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# Use of Milk Urea Nitrogen to Improve Dairy Cow Diets[1]

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## ABSTRACT

The hypothesis of this field study was that providing farmers with information regarding their herd's milk urea nitrogen (MUN) would result in more accurate feed management and a change in MUN toward target values. All dairy herd bulk tanks (n = 1156) in the Maryland and Virginia Milk Producers' Cooperative were tested for MUN each month for six months ending in May 1999. Farmers (n = 454) who returned a survey were provided with the results of their MUN analysis each month along with interpretive information. Survey results indicated that most (89.5%) dairy farmers did not routinely use MUN prior to participating in the project, but most (88%) extension agents and nutritionists in the region recommended it. The average MUN across all farms in the study increased in the spring, but the increase was 0.52 mg/dl lower for farmers receiving MUN results than for those who did not participate in the program. Farmers who indicated they increased dietary crude protein (CP) due to low MUN started with MUN values that were 3 mg/dl below target but ended with target values. Farmers who indicated that they decreased CP due to high MUN began the project with high MUN but decreased it by 1 mg/dl compared to non-participating farmers. At the end of the project, 30% of farmers responding to a follow-up survey indicated they would use MUN analysis in the future. Providing MUN results and interpretive information to farmers was documented to change feeding practices and subsequent MUN results.
(**Key words:** milk urea nitrogen, water quality, dairy farming, nonpoint N))

**Abbreviation key: MUN** = milk urea nitrogen.

## INTRODUCTION

Nonpoint nutrient loading to surface water is a major environmental problem in the Chesapeake Bay Drainage Basin (Thomann et al., 1994). Dairy farming is a large agricultural enterprise in this region, making it a major contributor of N loading to the Bay (Shirmohammadi et al., 1997). Most manure or other fertilizer applied to crops runs off, leaches, or volatilizes and eventually contributes to nutrient loading, even when the nutrients are optimally managed. Therefore, reducing nutrient losses requires better feeding and herd management to reduce the need for crops and manure application (Kohn et al., 1997).

Milk urea N (**MUN**) may be used as a management tool to improve dairy herd nutrition and monitor the nutritional status of lactating dairy cows. Urinary N excretion has been shown to have a positive linear relationship with MUN (Ciszuk and Gebregziabher, 1994; Jonker et al., 1998). Elevated MUN indicates excess protein has been fed to the dairy cow for her given level of production (Broderick and Clayton, 1997; Jonker et al., 1998) and identifies excess nutrient loading to water resources (Jonker et al., 2002). Therefore, implementing routine use of MUN on dairy farms could reduce nutrient loading and improve farm profitability.

The hypothesis of this study is that providing farmers with information regarding their herd's MUN will result in more accurate feed management and a change in MUN toward target values. The objectives for this project were 1) to quantify attitudes and practices among nutritionists and dairy farmers toward using MUN, 2) to introduce dairy farmers in the Chesapeake Bay Drainage Basin to the use of MUN to improve herd nutrition, and 3) to evaluate the economic and environmental impact of the program.

## MATERIALS AND METHODS

### Surveys

A confidential survey was conducted by mail in December 1998 with members of the Maryland and Virginia Milk Producers Cooperative (West Reston, VA). Survey questions pertained to dairy herd characteris-

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tics, milk production, crop production, feed inputs, management characteristics, and MUN knowledge and use. An introductory letter was mailed one week prior to and a reminder letter was sent one week after the survey. The cooperative had 1156 members located throughout most of the Chesapeake Bay Drainage Basin including Delaware (n = 23), Maryland (n = 432), Pennsylvania (n = 519), Virginia (n = 172), and West Virginia (n = 18). Participants returning the survey were offered monthly bulk tank milk analysis of MUN for 6 months as an incentive.

A companion survey was conducted among 66 dairy nutrition consultants who were likely to interact with participants from the cooperative. The dairy nutrition consultants were identified through Cooperative Extension (dairy agents) and feed manufactures (feed salespersons and nutritionists). The confidential survey was conducted by mail in December 1998 for dairy consultants in Delaware, Maryland, Pennsylvania, Virginia, and West Virginia. Consultants were informed of the ongoing MUN program with the Maryland and Virginia Milk Producers' Cooperative. The survey included sections on experience, education, MUN knowledge, and MUN use. The education section included information on education level and participation in continuing education. The MUN knowledge section explored beliefs regarding nutritional and reproductive consequences of MUN. Finally, the MUN use section explored current recommendations for using MUN on dairy farms.

Upon completion of the extension project, participating dairy farmers were asked by mail to complete a confidential follow-up survey. A reminder letter was sent one week after the survey. The survey asked dairy farmers to evaluate the extension program on a scale of 1 to 5 for its relevance, quality, utility, and overall usefulness. Use of MUN results were also queried in the survey.

### MUN Analysis

Bulk tank MUN analyses were performed monthly for six months for 1156 dairy farms from the Maryland and Virginia Milk Producers' Cooperative (West Reston, VA) from December 1998 through May 1999. Milk samples were collected during regular milk pickup by the cooperative for routine analyses and treated with an antimicrobial preservative (Broad Spectrum Microtabs II, D & F Control Systems, San Ramon, CA). After the routine analyses, samples were mailed to Lancaster DHIA (Manheim, PA) for MUN analysis by Bently Chemspec procedure (Bently Instruments, Chaska, MN).

Two sets of standards were sent with weekly bulk tank samples for MUN analysis. Five distilled water standards were prepared with 0, 4.02, 5.69, 9.66, 13.67, or 17.70 mg/dl added urea. Four milk standards were prepared from a bulk tank milk sample from the USDA-BARC dairy herd (Beltsville, MD) and 0, 2.00, 3.99, and 6.00 mg/dl added urea. Both standards were preserved with an antimicrobial preservative and frozen until required for analysis.

### Extension Project

Dairy farmers who returned the survey were considered "participants" in this study, and they received results of monthly MUN analysis and interpretive information. Target MUN concentrations were determined for each participating farm according to the method of Jonker et al. (1999). Target MUN was estimated as the predicted MUN when feeding a group of cows according to NRC (1989) recommendations. Target MUN calculations assumed feeding to the production level of the 83rd percentile cow (i.e., mean milk production plus 1 standard deviation). These target values were an average of 4.0 mg/dl higher than we would currently recommend, because DHIA labs began reporting lower MUN values in the fall of 1998 (Kohn et al., 2002), yet the model used to determine target values was calibrated to older results. The values reported by DHIA had just decreased prior to this extension project, and we were unable to revise the target recommendations in time; thus, target values given to farmers were an average of 4 mg/dl higher than they should have been. After their monthly MUN analysis occurred, each farmer received a summary of all monthly MUN results to date, their herd's target concentrations, and a fact sheet on interpretation of results. The fact sheets informed dairy farmers on target MUN concentrations, cause of elevated MUN, frequently asked questions regarding MUN, economic consequences of elevated MUN, and the relationship between protein and energy effects on MUN. We recommended that if MUN fell outside the target range, a list of questions should be asked to determine the reason: 1) Did milk production meet the expectations for which the diets were formulated? 2) Did cows consume the amount of feed that was expected when formulating diets? 3) Was the diet formulated correctly for the feeds available? 4) Were the forages recently analyzed, and is it possible that composition of an ingredient changed? 5) For low MUN, is there a possibility of heat damage? 6) Were the cows fed the diets that were formulated? 7) Did all cows have adequate access to the feed or did they sort feeds? Farmers were not encouraged to change CP feeding levels based solely on MUN results, but rather to use the results to highlight a potential problem with the feeding or management. If they changed the diets, they were encouraged to observe any changes in milk production or milk protein percentage within 3 to 5 d of making the change.

### Statistical Analysis

Monthly MUN results were compared for dairy farmers who participated in the survey to those who did not. Repeated measures analysis was performed with JMP (1995) on monthly MUN concentrations and MUN deviation from target values (observed – target). The model included treatment, month, and treatment by month interaction. Treatments included whether or not they participated in the project (i.e., they returned original survey and received monthly results). Other variables were considered among the participants, including whether they indicated they had increased or decreased dietary CP. The milk standard was used as a covariate, but the water standard was not used because results were the same for water standards as for milk standards (data not shown). Dairy farm was a random variable nested within effect. Statistical significance was declared at $P < 0.05$ unless otherwise stated.

### Economic and Environmental Impacts

The changes in CP intake and urinary and fecal N excretion that resulted from the program were determined using the MUN concentration and the model of Jonker et al. (1998) with revision of the urinary N prediction according to Kauffman and St-Pierre (2001). The change in N intake and excretion from the beginning of the program to the end was compared for participants (who received MUN results and interpretive information) and non-participants (who received no information after the initial survey). In addition, the change in MUN and predicted N intake and excretion were compared for participants who reported increasing CP, decreasing CP, or not changing CP in diets. Specifically, the change in urinary N (g/d) was estimated as 17.64 times the change in MUN (mg/dl; Kauffman and St-Pierre, 2001). The change in N intake (g/d) was estimated as the change in urinary N divided by true digestibility of 0.84 (Jonker et al., 1998). The change in fecal N was the difference between the change in N intake and change in urinary N (Jonker et al., 1998). The cost or savings of feed N was estimated by assuming the change in CP intake was orchestrated by substituting corn grain with soybean meal (44%) or vice-versa. The five-yr average prices (1996 to 2000) for soybean meal ($0.210/kg) and corn grain ($0.097/kg) were used (Bridge Information Systems, Inc, 2000). Estimates of urinary and fecal N were used to quantify the environmental impact of the program. Seventy-five percent of the change in manure N (mostly urinary) was expected to be lost on a dairy farm from runoff, volatilization, or leaching (Kohn et al., 1997). Additionally, reduction in N loading is expected because reduced losses of N from soybean production would result from the decreased need to grow soybeans. This change was not considered because the extra soybean meal would be imported from outside the watershed.

## RESULTS AND DISCUSSION

### Attitudes and Practices

A total of 472 dairy farmers responded to the survey, for a 40.8% rate of return. Over 60% of the responding dairy farms indicated prior knowledge of MUN (Table 1). However, prior to the survey, over two-thirds of the dairy farms had not tested for MUN. Of the farms that had previously tested for MUN, most had tested only once. One-third of the dairy farms reported using MUN results for reproductive reasons, while 88.3% indicated using results for nutritional reasons. No relationship of herd size with knowledge or testing of MUN was observed (data not shown) prior to the survey. Often, larger herd size is associated with quicker adoption of new technology, but clearly for MUN there has been a lack of adoption among farms of all herd sizes. Use of TMR feeding, DHIA, and bST were correlated with an increase in prior knowledge and testing of MUN ($P < 0.01$). Increasing forage testing and ration balancing frequency were also correlated with increased likelihood of prior MUN testing. Other management factors had no effect on prior MUN knowledge or testing before the survey.

A total of 33 dairy nutrition consultants responded to the survey, for a 50.0% return rate. Cooperative Extension agents and feed salespersons accounted for 85% of the returned surveys. Two independent consultants and three other dairy nutrition consultants accounted for the remainder of the returned questionnaires. The consultants averaged 13.2 yr (SD = 9.6 yr) experience. Seventy-three percent of consultants used or recommended use of MUN (Table 2). A large majority recommended monthly testing. Responses from consultants varied on the number of MUN samples they recommended per farm. Nearly half recommended a bulk tank sample while another quarter recommended all cows be sampled (Table 2). In spite of the widespread belief in MUN testing among consultants, dairy farmers were not aware of using the technology themselves.

### MUN Analysis

Two sets of standards were sent to the laboratory for analysis each week. Standards had been prepared by

**Table 1**. Milk urea N (MUN) use reported by surveyed farmers (n = 454).

| Question | Number[1] | Percentage |
|---|---|---|
| Is respondent familiar with MUN? | | |
| Yes | 265 | 60.1 |
| No | 176 | 39.9 |
| How frequently is MUN analyzed? | | |
| Never | 307 | 68.5 |
| Once | 57 | 12.7 |
| Seasonally | 13 | 2.9 |
| Monthly | 34 | 7.6 |
| Other[3] | 37 | 8.3 |
| For what purpose is MUN analyzed? | | |
| Nutrition | 106 | 88.3 |
| Reproduction | 40 | 33.3 |
| Other[4] | 5 | 4.2 |

[1]Total farms responding.

[2]Percentage of farms responding.

[3]Includes periodic and infrequent testing.

[4]Includes curiosity and Penn State health survey.

adding known amounts of urea to either distilled water or milk. The standard deviation among residuals (known MUN minus measured MUN) was 0.92 and 1.32 mg/dl for water and milk samples, respectively. Multivariate regression of residual MUN versus week (as discrete effect) or standard MUN concentration indicated that variation from week to week explained 75% of the variation in residuals (i.e., $r^2 = 0.75$) while standard MUN concentration (incomplete recovery) explained 13% of the variation. In general, recovery of MUN in water and milk was higher the first 10 wk than subsequently. The slope of the line from MUN observed versus known MUN concentration is the fractional recovery of MUN. For the water standards, this recovery was 1.04 (SE = 0.01), and for milk standards it was 0.87 (SE = 0.03). The fractional recovery greater than 1 for water samples was expected because the standard curve developed from milk samples compensates for imperfect recovery of urea in milk. The fractional recovery less than 1 for milk samples shows that the compensation was not adequate for the milk used to develop the standards in this study. Incomplete recovery of urea in milk might occur because of absorption of light by milk fat or protein during spectrophotometric analysis. The one lot of milk used to develop standards in this study may have blocked more light than the milk used to develop the original standard curve. This variation that occurred over time was likely due to

**Table 2**. Milk urea N (MUN) use among surveyed consultants (n = 33).

| Question | Number[1] | Percentage |
|---|---|---|
| Does respondent use MUN? | | |
| Yes | 24 | 73 |
| No | 9 | 27 |
| How frequently should MUN be analyzed? | | |
| Monthly | 20 | 80 |
| Quarterly | 2 | 8 |
| Other[3] | 3 | 12 |
| What should be sampled? | | |
| Bulk tank | 11 | 42 |
| Several cows | 5 | 19 |
| All cows | 7 | 27 |
| Production groups | 3 | 12 |
| For what purpose is MUN analyzed? | | |
| Nutrition | 22 | 60 |
| Reproduction | 14 | 38 |
| Waste management | 1 | 3 |

[1]Total farms responding.

[2]Percentage of farms responding.

[3]Includes weekly, when problems arise.

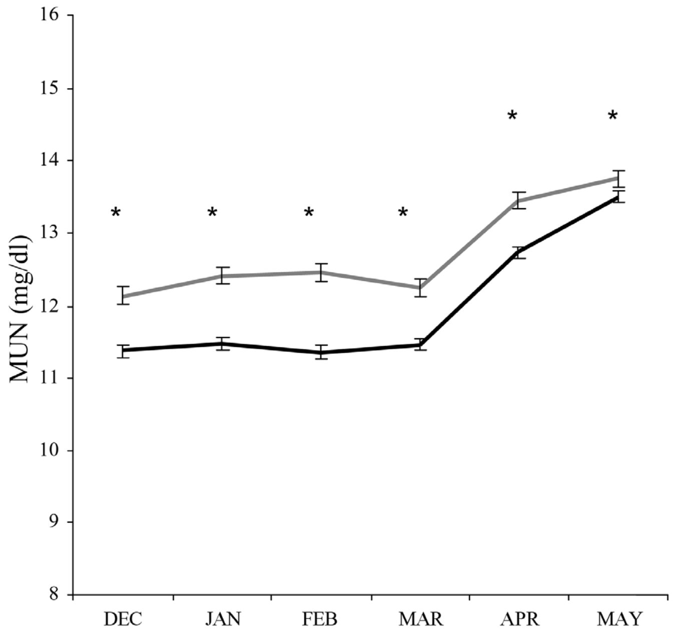


**Figure 1**. Monthly milk urea N (MUN, mg/dl) concentrations for dairy farms that participated in the program (top line) compared to those who chose not to participate (bottom line). *Contrasts by month differ by $P < 0.05$.

changes in the standards used to develop the standard curve in that it paralleled that of the water standards. To adjust for the variation that occurred over time, average milk standard MUN was included as a covariate for all analyses.

Eighteen of the original 472 farms were removed from the program before it ended because they stopped shipping milk. For the first sample obtained on each farm, least square mean MUN concentration for survey participants was significantly higher (12.8 mg/dl ± 2.65 SD; n = 454) than for those who did not complete the initial survey (12.1 mg/dl ± 3.16 SD; n = 684). Overall, least square mean MUN concentration for all farms was 12.4 mg/dl (± 3.01 SD; n = 1138). Month, survey participation, and their interaction were significant ($P < 0.001$) on MUN concentration during the 6-mo period (Figure 1). The MUN level remained relatively constant during the first 4 mo but increased during the last 2 mo as production increased and pastures became available. During the last 2 mo of the MUN program, half of the dairy farms were routinely feeding pasture. Increases in MUN at that time could be expected because lush spring grass is high in readily available N. We observed a greater increase in MUN concentrations for farms feeding alfalfa pasture, grass pasture, and intensive grazing during the last several months compared to those who did not ($P < 0.05$; data not shown). However, an increase in MUN concentration during this time period is also likely the result of the increase in milk production that occurs during this time period each year. This increase in milk production would be expected to increase MUN due to higher protein requirements for milk production (Jonker et al., 1999).

Dairy farmers who participated in the survey (n = 454) had higher MUN concentrations, but their MUN increase during the last 2 mo was less than for nonparticipating farmers. At the beginning of the study, participants' MUN concentrations were 0.77 mg/dl higher than nonparticipating dairy farms. However, by the last month of the study, participating dairy farms were only 0.25 mg/dl higher than nonparticipating dairy farms. In this study, dairy farmers participating in the monthly MUN testing program saw a relative decrease in their MUN concentration by 0.52 mg/dl from the beginning to the end of the testing period compared to nonparticipating farmers (Figure 1). The significant interaction between month and survey participation suggests that the educational component of the study was responsible for this change. This type of approach (survey, education, and analysis for individual dairy farms) provides a mechanism to evaluate the effect of an extension program for the introduction of MUN to dairy farmers. Furthermore, using MUN may be appropriate to evaluate the effect of introducing other nutritional technologies to dairy farmers.

## MUN Extension Project

Of the 454 participants remaining in the program at the end, 190 responded to the follow-up survey (41.9%

**Table 3**. Dairy farmer evaluation of the project.

| Question | Total[1] number | Mean[2] | Mode |
|---|---|---|---|
| Was the program relevant to you or your business? | 188 | 4.3 | 4 |
| Was the program current and up-to-date? | 185 | 4.0 | 5 |
| Was the program understandable? | 187 | 4.3 | 5 |
| Was the program presented in an interesting way? | 188 | 4.0 | 4 |
| Was the program informative? | 184 | 3.9 | 4 |
| Was the program worth your time and effort? | 178 | 4.0 | 5 |

[1]From a total of 190 returned surveys.

[2]Ranking: 1 = "No, not at all", 5 = "Yes, very much so."

**Table 4**. Response to question, "With whom did you share results of MUN analysis?".

| Associate | Number[1] | Percentage |
|---|---|---|
| Employees | 39 | 21 |
| Feed salesperson | 95 | 51 |
| Cooperative extension | 7 | 4 |
| Nutritionist | 116 | 62 |
| Veterinarian | 64 | 34 |
| Other | 9 | 5 |

[1]From a total of 190 returned surveys.

return rate). Overall, 70.5% of the respondents reported using results from the MUN program, and 30% indicated that they planned to use MUN analysis again. While most farmers were unsure of the economic impact the program had, several reported positive returns of up to $1,500 from the program, due to reduced feeding costs.

Results from farmer evaluation of the project are reported in Table 3. Overall, on a 1 (low) to 5 (high) scale, 69.1% of returned surveys reported a 4 or 5 to the question, "Was the program worth your time and effort?" The highest score was for project understandability with 50% of returned surveys rating a 5 in that regard. The largest criticism of the program was in timeliness of receiving results. Due to sampling procedure, farms generally received their test results 2 to 3 weeks after sampling occurred. A majority of the dairy farmers shared their test results with their feed salespersons or nutritionists (Table 4). Another third shared their results with their veterinarians. Seventy percent of dairy farmers used their MUN test results to examine their ration formulation, with over half of those reformulating their ration because of their results.

One third of respondents indicated that they increased dietary CP as a result of the program, which was similar to the number that decreased it (Table 5). A stratification of MUN deviation from target was observed among farms reporting increasing, decreasing, or not changing their dietary CP (Figure 2). Initially, observed MUN – target MUN was significantly higher ($P < 0.05$) for dairy farmers reporting they decreased dietary CP than for farmers not changing or increasing dietary CP. Dairy farmers reporting they increased dietary CP had lower MUN relative to target compared to farmers making no change for all months except for the last month of the study. For farms that indicated they increased dietary CP, MUN increased during the last 3 mo of the program. However, for dairy farmers that indicated they decreased dietary CP (% DM), no subsequent decrease in MUN was observed. Nonetheless, for farmers decreasing CP, the MUN increased by only 1 mg/dl from beginning to end of the

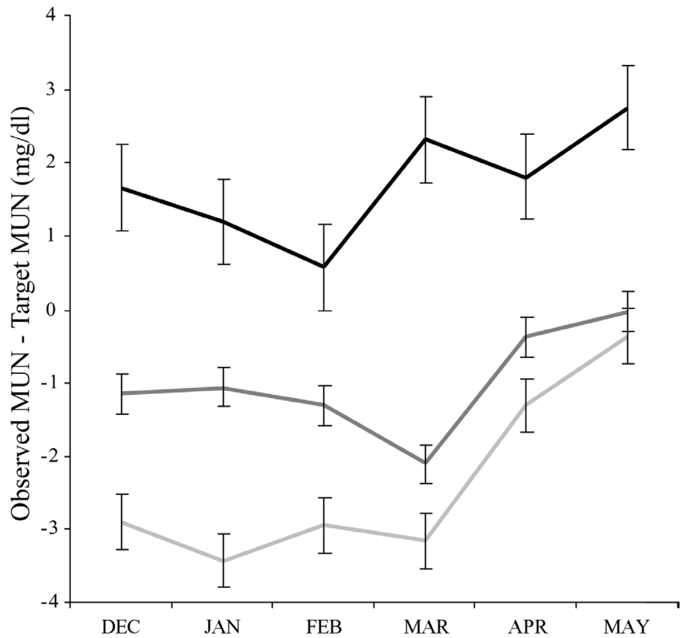


**Figure 2**. Monthly milk urea N (MUN) minus target MUN for dairy farms that reported decreasing dietary CP (top line), increasing dietary CP (bottom line), or not changing dietary CP (middle line).

**Table 5**. Response to the question, "Did you do any of the following because of MUN results provided by this project?"

| Action | Yes, number[1] | No, number | Yes, percentage |
|---|---|---|---|
| Examine ration | 80 | 34 | 70 |
| Reformulate ration | 64 | 82 | 44 |
| Analyze forage nutrients | 51 | 83 | 38 |
| Analyze concentrate nutrients | 25 | 101 | 25 |
| Change ration ingredients | 44 | 95 | 32 |
| Increase ration CP | 45 | 90 | 33 |
| Decrease ration CP | 44 | 97 | 31 |
| Increase ration energy | 37 | 106 | 26 |
| Decrease ration energy | 10 | 115 | 8 |
| Change cow grouping | 6 | 114 | 5 |

[1]From a total of 190 returned surveys.

study (Figure 2), compared to the 2 mg/dl increase in MUN for nonparticipants (Figure 1).

Although MUN has been available as a management tool for some time, farmers have not readily adopted it for routine use, despite widespread recommendations by dairy nutrition consultants. After this project, approximately 30% of the farms indicated they would routinely test MUN in the future. Overall, the MUN program met its goals of introducing MUN for routine evaluation of dairy cattle diets. Rankings for various qualitative aspects of the program were high (Table 3). Furthermore, many of the farmers enacted changes in their herd feeding management that led to observed changes in their monthly MUN results. Herds that had low MUN may have had a protein deficiency, so some farmers opted to increase dietary CP, and MUN levels increased (Figure 2).

### Economic and Environmental Impact

In this study, dairy farmers participating in the monthly MUN testing program saw a relative decrease in their MUN concentration by 0.52 mg/dl from the beginning to the end of the testing period compared to nonparticipating farmers (Figure 1). Assuming no change in milk production by feeding closer to NRC (1989) recommendations, this change in MUN reflects an average decrease of 9.2 g/d in urinary N and of 1.9 g/d in fecal N for lactating cows, according to the model of Jonker et al. (1998), as modified by Kauffman and St-Pierre (2001). Assuming 305 d of lactation, the average annual decrease in N excretion would be 3.4 kg/yr per cow [9.2 + 1.9) × 305/1000]. The average herd size was 109 cows and 454 farmers participated (J. S. Jonker and R. A. Kohn, in press). Thus, the program appeared to help decrease manure N by 168 tonne/yr [3.4 × 109 × 454/1000] for the 49,486 cows (109 × 472) involved in this study. If 75% of this N was destined to eventually contribute to water resources, then 126 tonne N/yr would have been saved from contributing to ground and surface water resources.

The 0.52 mg/dl decrease in MUN also reflects an 11.05 g/d per cow decrease in N intake. If this decreased intake resulted from replacing soybean meal (50% CP) with corn grain (10% CP), then 0.17 kg of soybean meal would have been substituted per cow per day (11.05 g N × 6.25 CP per N ÷ 400 g CP per kg feed substituted). The average substitution of soybean meal with corn would have been 52.7 kg/yr per cow (0.17 × 305 d). The savings from this substitution would have been $0.113/kg (cost of soybean meal-cost of corn grain) for a total of $5.95/cow per year. The typical farm could save $595/yr in feed cost while spending $60/yr on MUN analysis. In the final month of the current project, participants would have saved an average of $0.50/cow or a total of $24,743 ($0.50 × 49,486 cows). Thus, we can document a recovery of most of the cost of the project in just 1 mo. Hopefully, participants will have learned to use MUN to save money in future months.

The total savings from this project should have been greater than just calculated for reduced feed costs. The mean decrease in MUN included 45 farmers who increased CP feeding as well as the 44 farmers who decreased it (Table 5). Those who increased CP feeding increased MUN by more than 3 mg/dl while those who decreased CP decreased MUN by 1 mg/dl (Figure 2) compared to nonparticipants (Figure 1). Even those who did not report changing CP feeding appear to have reduced MUN by nearly 1 mg/dl compared to nonparticipants (Figure 2). If farmers realized increased milk production from increasing CP after low MUN helped identify a mistake in the feeding program, the savings from the project would be greater.

Nonpoint source nutrients are nutrients that enter a watershed during storm water runoff event (USEPA, 1983) from nondiscrete sources such as a field or leach bed rather than a discharge pipe. Nonpoint source nutrients can be from agricultural, urban, forest lands, and base flow in streams. In the base year (1985), 28% of P and 45% of N total nutrient loading to the Chesapeake Bay were from nonpoint sources (Thomann et al., 1994). Animal agriculture has been identified as a major source of nonpoint N pollution of water resources (Thomann et al., 1994). Animal wastes can contribute N pollution to the environment as ammonia volatilized to the air, nitrate leached to ground water, and N that runs off to surface water. In 1996, agricultural enterprises were estimated to contribute 62.8 million-kg N and 4.7 million-kg P annually in nutrient loading to the Chesapeake Bay (Anonymous, 1998). This represented 44% and 56% of total N and P loading to the Bay, respectively. However, total agricultural contribution to nutrient loading has decreased by 12% for both nutrients since 1985 (Anonymous, 1998).

Improvement of the N utilization efficiency by domestic animals decreases N losses from farms (Kohn et al., 1997). A majority of manure N applied to fields is subsequently lost to water resources even under the best management conditions. Therefore, it is important to reduce manure N output by improving N utilization in the animal. Furthermore, much fertilizer N applied to crops is also lost to water resources before crop uptake. Therefore, improving nutrient utilization in the animal to reduce the need for crop production further decreases N losses from animal agriculture.

Because dairy farming is such a large agricultural enterprise in the Chesapeake Bay drainage basin, changes in technology that affect N excretion could have a large impact on nonpoint N loading. Development of new technologies that improve nutrient utilization of dairy cows will be beneficial to further decreasing nutrient loading to the Chesapeake Bay. The use of MUN can be used, as it was in the present program, to test the impact of these technology transfer programs on the environment and farm economics.

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## REFERENCES

Anonymous. 1998. Bay Journal Special Report April 1998. 8:2. Alliance for the Chesapeake Bay, Inc., Baltimore, MD.

Bridge Information Systems, Inc. 2000. The CRB Commodity Yearbook, John Wiley & Sons, Inc., New York.

Broderick, G. A., and M. K. Clayton. 1997. A statistical evaluation of animal and nutritional factors influencing concentrations of milk urea nitrogen. J. Dairy Sci. 80:2964–2971.

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

JMP User's Guide, Version 3.1.5 Ed. 1995. SAS Inst., Inc., Cary, NC.

Jonker, J. S., R. A. Kohn, and R. A. Erdman. 1998. Using milk urea nitrogen to predict nitrogen excretion and utilization efficiency in lactating dairy cattle. J. Dairy Sci. 81:2681–2692.

Jonker, J. S., R. A. Kohn, and R. A. Erdman. 1999. Milk urea nitrogen target concentrations for lactating dairy cows fed according to national research council recommendations. J. Dairy Sci. 82:1261–1273.

Jonker, J. S., R. A. Kohn, and J. High. 2002. Dairy herd management practices that impact nitrogen utilization efficiency. J. Dairy Sci. Accepted.

Kauffman, A. J., and N. St-Pierre. 2001. The relationship of milk urea nitrogen to urine nitrogen excretion in Holstein and Jersey cows. J. Dairy Sci. 84:2284–2294.

Kohn, R. A., Z. Dou, J. D. Ferguson, and R. C. Boston. 1997. A sensitivity analysis of nitrogen losses from dairy farms. J. Environ. Manage. 50:417–428.

Kohn, R. A., K. F. Kalscheur, and E. Russek-Cohen. 2002. Evaluation of models to estimate urinary nitrogen and expected milk urea nitrogen. J. Dairy Sci. 85:227–233.

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

Shirmohammadi, A., K. S. Yoon, and W. L. Magette. 1997. Water quality in mixed land-use watershed—Piedmont region in Maryland. Transactions of ASAE. 40:1563–1572.

Thomann, R. V., J. R. Collier, A. Butt, E. Casman, and L. C. Linker. 1994. Response of the Chesapeake Bay Water Quality Model to Loading Scenarios. Environmental Protection Agency, Washington DC.

United States Environmental Protection Agency (USEPA). 1983. Chesapeake Bay: A Framework for Action. EPA, Region 3, Philadelphia, PA.