P<.05$).

The increased digestibility of the crude protein with alfalfa hay resulted in correspondingly lower values for fecal nitrogen excreted and higher urinary nitrogen excreted than the other two alfalfa diets. The dehydrated alfalfa diets with their intermediate digestibility coefficients exhibited approximately equal amounts of nitrogen excreted as urine and feces. Steers fed the alfalfa press cake, on the other extreme of the alfalfa hay, exhibited higher fecal nitrogen losses due to lower digestibility. However, urinary nitrogen losses were significantly lower than the other two alfalfa diets. It was interesting to note that there was no difference in nitrogen retention. In fact, the trend of the nitrogen retention values tended to show increased retention with decreased digestibility. The press cake diets tended to have the highest retention but the lowest digestibility, with the dehydrated alfalfa intermediate and the alfalfa diets the opposite.

TABLE 8. DIGESTIBILITY IN STEERS OF CORN STOVER SILAGE WITH VARIOUS ALFALFA PRODUCTS

Item	Alfalfa hay	Dehydrated alfalfa	Press cake	$S\bar{x}$
Number of animals	4	4	3	--
Avg weight, kg	300	299	301	--
Dry matter intake, kg	4.5	5.4	5.5	--
Nitrogen intake, g	86.7	101.0	93.5	--
Digestibility, %				
Dry matter	60.28[a]	56.53[b]	55.62[b]	±.86
Crude protein	66.93[a]	59.95[b]	52.78[c]	±1.06
Energy	58.60[a]	56.58[a,b]	53.95[b]	±.93
Organic matter	61.61[a]	57.50[b]	57.02[b]	±1.05
Nitrogen (N) retention				
Fecal N excreted, g	28.6[a]	40.5[b]	44.2[b]	±8.84
Urinary N excreted, g	42.1[a]	41.1[a]	30.5[b]	±10.88
Total N excreted, g	70.7	81.6	74.7	--
Percent N retained	18.6	19.3	20.0	±1.82

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

Another digestion trial (table 9) in experiment I was conducted with the three alfalfa products and ground stover. Digestibility of crude protein was significantly lower ($P<.01$) for the press cake-supplemented diets than for the other two alfalfa-supplemented diets, even though dry matter intake was lower for the steers fed the press cake diets. Crude protein digestibility of the alfalfa supplements when analyzed at the .05 level exhibited significant differences among all three alfalfa products. There were no differences in digestible dry matter, organic matter or energy among the three alfalfa products. This suggested that the Pro-Xan fraction extracted the higher quality protein and perhaps the more soluble proteins, leaving the less digestible proteins in the press cake fraction. Protein quality was

TABLE 9. DIGESTIBILITY IN STEERS OF GROUND STOVER STACKS WITH VARIOUS ALFALFA PRODUCTS

Item	Alfalfa hay	Dehydrated alfalfa	Press cake	$S\bar{x}$
Number of animals	4	4	4	--
Avg weight, kg	307	307	297[a]	--
Dry matter intake, kg	5.6	6.6	5.5	--
Nitrogen intake, g	121.7	146.3	99.6	--
Digestibility, %				
Dry matter	56.95	55.53	57.31	±1.03
Crude protein	66.19[b]	61.66[c]	54.13[d,e]	±1.06
Energy	60.15	60.61	60.94	±.69
Organic matter	61.41	60.97	61.33	±1.04
Nitrogen (N) retention				
Fecal N excreted, g	41.1	56.2	45.7	±17.35
Urinary N excreted, g	56.5[a]	58.0[a]	30.5[b]	±11.09
Total N excreted, g	97.6	114.2	76.2	--
Percent N retained	19.8	22.0	23.3	±1.30

[a] One steer from the first digestion trial replaced with a lighter steer.

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

[e] Means differ significantly ($P<.01$).

not examined in this experiment since crude protein as determined by Kjeldahl nitrogen or total nitrogen analysis does not evaluate protein quality. However, some conclusions as to the protein quality could be drawn from the differences in digestibility of the crude protein and the nitrogen excretion and retention.

Fecal nitrogen excreted and urinary nitrogen excreted were significantly different ($P<.05$) for the alfalfa supplements when analyzed by least squares analysis. When subjected to Duncan's new multiple range test, however, no differences could be detected among alfalfa supplements in fecal nitrogen excreted. Urinary nitrogen excreted by the steers fed the press cake diets was significantly lower (P<.01) than by steers fed the other two alfalfa diets. No differences (P<.05) could be detected between the alfalfa hay and the dehydrated alfalfa fed steers in either urinary nitrogen excreted or fecal nitrogen excreted.

EXPERIMENT II

General

Experiment II was conducted in the fall of 1980 and the spring of 1981. A feeding trial complimented with two 5-day total collection digestion-nitrogen balance trials was conducted with finishing steers to evaluate the fiber benefits of the three alfalfa products, alfalfa haylage, dehydrated alfalfa and alfalfa press cake (with solubles added), in corn-based diets. Digestion trial rations were similar in composition to the feedlot rations. All trials were conducted in a completely randomized design.

Experimental Procedures

Feeds Used in Feedlot and Digestion Trials. Field harvested, number 2, yellow, dent corn was reconstituted with water using a 2.5-cm pipe perforated with twelve .6-cm holes attached to a common garden hose. The corn was stored and ensiled in a Harvestore silo at the Beef Cattle and Sheep Nutrition Unit at South Dakota State University. Samples were collected for moisture and other chemical analyses prior to the initiation of the trial for ration formulation (table 10) and as the material was removed for feeding.

Alfalfa hay bales (89.15% dry matter) were ground and reconstituted with water using the same perforated pipe used in the reconstitution of the corn. The reconstituted alfalfa was also stored and ensiled in a Harvestore silo. Samples were collected for moisture and chemical analyses at the time of storage (table 10) and as the material was removed for feeding.

TABLE 10. PROXIMATE ANALYSIS OF FEEDS USED IN RATION FORMULATION FOR THE FEEDLOT TRIAL ON A DRY BASIS

Item	Dehydrated alfalfa	Alfalfa haylage	Alfalfa press cake	Corn
NRC Feed Reference No.	1-00-023	1-00-063	--	4-02-931
Dry matter	94.0	59.0	94.0	70.0
Crude protein	18.9	17.1	17.2	11.6
Crude fiber	26.6	35.7	24.3	2.0
Ether extract	2.9	2.4	2.8	4.5
Ash	10.9	9.6	12.3	1.7
Nitrogen free-extract	40.7	35.1	43.4	80.2

Pelleted dehydrated alfalfa was purchased through the local university feed mill with samples taken upon delivery for analysis (table 10). The same batch of pelleted alfalfa press cake delivered from Sterling, Colorado, for experiment I was also used in experiment II. Thus, the same analysis obtained from the composite in the first feedlot trial was used for ration formulation in the second feedlot trial (experiment II) and is shown in table 10. Additional samples were collected throughout the trial as the dehydrated alfalfa and the alfalfa press cake were removed for feeding.

In the initial analysis of the corn, it was found that the crude protein (11.6%) was adequate to meet the requirements of the animals (NRC, 1976). In order to minimize any effect of additional protein and still test the effect of fiber in the diet treatments, the following rations were formulated (dry matter basis) and used for the feedlot and digestion trials: 100% corn (control), 92% corn-8% alfalfa haylage, 92% corn-8% dehydrated alfalfa and 92% corn-8% alfalfa press cake with solubles.

Chemical analyses of all feeds, orts, feces and urines were conducted using AOAC methods (1975). Moisture contents of orts, feeds and feces samples were determined by oven drying for 72 hr at 70 C. Van Soest's (1963) method of analyzing acid detergent fiber was also used on feeds, orts and feces.

Feedlot Trial. Sixty-four Hereford x Angus and 32 Hereford x Simmental crossbred cattle averaging 326 kg (shrunk) were allotted according to size and breed into four treatments with four replications per treatment and six steers per replication. Blocks of four pens were established so that one replication of each treatment was randomly assigned within each block. The steers used in experiment I were carried over into experiment II for finishing. Additional animals were purchased to bring the total up to 96 crossbred steers. All animals were implanted with Ralgro, poured with Warbex, injected with 3 million IU of vitamin A and injected with Bovibac 3 (an attenuated suspension of Escherichia coli, Salmonella typhimurium, Pasteurella multicoda and Pasteurella haemolytica) for prevention of pinkeye. Steers from two blocks or two replications of each treatment were also injected with Tramisol, an antihelminth. Fecal samples were collected from these same steers in order to estimate the parasitic load or infestation of the animals used. The Tramisol study was superimposed on this experiment to be used as a part of a long-term study being conducted at South Dakota State University.

The steers were then allowed a 10-day ration adaptation period in order to adjust the animals to the high-concentrate diets. The animals were given 9.1 kg of alfalfa haylage and 2.3 kg of corn (as fed). The corn was increased daily at a rate of .5 kg per day as the alfalfa haylage was decreased daily at 5.5 kg per day (as fed). At the end of the 10-day adaptation period, the animals were reweighed and fed the experimental rations. A 50:50 mixture of limestone and trace mineral salt was provided throughout the trial to all animals on a free-choice basis with weighbacks taken regularly to establish mineral intake. Shrunk weights were taken at the beginning and at the conclusion of the trial. Filled weights were taken 0, 28, 56, 84 and 111 days into the trial. Feed samples were taken monthly for moisture determination and composited for additional chemical analyses. All animals were allowed maximum feed intake after adjusting to the rations. Orts collected were subtracted from the corn. Feed intake, average daily gain and feed efficiency values were calculated and subjected to least squares analysis. Any significant differences were then subjected to Duncan's new multiple range test (Steel and Torrie, 1960).

Digestion-Metabolism Trials. Total collection digestion-metabolism trials were conducted with the rations similar to those used in the feedlot study. However, dry cracked corn was substituted in the digestion trials for the high-moisture corn utilized in the feedlot trial on an equal dry matter basis. The two digestion trials were conducted using similar procedures. Twelve Limousin crossbred steers were weighed and allotted to the four treatments with three steers per treatment. Initially, the steers were allowed 5 weeks to adapt to the high-concentrate diets, with a 2-week adaptation period between trials to adjust to a treatment switch. Maximum feed intake was established during the adjustment period. The steers were then reweighed and placed in the metabolism crates and allowed 4 days to adapt to the crate. The steers were fed 95% of their maximum intake once daily. Collection vessels for urine and feces were positioned on the morning of the first collection day. Twenty ml of 50:50 HCl were pipetted daily into each urine vessel for the duration of the collection period as a preservative for the urine. Fecal collections were taken in the morning for each of the 5 collection days. Urine collections were taken in the evening, with the final collection made the morning of the last fecal collection. Ten percent aliquots were saved from all fecal and urine collections with a composite retained for each steer. Representative samples of feeds were also collected daily and composited for chemical analyses.

Results and Discussion

Feeds Used in Feedlot and Digestion Trials. Chemical analyses of the composite samples of feeds used in the feedlot trial are listed in table 11. In all feeds used, the protein content was slightly less in the subsequent analysis than in the initial analysis (see table 10). Feed moisture content remained fairly constant throughout the trial.

TABLE 11. PROXIMATE ANALYSIS OF FEEDS USED IN FEEDLOT TRIAL ON A DRY MATTER BASIS

Item	Alfalfa haylage	Dehydrated alfalfa	Alfalfa press cake	Corn
NRC Feed Reference No.	1-00-063	1-00-023	--	4-02-931
Dry matter	62.26	93.99	93.34	73.01
Crude protein	16.0	18.1	15.5	11.0
Crude fiber	32.4	26.2	25.6	2.07
Ether extract	2.13	2.74	2.36	4.62
Ash	8.95	10.3	12.06	1.68
Nitrogen-free extract	40.6	42.6	44.4	80.6
Acid detergent fiber[a]	38.30	32.04	33.26	4.85

[a] As analyzed by Van Soest (1963).

Chemical analyses of the feeds used in the digestion trials are listed in table 12. The protein value of the alfalfa haylage was 3% higher in the digestion trial feeds than in the feedlot feeds, probably due to variation within the silo. Acid detergent fiber content of the three alfalfa products followed the same pattern as the feedlot feeds with alfalfa haylage the highest, followed in order by the alfalfa press cake and the dehydrated alfalfa. The alfalfa haylage had the lowest ash content of the alfalfa products, with alfalfa press cake the highest in ash and the dehydrated alfalfa intermediate. As noted later, this ash content may have some bearing on mineral consumption, as those steers fed diets containing less ash consumed more mineral. The corn used in the digestion trial was dry cracked corn (average 87% dry matter), while the feedlot trial was conducted using high-moisture corn (73% dry matter).

TABLE 12. ANALYSIS OF FEEDS USED IN DIGESTION TRIALS ON A DRY MATTER BASIS

Item	Alfalfa haylage	Dehydrated alfalfa	Alfalfa press cake	Corn
NRC Feed Reference No.	1-00-063	1-00-023	--	4-02-931
	Digestion Trial 3			
Dry matter	56.77	92.70	94.20	87.16
Crude protein	19.38	18.63	16.19	9.94
Ash	9.57	10.23	11.46	1.70
Acid detergent fiber	35.46	32.83	33.48	6.01
	Digestion Trial 4			
Dry matter	55.09	92.46	94.08	86.89
Crude protein	19.38	19.06	15.88	10.94
Ash	8.70	9.86	10.95	2.03
Acid detergent fiber	35.47	32.82	33.66	5.36

Feedlot Trial. A very low parasitic load was noted in this group of cattle. Thus, the superimposing of Tramisol may not have been necessary but should contribute to the potential for maximum gain and efficiency. The initial parasitic load included a moderate load of *Coccidia*, a few nematodes, with very few *Nematodirus*. Steers were practically devoid of *Trichuris*.

Results of the feedlot study are listed in table 13. Feed intake of the steers fed the four treatment diets was not significantly different, although it would appear that steers fed the control diet (100% corn) did have the lowest feed intake. Average daily gain of the feedlot steers was numerically highest with the dehydrated alfalfa

TABLE 13. FEEDLOT PERFORMANCE OF STEERS FED CORN-ALFALFA DIETS (AUGUST 1-NOVEMBER 20, 1980--111 DAYS)

Item	92% corn 8% haylage	92% corn 8% alfalfa press cake	92% corn 8% dehydrated alfalfa	100% corn	$S\bar{x}$
Number of animals	24	24	24	24	--
Initial filled weight, kg	303	303	301	303	--
Final filled weight, kg	522	513	523	504	--
Initial shrunk weight, kg	298	300	295	298	--
Final shrunk weight, kg	510	502	513	493	--
Avg feed intake (DM basis), kg	10.01	10.02	10.14	9.29	±.000
Avg daily gain (shrunk), kg	1.91[a]	1.83[a,b]	1.96[a]	1.76[b]	±.225
Feed/kg gain (shrunk), kg	5.25	5.49	5.18	5.30	±.000

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

supplemented diets (1.96 kg), followed in order by the alfalfa haylage supplemented diets (1.91 kg), alfalfa press cake supplemented diets (1.83 kg) and the control diets (1.76 kg). Steers fed the control diets had significantly lower average daily gains than those steers fed the dehydrated alfalfa supplemented diets and the alfalfa haylage supplemented diets. There was no difference among the three alfalfa supplemented diets for average daily gain. Feed efficiency, although not significantly different, showed a trend suggesting that dehydrated alfalfa supplemented diets were utilized the most efficiently followed in order by the alfalfa haylage supplemented diets, control diets and alfalfa press cake supplemented diets.

Animals in this trial utilized their feed extremely well and also exhibited extraordinarily high average daily gains. Some of this improved performance over the average expected performance could be accounted for by the good health of the animals and the extremely good weather conditions experienced during the course of this study which was conducted in the fall, 1980. The animals may also have exhibited some compensatory growth as noted in other studies (Meyer et al., 1965; Fox et al., 1972). Compensatory growth was possibly due to the fact that the majority of the animals used in this experiment were also utilized in experiment I. The steers were fed a very low quality, high-roughage diet in experiment I when their gains were very poor. These poor gains may have been compensated for during experiment II, when the animals were given every opportunity to reach maximum gains and efficiency.

In summarizing the performance of the animals in this study, it can be concluded that alfalfa supplementation to corn diets did improve steer performance over feeding the all-corn control diets. Although not significantly different, the dehydrated diets tended to give the highest performance of the three alfalfa supplemented diets, and the alfalfa press cake tended to give the lowest performance with the alfalfa haylage supplemented diets intermediate. However, these differences were not significant and should therefore be noted as having no differences among alfalfa treatments.

Mineral consumption of the various treatment groups as collected throughout the trial is listed in table 14. The mineral mix, a 50:50 mixture of limestone and trace mineral salt, was consumed more readily by those animals fed the control and the alfalfa haylage diets than those animals fed the dehydrated alfalfa and the alfalfa press cake supplemented diets.

Digestion-Metabolism Trials. In the first digestion trial of experiment II (IIa, table 15) there was no significant difference in the digestibilities of dry matter, crude protein, acid detergent fiber or organic matter in steers. Dry matter intake was the highest in steers fed the corn-haylage diet (28.6 kg), followed in order by the corn-press cake (25.5 kg), corn-dehydrated alfalfa (23.9 kg) and all-corn control (22.5 kg). Dry matter, crude protein, acid detergent fiber and organic matter digestibilities tended to follow the reverse of the dry matter intake, with the steers fed the all-corn diets the

TABLE 14. TOTAL MINERAL CONSUMPTION BY FEEDLOT STEERS (111 DAYS)[a]

Pen number	Total mineral consumed kg	Avg mineral consumed per steer kg
	Dehydrated Alfalfa Diets	
9	93.8	
16	57.7	
20	61.2	
23	93.4	
Avg	76.5	12.8
	Haylage Diets	
10	111.5	
13	83.4	
19	92.9	
22	74.4	
Avg	90.6	15.1
	Alfalfa Press Cake Diets	
11	82.6	
15	71.0	
18	79.8	
21	65.8	
Avg	74.8	12.5
	Control Corn Diets	
12	106.8	
14	109.4	
17	62.7	
24	84.5	
Avg	90.8	15.1

[a] Mineral mix composed of 50:50 limestone to trace mineral salt.

TABLE 15. DIGESTIBILITIES IN STEERS OF CORN AND CORN WITH ALFALFA PRODUCTS DIETS (EXPERIMENT IIa)

Item	100% corn	92% corn 8% alfalfa haylage	92% corn 8% alfalfa press cake	92% corn 8% dehydrated alfalfa	$S\bar{x}$
Number of animals	2	3	3	3	--
Average weight, kg	302	304	304	305	--
Dry matter intake, kg	4.5	5.7	5.1	4.8	--
Nitrogen intake, g	74.3	101.8	82.0	85.1	--
Digestibility, %					
Dry matter	84.7	73.4	77.5	80.3	± 2.60
Crude protein	68.5	63.3	64.8	65.7	± 2.47
Acid detergent fiber	53.5	39.1	49.2	52.8	± 4.71
Organic matter	85.4	73.9	78.1	81.0	± 2.65
Nitrogen (N) retention					
Fecal N excreted, g	23.5	37.4	28.3	28.3	± 7.57
Urinary N excreted, g	131.7	145.1	160.7	218.0	±49.56
Total N excreted, g	155.2	182.5	188.0	246.3	--
Percent N retained	-108.9	-79.4	-130.6	-189.6	±20.36

highest, followed by the corn-dehydrated alfalfa diets, corn-press cake diets and the corn-haylage diets.

In the second digestion trial of Experiment II (IIb, table 16), the same treatment diets were tested except that the animals were switched to different treatments. Dry matter, crude protein, acid detergent fiber and organic matter digestibilities were not significantly different. However, the digestibility coefficients did not inversely relate to the dry matter intake as in the first digestion trial. For example, dry matter intake of the corn-dehydrated alfalfa fed steers was the highest of the four treatment diets. Dry matter, crude protein and organic matter digestibilities of the corn-dehydrated alfalfa fed steers were also the highest of the four treatment diets. The steers fed the corn-press cake diets were intermediate in dry matter intake but had the lowest digestibility of dry matter, crude protein, acid detergent fiber and organic matter. In both digestion trials, the steers fed the all-corn control had the lowest feed intake.

The animals used in the digestion trials of experiment II were difficult animals to work with. Several problems with ringworm, acidosis and ration adaptation were noted. It was very difficult to establish maximum feed intake as the animals went off feed several times. The problems appeared to be much more severe in digestion trial IIa than in digestion trial IIb, as several animals went off feed in the middle of the collection period in IIa. For this reason, the data from the two digestion trials were not pooled for statistical analysis. In

TABLE 16. DIGESTIBILITIES IN STEERS OF CORN AND CORN WITH ALFALFA PRODUCTS DIETS (EXPERIMENT IIb)

Item	100% corn	92% corn 8% alfalfa haylage	92% corn 8% alfalfa press cake	92% corn 8% dehydrated alfalfa	$S\bar{x}$
Number of animals	3	3	3	2	--
Average weight, kg	325	327	333	333	--
Dry matter intake, kg	4.5	5.3	5.1	5.7	--
Nitrogen intake, g	81.7	100.8	95.9	108.6	--
Digestibility, %					
Dry matter	78.7	76.6	76.1	80.4	± 2.36
Crude protein	65.7	63.8	60.8	70.1	± 3.00
Acid detergent fiber	46.3	39.6	30.5	45.8	± 5.19
Organic matter	79.1	77.0	76.5	80.7	± 2.41
Nitrogen (N) retention					
Fecal N excreted, g	27.7	36.7	36.7	33.0	±13.77
Urinary N excreted, g	197.6	189.0	191.8	146.6	±72.26
Total N excreted, g	225.3	225.7	228.5	179.6	--
Percent N retained	-175.8	-123.8	-138.4	-65.4	±23.22

both digestion trials of experiment II, the steers tended to lose or barely maintain their initial weight while in the metabolism crates. This was evidenced by a negative nitrogen balance in all steers on trial.

SUMMARY

In a feedlot study conducted with 72 growing Angus x Hereford calves, supplementation of ground corn stover and corn stover silage with dehydrated alfalfa and alfalfa press cake significantly improved average daily gain over supplementation with alfalfa hay (.40 kg, .38 kg and .29 kg, respectively). Feed intake was the highest with the steers fed stover supplemented with dehydrated alfalfa, followed in order by alfalfa hay and alfalfa press cake. Feed efficiency tended to be improved more by supplementation with alfalfa press cake (16.2 kg) than with dehydrated alfalfa (17.0 kg) or alfalfa hay (22.0 kg). There appeared to be no significant advantage in using either ground corn stover or corn stover silage in feed efficiency or average daily gain.

Two digestion-metabolism trials were also conducted with steers on the same rations. Although dry matter, organic matter and energy digestibilities were not consistently different in either trial, crude protein digestibility among treatments within each trial was significantly different. Corn stover supplemented with alfalfa hay had the highest digestibility in steers with dehydrated alfalfa supplemented diets intermediate and alfalfa press cake the lowest. Even though the alfalfa press cake supplemented diets had the lowest crude protein digestibility, the steers fed these diets had the greatest nitrogen retention followed in order by steers fed the dehydrated alfalfa and the alfalfa hay diets.

Results of the second feedlot study conducted with 96 crossbred steers finished with corn supplemented with alfalfa products suggested no significant benefit in feed efficiency or feed intake from the supplementation of the alfalfa products. A significant benefit in average daily gain was observed by the addition of the three alfalfa products to an all-corn diet. Even though a benefit in average daily gain was noted by supplementation with the alfalfa products, no differences could be detected among the alfalfa products.

Two digestion-metabolism trials conducted with the same finishing rations of corn supplemented with the alfalfa products exhibited no significant differences in digestibility of dry matter, crude protein, organic matter or acid detergent fiber.

In retrospect from results obtained from this study, it would appear that alfalfa press cake would make a more desirable supplement to corn stover than alfalfa hay. Alfalfa press cake would also make a suitable substitute for dehydrated alfalfa if dehydrated alfalfa would become cost prohibitive. Although the corn stover-alfalfa rations were balanced for 11% protein, gains were still disappointing. Although fiber digestibility *per se* was not determined, dry matter digestibility (55 to 60%) would suggest higher possible gains. It has been suggested that ammoniating fibrous feedstuffs can increase utilization. This ammoniation supplemented with a higher energy feedstuff may increase the gains with diets such as corn stover.

From the results of experiment II, alfalfa products appear to be a beneficial supplement to high corn diets as reflected in higher gains. Gains were not different among steers fed the alfalfa supplements. However, the gains of steers fed the alfalfa supplements were significantly improved over those for steers fed all-corn diets. This slight improvement in average daily gain may warrant the roughage addition. These results suggest that any of the three alfalfa products when supplemented at low levels to all-corn diets would give similar gains. Any type of roughage addition has been shown to alleviate many management problems with lower occurrences of liver abscesses.

In conclusion, this study has been helpful in demonstrating the potential of alfalfa press cake as a protein supplement. This study has raised other questions, however, that need additional research. Alfalfa press cake has proved to be comparable to dehydrated alfalfa and alfalfa hay in steer performance; but, as evidenced in the digestion trials, it is utilized differently, possibly due to some rumen bypass qualities. However, it was not the purpose of this study to analyze for rumen bypass qualities per se. Thus, additional information on how this protein is utilized may help to understand the effectiveness of the press cake product. In order to study this difference in utilization, the alfalfa products would have to be the major component in the diet rather than a supplement.

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