PROTEIN INTAKE AND REPRODUCTIVE PERFORMANCE OF DAIRY COWS: A REVIEW, A SUGGESTED MECHANISM, AND BLOOD AND MILK UREA MEASUREMENTS

Charles R. Staples, Carlos Garcia-Bojalil, Bradley S. Oldick,
William W. Thatcher, and Carlos A. Risco
University of Florida, Gainesville 32611

Introduction

The effects of high crude protein (CP) intakes on reproduction of lactating dairy cows is a controversial issue in the dairy sciences and industries. Published results representing several laboratories indicate both harmful and innocuous effects of elevated intake of protein on recrudescence of estrus, conception, days open, and embryo survival. The purpose of this paper is to summarize these studies, to discuss one mechanism of action potentially responsible for reduced performance in light of recent results, and to discuss the feasibility of using blood and milk urea nitrogen concentrations as indicators of nutritive and reproductive status of cows.

Sources of Systemic Nitrogen

Feeding of Crude Protein

Metabolism. Dietary protein is hydrolyzed to peptides and amino acids by ruminal microorganisms. Amino acids can be degraded further to organic acids, carbon dioxide, and ammonia. For example, valine is catabolized to the branched chain fatty acid, isobutyrate, and ammonia. Proline is catabolized to the five carbon fatty acid, valeric acid, and ammonia. Ruminal microorganisms normally utilize ammonia for protein synthesis. Often times the liberation of ammonia is very rapid, such that microorganisms can not capture all available ammonia. Unutilized ammonia is absorbed through the wall of the rumen, enters the portal vein, transported to the liver, and converted to urea which is excreted partially in the urine and partially recycled back to the rumen via saliva. Elevated concentrations of ammonia in the rumen will elevate ruminal pH which increases the absorption rate of ammonia and serves to aggravate the excess supply of ammonia to the liver. The degree of solubility of dietary protein often is related positively to ruminal ammonia concentrations.

Fermentation in Rumen. Feedstuffs differ in the degradabilities of their protein fraction, ranging from 100% for urea to about 20% for blood meal. Therefore, diets may be equal in CP concentration but different in ruminal degradability of CP. Recommended (NRC, 1989) concentration of degradable intake protein (DIP) is 57.4% of total dietary CP during weeks 0 to 3 postpartum due to lower DM intakes, increasing to about 63% for the duration of lactation. If dietary DIP is in excess of requirement, ruminal ammonia concentrations will increase leading to increases in urea concentrations of body fluids.

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Amount. National Research Council (NRC; 1989) recommends feeding diets containing 19% CP during the first 3 weeks of lactation and 16 to 18% thereafter depending upon the amount of milk being produced. However, many dairies with high rolling herd averages continue to feed 19% CP diets for months beyond the 3 week guideline and on into the breeding period. Daily intake of CP is correlated positively with intake of DM, gradually increasing postpartum, and plateauing at the same time cows are being bred. Excess dietary protein results in elevated concentrations of blood urea nitrogen (BUN) and occasionally of blood ammonia. These elevated concentrations are thought to influence reproductive performance.

Mobilization of Body Protein Reserves

Additional nitrogen (ammonia) is added to the animal's system as amino acids stored in body reserves are mobilized (11 to 15 kg of body protein the first 60 days postpartum [NRC, 1989]) for synthesis of milk protein and glucose. Liberated ammonia from gluconeogenesis is transformed into urea by the liver and other tissues thus increasing the energy costs to these tissues.

Elevated CP Intake and Reproduction

The reproductive tract undergoes extensive changes during these first weeks postpartum. As the cow shifts from a pregnant to a nonpregnant state, the endocrine functions of the pituitary and hypothalamus change, the uterus experiences morphological and histological changes, and the ovaries return to follicular growth, ovulation, and CL formation. Insemination often is initiated at 7 to 10 weeks postpartum which follows this dynamic scenario. Physiological changes often are accompanied by dramatically changing energy and protein states of the animal. In fact, changes in these nutritional conditions have been shown to influence physiological changes associated with reproduction.

If more CP is fed than can be utilized by the cow, urea concentrations in body tissues can be elevated. A search of the scientific literature indicated that the feeding of diets containing 19 to 21% CP resulted in elevated BUN concentrations and frequently in lowered conception rates compared with cows fed 15 to 16% CP diets (Table 1). Depression in conception rates over the eight studies averaged 12 percentage units. In some studies, parity was an important factor in whether elevated dietary CP had a depressing effect on conception rate. Older cows were more likely to be affected negatively by elevated dietary CP than younger cows (Bruckental et al., 1990; Ferguson et al., 1986; Kaim et al., 1983). However, primiparous cows also showed a greater sensitivity over cows in their second or third lactation (Bruckental et al., 1990; Carroll et al., 1988).

Not only has the total CP content of a diet proven important for reproductive performance but also the dietary concentration of DIP. In the six experiments summarized in Table 2, replacing soybean meal with a less ruminally degradable protein feedstuff such as fish meal, corn gluten meal, etc. alleviated some reproductive inefficiency, including delayed first ovulation, lowered conception rates, and elevated embryonic deaths. Across the published literature, in more cases than not, the feeding of excess protein leading to

elevated BUN concentrations resulted in some deficiency in reproductive performance of lactating dairy cows.

Table 1. Conception Rates (CR) and Blood Urea Nitrogen (BUN) Concentrations of Lactating Cows Fed Diets of Moderate or Elevated CP Content.

	% Dietary CP			
	15-16		19-21	
Reference	CR (%)	BUN (mg%)	CR (%)	BUN (mg%)
Jordan and Swanson, 1979[1,2]	53	NR[4]	40	NR
Folman et al., 1981	56	8.8	44	15.4
Kaim et al., 1983[2]	57	9	43	17
Howard et al., 1987	87	15	85	26
Carroll et al., 1988[3]	64	11	56	24
Bruckental et al., 1990[2]	65	25	52	32
Canfield et al., 1990[2,3]	48	12	31	19
Elrod and Butler, 1991[2,3]	83	<16	62	>16
Average	62	13.8	48	21.3

[1]Of cows conceiving.
[2]$P < .05$.
[3]First service.
[4]Not reported.

Table 2. Beneficial Effect of Replacing Soybean Meal with a Less Degradable Protein Feedstuff on Reproductive Performance.

Reference	% Dietary CP (% degradable intake protein)	Protein Concentrate[1]	BUN mg%	Adverse Effect of SBM on Reproductive Response
Garcia et al. 1992	20.0 (70% DIP)	SBM/Urea	21.8	13 Day Delay to First Ovulation
	19.9 (54% DIP)	CGM/FM/BM/MBM	17.3	
McCormick et al., 1992	17.2	SBM	20.1	Early Embryonic Deaths
	17.2	CGM/FM	18.2	53 vs 31% (NS)
Figueroa, et al., 1992	20 (65% DIP)	NR[2]	20.0	16 Day Delay to First Ovulation
	20 (60% DIP)		20.7	
Armstrong et al., 1990	>16.6	SBM	SBM < FM	Lower Conception Rate
	>16.6	FM		44% vs 64%
Bruckental et al., 1990	21.6	SBM	32	Lower Conception Rate
	21.6	FM	28	52% vs 72%
Folmon et al., 1981	16	SBM	8.8	Nonsignificant CR Change
	16	Formaldehyde SBM	8.4	56 vs 69

[1]SBM = soybean meal; CGM = corn gluten meal; FM = fish meal; BM = blood meal; MBM = meat and bone meal.
[2]Not reported.

Proposed Mechanism of Elevated Intake of CP on Reproductive Performance

Several hypotheses have been proposed regarding the often-observed negative effect of elevated CP intake on reproductive performance (Staples et al., 1992). Concentrations of ammonia, urea, or other unknown nitrogenous compounds are thought to be sufficiently high in body tissues to hamper normal processes leading toward fertilization, embryo development, and implantation of the conceptus, thereby retarding genesis of a new calf. Hypothetical sites of potential regulation by nitrogenous compounds include the hypophyseal-pituitary-ovarian axis, gametes, developing embryo in the oviduct and uterus, and the immune system.

A second viable mode of action of high concentrations of systemic nitrogen on reproductive performance is that of "weakening" the energy status of the animal. Early postpartum dairy cows lose body weight (condition) in order to support milk yields unable to be supported through energy intakes. Negative energy status is the normal condition for 6 to 8 weeks postpartum (Staples et al., 1990). Extent of negative energy status is one the most important factors affecting return to normal ovarian activity after calving. First ovulation was pushed back an average of 2.75 days for every 1 Mcal of negative energy status experienced during the first 20 days postpartum (Butler et al., 1981).

The need to detoxify ammonia by animal tissues can be energetically costly. The conversion of an ammonia molecule to urea (urea cycle) by the liver costs 3 ATP's. In other tissues (kidney, muscle, brain), glutamic acid reacts with ammonia to form glutamine which costs 1 ATP. The immediate source for glutamic acid is α-keto-glutarate (conversion cost of 1 ATP), an intermediate compound of the Citric Acid Cycle which is key to energy generation for the animal. If the demand for α-keto-glutarate is high, might the workings of the Citric Acid Cycle be compromised, further aggravating a negative energy state? The excretion of one gram of nitrogen in urine costs 5.45 kcal for detoxification of ammonia to urea (Blaxter, 1962). Feeding 100 g of unutilized CP results in a loss of 0.2 Mcal of energy (Twigge and Van Gils, 1988). If 500 to 1000 g of excess protein is consumed, energy costs could be a quite substantial 2 Mcal/d (up to 7% of NEL requirement for maintenance and production of 30 kg of milk). With energy status averaging about -11 Mcal/d during the first three weeks postpartum (Staples et al., 1990), an additional 1 to 2 Mcal/d cost is not small. This energy cost is likely to push early postpartum cows even further into negative or less positive energy states. The effect of negative energy status on ovarian activity is becoming clearer. Lucy et al. (1991) found that as energy status became more positive in the early postpartum period, the diameter of the largest follicle on day 10 increased, the number of double ovulations increased, the day of detection of the first corpus luteum was earlier, and the average pulse amplitude of luteinizing hormone increased. These changes likely will reduce days open and may improve conception at first service if estrous cycles are initiated early postpartum.

To test the effects of intake of energy and DIP on reproductive performance of lactating dairy cows, 40 cows were assigned at calving to 20% CP diets containing either 72.5% or 56.5% DIP and 0 or 2.2% calcium salts of long chain fatty acids (CaLCFA; Megalac^{R}). Crude protein intake was 1100 g greater than required for milk produced (NRC, 1989). Treatments continued through 120 days in milk. Cows fed the highly degradable protein diets had greater BUN values (22.0 vs. 17.3 mg%; P=.01). Based upon progesterone concentrations of blood samples taken three times per week, cows fed the 72.5% DIP diets experienced more days to first luteal phase postpartum (39 days) than cows fed other diets (26 days; P=.0001; Table 3). All cows on experiment were synchronized to estrus between days 50 and 57. Cows not cycling prior to synchronization were assigned 50 days to first luteal activity. If cows had not been synchronized, the number of days to first luteal activity likely would have been even greater for cows fed the 72.5% DIP diets. Others have reported more days to first ovulation due to feeding of excess protein (Figueroa et al.,

Table 3. Effect of Degradable Intake Protein (DIP) and Calcium Salts of Long Chain Fatty Acids (FAT) Supplementation on First Luteal Phase of Lactating Dairy Cows Within the First 50 Days Postpartum.

	72 DIP		56 DIP			STATISTICAL CONTRAST		
Measurement	-FAT	+FAT	-FAT	+FAT	SEM	FAT	DIP	INT
Number of cows	10	11	13	11				
Anestrus cows	4	1	1	1		Probability		
Days to CL	41.8	35.7	25.8	25.2	3.1	.29	.0001	.38
Luteal Length, d	7.5	12.4	16.4	19.8	2.9	.16	.007	.80
Peak Plasma P_4[a], ng/ml	3.9	7.3	8.1	8.3	1.4	.18	.06	.24
Accumulated Plasma P_4, ng	371	702	848	1007	99	.019	.0003	.39

[a]Progesterone (P_4).

1992; Carroll et al., 1988). Four out of 10 cows fed 72% DIP diet without CaLCFA were anestrus at synchronization compared with only three out of 35 cows fed the other dietary treatments. These prolonged days to recrudescence of ovarian activity and the anestrus condition were matched with greater loss of body weight and body condition by these cows (Figures 1 and 2). Cows fed 72.5% DIP diets lost more body weight and for a longer period of time compared with cows fed 56.5% DIP diets (44 kg at 28 days postpartum vs. 18 kg at 20 days postpartum; Figure 1). The absence of CaLCFA resulted in a 10 kg greater loss in BW of cows fed 72.5% DIP diets. In addition, body condition loss was greater and more prolonged by cows fed the CaLCFA-free, 72.5% DIP diet (Figure 2). The additional energy costs of detoxifying ammonia from highly degradable dietary protein possibly led to a greater reliance on body energy stores for milk production. This resulted in a more severe energy state that delayed ovarian activity. By including energy dense feedstuffs in the diet (CaLCFA), the energy shortage was somewhat alleviated allowing cows to rely more on feed energy and less on body reserves for milk production.

Other studies have reported greater body weight losses by cows consuming elevated amounts of CP. It was older cows ($\geq$ 4 lactations) which lost the most BW which had conception rates lowered from 77 to 52% when dietary CP increased from 15-16% to 19-20% (Kaim et al. 1983). Cows fed 20% CP diets lost 14.7% of BW compared with cows fed 15% CP diets which lost 7.9% of BW (Holtz et al. 1986). In the study of Bruckental et al. (1989), cows were fed diets of 17% CP with SBM, 21.6% with SBM, or 21.6% with SBM and fish meal. Body weight gain from time of postpartum minimal BW to 24 weeks postpartum was 220^a, 170^b, and 230^a g/day for primiparous cows and $220^{a,b}$, 160^a, and 310^b g/d for multiparous cows fed diets described above, respectively. Multiparous cows in their

Figure 1. Effect of Degradable Intake Protein (DIP) and Ca-LCFA (Fat) on Body Weight Change in Lactating Cows.

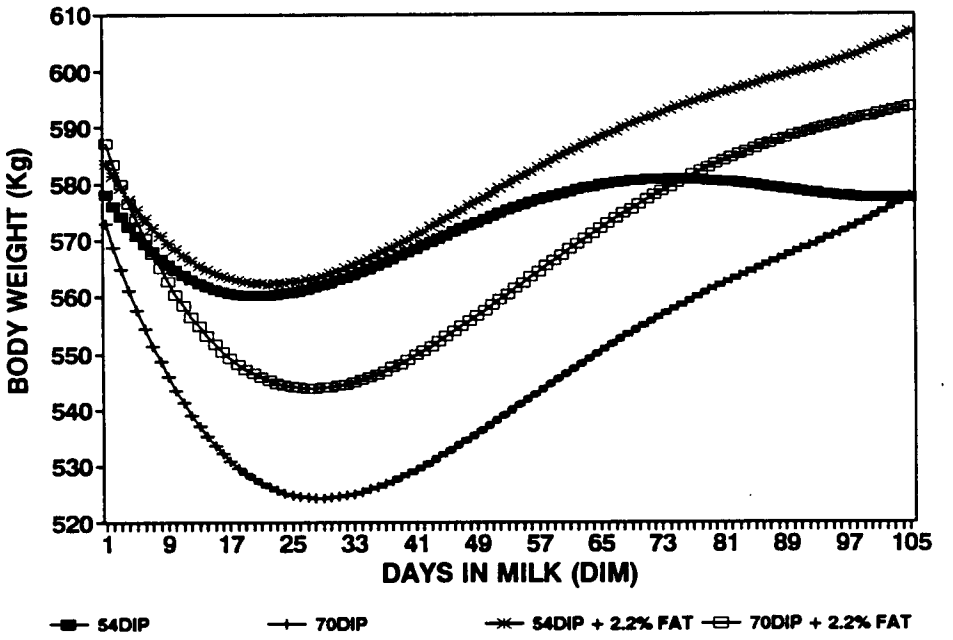
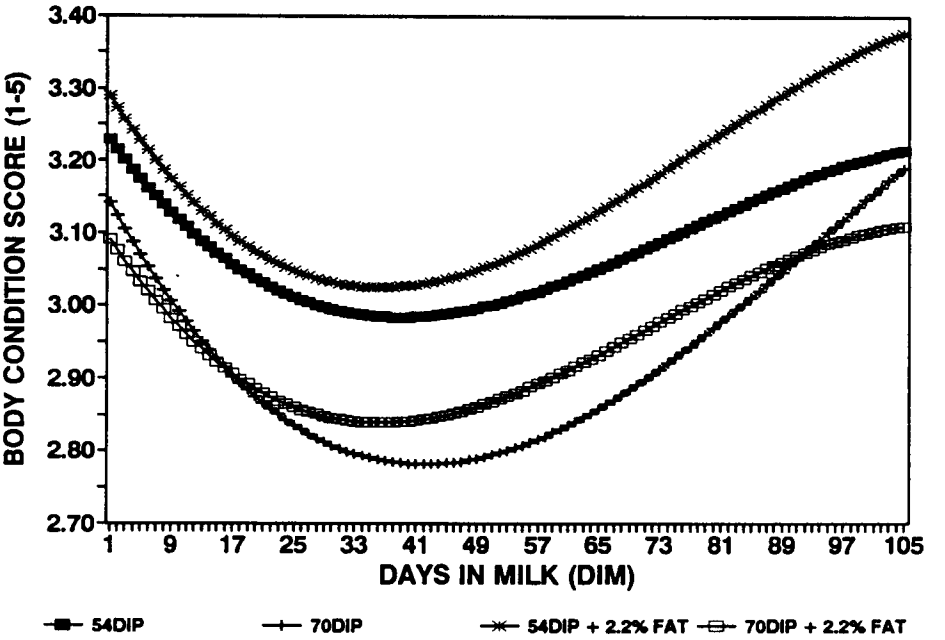


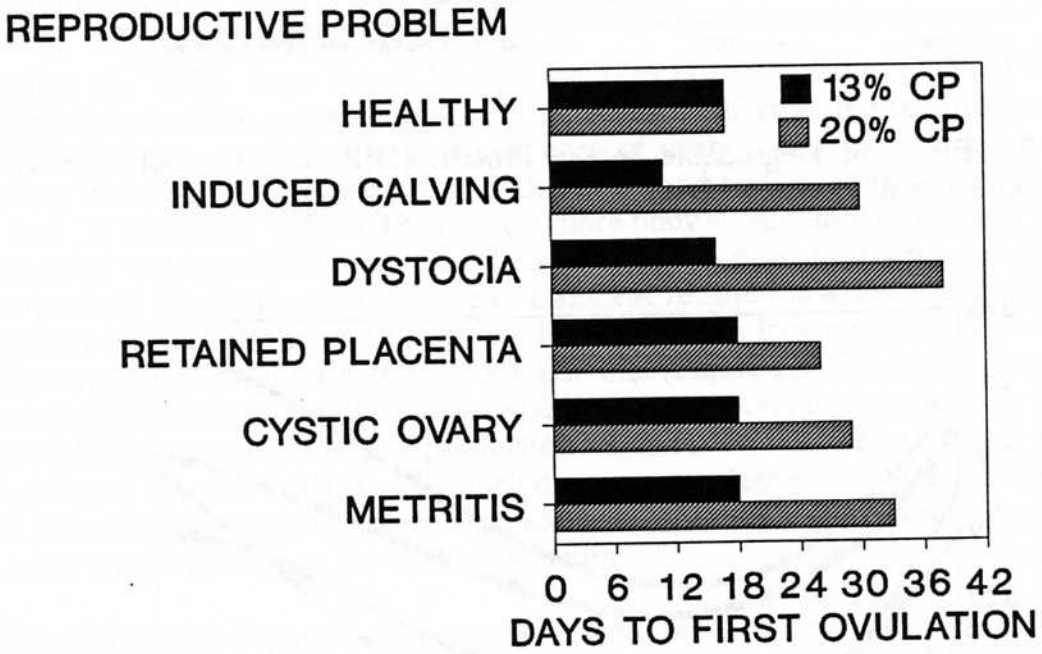
Figure 2. Effect of Degradable Intake Protein (DIP) and Ca-LCFA (Fat) on Body Condition Score of Lactating Cows.



fourth or greater lactation gained even less weight than cows in their second or third lactation (170, 80, and 210 vs. 240, 180, and 340 g/d, respectively) due to CP source. (Treatment LS means with different superscript letters are different at $P<.05$).

Energetic inefficiency also characterizes cows laboring under health problems. The feeding of excess protein to cows in poor health may lower their resistance to infectious agents and compromise their ability to recover from reproductive disorders. Anderson and Barton (1988) found that early postpartum cows fed 20% CP diets had more reproductive health problems than cows fed 13% CP diets (17/27 compared with 12/29). Problems included induced labor, dystocia, retained fetal membranes, cystic ovaries, and metritis. Unhealthy cows fed high amounts of CP had nearly double the days to first ovulation compared with unhealthy cows fed low CP diets (31 vs. 16 days: Figure 3). Dietary CP had no effect on days to first ovulation if cows were healthy.

Figure 3. Effects of Dietary CP Concentration on Days to First Ovulation in Healthy Cows and Those Having Reproductive Problems.



ANDERSON AND BARTON, 1988

ROLE OF UREA CONCENTRATIONS IN BLOOD AND MILK

Previous Studies

What role might BUN values play in warning producers that a potential reproductive inefficiency might be occurring? In Table 1, cows fed elevated CP diets averaged greater BUN concentrations than cows fed lower CP diets (21.3 vs 13.8 mg/100 ml). However, the

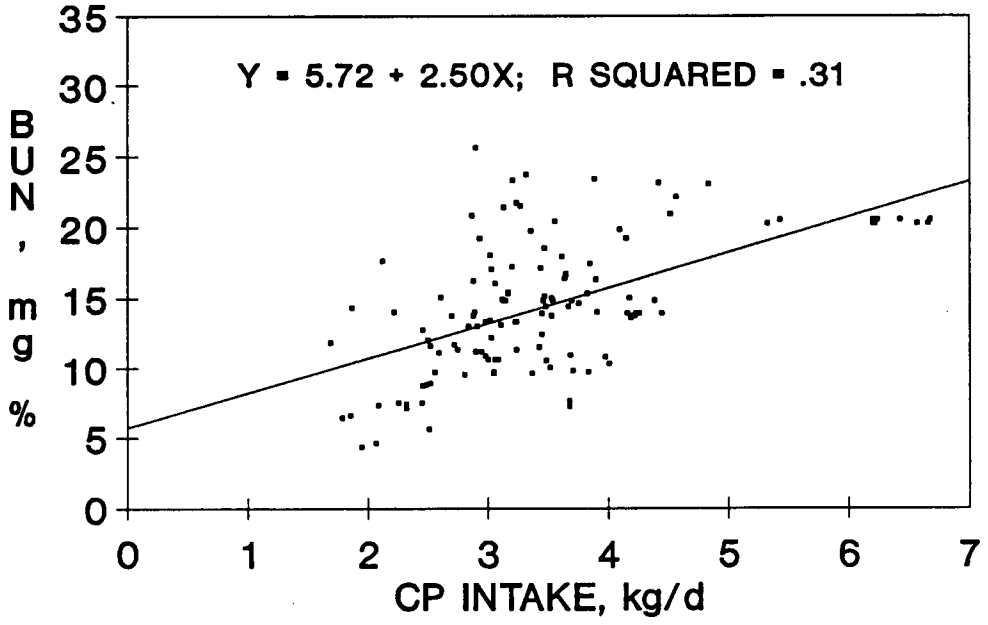
point at which BUN values led to lowered conception rates was very wide. In four studies (Kaim et al., 1983; Bruckental et al., 1990; Canfield et al., 1990; and Elrod and Butler, 1991) in which conception rates were lowered ($P<.05$), BUN values exceeded 16 mg/100 ml (range of 16 to 32 mg%). However, in two cases (Howard et al., 1987; Carroll et al., 1988), BUN values were elevated (26 and 19 mg%, respectively) by feeding high CP diets with no detrimental effect on CR reported. Carroll et al. (1988), however, reported that time to first ovulation was increased by 5 days in cows with BUN values of 19 mg%.

In Table 2, feeding diets containing equal CP but elevated degradable CP contents resulted in slightly greater BUN values with two exceptions. Replacement of soybean meal with fish meal resulted in greater CP intake and therefore greater BUN values (Armstrong et al., 1990). A small change in dietary DIP concentration did not influence BUN values of Figueroa et al. (1992). In these two studies, some reproductive measurements were improved regardless of a change in measured BUN values. Whether this was due to an inopportune time of blood sampling or the lack of relationship of BUN to reproduction can not be stated with certainty. Nevertheless, the measurement of BUN for predicting animal reproduction was not reliable in these studies.

Factors Influencing BUN Concentrations

Intake of Crude Protein. Intake of the same amounts of crude protein does not result in the same BUN values. Twenty-two articles, representing 125 dietary treatments, from the Journal of Dairy Science since 1980 to present, reported BUN values along with daily CP intake. Analysis of these data resulted in the regression equation of $Y = 5.72 + 2.50X$ ($R^2 = .31$) where Y = BUN in mg% and X = CP intake (kg/d) (Figure 4). A cow

Figure 4. Relationship Between Blood Urea Nitrogen (BUN) Concentrations and Intake of CP.



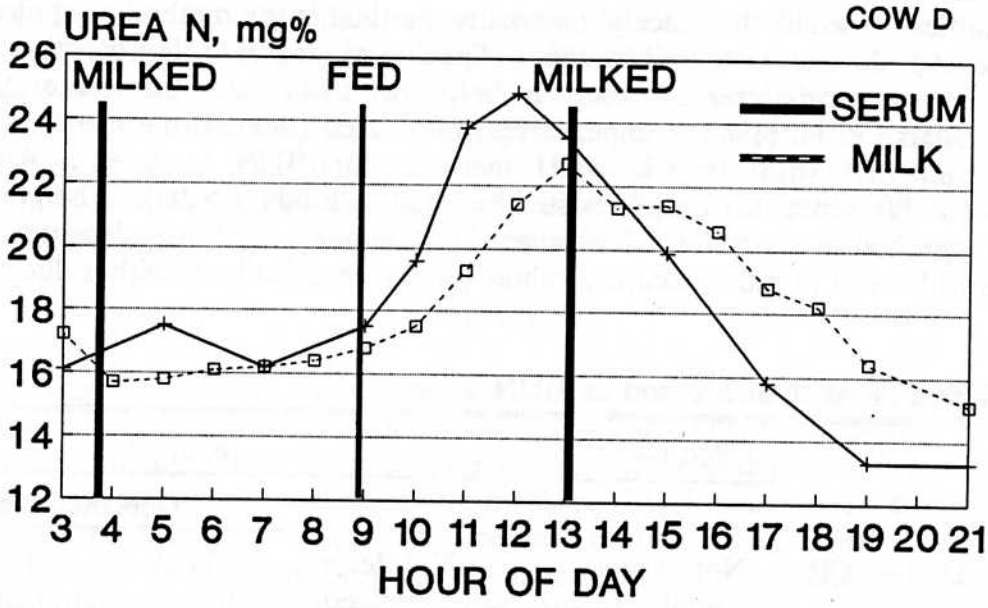
consuming 20 kg of a 20% CP diet daily consumes 4 kg/d of CP resulting in a BUN concentration of 16.2 mg%. However, according to Figure 4, cows consuming 4 kg/d of CP were reported to have BUN values ranging from about 8 to 23 mg%. Therefore, BUN is not a good indicator of CP intake. It can be a good indicator of unutilized dietary CP. Cows fed diets containing 19 to 21% CP concentrations may experience acceptable BUN concentrations if nitrogen is utilized efficiently in the rumen (right balance of amino acids and readily available energy source).

Sampling Time. Soon after consuming a meal, ruminal ammonia concentrations increase leading to an increase in BUN concentrations. Time of blood sampling in relation to meal time, therefore, can influence BUN values. Concentrations of BUN varied from 16 to 25 mg% for cow D (Figure 5) and from 13 to 22 mg% for cow A (Figure 6). These cows were fed ad libitum, a totally mixed diet once per day. If feedings occurred more frequently, such as 2 to 4 times daily, cows would consume more meals daily and diurnal variation in BUN would be reduced although number of BUN peaks would increase and hours spent above a certain BUN concentration might increase. BUN values rarely remain stable for any length of time. From cow D, sampling at time of feeding or 7 hours post feeding tended to result in BUN values representative of the 18 hour period. For cow A, sampling 1 hour prefeeding or 6 hours postfeeding would result in representative BUN values experienced by the cow over the 12 sampling period. Being aware of meal time in relation to bleeding will help one evaluate whether BUN readings are potentially "high", "low", etc. Obviously, the more meals a cow eats per day, the less variable her BUN values will be, making sampling time a less critical decision.

Method of BUN Analysis. Two colorimetric methods of BUN analyses were compared in our lab using plasma. Method 1 (Sigma Kit 640 "Urea Nitrogen") involves the hydrolysis of urea to ammonia and carbon dioxide using urease; then the conversion of ammonia to indophenol using alkaline hypochlorite and phenol. Plasma samples were not deproteinized prior to processing per instructions. Method 2 (Sigma Kit 535 "Blood Urea Nitrogen") converts urea to chromogen with diacetyl monoxime and ferric chloride. Kit 535 suggests that specimens should be deproteinized prior to processing if they are icteric (yellow) or hemolyzed.

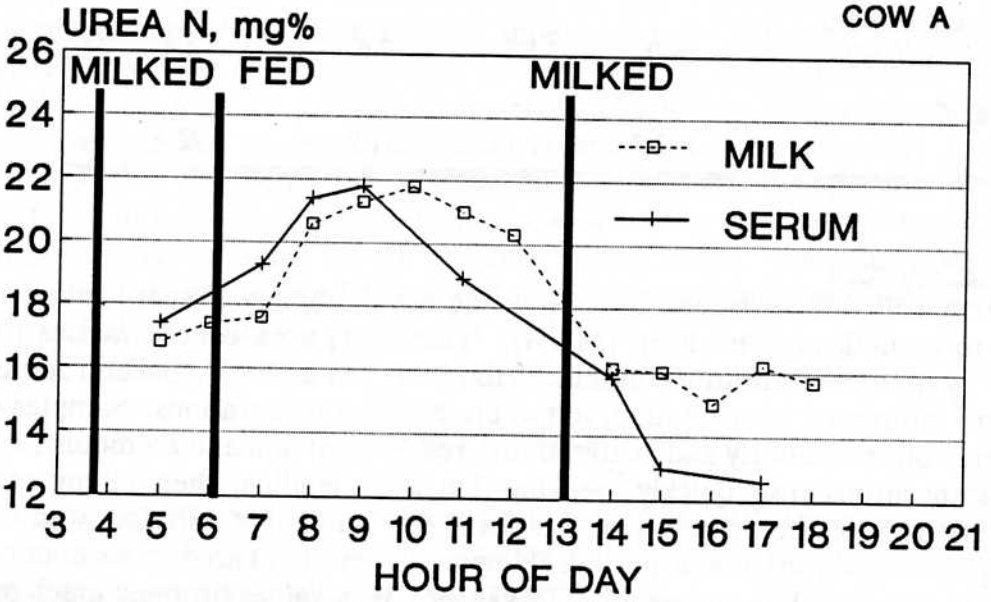
Two cows were fed alternately a high protein (27%) and a low protein (12%) diet. Jugular blood samples were collected into heparinized tubes and plasma harvested. Samples were analyzed using Sigma Kit 640 and Sigma Kit 535. When using Kit 535, specimens were not deproteinized or were deproteinized using either trichloroacetic acid (TCA) or tungstic acid prior to analysis. Specimens were analyzed in four assays and in duplicate per assay. BUN values for Sigma Kit 535 were greatest when plasma was not first deproteinized indicating the need for a deproteinization step (Table 4). A failure to deproteinize samples appears to increase BUN values from 12 to 41% (comparison of non-deproteinized to tungstic acid). Tungstic acid appeared to be a better deproteinizing chemical than TCA due to smaller coefficients of variability (CV) and better recoveries of spiked urea. Results from Kit 640 were similar to results using Kit 535 with the tungstic acid step although CV's were greater.

Figure 5. Comparison of Urea N Concentrations Between Milk and Blood Serum Samples. For Cow D.



ADAPTED FROM GUSTAFSSON AND PALMQUIST, JDS 1993

Figure 6. Comparison of Urea N Concentrations Between Milk and Blood Serum Samples. For Cow A.



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Both the urease (8 studies) and the diacetyl-monoxime (6 studies) methods were cited frequently in those same 22 JDS papers referred to previously. An autoanalyzer was used often (6 studies) in which the diacetyl-monoxime method is the method of choice over the urease method due to time constraints. Specimens are not deproteinized prior to autoanalyzer use. A dialyzer is present to help prevent proteins from entering reaction pathways. Marsh et al. (1965) compared the automated (nondeproteinized) and manual (deproteinized first with tungstic acid) methods for BUN analyses. An average, nonsignificant difference of 1.7 mg% existed between methods ($P > .05$). When the diacetyl-monoxime method is used for BUN analysis, it appears that the deproteinization of specimens will result in more accurate values (either chemically or with a dialyzer).

Table 4. Effect of Analysis Method on BUN Values.

		Kit 640	Kit 535		
				Deproteinized	
Cow	Diet % CP	Not deproteinized	Not deproteinized	TCA	Tungstic Acid
8927	12	20.7 ± 2.1	23.3 ± 3.5	18.5 ± .5	19.4 ± .4
8927	27	39.6 ± 3.1	44.2 ± 0.8	37.8 ± .9	39.3 ± .4
8965	12	13.8 ± 1.0	15.4 ± 1.0	10.2 ± .3	10.9 ± .3
8965	27	22.8 ± 1.6	23.7 ± 1.7	20.1 ± .4	21.1 ± .3
Average coefficient of variation (CV)		8.0	6.6	2.4	1.5
Average % Recovery		103.2	91.9	92.4	98.0

Milk Urea Nitrogen

Urea will diffuse freely from blood across mammary tissues ending up in milk, referred to as milk urea nitrogen (MUN). Therefore, urea concentrations in blood are reflected by urea concentrations in milk. However, just as BUN concentrations at a point in time are influenced by meal time, so too are MUN concentrations. Samples of milk and blood were collected hourly and analyzed for urea (Gustafsson and Palmquist, 1993). Blood urea concentrations rose quickly, peaking 3 h after feeding, then falling to prefeeding concentrations 5 to 6 hours later (Figures 5 and 6). Values for milk followed a similar rise and fall pattern over a 10 hour period. However, there appeared to be about a one hour delay between peak BUN and peak MUN values. BUN values dropped much more quickly than did MUN values.

Are milk samples taken at regular milking times representative of urea circulating in the blood? The answer is yes but the relationship is not constant and fluctuates between

a negative and a positive one depending upon when the milk sample is taken relative to when a meal is consumed. Using Cow D as an example and picking the worst case scenario, if milking time was at 1200 h, MUN values would be less than BUN values (25 vs. 21.5 mg/100 ml) (Figure 5). If milking time was at 1700 h, MUN values would be greater than BUN values (19 vs. 15.8 mg/100 ml). Therefore, MUN values are often within 3 to 4 mg/100 ml of BUN values, but they do not represent the average BUN status of the cow. The problem of selecting a sampling time for blood which would reflect the mean BUN concentration of the cow appears to hold true for milk as well. Urea concentrations in milk may provide some insight into systemic urea status but error rates can be large.

SUMMARY

In relating variability in BUN concentrations to conception rates, it is not surprising that a clear predictable relationship does not exist. Variability in BUN due to sampling time in relation to feeding time, amount of CP intake, degree of degradability of dietary CP, and choice of a laboratory technique to measure BUN collectively contribute to a relationship to fertility that is not documented clearly. Furthermore, reproductive performance of the postpartum dairy cow is dependent upon a sequence of events that eventually culminate in a diagnosed pregnancy. Whether ammonia or urea per se, or the metabolic consequences of ammonia or urea metabolism alters the sequence of reproductive events leading to conception (eg. postpartum development and ovulation, uterine regression, corpus luteum differentiation and maintenance, secretion of uterine histotrophe for nourishment of conceptus, capacitation of sperm, fertilization of ova, embryo development, and maintenance of pregnancy) has not been elucidated at the current time. Garcia et al. (1991) showed no adverse effects of elevated plasma ammonia and BUN concentrations on ovarian follicle development or embryo quality at day 7 postinsemination in energy adequate, nonlactating dairy cows that were superovulated. Although Elrod and Butler (1991) demonstrated that conception rates in heifers were reduced from 83 to 62% by increasing CP of diets from 15 to 21%, diets were fed at 70% of ME requirements (NRC, 1989). It was only under an energy deficient condition that elevated CP intakes were detrimental. Dietary supplementation with fat in the early postpartum period may compensate for additional energy costs to the cow of having to detoxify ammonia arising from feeding elevated amounts of CP (Garcia et al; 1992). Specific experiments to document effects of dietary CP or BUN on pituitary responsiveness to GnRH have shown no alteration in LH secretion (Blauwinkel et al., 1986).

CONCLUSIONS

1. Feeding of diets containing excess protein (CP or DIP) frequently is associated with reduced reproductive performance of lactating dairy cows (eg. lowered conception rates and/or longer delays to first ovulation postpartum).

2. Exacerbated energy stress due to additional detoxification of ammonia from excess feeding of protein may account for reduced reproductive performance.

3. BUN and MUN values are influenced by the time of sampling in relation to feeding time. In order to obtain a "typical" BUN value, sampling time may be most appropriate at feeding time or 6 to 7 hours postfeeding.

4. Milk urea nitrogen values are often within 3 to 4 mg% of BUN values, but they do not represent the average BUN status of the cow.

5. Method of chemical analysis will influence BUN values.

6. BUN values are not reliable indicators of potential reproductive disorders although values >16 mg% may be early warning signals.

REFERENCES

Anderson, G.W. and B.A. Barton. 1988. Reproductive efficiency: Potential Nutrition-Management Interactions. Page 107 in Proc. Winter Dairy Mgmt Schools. Univ. Maine, Orono.

Armstrong, J.D., E.A. Goodall, F.J. Gordon, D.A. Rice, and W.J. McCaughey. 1990. The effects of levels of concentrate offered and inclusion of maize gluten or fish meal in the concentrate on reproductive performance and blood parameters of dairy cows. Anim. Prod. 50:1.

Blauwiekel, R., R.L. Kincaid, and J.J. Reeves. 1986. Effect of high crude protein on pituitary and ovarian function in Holstein cows. J. Dairy Sci. 69:439.

Blaxter, K.L. 1962. The Energy Metabolism of Ruminants. Hutchinson & Co., London.

Bruckental, I., D. Drori, M. Kaim, H. Lehrer, and Y. Folman. 1989. Effects of source and level of protein on milk yield and reproductive performance of high-producing primiparous and multiparous dairy cows. Anim. Prod. 48:319.

Butler, W.R. and C.C. Elrod. 1991. Nutrition and reproduction relationships in dairy cattle. Page 73 in Cornell Nutr. Conf., Ithaca, NY.

Butler, W.R., R.W. Everett, and C.E. Coppock. 1981. The relationship between energy balance, milk production, and ovulation in postpartum dairy cows. J. Anim. Sci. 53:742.

Canfield, R.W., C.J. Sniffen, and W.R. Butler. 1990. Effects of excess degradable protein on postpartum reproduction and energy balance in dairy cattle. J. Dairy Sci. 73:2342.

Carroll, D.J., B.A. Barton, G.W. Anderson, and R.D. Smith. 1988. Influence of protein intake and feeding strategy on reproductive performance od dairy cows. J. Dairy Sci. 71:3470.

Ferguson, J.D., T.L. Blanchard, S. Shotzberger, and W. Chalupa. 1986. Effect of rumen degradable protein on fertility. J. Dairy Sci. 69 (Suppl. 1):121.

Figueroa, M.R., D.P. Dawson, D.Y. Kim, C.E. Batallas, B.A. Kent, M.J. Arambel, and J.L. Waters. 1992. Effect of rumen undegradable intake protein on reproductive parameters in postpartum lactating cows. J. Dairy Sci. 75(Suppl. 1):203.

Folman, Y., H. Neumark, M. Kaim, and W. Kaufmann. 1981. Performance, rumen and blood metabolites in high-yielding cows fed varying protein percents and protected soybean. J. Dairy Sci. 64:759.

Garcia-Bojalil, C.M., C.R. Staples, J.D. Savio, M. Drost, and W.W. Thatcher. 1991. Effect of dietary protein on follicle growth and embryo development of superovulated nonlactating Holstein cows. J. Dairy Sci. 74 (Suppl. 1):195.

Garcia-Bojalil, C.M., C.R. Staples, W.W. Thatcher, J.D. Savio, and C. Risco. 1992. Effect of dietary protein degradability and calcium salts of long chain fatty acids (CaLCFA) on reproductive performance of lactating Holstein cows. In preparation.

Gustafsson, A.H. and D.L. Palmquist. 1993. Diurnal variation of rumen ammonia and serum and milk urea in dairy cows at high and low yield. J. Dairy Sci. 76: In Press.

Holtz, C.R., R.D. Smith, C.J. Sniffen, and W. Chalupa. 1986. Reproductive and metabolic responses of dairy cattle to the level and degradability of dietary protein. J. Dairy Sci. 69 (Suppl. 1):243.

Howard, H.J., E.P. Aalseth, G.D. Adams, and L.J. Bush, R.W. McNew, and L. J. Dawson. 1985. Influence of dietary protein on reproductive performance of dairy cows. J. Dairy Sci. 70:1563.

Jordon, E.R. and L.V. Swanson. 1979. Serum progesterone and luteinizing hormone in dairy cattle fed varying levels of crude protein. J. Anim. Sci. 48:1154.

Kaim, M., Y. Folman, H. Neumark, and W. Kaufmann. 1983. The effect of protein intake and lactation number on post-partum body weight loss and reproductive performance of dairy cows. Anim. Prod. 37:229.

Lucy, M.C., C.R. Staples, F.M. Michel, and W.W. Thatcher. 1991. Energy balance and size of and number of ovarian follicles detected by ultrasonography in early postpartum dairy cows. J. Dairy Sci. 74:473.

Marsh, W.H., B. Fingerhut, and H. Miller. 1965. Automated and manual direct methods for the determination of blood urea. Clin. Chem. 11:624.

McCormick, M.E., D.D. French, T.F. Brown, J.F. Beatty, and A.M. Saxon. 1992. Plasma urea nitrogen concentrations and associated reproductive performance of Holstein cows grazing ryegrass. J. Dairy Sci. 75(Suppl. 1):309.

National Research Council, 1989. Nutrient requirements of dairy cattle. 6th rev. ed. Natl. Acad. Sci., Washington, DC.

Staples, C.R., W.W. Thatcher, and J.H. Clark. 1990. Relationship between ovarian activity and energy status during the early postpartum period of high producing dairy cows. J. Dairy Sci. 73:938.

Staples, C.R., W.W. Thatcher, C.M. Garcia-Bojalil, and M.C. Lucy. 1993. Nutritional Influences on Reproductive Function. Chapter 39 in Large Dairy Herd Management, H.H. Van Horn and C.J. Wilcox, eds. ADSA. (In press).

Twigge, J.R. and L.G.M. Van Gils. 1988. Practical aspects of feeding protein to dairy cows. Page 196 in Recent Developments in Ruminant Nutrition 2. W. Haresign and D.J.A. Cole, eds. Butterworths, London.