INTRODUCTION

The majority of ruminant livestock production occurs in temperate grasslands where animals are allowed to graze or are fed harvested forages (i.e., hays or silages). As a result, forages comprise 50 to 90% of total feed consumed by ruminants during their production cycle (Reid and Jung, 1982). In the U.S., beef cattle production is often viewed as an intensive enterprise because of finishing cattle on high-grain diets in the feedlot. In fact, this stage represents only a minor segment of the production cycle because more than 75% of the total feed units used by beef cattle in the U.S. consist of forages. This estimate is probably low because the contribution of grazing towards this figure is usually underestimated.

THE RUMINAL FERMENTATION

The pregastric fermentation by the rumen microorganisms (i.e., bacteria, protozoa, and fungi) enables ruminants to utilize structural carbohydrates (e.g., cellulose and hemicellulose) which cannot be digested by mammalian enzymes. The end-products of such fermentation are volatile fatty acids (VFA; absorbed in the rumen) and microbial cells (i.e., containing 30 to 50% true protein that is digested to amino acids [AA] and absorbed in the small intestine). These end-products are essential as they provide ruminants with the majority of the energy (VFA) and AA requirements. Because of the insignificant contribution of protozoa and fungi to total microbial protein flowing to the small intestine, most of the microbial protein is accounted for by bacteria (Nolan, 1993).

RUMINAL PROTEIN METABOLISM

Protein metabolism in the rumen is a complex process. Most of the rumen bacteria synthesize their AA from simple carbon compounds and dietary or endogenous non-protein nitrogen (NPN). Having this advantage, the ruminant animal can subsist and produce at modest levels on diets containing virtually no true protein (Virtanen, 1966). The presence of other sources of NPN (recycled urea [through saliva or the rumen wall] and microbial AA and nucleic acids) reduce the dietary requirements for N and true protein. Recycled N cannot always overcome a deficit of N for bacterial protein synthesis when the animal’s diet is low in crude protein (CP) content. Therefore, ruminal bacterial protein synthesis in animals consuming low quality forage (having less than 50% dry matter [DM] digestibility and less than 10% CP on a DM basis) may be stimulated by NPN (e.g., urea) supplementation. In contrast, when the diet is high in true protein (e.g., feeding high quality legumes such as alfalfa), the protein is rather inefficiently used. In the rumen, the majority of this protein is degraded to oligopeptides (hydrolysis by extracellular microbial proteases), then to smaller peptides and AA. The latter can be incorporated into bacterial protein or deaminated intracellularly to various VFA and ammonia. The ammonia is then available for assimilation and resynthesis of AA and bacterial protein. When the diet is high in ruminal degradable protein and low in readily fermentable energy sources, excess ammonia is absorbed across the rumen wall, converted to urea in the liver, and subsequently excreted in the urine as a waste of N.
fraction of dietary protein that is not degraded in the rumen is often referred to as 'ruminally undegraded (bypass or escape) protein'. Dietary proteins escaping the ruminal degradation, together with bacterial protein leaving the ruminal fermentation, constitute the major sources of AA that could be digested and absorbed in the small intestine (Merchen, 1990).

**RUMINAL DEGRADATION OF FORAGE PROTEIN**

A large fraction of N in forages, especially those of high quality, is highly soluble and almost instantaneously degraded by the rumen microorganisms. The rate of breakdown of the potentially degraded CP fraction is high (Beever et al., 1986) and is not always synchronized with energy release from forages (Van Vuuren et al., 1990). High rates of ruminal CP degradation may result in no more than 15% of the CP intake escaping the ruminal degradation (Cruickshank et al., 1992). Only 28% of alfalfa hay CP escapes the ruminal degradation (NRC, 1985). This can explain why most of the protein in high quality forages often never reaches the small intestine (Beever, 1993; Van Vuuren et al., 1990). Because of this, a paradoxical situation occurs in which animals consuming forage diets that are high in protein may be actually limited in performance by the AA supply to small intestine for digestion and absorption. This explains why animals grazing high quality forages often perform at levels below those expected from forage composition (Beever, 1993).

**ENERGY SUPPLEMENTATION**

Forage species has an important effect on CP supply to the small intestine of the ruminant animal. Animals consuming legumes have considerably higher intakes and higher duodenal flows of CP and AA than animals consuming grasses (Cruickshank et al., 1992; Beever, 1993) but legumes also result in higher ruminal N losses, mainly as ammonia. To reduce ruminal N losses and thus increase intestinal AA supply, it is necessary to increase the amount of ammonia (resulting from ruminal degradation of forage CP) incorporated into bacterial protein. The amount of bacterial protein synthesized in the rumen is driven largely by the supply of fermentable energy (e.g., total nonstructural carbohydrates) in the diet (e.g., grain supplementation). In order to be effective there must be a synchrony between energy and ammonia release (Broderick et al., 1991). The strategic use of energy supplements is to balance between degradation of CP and fermentation of organic matter (OM) as indicated by Beever and Siddons (1986) and Van Vuuren et al. (1990). With regard to energy sources, it is likely that grains and highly fermentable by-products (e.g., soybean hulls, wheat bran, and corn gluten feed) would differ markedly in the amount and rate of ruminal OM fermentation, in the capture of ammonia and synthesis of bacterial protein, and consequently in the AA supply to the animal. Despite the essentiality of such information, if meaningful strategies of energy supplementation are to be devised, published reports on the effects of different sources and levels of energy on ruminal ammonia capture are limited (Poppi and McLennan, 1995). In general, the amount of research on high quality forages such as alfalfa hay is quite small. Paterson et al. (1994) summarized data from 52 experiments on forage supplementation and reported that only nine experiments were done with high quality forages. In another survey (Galyean and Goetsch, 1993), it was concluded that most published reports on energy supplementation dealt with animal performance without mechanisms to explain the response reported. Galyean and Goetsch (1993) explained the lower contribution of research in this area (when compared with overall research in ruminant nutrition) to the lack of funding and to the difficulty in conducting forage research with a mechanistic approach.
THE NEED FOR A STRONG BEEF INDUSTRY

In Nevada, the human population has almost doubled (from .875 million [1987] to 1.625 million [1996]) in the last decade (Nevada Agricultural Statistics, 1997). However, the land area (farms or ranches) for beef production did not change (i.e., 8.8 million acres). In fact, the number of farms or ranches raising beef cattle declined from 1,700 in 1987 to 1,600 in the last three years. The number of beef cattle also declined from its highest (i.e., 700,000) in 1982 to as low as 500,000 in 1996. These trends reflect the fact that farming has been under increasing pressure from many sources (e.g., tightening markets, urban demands, and constricting regulations). The seriousness of the problem also was emphasized by Governor Miller (Nevada Agricultural Statistics, 1997) who indicated that the economic viability of such agricultural sector has eroded to the point where we are losing farms. Therefore, developing a dynamic and progressive beef industry is an essential element in sustaining Nevada’s economy and in keeping agriculture viable. Considering the limitation of natural resources (e.g., feed) in Nevada, any basic and applied research focusing on developing strategies to improve the efficiency of feed utilization by beef cattle would be a positive step towards sustaining agriculture and increasing beef production for our growing population.

THE IMPORTANCE OF ALFALFA HAY

In the state of Nevada, 9.1% of the total land in farms and ranches is cropland (Nevada Agricultural Statistics, 1997) with almost half of it being utilized for harvested forages (i.e., hays). In terms of the relative importance of alfalfa hay to all hays, the 1996 statistics showed that 1.08 million tons (i.e., 72% of all hay yield) of alfalfa hay was produced from 240,000 acres (i.e., 50% of all hay acres) with a cash value of $106 million (i.e., 76% of all hay dollars). These data clearly show the important role that alfalfa hay can play in improving our beef industry if its nutrients are utilized efficiently. Another advantage to alfalfa hay as a legume forage is its high protein content (18 to 20% CP on a DM basis) when compared with other hays (mostly grasses with less than 10% CP on a DM basis) produced. However, this CP is often utilized less efficiently by cattle because of its high ruminal microbial degradation. As a result, animals consuming alfalfa hay may be actually limited in performance by AA supply to the small intestine. Therefore, it seems counterproductive to present an animal with a diet (based on alfalfa hay) that greatly exceeds the requirement for a nutrient (i.e., protein) and then find that the animal’s productivity is limited because that nutrient is so poorly utilized. Based on the above statistics, efficient utilization of CP in alfalfa hay should benefit our beef industry which is continually challenged to increase production while maintaining or reducing feed costs.

THE UNR APPROACH

A research project is designed and will be implemented over a 5-year period to utilize basic (mechanistic) and applied (performance) approaches to address the problem of poor utilization of CP in alfalfa hay. The main objective of this research is to establish strategies for energy supplementation of alfalfa hay. Such strategies should minimize ammonia loss and maximize ruminal bacterial protein synthesis. This will be accomplished at two stages. In the first stage, the focus will be on characterization of CP in alfalfa hay at different stages of maturity (1st, 2nd, and 3rd cuts). This characterization includes the composition (by fractionation of CP according to availability [i.e., solubilities]) and the nutritional value (by determining the rates of ruminal degradation of CP, OM, and fiber). In the second stage, the focus will be on the development and evaluation of strategic supplementation of alfalfa hay with energy sources (e.g., grains and by-products with fermentable fibers) at optimum levels.
The development of the supplementation strategies will be achieved by using the dual flow continuous culture fermenter system which is currently under construction in our laboratory. The evaluation of such strategies, however, will be achieved by conducting feeding trials with growing and finishing beef cattle. In these trials, the sources and levels of energy will be based on those which are proven beneficial in the continuous culture experiments. Finally, an economic analysis will be conducted to determine the net return to the beef producers from adapting such supplementation strategies.

THE DUAL FLOW CONTINUOUS CULTURE FERMENTER SYSTEM

The ruminal metabolic responses to supplementing alfalfa hay with various sources and levels of energy will be determined in vitro by using the dual flow continuous culture fermenter system. This system (Figure 1) is the closest in vitro system to simulate the ruminal fermentation. It was developed by Hoover et al. (1976) and was modified by Hannah et al. (1986). The complete assembly consists of eight fermentation vessels. In this system, the fermenters are inoculated with rumen fluid obtained from ruminally-cannulated cattle, are continuously fed with the experimental diets, and are continuously infused with artificial saliva. The fermenters maintain temperature at 39°C, stable pH, anaerobic conditions, and continuous flow of digesta at rates matching those found in cattle consuming similar diets. This system was proven successful in providing accurate measurements of the ruminal metabolic responses to diets (Hussein et al., 1991a) that also were fed to ruminants (Hussein et al., 1991b).

Figure 1. (A) General schematic of dual flow continuous culture system. (B) Schematic of fermenter flask components. A, automatic feeding device and feed input port; B, magnetic impeller assembly; C, sodium hydroxide infusion port; D, hydrochloric acid infusion port; E, filters; F, buffer infusion port; G, nitrogen sparger; H, thermocouple assembly; I, coaxial heat exchanger apparatus; J, pH electrode; K, overflow port.
CONCLUSIONS

Improving forage utilization has been identified by most beef producers as a major factor that can be exploited to reduce the costs in cow-calf production. In a more recent survey (Hermel, 1996) published in BEEF magazine, 18 items were identified as "most practical methods" for reducing production costs. Of these items, 14 were related to feed utilization and 12 were related to some aspect of forage feeding or utilization. Successful completion of the proposed research will provide directions to Nevada beef producers as to approaches that can be implemented to make maximal use of the CP in alfalfa hay. These approaches will involve the implementation of strategic supplementations (i.e., the optimal sources and levels of supplemental energy that maximize production of bacterial protein from ammonia in the rumen) to improve production and to increase efficiency. Therefore, such strategic supplementations should give cattle producers an opportunity to reduce input costs. This can be accomplished by reducing the need for other feeds (e.g., cereal grains and protein supplements) and by making more effective use of inputs currently being made (i.e., CP in alfalfa hay). Those other feeds are usually expensive and have competitive markets with non-ruminants and humans.

LITERATURE CITED


