

Use of Milk Urea Nitrogen to Improve Nitrogen Efficiency and Reduce Environmental Impact of Dairy Cows

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The global human population is projected to increase from its current estimate of 7.1 to 9.4 billion by the year 2050 (U.S. Census Bureau, 2008). These projections are alarming since food production will have to increase between 40 and 65% (Hubert et al., 2010) and meeting such demand will be a challenge as arable land and other resources for food production are limited (Rockstrom et al., 2009; Hertel, 2011). Meeting this demand will require increased efficiency of production in all facets of the system. Additionally, gains in productivity cannot come at the expense of environmental health or the gains will not be sustainable. Nitrogen export to the environment can result in eutrophication of aquatic ecosystems; increased atmospheric particulates; decreased stratospheric ozone concentration; greenhouse warming; increased acidity of soil, precipitation, and surface water; coastal hypoxia; and methemoglobinemia in infants (Wolfe and Patz, 2002). The use of management tools, such as milk urea nitrogen (MUN), can help improve the efficiency of milk production, reduce feed costs, and reduce environmental problems associated with dairy production (Jonker et al., 2002b).

The Impact of Nitrogen Excretion on the Environment

Excess nitrogen fed to dairy cattle and other animals is excreted as urea in manure

(Lobley et al., 2000; Lapierre and Lobley, 2001; Reynolds and Kristensen, 2008), much of which is converted into ammonia and volatilized into the atmosphere (James et al., 1999; Li et al., 2009). Ammonia emissions to the atmosphere are a concern as they can form particles less than 2.5 microns in size (**PM_{2.5}**), which cause haze and contribute to lung and asthma problems in humans (WHO, 2005). Excess soil nitrogen can result in high levels of nitrate in drinking water or the leeching of nitrogen into surface water (Dinnes et al., 2002). Consumption of water with nitrates causes severe health problems in infants (methemoglobinemia), while nitrogen in surface water results in eutrophication and other serious environmental problems (Wolfe and Patz, 2002). Thus, the use of management practices that improve nitrogen efficiency of lactating dairy cattle may aid in the reduction of environmental and health risks.

Use of MUN to Achieve Optimum Return

High producing dairy cows have an overall average nitrogen efficiency between 25 and 28% (Jonker et al., 2002a; Hristov et al., 2004), which is less than half the post-absorptive efficiencies of precision-fed growing pigs and poultry (Baker, 1991, 1996; Nahm, 2002). Higher efficiencies can be achieved in poultry and pigs since they are fed diets that perfectly match their amino acid requirements (precision feeding). Unfortunately, we do not

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currently possess the same level of knowledge of amino acid requirements in ruminants. However, because nitrogen efficiency is related to blood and milk urea nitrogen concentrations in dairy cattle (Jonker et al., 1998), we can use MUN values as a management tool to monitor and improve nitrogen efficiency.

Milk urea is a product of nitrogen breakdown in the body and is highly correlated to dietary nitrogen and nitrogen balance of a cow (Oltner and Wiktorsson, 1983; Broderick and Clayton, 1997). Dietary protein is the major determinant of MUN concentrations (Jonker et al., 1998). If protein in the diet is deficient relative to the cow's requirements, MUN concentrations will be low. Conversely, if protein in the diet is in excess of the cow's requirements, MUN concentrations will be high (Figure 1). If this were the whole story, using MUN would be simple. Unfortunately, there are several additional factors that influence MUN concentrations, although they do not negate the relationship. These include time of milk sampling, season of the year, BW, DIM, breed, level of production, and other nutritional factors (DePeters and Cant, 1992; Broderick and Clayton, 1997; Kauffman and St-Pierre, 2001). Dehydration results in increased blood urea nitrogen and MUN (Weeth and Lesperance, 1965; Steiger Burgos et al., 2001), while high salt content in the diet causes reduced MUN (Spek et al., 2012).

Starch is commonly suggested as one of the nutritional factors controlling MUN, and indeed, it will alter MUN, but only if it impacts milk protein production (Kauffman and St-Pierre, 2001). If we take a hypothetical cow being fed 50 lb/day of DM with 17% CP and a moderate level of dietary starch, nitrogen intake will be 1.36 lb/day. If she is producing 80 lb/day of milk at 3.0% protein, she is secreting 2.4 lb/day of milk protein or 0.38 lb/day of milk

nitrogen. Much of the remaining 0.98 lb/day of nitrogen that was consumed but not converted to milk protein will be converted to urea and eventually excreted. If we increase the dietary starch content by addition of finely ground starch so that it is ruminally available, it very likely will stimulate microbial growth in the rumen (Aldrich et al., 1993), which will use more of the waste nitrogen generated in the rumen, and thus less ammonia will be absorbed and converted to urea by the cow. However, the resulting extra microbial protein flows to the small intestine, where it is mostly digested and absorbed as amino acids. If those amino acids are not used to make more milk protein, the cow will simply degrade them and convert the nitrogen to urea. So the defining event is an increase in milk protein production. In the absence of a milk protein production response, nothing has been gained and the blood and milk urea nitrogen contents will be the same for both levels of dietary starch.

The target level for MUN across herds is generally 12 mg/dl (Jonker et al., 1999). If MUN is greater than that, the herd is likely fed protein in excess of needs. If MUN is below 12 mg/dl, the herd may be experiencing a protein deficiency. However, there are differences among herds and among cows within a herd after all of the above factors have been considered, suggesting that the genetic makeup of the herd may play a role in determining herd and cow MUN concentrations (Aguilar et al., 2012). This is confirmed by the observation that MUN is genetically heritable (Wood et al., 2003). Thus, 2 hypothetical herds with the same breed and BW of cows fed the same diet, with the same milk production, and at the same stage of lactation could have different MUN concentrations. Therefore, reducing MUN concentrations below 12 mg/dl without losing milk production may not be possible for all herds. Conversely, some herds may be able

to achieve concentrations below 12 mg/dl and are wasting nitrogen at 12 mg/dl. To achieve maximum nitrogen efficiency and minimize ration costs, herds should establish their own specific targets for MUN.

Establishing a Herd Specific MUN Target

Use the following strategy to establish a target MUN concentration for your herd. If you have a one-group TMR, then it is quite straightforward. If you feed multiple rations to lactating cows, then it is a bit more tedious as the following process will have to be repeated for each group:

1. Balance the diet to just meet (NRC, 2001) requirements for energy, rumen degradable protein (**RDP**), metabolizable protein (**MP**), and sodium chloride, and ensure that the animals have adequate access to water. Feed the diet for 2 weeks and record the herd or group MUN value (1 bulk tank sample).
2. As dietary rumen undegradable protein (**RUP**) is generally more expensive than RDP, start with RUP, although either way works. Reduce RUP content by 0.25% units while holding energy, RDP, and salt content constant. Feed the diet for 2 weeks and record the ending milk production, DM intake, and MUN concentration.
3. Repeat step 2 until the cows decrease milk production or DM intake.
4. The step immediately before the cows lose milk production or DM intake is the requirement for RUP for your herd.
5. If there is a loss in production on the very first reduction in RUP, it is possible that the cows were already being fed a deficient diet. In this case, try adding 0.25% units of RUP to the first ration to see if you get an increase in milk production.
6. Once a herd specific RUP level is determined, repeat the same process for RDP content using 0.5% unit reductions while holding energy constant and RUP at the threshold level established above until a loss in milk production or DM intake is experienced.
7. The last RDP reduction step before a loss in milk production or DM intake was observed is your herd specific RDP requirement.
8. The final values for RDP, RUP, MP, and MUN are your herd's target levels.

Feeding to meet but not exceed your herd specific target RDP and RUP levels will result in the maximum achievable nitrogen efficiency under current feeding conditions and knowledge, and herd MUN values can be compared to target MUN concentrations to determine if the feeding program is staying on target. If MUN increases above the target, the cows are being fed more protein than needed and nitrogen efficiency has declined. If MUN drops below the target, it is likely that a loss in milk production has occurred or will in the near future, and corrective measures should be taken. In either case, MUN does not provide information regarding the source of the problem. It simply indicates that the animals are deficient in nitrogen or have an excess of nitrogen, and you will have to determine whether it is a problem with RDP, RUP, other dietary factors, feed formulation, or animal health. It is also important to recognize that all of the safety margin associated with overfeeding protein has been removed, and thus managing the feeding program to maintain consistency is critical to avoid a loss in production. Silages should be frequently assessed for DM content, and nutrient analyses of dietary ingredients

should be monitored to maintain diet consistency. The frequency of nutrient analyses assessment is a function of herd size and cost of the analyses. St-Pierre and Cobanov (2007) provide suggested monitoring frequencies for herds of varying size at different analytical costs that can be used to establish a monitoring program.

The target MUN value should be valid for several years unless you dramatically change your facilities, import different cattle, change salt feeding practices, or water availability becomes restricted. However, keep in mind that the diet required to obtain the target MUN value may change across several years. Eventually, it may drift due to genetic selection in your herd and should probably be reassessed in 5 years. Thus, you can monitor your herd's milk urea nitrogen to keep a handle on your nitrogen feeding program and improve animal nitrogen efficiency, while simultaneously reducing feeding costs and nitrogen excretion to the environment.

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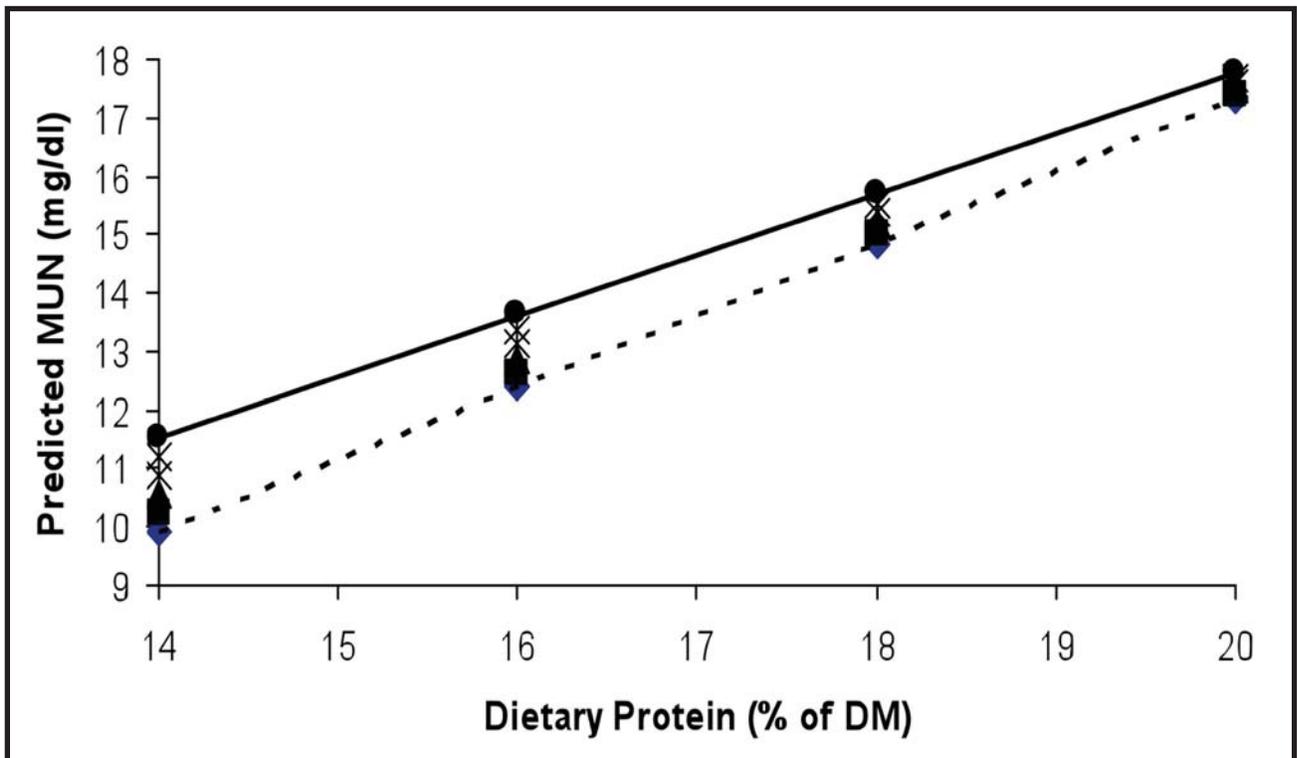


Figure 1. Least squares mean estimates for MUN versus dietary CP predicted from a statistical model with varying milk yield and the observed mean inputs for milk protein content, dietary NDF content, and days in milk set to mean values for the study [\bullet = 6.6 lb/day milk, \blacksquare = 70.4 lb/day milk, \blacktriangle = 74.8 lb/day milk, \times = 79.2 lb/day milk, $*$ = 83.6 lb/day milk, \bullet = 88.0 lb/day milk, solid line = 88.0 lb/day milk regression ($y = 1.04 \text{ CP} - 3.0$), dashed line = 66.0 lb/day milk regression ($y = 1.23 \text{ CP} - 7.34$); Aguilar et al., 2012].