USE OF BLOOD UREA NITROGEN CONCENTRATION TO GUIDE PROTEIN SUPPLEMENTATION IN CATTLE

by

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INTRODUCTION

"Changes in the diet lead to different levels of blood-urea concentration which can be correlated with different rumen-ammonia concentrations . . . ."

Lewis (1957)

Digestible protein in the diet of ruminants is either degraded in the rumen or escapes to the abomasum then small intestine where it is degraded to amino acids and small peptides then absorbed into the portal blood system. Nitrogen from protein that is degraded in the rumen is used for microbial protein synthesis either by incorporation of free amino acids liberated by the process of proteolysis or by incorporation of ammonia nitrogen that arises from deamination of amino acids. Nonprotein nitrogen (NPN) also can be made into ruminal microbial protein by the incorporation of ammonia liberated by the enzymatic breakdown of NPN. Yield of microbial protein produced in the rumen is maximized when the ratio of available energy (fermentable organic matter) to nitrogen (protein) is optimized. When there is an excess of nitrogen relative to energy in the rumen, ruminal ammonia concentrations increase. Unused ruminal ammonia enters the portal blood through the rumen wall and is transported to the liver where it is detoxified by conversion to urea. Urea then circulates in the blood to the kidneys and is excreted with the urine or it can diffuse from the blood back into the rumen, into saliva and back into the rumen, or diffuse from the blood into milk in the case of lactating females. When there is a deficiency of dietary protein, ruminal ammonia concentrations are relatively low and recycling of nitrogen back to the rumen as urea is increased.

As a result of these metabolic transactions, blood urea nitrogen (BUN) concentrations are highly correlated with ruminal ammonia nitrogen concentrations (Egan and Kellaway, 1971; Hammond, 1983a) and are indicative of the protein to energy ratio in the diet (Hammond, 1983b; Huntington, 1980). One word of caution, however, is that these principles hold only for healthy ruminants. Severe nutritional depletion as a result of prolonged undernutrition or disease can cause catabolism of tissue protein and result in high concentrations of BUN. Also, renal disease can interfere with excretion of urea and result in elevated BUN.

For the purposes of this presentation, BUN will be used as a generic term for plasma, serum and whole blood urea nitrogen, although subtle differences in values have been reported depending on the sample matrix. Small but significant differences were obtained when the same blood samples were analyzed as plasma, serum or hemolyzed then dialyzed whole blood (Hammond, 1983b). We repeated these observations at our laboratory in

Presented at the 3rd Florida Ruminant Nutrition Symposium, Gainesville, January 23-24, 1992

Brooksville and found that concentrations of urea in whole blood were highly correlated (r=.99) with concentrations in plasma, however, whole blood values were nearly 1 mg/dl lower than plasma values when analyzed with our procedures. The method we use for analysis of BUN is an automated procedure (Technicon AutoAnalyzer II Industrial Method #339-01, Technicon Instruments Corporation, Tarrytown, NY 10591) that includes a protein dialysis step and is based on the diacetyl monoxime method of Marsh et al. (1965).

EFFECTS OF DIET ON BLOOD UREA

Dietary factors affecting BUN concentrations in cattle were reviewed by Hammond (1983b). The main points of that review with regard to diet are briefly outlined below along with new information developed in our laboratory at Brooksville and derived from the current literature.

EFFECTS OF PROTEIN LEVEL

When energy intake is held constant, increasing dietary protein increases blood urea nitrogen concentrations. This was illustrated in a trial by Hammond (1983ab) in which isocaloric semipurified diets with three levels of crude protein were fed to 525 lb. steers at equal intakes of 11 lb./day. Mean BUN concentrations increased from 2.6 mg/dl to 11.1 mg/dl as dietary crude protein increased from 6 to 18% of the diet (Table 1). Based

TABLE 1. EFFECT OF CONCENTRATION OF CRUDE PROTEIN (CP) ON BUN CONCENTRATIONS IN STEERS FED ISOCALORIC DIETS[a]

Diet CP, %	BUN, mg/dl
6	2.6
12	4.0
18	11.1

[a]From Hammond (1983ab).

on work with sheep, Preston et al. (1965) suggested that BUN concentrations in excess of 10 mg/dl indicated protein wastage. With finishing steers, maximum performance was associated with BUN concentrations of 7 to 8 mg/dl (Preston et al., 1978). For growing steers, BUN levels between 11 and 15 mg/dl were associated with maximum rates of gain leading Byers and Moxon (1980) to suggest that BUN levels consistent with maximum performance may be higher for growing cattle than for finishing cattle.

EFFECTS OF PROTEIN DEGRADABILITY

Increased solubility or degradability of dietary protein can lead to increased ruminal ammonia concentrations resulting in increased circulating urea concentrations. However, varying dietary nitrogen solubility by varying source of dietary nitrogen has not always resulted in altered blood urea nitrogen concentrations. In a study with yearling steers fed corn silage diets supplemented with soybean meal or urea to meet 85 or 100% of requirements for crude protein, BUN concentrations did not differ between sources of protein (Cross et al., 1974). In contrast, steers fed corn-cottonseed hull diets supplemented with soybean meal or urea had higher BUN concentrations when supplemented with urea than when supplemented with soybean meal (Burris et al., 1975). Using isocaloric diets that differed widely in nitrogen solubility, Hammond (1983ab) reported an average difference in BUN of over 6 mg/dl (Table 2).

TABLE 2. EFFECT OF PROTEIN SOLUBILITY ON BUN CONCENTRATIONS IN STEERS FED ISOCALORIC DIETS AVERAGING 12% CRUDE PROTEIN[a]

Ruminal fluid soluble CP, %	BUN, mg/dl
2.5	3.8
9.6	10.4

[a]Calculated from the data of Hammond (1983ab).

EFFECTS OF ENERGY LEVEL AND PROTEIN TO ENERGY RATIO

Increasing dietary energy intake while holding protein intake constant (decreasing protein:energy ratio) would be expected to decrease circulating concentrations of urea. This was well demonstrated in an experiment with bulls at our station in Brooksville where diets were rationed to provide 75 or 150% of maintenance energy requirements but equal crude protein intake (Chase et al., 1990). At the high level of energy intake, BUN averaged 5.6 mg/dl and at the low level of energy intake averaged 19.7 mg/dl (Table 3). In an experiment conducted by Huntington (1980), BUN concentrations in steers were more highly correlated with the ratio between energy and protein intake than with either energy intake or protein intake alone.

TABLE 3. EFFECT OF AMOUNT OF ENERGY INTAKE ON BUN CONCENTRATIONS IN BULLS FED EQUAL AMOUNTS OF CRUDE PROTEIN[a]

Fraction of maintenance energy intake, %	BUN, mg/dl
75	19.7
150	5.6

[a]From Chase et al., 1990.

EFFECTS OF INTAKE LEVEL

The effect of increased level of feed intake on BUN concentrations appears to be similar to the effect associated with increased energy intake. Vercoe (1967) reported that on both high quality and low quality forage diets, BUN decreased with increased levels of feed intake.

OTHER FACTORS

Other dietary factors that affect efficiency of protein utilization in cattle may affect BUN concentrations. Kennedy and Siebert (1972) demonstrated that addition of sulfur to diets of sheep and cattle deficient in sulphur resulted in decreased BUN concentrations associated with increased production. Factors that may affect BUN concentrations other than diet include health of the animal (previously mentioned), physiological state, level of production and breed. The magnitude of difference caused by these factors, except for certain disease conditions, is generally less than the dietary factors presented above, but can be significant. In dairy cows, Peterson and Waldern (1981) reported that BUN increased as cows progressed from the dry stage through early lactation and the lactating pregnant period, and that BUN increased with increasing age. In beef cattle, the use of growth promotants generally decrease concentrations of blood urea (Preston et al., 1978; Galbraith, 1980; Eisemann et al., 1989) while the use of feed additives to increase feed efficiency has resulted in variable effects on blood urea concentrations (Steen et al., 1978; Thompson and Riley, 1980). At Brooksville, we have observed lower concentrations of BUN in Hereford cows compared to Senepol cows (Padgett et al., 1990) suggesting differences in protein metabolism between Hereford and Senepol cattle. Similar differences were observed between Hereford and Brahman cattle by Hunter and Siebert (1985) and between Angus X Hereford cattle and Brahman crosses by Coleman and Frahm (1987). Time of blood sampling also can affect BUN concentrations. With blood samples collected hourly for 48 hours from steers fed every 12 hours, the effect of time after feeding on BUN was significant ($P < .001$) but was small in magnitude (about 1 mg/dl difference from highest mean BUN to lowest mean BUN; Hammond, 1983b). In a recent experiment at Brooksville with a protein supplement (cottonseed meal) fed only 3 times per week to cows on a low quality forage diet, BUN decreased an average of about 4 mg/dl in 48 hours following supplement feeding (Hammond, unpublished).

BUN IN GRAZING CATTLE

Predicting response to protein or energy supplementation in grazing cattle using BUN as a guide is complicated by the fact that forage intake is not known and varies among animals. Although neither energy nor protein intake is known in free-grazing cattle, the protein to energy ratio of the diet should be reflected in circulating concentrations of urea. To determine whether BUN could predict the biological response (change in average daily body weight gain, ADG) in steers and heifers grazing warm season grass pastures, data from six summer grazing trials conducted over 5 years at Gainesville, Florida (Kunkle et al., 1987; Kunkle et al., 1989; Biggerstaff et al., 1990; Holderbaum et al., 1991; Kunkle et al., unpublished) were summarized. Pasture grass species involved were bahiagrass (<u>Paspalum</u>

notatum) and limpograss (Hemarthria altissima). Eight comparisons between protein supplement treatments and various controls were analyzed (Figure 1).

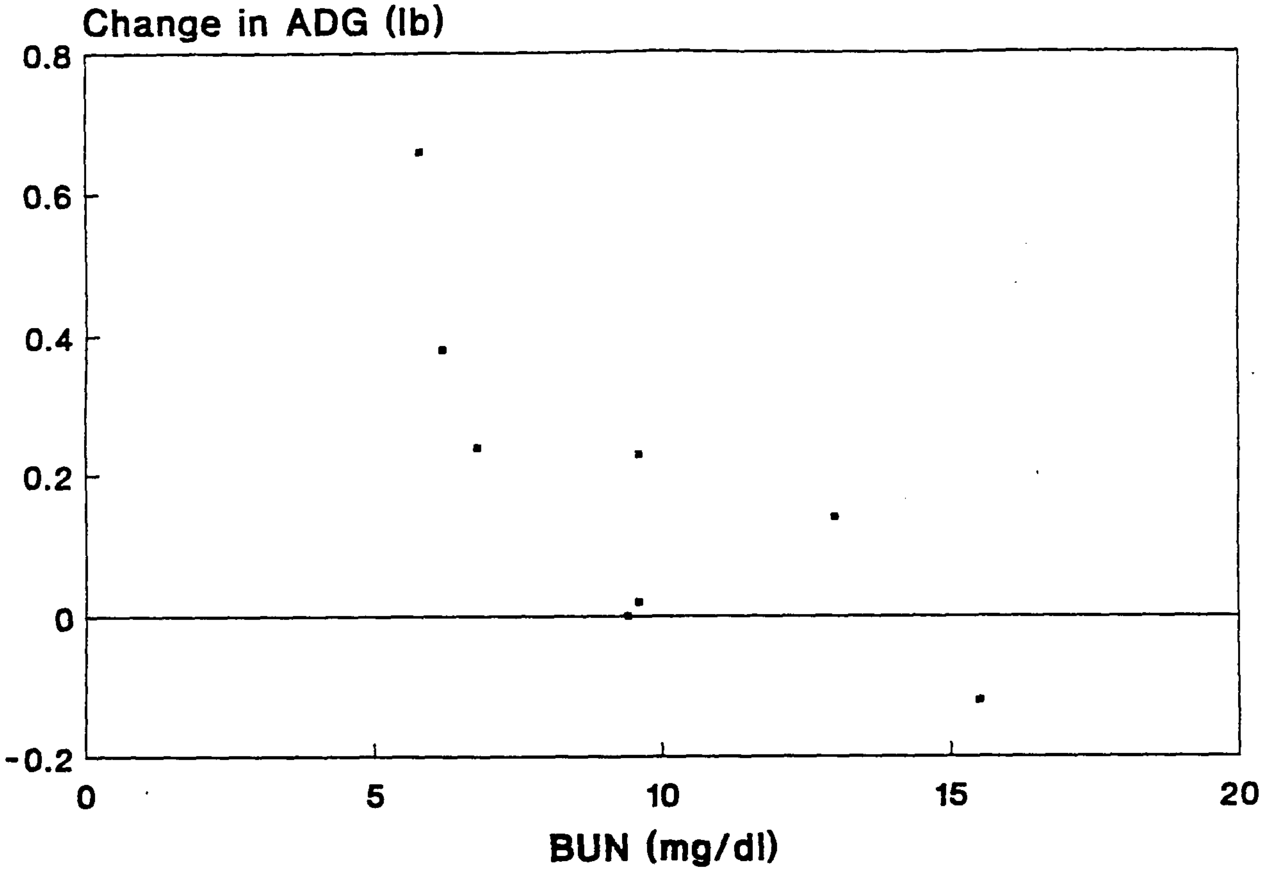

Figure 1. Response in ADG to protein supplementation as a function of BUN concentration in unsupplemented controls.

Mean BUN in controls ranged from 6.2 to 15.5 mg/dl. No significant increase in ADG was obtained in response to protein supplementation when mean control BUN was above 10 mg/dl. When mean control BUN was less than 7 mg/dl, ADG was increased in response to protein supplementation from 21 to 133% of control ADG. Seven comparisons between energy supplement treatments and controls were analyzed (Figure 2). In these trials, mean BUN in controls ranged from 9.6 to 17.6 mg/dl. Positive responses in ADG to energy supplementation were obtained with the entire range of control BUN. Energy supplementation was not tested in trials with lower control BUN values, but based on results of trials involving protein supplementation little response to energy supplementation would be expected when control BUN was less than 7 mg/dl.

EFFECT OF PROTEIN DEGRADABILITY

A trial similar to ours at Gainesville was conducted at a subtropical location in Australia (Hennessy and Williamson, 1990) using steers and heifers fed hay from a pasture that was predominantly carpetgrass (Axonopus affinus). The basal hay diet resulted in average BUN concentrations of 2.1

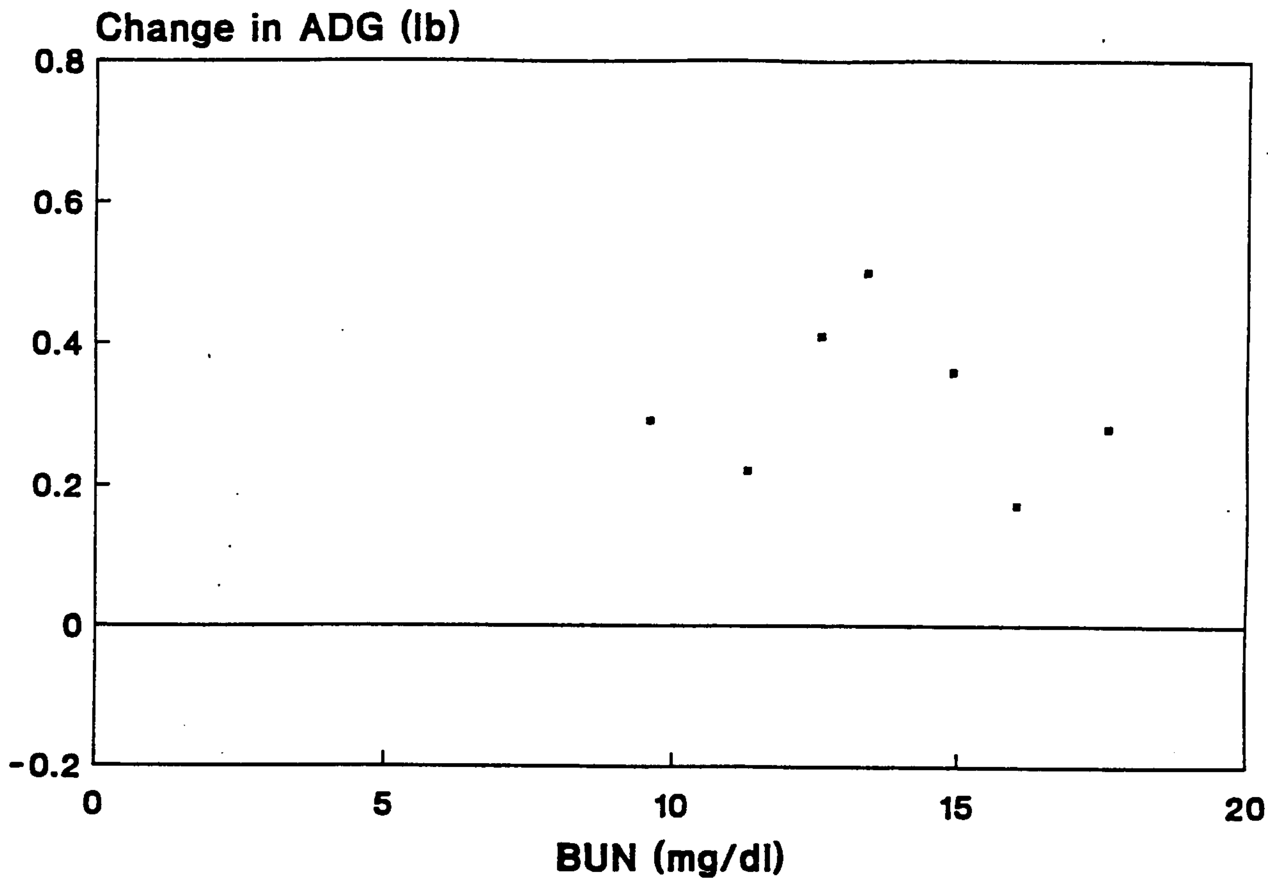

Figure 2. Response in ADG to energy supplementation as a function of BUN concentration in unsupplemented controls.

mg/dl that were increased to 10.5 mg/dl with urea supplementation or 8.5 mg/dl with protected casein supplementation. These increases in BUN were associated with significant increases in ADG from .2 lb./day on hay alone to .6 lb./day on hay supplemented with urea or 1.3 lb./day on hay supplemented with protected casein. These data suggest that nitrogen supplemented in the less degradable form of protected casein was more efficiently used, resulting in a greater increase in ADG and a lesser increase in BUN compared to supplementation with urea.

EFFECT OF NITROGEN FERTILIZATION

Nitrogen fertilization of pasture can affect BUN in grazing cattle due to the increase in forage nitrogen content. Carver et al. (1978) found a positive linear response in BUN of steers to nitrogen fertilization of 'Midland' bermudagrass pastures between 0 and 448 kg N/ha/year. Actual body weight gains of these steers were not reported, but when these data were combined with those obtained on common bermudagrass and orchardgrass-ladino pastures, BUN was positively correlated (r=.53) with ADG.

PROPOSED APPROACHES

Among dietary supplements for cattle (minerals, vitamins, protein, energy), protein is usually the most expensive on a cost/head/day basis. Strategic use of protein supplements aimed at optimizing timing and level of protein supplementation could increase production efficiency and reduce unit cost of production. Use of BUN as a tool in applying protein supplementation strategies could take several approaches. First, BUN can serve as a useful retrospective diagnostic tool to analyze biological responses to protein supplementation. In a two year study at Brooksville, we monitored BUN in cows and heifers wintered on bahiagrass hay, molasses and perennial peanut hay or a 20% crude protein range cube (Padgett et al., 1990). Five pounds of perennial peanut hay resulted in performance equal to that of 2 lb. of the range cubes and similar BUN concentrations. Main sources of protein in the range cubes were cottonseed meal and urea. More importantly, however, average monthly BUN concentrations suggested that we did not initiate protein supplementation early enough in the winter and that we supplemented with protein longer in the spring than necessary. A second approach would be to make real time adjustments in protein supplementation based on BUN concentrations. In cooperation with the Deseret Ranches of Florida and the Department of Animal Science at Gainesville, we are currently conducting a winter supplementation trial involving a total of 1,683 cows in ten herds at Deseret. Five of these herds will be supplemented using Deseret's standard supplementation protocol. The other five herds will be supplemented with energy in the same manner as the five control herds but protein supplementation will be guided by BUN concentrations in a sample of 25 cows from each herd. The criterion for initiation of protein supplement feeding (equivalent to a rate of 1 lb/head/day of a 32% crude protein supplement fed twice a week) in BUN guided herds will be a mean BUN less than 7 mg/dl or 25% of the individuals in a herd less than 6 mg/dl. Similar criteria will be used to adjust level of protein supplement feeding and to terminate supplement feeding in the spring. A third approach, would be to use BUN concentrations to sort cattle into groups with similar protein requirements. Some factors other than diet that contribute to variation in BUN among individual animals were mentioned above. In work with lambs, Pfander et al. (1975) reported that superior performance could be obtained if individuals were grouped on the basis of BUN following feeding of a common diet then fed to maintain BUN at about 15 mg/dl.

MILK UREA NITROGEN IN DAIRY CATTLE

In dairy cows, BUN and milk urea nitrogen (MUN) concentration are highly correlated and MUN has been investigated for its potential as an indicator of the adequacy of protein in the diet much the same way as suggested for BUN (Oltner and Wiktorsson, 1983; Miettinen and Juvonen, 1990). Monitoring of MUN is noninvasive and average values for entire herds have been obtained by analyzing milk samples from bulk tanks (Refsdal et al., 1985). Roseler et al. (1990) fed isocaloric diets with different amounts of degradable and undegradable protein to lactating Holsteins. At protein levels equaling 100% of requirement, least-squares mean MUN was 9.9 mg/dl and significantly decreased at protein levels below requirement or increased at protein levels above requirement regardless of the form of protein (degradable or undegradable). Oltner and Wiktorsson (1983) found little day-to-day variation in MUN and similar MUN concentrations in morning and afternoon milk. The major factor they found that affected MUN was the protein to energy ratio in the diet.

SUMMARY AND CONCLUSIONS

Urea is produced in the liver of mammals to detoxify ammonia, the end product of protein catabolism (breakdown). Urea is excreted in the urine or, in ruminants, may be partially recycled to the gastrointestinal tract. In cattle, the concentration of blood urea nitrogen (BUN) is highly correlated with the concentration of ammonia in the rumen. Excess ruminal ammonia beyond what can be incorporated into bacterial protein is lost to the system (absorbed into the blood, converted to urea in the liver, and a excreted via the kidneys). Inadequate ruminal ammonia limits ruminal microbial protein production and results in inefficient use of feed energy and a reduction in animal performance. Concentrations of BUN associated with maximum performance of growing feedlot steers range between 11 and 15 mg/dl. For finishing cattle, maximum performance has been associated with lower levels of BUN, about 7 to 8 mg/dl. It has been suggested that BUN concentrations above 10 mg/dl are generally indicative of protein wastage. Optimum concentrations of BUN for wintering cows has not been determined but based on the principles outlined above, BUN concentrations of about 8 to 10 mg/dl would be indicative of a relative good balance between digestible protein and energy intake. Therefore, concentration of blood urea may be a useful tool for predicting biological response to protein supplementation in free-grazing or wintering beef cattle. In lactating dairy cows, milk urea nitrogen (MUN) is highly correlated with BUN. Therefore, potential exists for MUN to be used as a noninvasive approach to optimizing protein in dairy cow diets or for grouping dairy cows of similar metabolic efficiency for optimum management.

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