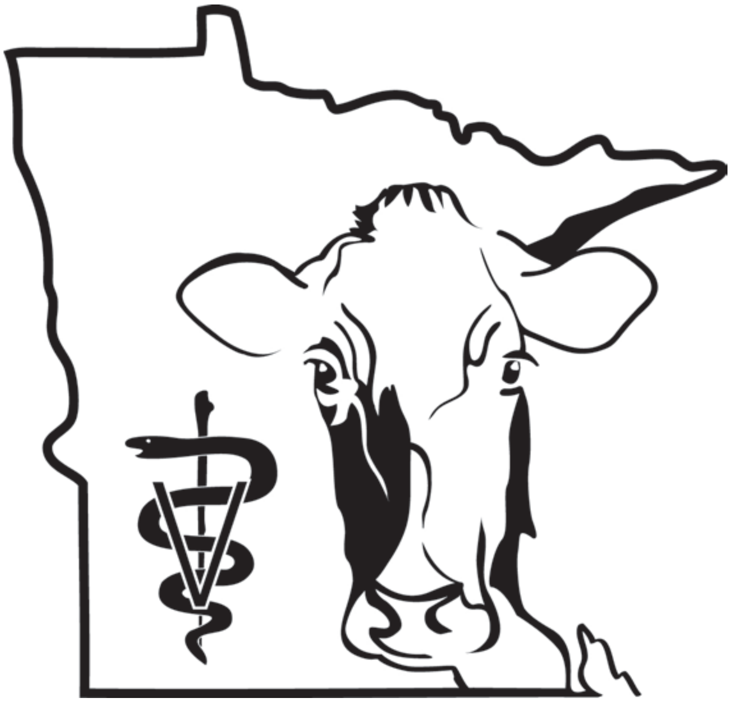

The Relationship of Serum and Milk Urea Nitrogen to Diet and Reproductive Performance of Dairy Cattle

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Introduction

Urea in serum and milk is derived from either ammonia that is absorbed through the rumen wall and converted to urea by the liver or as a byproduct of metabolism of protein absorbed from the intestine or mobilized from tissue and a subsequent deamination of the amino acids. The rumen ammonia pool results from either the direct ingestion of ammonia from sources such as ammoniated silages or ammonia containing compounds such as urea and urea recycled in saliva or indirectly from the degradation of dietary crude protein and release of ammonia. Rumen ammonia, amino acids, and peptides are produced when dietary protein consumed by cattle is broken down by rumen microbes. Rumen microbes use fermentable carbohydrates to provide the energy and organic acids and ammonia to form amino acids and subsequently microbial proteins. When rumen ammonia concentrations exceed the ability of rumen microbes to incorporate ammonia into microbial protein, ammonia is absorbed through the rumen wall and converted to urea by the liver. Urea produced by the liver may either be recycled to the rumen through saliva or excreted by the kidney. Urea may also be produced when proteins from body tissues or amino acids absorbed from the intestine are catabolized for gluconeogenesis. Urea concentrations in blood (BUN), serum (SUN), plasma (PUN), or milk (MUN) are related to dietary crude protein intake, degraded intake protein (DIP), undegraded intake protein (UIP) and fermentable energy available in the rumen. Elevated BUN, SUN, PUN, and MUN have been associated with reduced fertility of cows. Since analysis for urea concentrations in body fluid can be preformed inexpensively, urea concentrations have been used to monitor the adequacy of dietary protein and to diagnosis infertility associated with protein malnutrition. The purpose of this paper is to discuss the BUN, SUN, PUN, and MUN as indicators of protein nutrition, and nutritional infertility in cattle.

Factors Influencing Urea Concentrations in Blood, Serum, Plasma, and Milk of Cows

Crude Protein Intake and Blood Urea Nitrogen. Staples, et al., 1993, reviewed 22 articles representing 125 dietary treatments published in the Journal of Dairy Science between 1980 and 1993 which reported crude protein intakes and BUN concentrations. Analysis of the data described the relationship between crude protein intake and BUN by the regression $Y = 5.72 + 1.14X$ ($R^2 = .31$) where Y = BUN in mg/dl and X = CP intake (lb/d) (Figure 1). Only 31% of the variation in BUN levels could be accounted for from the crude protein intake. In other words, knowing the crude protein intake of a cow is not an accurate means of predicting BUN levels and, conversely, BUN level is not a good predictor of CP intake. However, BUN can be a good indicator of unutilized dietary crude protein. The correlation also implies that other factors must be considered if the prediction or evaluation of BUN levels is too useful.

Effect of UIP and DIP on Blood Urea Nitrogen. Several trials have compared protein sources of varying degradability and reported the resulting BUN, PUN, SUN, and MUN. Owens and Larson, 1991, compared rations using soybean meal (SBM) or dried distillers grains with solubles (DDGS) formulated at either 14.5 or 18% crude protein. The SUN levels for diets formulated at 14.6% CP with SBM and DDGS 13.0 and 10.5 mg/dl, and for rations formulated at 18% CP the values were 18.0 and 14.0 mg/dl, respectively. The higher UIP value for DDGS resulted in lower SUN. Sklan and Tinsky, 1993, observed a reduction of PUN from 20.7 to 16.7 mg/dl when the UIP was increased from 6.0 to 6.8% in rations with 17.5% crude protein. Increasing the proportion of UIP in the ration may decrease BUN and SUN levels when CP level is held constant.

Diurnal variation in SUN and MUN. Gustafsson and Palmquist, 1993, evaluated rumen ammonia levels and SUN and MUN concentrations in four cows to study diurnal variation of urea content. When cows were fed a total mixed ration ad libitum once a day, rumen ammonia levels peaked within an hour post-feeding. SUN reached peak concentrations 1.5 to 2.0 hours after the rumen ammonia peak. Milk urea concentrations paralleled serum concentrations but with a lag of 1.5 to 2.0 hours. Figures 2 and 3 demonstrate the changes in SUN and MUN concentrations relative to milking and feeding. Cow A was 36 days in milk and Cow D was 88 days in milk. Cows A and D consumed 45 lbs and 55 lbs dry matter at 17 to 18% crude protein and produced 83 and 89 lbs of milk, respectively. In Cow A, SUN concentrations varied from a peak of 22 mg/dl to a nadir of 13 mg/dl and for Cow D the peak was 25mg/dl and nadir was 13 mg/dl. These two cows demonstrate the diurnal variation in SUN concentrations and the problem of the timing of sample collection relative to feeding for evaluation of SUN. Elrod and Butler, 1993, fed Holstein heifers total mixed rations of either 15.45 or 21.8% crude protein. Peak plasma urea N (PUN) levels occurred 8 hours post-feeding in both heifers fed normal or high protein rations. The prefeeding and peak PUN levels were 10.2 and 17.5 mg/dl, respectively, for the normal protein group and 14.8 and 23.6 mg/dl, respectively, for the high protein group. For the heifers, interval from feeding to peak SUN was considerably longer than in the cows. Carlsson and Bergstrom, 1994, reported the diurnal variation in MUN of 6 dairy cows fed a ration of hay, grass silage, and concentrate twice a day. The highest MUN values occurred 3 to 5 hours after the beginning of the morning feeding and the lowest values during the night. Interestingly, MUN values increased after the morning feeding but decreased after the afternoon feeding.

Postpartum Interval and SUN. Howard, et al., 1987, fed cows rations of either 15 or 20% crude protein to determine the effect on reproductive traits. Figure 4 demonstrates the relationship between dietary crude protein intake and PUN between calving and 150 days in milk. The PUN increases rapidly during the first month following calving and slowly from one to five months of lactation with PUN averages 11 mg/dl greater for the cows fed the 20% crude protein ration. It is apparent that PUN concentrations would be difficult to interpret when values are changing rapidly during the early postpartum period. Thus, samples for urea nitrogen determination should be avoided during the first month post calving.

Protein Nutrition and Reproductive Performance

Protein Nutrition and Conception Rate. Table 1 summarizes 11 trials in which the level of dietary protein, the BUN, SUN, or PUN concentration and the conception rates were reported. In most cases, as the level of dietary crude protein increased, the level of blood urea nitrogen increased. In some studies, the degradability of the dietary protein was manipulated by feeding different protein sources. As expected, as the degradability of the protein in the rations decreased, the BUN decreased. With few exceptions, there is a clear trend for the conception rate to decrease as the BUN increases. However, the results of these trials present several problems in applying the information in these trials to evaluate the effects of protein nutrition, and BUN and MUN values on reproductive performance of individual dairy farms. In most trials, the time at which samples were collected for BUN or SUN determinations is stated relative to time the animals were fed. However, as previously stated, there is considered diurnal variation in BUN and MUN values and the relative differences in urea nitrogen values reported within trials provide evidence of the effect of BUN and SUN upon conception rates but the absolute values are not readily transferrable between trials or to values obtained from field investigations. Second, it takes relatively large number of cows to detect differences in fertility. To detect a 5% difference with a P value < 0.05 in conception rate between two groups, it would require 150 cows per treatment. Only 3 of the 11 trials in Table 1 detected significant differences in conception rate. Ferguson, et al., 1993, collected the results of 627 AI's in 9 herds while examining the relationship between SUN concentration to conception rate (Figure 6). Conception rate varied little when SUN concentration was between 10 to 25 mg/dl. However, conception rate decreased by about 13 percentage when SUN exceeded 25 mg/dl. The variation of SUN within herd further compounds the problem of identifying the effect of SUN on reproductinve performance. Third, there are many potential causes of infertility in herds and many herd causes of infertility don't have a single definitive diagnostic tests to identify the etiology.

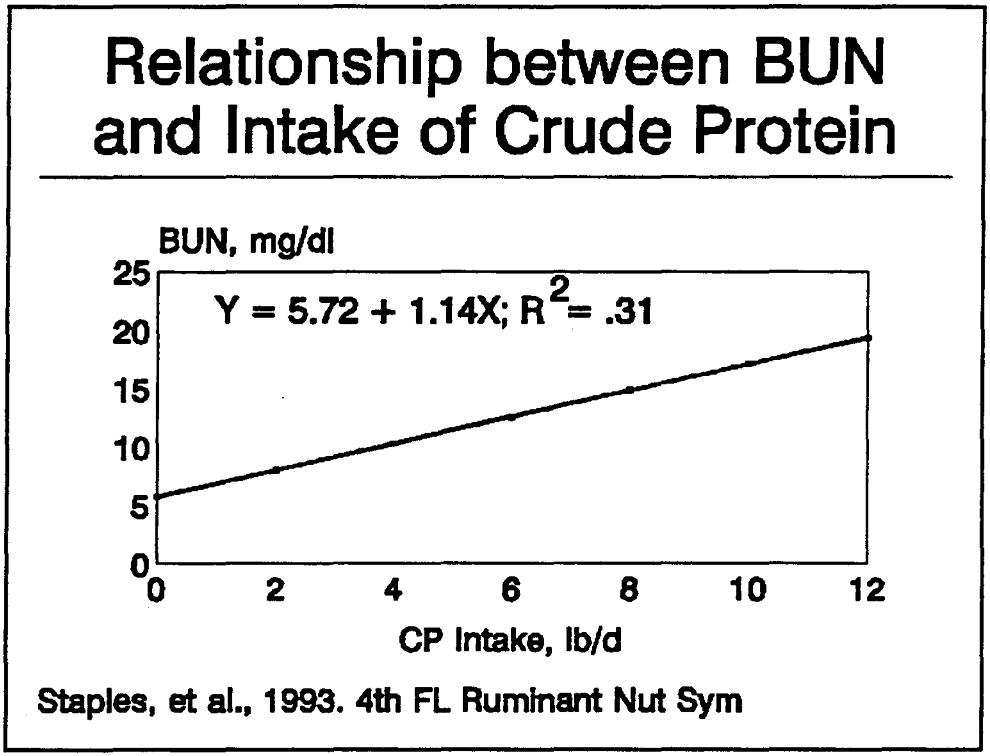
Mechanisms for Protein Effect on Reproduction. One possible mechanism for the adverse effect of excess protein on reproductive performance may be through extracting an additional energy requirement from the cow. Butler, et al., 1981, determined that the interval to first ovulation was increased by 2.75 days for each average 1 Mcal Nel of negative energy. Several studies have demonstrated that the conception rates of cows in a negative energy balance are lower than herdmates that are in a positive energy balance. The conversion of ammonia to urea requires energy. For each 100 g of unutilized crude protein fed, there is an energetic cost of 0.2 Mcal. Overfeeding 1000 g of excess crude protein could cost the cow 2 Mcal/d.

Elrod, et al., 1993, fed 3 isoenergetic total mixed rations to Holstein cows in early lactation. The control ration met both the UIP and DIP requirements (Balanced). A High UIP ration met DIP requirements and exceeded DIP requirements by 25%; a High DIP ration met UIP requirements and exceeded DIP by 25%. Uterine pH of all groups of cows averaged 6.83 at estrus but 7 days post estrus, the uterine pH in both the UIP and DIP groups was significantly lower. Feeding excess protein altered the uterine environment which may be related to reduced fertility.

Conclusions

1. Bulk tank milk urea nitrogen has the potential of being a useful a screening test to monitor protein nutrition and identifying herds where high urea nitrogen in blood or milk is associated with reduced fertility. The potential advantages of bulk tank milk urea nitrogen as a screening test is that it is inexpensive, it is a "weighted average" of milk with greatest contribution from cows which are resuming estrous cycles and are being bred, and it is a "diurnal average." The average MUN values for 110 bulk tank samples in Minnesota were 16 mg/dl with a standard deviation of 4 mg/dl (Figure 5).

2. In comparative trials, feeding rations containing higher levels of crude protein or DIP have resulted in higher levels of BUN or MUN and reduced reproductive performance of both lactating dairy cows and nulliparous heifers. At the present time, it is unclear whether the peak BUN, the BUN level at the nadir of a period, or the average BUN over a period of time is the most important factor affecting reproductive performance. This is further complicated by diurnal variation in BUN and MUN and by effect of sampling time relative to feeding.

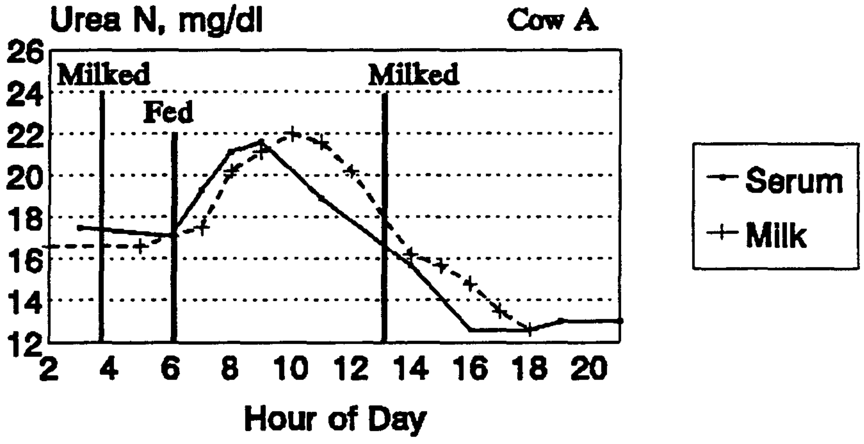


Relationship between BUN and Intake of Crude Protein

Staples, et al., 1993. 4th FL Ruminant Nut Sym

Figure 1

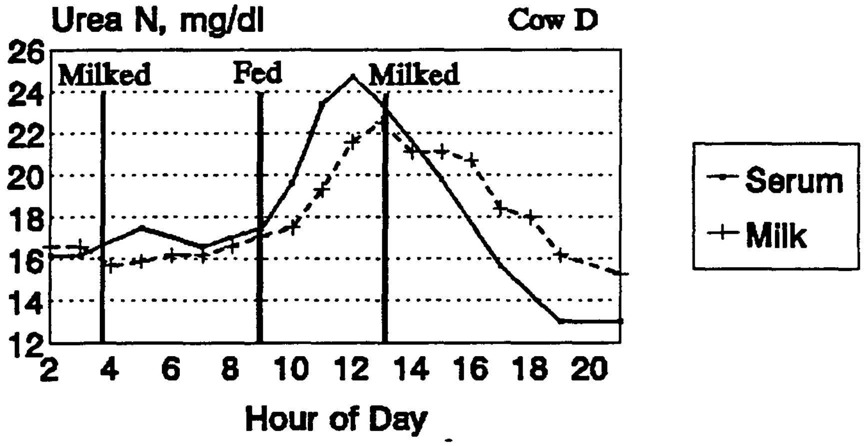
Relationship of Urea N in Serum to Milk



Gustafsson and Palmquist, 1993. JDS 76:475

Figure 2

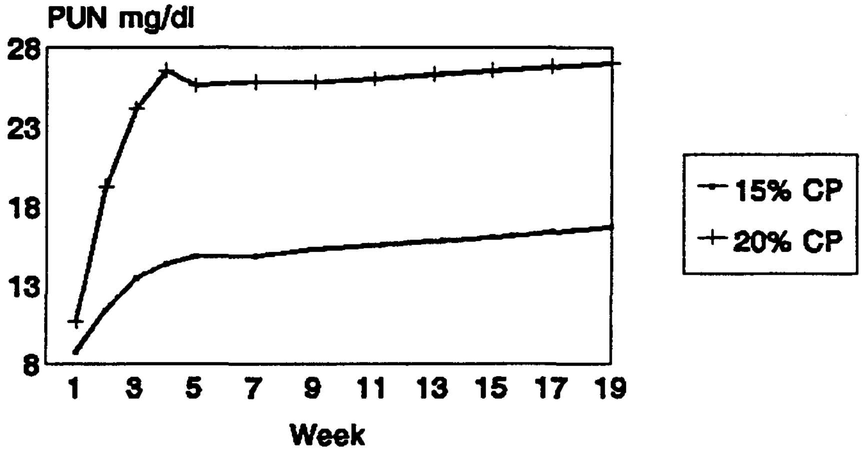
Relationship of Urea N in Serum to Milk



Gustafsson and Palmquist, 1993. JDS 76:475

Figure 3

Relationship of Postpartum Interval to Plasma Urea Nitrogen

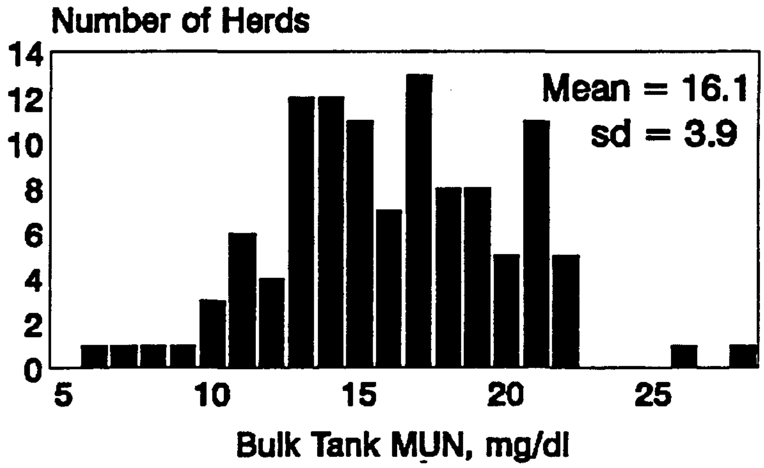


Howard, et al., 1987. JDS 70:1563-1571

Figure 4

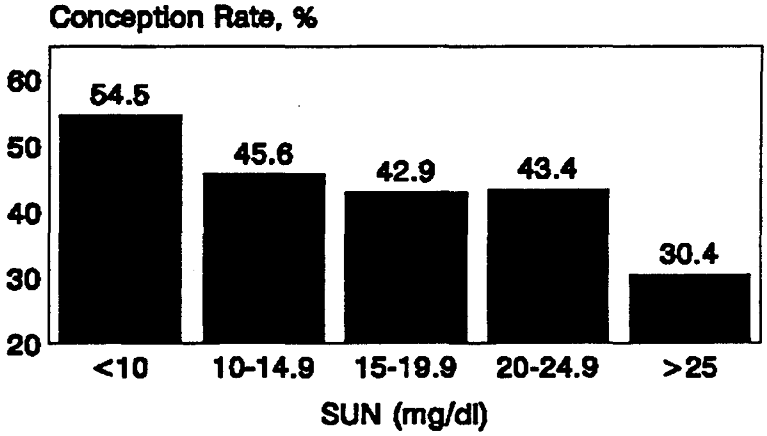
Concentration of MUN in Bulk Tank Milk

111 Minnesota Herds



Relationship between SUN and Conception Rate

332 Cows



Ferguson, et al., 1993. JDS 76:3742

Table 1. Relationship of Protein Nutrition to Conception Rate

Study	No. of Cows	Diet CP%	BUN mg/dl	Conc Rate
Jordan and Swanson, 1979	15	12.7	9.1	68.0^{a}
	15	16.3	9.1	53.5^{b}
	15	19.3	18.3	40.5^{c}
Folman, et al., 1981	20	16 SBM	8.4	69
	19	16 SBM Tx	8.8	56
	20	19 SBM	15.4	< 44
Kaim, et al., 1983	89	15-16	8.0	56.6^{a}
	98	19-20	16.8	43.1^{b}
Howard, et al., 1987	75	15	14.8	64.5
	71	20	24.4	68.0
Carroll, et al., 1988	29	13	10.0	64
	28	20	24.5	56
Ferguson, et al., 1988	59	16	18.2	47
	44	18.5	23.0	23
Bruckental, et al., 1989	50	17 LSBM	25.7	48
	50	21 HSBM	32.6	43
	50	21 HFM	26.9	52
Canfield, et al., 1990	32	16	12.3	48^{a}
	33	19	19.3	31^{b}
Owens and Larson, 1991	16	13.9 Ctrl	12.5	54.5
	15	14.6 SBM	13.0	63.6
	15	14.6 DDGS	10.5	62.5
	16	18.7 SBM	18.0	50.5
	11	17.7 DDGS	14.0	33.3
Elrod and Butler, 1993	40	15.45 CP 73.0 DIP	17.5	82
	40	21.8 CP 82.8 DIP	23.6	61
Sklan and Tinsky, 1993	53	17.5 (UIP 6.0%)	20.7	59.5
	53	17.5 (UIP 6.8%)	16.7	69.9

a,b,c Differing superscripts within a column indicate $P < 0.05$

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