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Milk Urea Nitrogen: Theory and Practice

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Milk urea nitrogen (MUN) has been proposed as a means to evaluate the reproduction and nutrition of dairy cattle. However, there is considerable confusion about the meaning of MUN and how specifically to use it to adjust feeding or management. In this paper, we will describe nitrogen metabolism in dairy cows in relation to nitrogen excretion as urea. This background will provide the foundation for interpreting MUN values. Field studies will provide some specific examples of how to use MUN to adjust feeding or management practices.

Nitrogen Metabolism

There are several important forms of nitrogen for dairy cows, and how these are handled is shown in Figure 1. Protein is required as a nutrient that is digested in the small intestine. Protein is comprised of amino acids, which are similar to carbohydrates except that they also contain amine (NH_2) groups. When amino acids are metabolized for energy, the amine groups are removed leaving the carbohydrate source and ammonia (NH_3). Ammonia is toxic to animal tissues and therefore is readily converted to urea in the liver. Urea is a less toxic way to store nitrogen in the system until it is filtered from the blood and excreted by the kidney.

The way the kidney functions in removing excess nitrogen is a process that is often studied(Swenson and Reece, 1993). Blood flows through the kidney and concentrates urea with a combination of diffusion and active transport processes. Because blood flow to the kidney is constant there is little variation in the amount of blood that can be filtered. Also, because the process of removing urea is dependent on diffusion, the amount of urea that can be removed increases as the concentration of urea in the blood increases. In general, the amount of urea excreted is directly proportional to its concentration in blood and milk (Ciszuk and Gebregziabher, 1994).

How does urea end up in milk? Urea is a small neutral molecule that readily diffuses into various tissues. Nearly everywhere that water can go, urea can go too. When milk accumulates in the mammary gland, urea diffuses into and out of the stored milk so that MUN equilibrates with blood plasma urea nitrogen. We once speculated that urea would accumulate in milk as the milk was formed, so that MUN would equal the average plasma nitrogen over the course of a day. However, a more recent study showed that MUN changes over the course of the day just the way that plasma nitrogen changes. Because MUN is associated with the aqueous (non-fat) portion of milk, if a milk sample is poorly mixed the MUN value will be inaccurate.

The level of MUN or PUN changes over the course of a day (Gustofsson and Palmquist, 1993). This effect is especially true if cows eat few meals per day and digest protein rapidly. Suppose that a cow consumes a diet high in ruminally available protein in the morning. The rumen microflora will digest the protein and release ammonia, which is in turn absorbed from the rumen wall to the blood. The ammonia is detoxified in the liver to urea, and is subsequently excreted via the kidney. The detoxification process is fast so as to prevent tissue damage, and the excretion process in the kidney is constant with respect to blood urea concentration. The level of PUN increases after feeding for about four hours or until the feed protein is digested, and then it decreases until the next meal. If the cow eats only one meal per day, MUN might range by 8 mg/dl, but if she eats more often this variation is reduced or eliminated.

Implications

In theory, urea concentrations in defatted milk samples would be similar to plasma urea levels. However, MUN often appears to be a bit lower than PUN (Roseler et al, 1993). The laboratory methods may explain the difference between MUN and PUN. If milk samples are not defatted before MUN is analyzed, the fat or other components may quench the MUN and result in an incomplete recovery (J.D. Ferguson, personal comunication) Nonetheless, MUN and PUN are highly correlated.

The timing of sampling for milk collection would reduce both the recorded MUN values and the variation. Most cows are fed immediately after milking so that milk samples are routinely taken when MUN is stabilized at its lowest level for the day. Plasma samples are taken more randomly which makes them more variable and higher on average than milk samples.

Milk urea is proportional to the amount of excess amino acids and ammonia which are absorbed into the body. High levels of ruminally degraded protein are reported to increase MUN levels (Baker, et al., 1995). However, nearly all excess feed N that is absorbed into the body is converted to urea and excreted. This relationship holds true whether that protein is first digested in the rumen, or absorbed as microbial protein or undegraded feed protein. Excess ammonia and excess absorbed amino acids are both converted to urea in the liver. High MUN therefore indicates that there is more than enough of any or all forms of protein, while low MUN may indicate a shortage of all forms of protein or that protein is being used very efficiently.

If we consider that MUN is a function of urea excretion, then besides N absorption, there are several factors that can affect excretion and consequently MUN concentration. The simplest relationship is: Absorbed N minus Product N (milk and meat) = N Excretion. How much N is absorbed is a function of diet formulation, feed delivery, and digestion. Therefore, herd MUN values can indicate a bias in diet formulation, forage analysis (Was less protein available than thought?), feeding (Did they eat what was predicted?), digestion (Was the forage damaged and indigestible?), and production.

Looking at the differences in MUN values in individual cows can potentially provide even more information. If one group of animals has higher or lower levels than another, perhaps the diets were formulated incorrectly for that group, or the feeds may not be mixed properly. However, cow to cow differences are even riskier to interpret because there are usually fewer samples from one cow or group than from the entire herd, and so we have less confidence in the values. Generally it is best to average the MUN from groups of at least 10 cows. If an individual cow value is *very* high or *very* low, it might be worth taking another sample from that cow. If it is still high or low, it could be a real difference and not just a lab error.

How many rations do you have in a single herd? There are the rations which are formulated, those that are fed, and those that are consumed by each cow. Of that which is consumed, there is the ration that is digested and absorbed, and that used for production or excreted. The use of MUN may help differentiate these rations.

If a MUN value seems high, what can you do? This may be an opportunity to ask yourself and others a few questions. Is too much protein being offered? Were the feeds analyzed accurately? Did the cows meet performance expectations? You may try reducing protein and see if production can be maintained. If not, you are likely to see the reduced milk production within the first week.

If MUN values are at the low range of normal, there may be too little protein in the diet. The same sort of analysis would be conducted, and one additional consideration may be that the protein is not well digested due to heat damage or excess maturity. Poorly digested protein will be high in acid detergent fiber nitrogen which can be determined by a forage lab. You may try increasing the protein to see if a response would be observed in a few days.

In addition to having the wrong amount of protein in a diet, MUN may be high or low due to having the wrong form of protein. When feeding dairy cows, there is a required amount of ruminally available protein needed to feed the rumen bacteria. If a diet is formulated with too little ruminally degraded protein, production may be reduced due to a protein deficiency in the rumen which can limit feed digestion and microbial protein synthesis. Although microbial protein might be reduced, the ruminally undegraded protein would be greater than expected and could substitute for missing microbial protein. Therefore, absorbed protein would be limited by intake because of the reduced digestion in the rumen, and with protein intake and production both being reduced, there may not be a response in MUN.

On the other hand, if ruminally undegraded protein (RUP) is low, total protein absorption from the small intestine may be reduced. There may be an excess of ruminally degraded protein, which would be absorbed and excreted. Therefore, production may be reduced due to a protein deficiency, but MUN would be higher. This scenario has been demonstrated in a research setting (Baker, et al., 1995).

If energy in the diet is too low, there may be reduced production, and at this production level, there may be excess protein leading to higher MUN. Finally, production may be reduced below expected levels due to hot weather, which reduces intake. Because both production and protein intake would be reduced, there would be no change in MUN.

This discussion should have demonstrated that there is no substitute for understanding nutrition and metabolism. Simply looking at MUN values cannot tell us what exactly is wrong with energy or protein feeding, but it can direct us where to look. The MUN may be right on the average and we may still have any number of problems with the diet. However, if the MUN is very high or very low, we are more likely to have problems than not.

Average Herd MUN Values

The average herd MUN values for farms analyzed by Lancaster DHIA over a three month period are plotted against average production per cow in Figure 2. If feeding protein deficient diets was a common phenomenon, we'd see some herds with low production and low MUN. It is apparent that some very high producing herds had relatively low MUN values. These herds may well be the most profitable because they appear to be feeding low protein diets and still getting the cows to milk well. The fact that there is no clear relationship between MUN and production indicates that we can allow the MUN levels to go fairly low and not have deficient diets.

In 106 herds analyzed by Lancaster DHIA from June to August 1996, the average herd MUN was 15.1 mg/dl, and the average standard deviation (SD) from herd to herd was 2.8 mg/dl. This means that 66% of the herds had MUN values within one standard deviation in either direction of the mean, or that most herds fell between 12 and 18 mg/dl. Ninety-five percent of the herds had average MUN values between 9.5 (2 SD) and 20.7. These values might give some indication of where we can expect MUN values to be. If the average for a herd is outside of these ranges, the herd may be unusual, although not necessarily wrong. Nonetheless, unusual herds should be investigated. A few herds had average MUN values of 8 mg/dl and none were lower. It is possible that 8 is a minimum threshold for a herd at these production levels. If less protein is fed, production might be reduced so that the remaining N is conserved and MUN levels maintained at 8 mg/dl.

The variation from cow to cow depends on the lab and so unusually high variation relative to other herds analyzed by the same lab might indicate some problems. Because all labs typically calibrate their samples against known standards, there is not likely to be much lab to lab variation in analysis across herds (many samples). However, there may be differences in individual sample values. Generally, a single observation would need to be less than 9 or greater than 21 to be considered outside the normal range. Before assuming a single cow is high or low, have their MUN analyzed a second time to rule out laboratory variation.

Bulk Tank vs. Individual Cows

Some farmers and consultants have bulk tank MUN analyzed rather than individual cow samples. This is a way to potentially save some of the cost of analysis, and it may be a good way to get started interpreting MUN. If the tank is stirred well (remember that MUN does not mix with the fat), it should give a weighted average for the herd. The weighting is according to production level. The higher producing cows put more milk in the tank and so they will have more influence on the tank sample.

The bulk tank sample would be less precise. If a hundred different samples are taken from a herd, the variation in sampling that is due to the lab analysis or sampling technique will on average be diminished. Some high samples will cancel the lower ones. However, if only one bulk tank sample is taken, the lab error may influence the result. If we compare 100 samples from the herd, we are more confident in the average value than we would be in a single bulk tank sample.

The standard error (SE) associated with a measurement indicates the level of confidence we can have that the measured value represents the true value rather than a lot of random error. We can be 95% confident that a measured value is within 2 SE of the actual one. For example, if the reported value is 15 mg/dl and the SE for a single sample is 3 mg/dl (a typical lab), we would be correct 95% of the time if we assumed the actual value was between 9 and 21. The SE for a group of samples is lower than for the individual sample, and can be calculated as: $SE_{mean} = SE_{sample}$ / SQRT(N), where N represents the number of samples. If the mean for 100 cows in a herd is 15 and the SE for each sample is 3, then SE for the herd mean is 0.3. We would be 95% confident that the herd average was between 14.7 and 15.3. It should be noted that confidence intervals only account for random error and not bias such as might be imposed from sample timing or diet type.

With bulk tank samples or herd averages, there would be no way of detecting grouping differences or problems with feed mixing. In these cases, for every high cow in one group there will be a low one in a different group, and so the bulk tank sample or herd average won't be affected. It may therefore be advantageous to analyze the average MUN for each group in the herd. In this way group differences can be detected, but because we average several samples, we can be fairly confident in the results.

Benefits of Using MUN

The benefits of using MUN analyses may be summarized as: economics, reproduction and the environment. There is a potential to save feed costs by reducing protein fed, or reducing lost production due to inadequate protein. Also reproductive efficiency may be improved by keeping excess protein out of the diet. High protein diets impair reproduction (Ferguson and Chalupa, 1989)because blood urea is toxic to reproductive tissues. High MUN is correlated with decreased conception rates (Butler, et al., 1996). It is generally recommended that MUN for most cows in the herd be below 19 mg/dl.

High MUN is often suggested to indicate a loss of energy from the cow. However, the energy cost of excreting excess N is often overstated. The process of urea synthesis requires 4.4 kcal of NEL per g of N converted (Tyrrell et al., 1970). For example, a 550-kg cow producing 50 kg of milk per day requires about 28 kg dry matter intake (DMI) per day at 16.6% crude protein (National Research Council, 1989). If you feed a diet containing 19.6% crude protein instead, an additional 135 g/d nitrogen would be excreted (3% higher times 28 kg DMI times 16% N per CP times 1000 g/kg), and the predicted loss in energy would be 0.6 Mcal per day (134 g/d times 4.4 kcal/g). This is about 1% of her total energy requirement.

Finally, there is a need to reduce nitrogen loading to ground water and estuaries. High protein diets result in more manure N. Regardless of how well manure is managed, there are substantial N losses from manure to water resources. Therefore, reducing manure N reduces N lost from manure to the environment. In addition, high protein diets require that crop be harvested. Increasing crop production results in more nitrogen losses to the environment (Kohn, 1996).

Conclusions

If the average MUN for a herd or group of 10 cows is outside the normal range (12 to 18) there are a series of issues to consider. Was the forage analysis accurate and was the diet formulation correct? Was the feed mixed properly and was it distributed evenly to all cows. Did the cows sort the feed or did they eat more or less protein than expected? Was production and dry matter intake what it was expected to be? Were the feeds digestible or could they have been heat damaged. You may be able to feed less or you may need more of either ruminally degraded protein or ruminally undegraded protein.

References

Ciszuk, A. U. and Gebregziabher T. 1994. Milk urea as an estimate of urine nitrogen of dairy cows and goats. Acta Agriculturae Scandinavica 44: 87-95.

Baker, L. D., J. D. Ferguson, and W. Chalupa. 1995. Responses in urea and true protein of milk to different protein feeding schemes for dairy cows. J. Dairy Sci. 78: 2424-2434.

Butler, W. R., Calaman, J. J., and Beam, S. W. 1996. Plasma and milk urea nitrogen in relation to pregnancy rate in lactating dairy cattle. J. Anim. Sci. 74:858-865.

Ferguson, J. D. and W. Chalupa. 1989. Symposium: interactions of nutrition and reproduction. Impact of protein nutrition on reproduction in dairy cows. J. Dairy Sci. 72: 746-766.

Gustafsson, A. H. and D. L. Palmquist. 1993. Diurnal variation of rumen ammonia, serum urea, and milk urea in dairy cows at high and low yields. J. Dairy Sci. 76: 475-484.

Kohn, R. A. 1996. Feeding strategies to reduce nutrient losses to the environment. Proceedings of the Maryland Nutrition Conference for Feed Manufacturers, pp. 102-112, March 21-22, Baltimore.

National Research Council. 1989. Nutrient Requirements of Dairy Cattle. 6th rev. ed. Natl. Acad. Sci., Washington, DC.

Swenson, M. J. and Reece, W. O. 1993. Dukes Physiology of Domestic Animals, 11th Edition, pp. 573 to 604. Cornell University Press, Ithaca.

Tyrrell, H. F., P. W. Moe, and W. P. Flatt. 1970. Influence of excess protein intake on energy metabolism of the dairy cow. Pages 68-71 in Publ. 16, European Assoc. Anim. Prod., London.

Roseler, D. K., J. D. Ferguson, C. J. Sniffen, and J. Herrema. 1993. Dietary protein degradability effects on plasma and milk urea nitrogen and milk nonprotein nitrogen in Holstein cows. J. Dairy Sci. 76: 525-534.

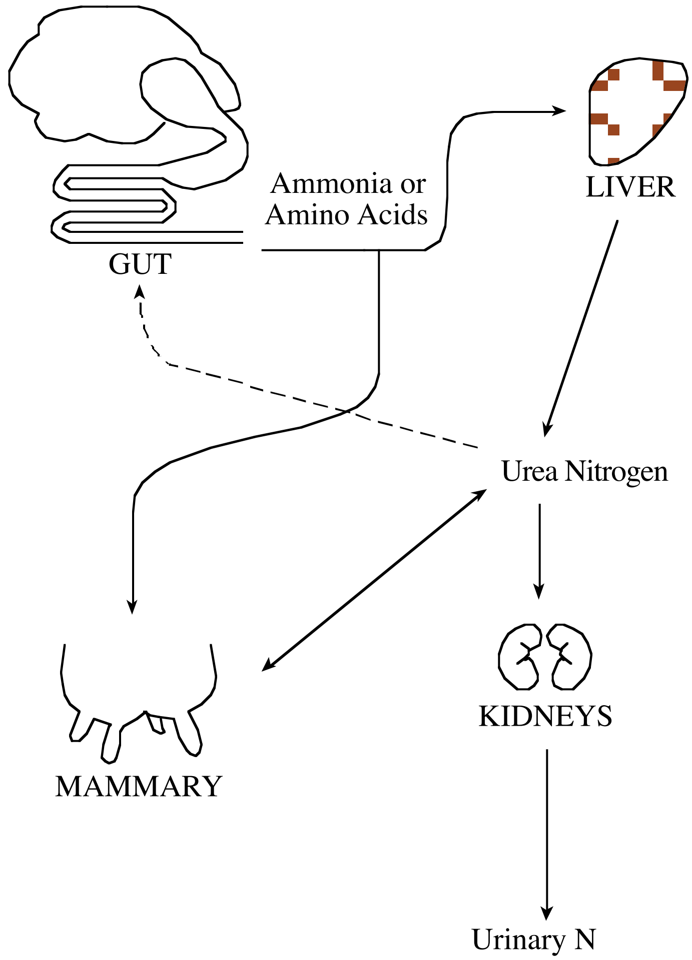

Figure 1. Nitrogen metabolism in a dairy cow. Nitrogen is absorbed as ammonia and amino acids. The amino acids are used for milk production and growth, while ammonia, excess amino acids and maintenance amino acids are converted to urea. The urea is filtered from the blood to the kidney. The blood urea equilibrates with that in milk.

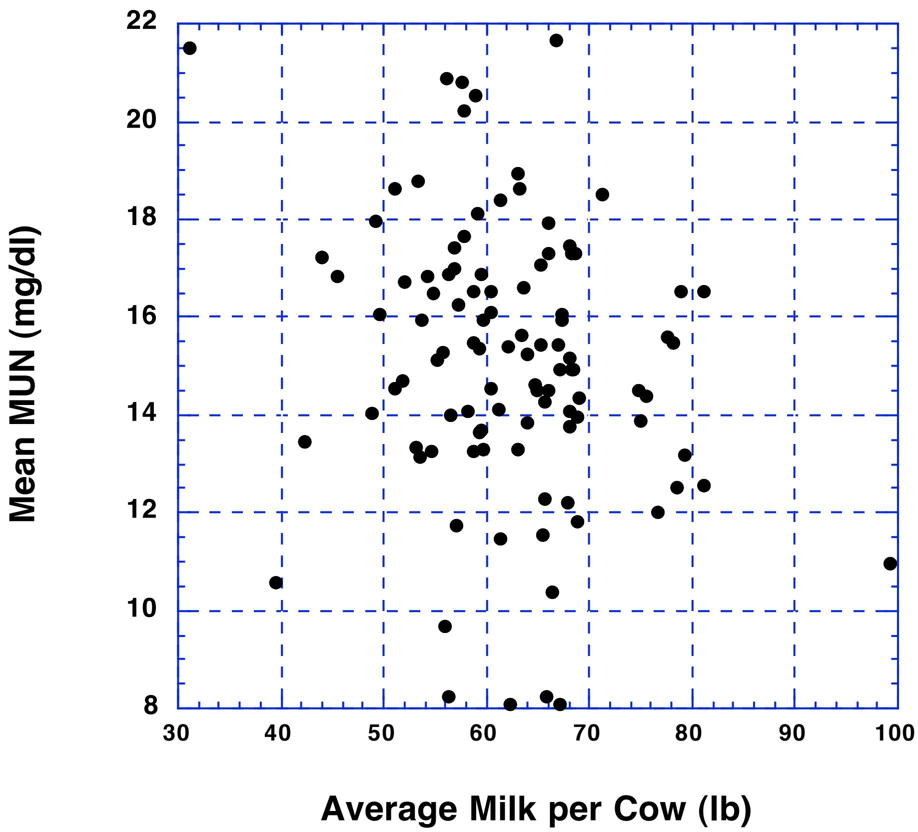

Figure 2. Relationship of average MUN (mg/dl) for all cows in each herd versus average milk production per cow (lbs). Low or high MUN doesn't necessarily mean low production. Data from Lancaster DHIA, Jere High.