The Use of Blood Urea Nitrogen Concentration as an Indicator of Protein Status in Cattle[1,2]

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Introduction

Measuring blood urea nitrogen (UN) concentration in ruminants has become a common technique for monitoring protein status both in livestock production research and the clinical environment. The technique is used world-wide and although there is a plethora of reports on values obtained under various conditions, caution should be given to interpretation of blood UN data due to the number of variables which can affect blood UN values (1-10). This is especially true when factors other than nutrition, such as health of the animal and physiological state or stage of production are involved. The advent of rapid and inexpensive automated analytical procedures, use of UN and other metabolic indicators is expected to continue in the future. Best use of this information can only be made with an understanding and consideration of the various factors that affect these metabolic parameters. The following is intended to be a useful overview of these factors and the practice of using blood UN concentration as an indicator of protein status in cattle.

Factors Affecting Blood Urea Nitrogen Concentration

Analytical methods. Laboratory methods for the analysis of urea vary from enzymatic conversion to ammonia and measurement of the increase in ammonia concentration (11-13) to colorimetric determination of urea derivatives (14-18). In general, similar values are obtained from various end-point colorimetric methods (1, 19). Probably of greater concern, analyses may be on serum (very common in metabolic profiles and blood screening programs), plasma (often used in ruminant nutrition research) or whole blood (12,20). Comparison of an automated colorimetric analysis (17) in our laboratory on the same blood samples prepared as plasma, serum, or hemolyzed then dialyzed whole blood (Table 1) shows the magnitude of difference is small among preparation methods but statistically significant ($P<.05$). Therefore, an attempt will be made in this paper, especially when discussing actual analytical values, to accurately report serum UN, plasma UN, or whole blood UN where possible. The term blood UN will be used where a more descriptive term is not appropriate.

Time of sampling. In a recently conducted experiment at Beltsville (2) we sampled jugular blood from 20 Hereford steers (239 ± 4 kg), which were fed isocaloric diets with three levels and two sources of dietary nitrogen, hourly for 48 hours. The effect of time after feeding on plasma UN was significant ($P<.001$) but was small in magnitude *(Figures 1 and 2).* Manston *et al.* (6) similarly found significant ($P<.001$) but small changes in serum UN measured hourly for 9 hours on 5 days in 10 lactating and 10 nonlactating dairy cows. Several other reports (21-24) of less intensive sampling over time generally support these observations of small but often statistically significant changes in blood UN with time of sampling in cattle.

Health or disease. Several disease conditions may lead to alteration in blood UN concentration. The best examples are in cases where there is likely an interaction between nutrition and disease such as neonatal diarrhea or scours. Several groups have reported increases in whole blood UN (25-26) or serum UN (27) concentrations in calves with diarrhea. This was likely in part due to severe nutritional depletion where catabolism of mobilized protein stores may have resulted in increased production of urea by the liver. An increase in blood UN concentration under such conditions of nutritional stress should not be confused with the increase in blood UN concentration seen with increased protein intake which will be discussed later. Another example of a

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[1] *Mention of a trade name, proprietary product or specific equipment does not constitute a guarantee or warranty by the U.S. Department of Agriculture and does not imply its approval to the exclusion of other products that may be available.*

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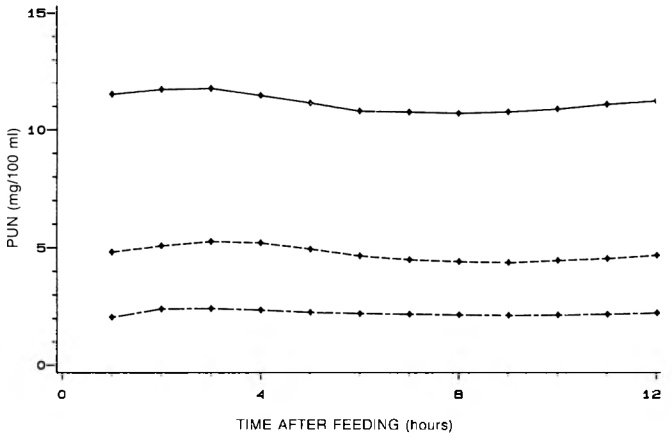
Table 1. Mean ± SEM of triplicate analyses of urea nitrogen concentration in plasma, serum, and whole blood from each of two common blood samples.

Source of sample	Matrix	Urea nitrogen concentration (mg/100 ml)
Growing steer, 290 kg	Plasma	13.9 ± .00[a]
	Serum	14.1 ± .03[b]
	Whole blood	12.9 ± .05[c]
Lactating first calf heifer, 440 kg	Plasma	15.1 ± .06[a]
	Serum	15.3 ± .07[a]
	Whole blood	14.0 ± .06[b]

[a,b,c]Means within source of sample with different superscripts are different (P<.05).

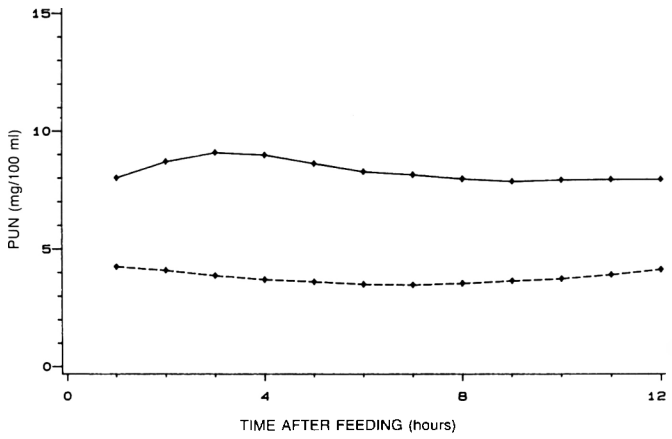
Figure 1. Mean plasma urea nitrogen concentration (PUN) at times after feeding at three levels of nitrogen intake (solid line, 139.2 g N/d, n=8; even broken line, 92.8 g N/d, n=6; uneven broken line, 46.4 g N/d, n=6). Data for each animal used in the analysis was the average over four feeding periods, i.e., 48 hour collection.



disease condition that may affect blood UN concentration is ammonia toxicity (28). Increased blood UN has also been associated with dehydration (29) and lactic acidosis (30).

Productive function. The major productive functions or physiological states of concern in cattle are growth, lactation, gestation and maintenance. Among these, measurement of blood UN concentration to monitor protein status is most often applied to lactating and gestating dairy cattle and to growing and finishing beef cattle. The most common use of blood UN values associated with dairy production is as one component in more elaborate metabolic profiles. These profiles were generally designed to monitor metabolic conditions as they relate to health and disease (31-39), but often have been applied in relation to nutritional status (32, 40-44). Blood UN concentration is only one

Figure 2. Mean plasma urea nitrogen concentration (PUN) at times after feeding at two levels of dietary nitrogen solubility (solid line, higher nitrogen solubility, n=12; broken line, lower nitrogen solubility, n=8). Data for each animal used in the analysis was the average over four feeding periods, i.e., 48 hour collection.



parameter considered in these profiles, but is the one most likely related to protein status (45). However, Kronfeld *et al.* (46) found that serum UN was not as highly correlated to dietary crude protein as several other blood parameters. Lee *et al.* (43) also concluded that serum UN was of limited value in detecting adequacy of protein intake. Others have demonstrated that blood UN is affected by protein intake in cattle (21, 23, 47-56). These and other dietary effects are discussed in greater detail below.

In dairy cattle, Peterson and Walden (57) showed that serum UN increased as cows progressed from the dry stage through early lactation and the lactating pregnant period. Belyea *et al.* (58) similarly observed an increase in serum UN with stage of lactation. In addition, several investigators have reported an increase in serum UN with age of cows (4-5, 57), but the magnitude of increase was small relative to effects of other factors. On the other hand, Glenn et al. observed no difference in plasma UN between lactating first calf heifers and lactating cows fed the same diets (59).

Optimum levels (those associated with maximum performance) of plasma UN in beef cattle are reported to be between 11 and 15 mg/100 ml for growing feedlot steers (47) and between 7 and 8 mg/100 ml for finishing cattle (51). These levels would be expected to vary from these ranges depending on adequacy of diet as discussed below. Without change in diet, circulating UN concentrations generally increase slightly with time on feed (10,60) which probably reflects a decreasing protein requirement with increasing age or maturity. Plasma UN levels required for growing steers to attain .5 kg live weight gain per day on pasture ranges from 5 to 25 mg/100 ml depending on type of pasture and fertilization rates (61). Productive function in beef cattle as it relates to growth promotants also affects blood UN levels. Use of hormonal growth promotants has generally been

associated with reduced levels of blood UN (51,62-64) although this does not always occur (65-66). Effects of feed additives which improve feed efficiency vary (55,67-68).

Diet. Four main characteristics of diet affects blood UN concentration in cattle: nitrogen content of the diet, nitrogen solubility or degradability of the diet, energy content of the diet, and level of feeding. Blood UN concentrations increase with increasing dietary nitrogen intake in feedlot cattle (2, 47-49, 51, 53-55) and lactating dairy cows (23, 50, 52, 59), and are positively correlated with ruminal ammonia nitrogen concentrations (2, 53, 55-56). These effects of increasing plasma UN with increasing dietary nitrogen level at times after feeding are illustrated in *Figure 1* with data from our experiments at Beltsville (2). Corresponding rumen ammonia nitrogen concentrations are shown in *Figure 3* to illustrate the relationship between plasma UN and rumen ammonia nitrogen concentrations. Preston *et al.* have suggested that blood UN levels in excess of 10 mg/100 ml is indicative of protein wastage (12,51). This would correspond to levels of ruminal ammonia nitrogen in excess of that which could be used by ruminal microorganisms (69). The effect of increased blood UN with increasing nitrogen intake may not hold true, however, if energy intake is varied. At constant nitrogen intake, increased energy intake would be expected to decrease blood UN concentration (12,49,62). Level of feeding, which also relates to energy intake can also affect blood UN concentrations (53). Futhermore, Huntington (49) showed serum UN to be more highly correlated with the ratio between energy and protein intake than with either energy intake or protein intake alone. This is also consistent with the concept of an optimum protein to energy ratio discussed by Preston, *et al.* (12). One other dietary characteristic to consider is the relative solubility or degradability of nitrogen in the diet. Increased solubility of dietary nitrogen can lead to increased ruminal ammonia concentrations and therefore increased blood UN concentrations (2,21,54,59,70-71). Although varying dietary nitrogen solubility by varying sources of dietary nitrogen does not always result in altered blood UN (23,72-73), data from our laboratory (2), using isocaloric diets that differed widely in nitrogen solubility, demonstrated an average difference in plasma UN of 6.6 mg/100 ml. The effects of increasing plasma UN with increasing dietary nitrogen solubility at times after feeding fromour previously mentioned experiment (2) are shown in *Figure 2. Figure 4* shows these same effects on corresponding rumen ammonia nitrogen concentrations.

Selected Reference Values

Several compilations of reference values for blood Un have been published. Values are often a mean or average, a range of values, and/or a mean with a statistical measure of variability (1,3,19-20,35-36,38,42-43,51,57,60,74-75). Unfortunately, information on diet of the animals used in developing these reference values is often not available.

Figure 3. Mean rumen ammonia nitrogen concentration (RAN) at times after feeding at three levels of nitrogen intake (solid line, 139.2 g N/d, n=8; even broken line, 92.8 g N/d, n=6; uneven broken line, 46.4 g N/d, n=6). Data for each animal used in the analysis was the average over four feeding periods, i.e., 48 hour collection.

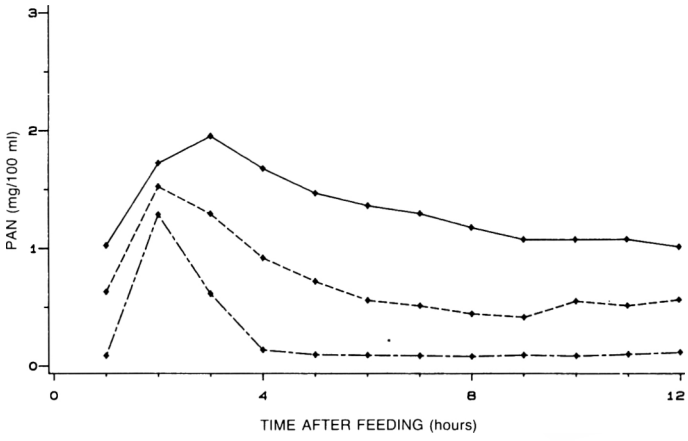
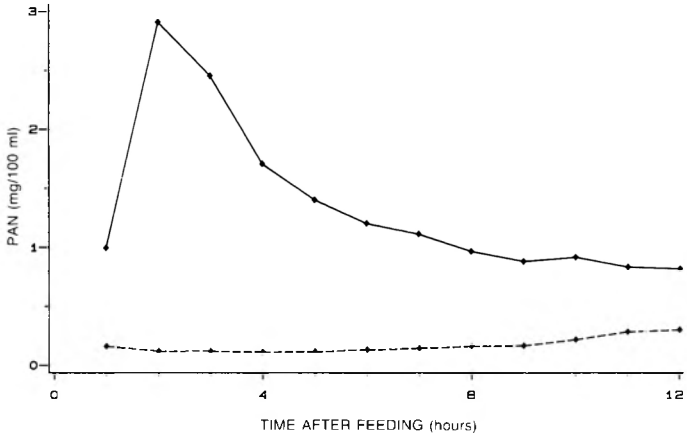


Figure 4. Mean rumen ammonia nitrogen concentration (RAN) at times after feeding at two levels of dietary nitrogen solubility (solid line, higher nitrogen solubility, n=12; broken line, lower nitrogen solubility, n=8). Data for each animal used in the analysis was the average over four feeding periods, i.e., 48 hour collection.



Statistical analysis of these reference values has at times been complicated by the demonstration that the population of blood UN data does not always fit a statistically normal distribution (39, 46). Nevertheless, published reference values can be useful guidelines when interpretation includes consideration of the factors that influence blood UN values as discussed above. *Table 2* is a compilation of some of the reference values available in the literature along with notes on factors to consider for each.

Table 2. Selected reference values for blood urea nitrogen concentrations (mg/100 ml) in cattle.

Mean	Range and/or Variation	Matrix	Reference	Notes
	Range = 10-20	Serum	1	Based on at least 30 clinically normal animals.
12.6	Range = 7.1-21.2	Serum	19	Based on 5 clinically and hematologically normal animals 4-8 weeks of age.
11.9	Range = 10.1-15.8	Serum	19	Based on 7 clinically and hematologically normal animals 3-4 months of age.
9.5	Range = 8.0-11.2	Serum	19	Based on 8 clinically and hematologically normal animals 11-18 months of age.
13.4	Range = 12.0-14.7	Serum	19	Based on 6 clinically and hematologically normal animals 6-11 years of age.
12.9	Range = 4.4-21.6	Whole blood	20	Samples from 59 calves and adult dairy cattle.
14.9	95% CL = 9.5-20.5	Serum	35	Normal values based on 2,400 samples analyzed from 13 dairy herds; animals included lactating and nonlactating cows.
14.4	SD = 2.5	Serum	36	Values based on samples collected from 75 dairy herds; animals included lactating and nonlactating cows.
14.0		Serum	37	Mean is of 9 samples each from 31 steers 4-16 months of age.
8.8		Serum	37	Bulls, barley beef management system, 6-9 months of age.
10.0		Serum	37	Bulls, grazing, 6 months of age.
12.0		Serum	37	Bulls, winter period, 10-12 months of age.
14.5	95% CL = 9.5-19.5	Serum	39	From 144 blood profiles including lactating and nonlactating dairy cows.
11.7	Range = 4.7-23.3	Serum	42	Mean based on average of 6 normal cows at 4-10 weeks post calving from each of 12 dairy herds; range is of 6 cow average; original data was in mg urea/100 ml.
9.5	SD = 4.8	Serum	43	Lactating cows from 5 normal herds.
11.2	SD = 5.2	Serum	43	Dry cows from 5 normal herds.
	Range = 11.1-15.2	Plasma	47	Minimum values associated with maximum performance of growing steers 230-350 kg.
	Range = 7-8	Plasma	51	Minimum values associated with maximum performance of feedlot steers.
18.4	Range = 13-24 SD = 3.57	Plasma	60	Growing steers, 340 kg, prior to grain feeding.
13.2	CV = 26.9%	Serum	74	From 130 weanling steers.
14.6	CV = 9.6%	Serum	74	Steers fed alfalfa hay.
8.0	CV = 21.7%	Serum	74	Steers fed 75% concentrates.
6.8	SD = 2.2	Serum	75	Multiple samples from 114 feedlot calves 170-235 kg.

Summary

Determination of blood UN concentration has become a common technique for monitoring protein status in cattle. It is not a panacea in and of itself, but it does give a general indication of dietary nitrogen intake. A blood UN value of about 10 mg/100 ml falls within most published normal ranges and in many cases would be a value indicative of protein adequacy. Major factors to consider in drawing conclusions about protein adequacy from blood UN values are energy intake, health of the animal, and physiological state or stage of production. Factors which can affect blood UN values but are of less concern because their effect is small in magnitude are specific analytical method used, time of sampling, and age of animal.

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