The Association Between Milk Urea Nitrogen and DHI Production Variables in Western Commercial Dairy Herds¹

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ABSTRACT

A retrospective observational study was conducted using data from Dairy Herd Improvement monthly tests to investigate the association between milk urea nitrogen (MUN) concentration and milk yield, milk protein, milk fat percentage, SCC, and parity for commercial Holstein and Jersey herds in Utah, Idaho, and Montana. Mean MUN for Holstein cows was 15.5 mg/dl (5.5 mmol/L) MUN and 14.1 mg/dl (5.0 mmol/L) for Jersey cows. Mean MUN, categorized by 30-d increments of days in milk (DIM), paralleled changes in milk values and followed a curvilinear shape. For Holstein cows, concentrations of MUN were different among lactation groups 1, 2, and 3+ for the first 90 DIM for Holsteins. Overall, concentrations of MUN were lower during for the first 30 DIM compared with all other DIM categories for both Holstein and Jersey cows. Multivariate regression models of MUN by milk protein showed that as the milk protein percentage increased, MUN concentration decreased; however, models for Jersey cows showed that MUN did not decrease significantly until above 3.4% milk protein. Milk fat percentage also decreased as MUN increased, but by only 1 mg/dl MUN over the range of 2.2 to 5.8% milk fat. Somatic cell count showed a negative relationship with MUN. Holstein cows with milk protein percentage >3.2% had lower MUN compared with cows having milk protein <3.2% for milk yields from 27.3 to 54.5 kg/d and lower than cows having a milk protein <3.0% for milk yield of 54.5 to 63.6 kg/d. In Jersey cows, MUN concentrations were not different among milk protein percentage categorized by milk yield. This study found that MUN was inversely associated with milk protein percentage and paralleled change in milk yield over time.

(Key words: milk urea nitrogen, milk protein, milk fat, Dairy Herd Improvement)

Abbreviation key: NUE = N utilization efficiency, UN = urinary N.

INTRODUCTION

Milk urea nitrogen is a rapid noninvasive tool to estimate urinary nitrogen (UN) excretion in dairy cows (Jonker et al., 1998). High concentrations of urea in the blood and milk can result from excess dietary protein (Baker et al., 1995; Broderick and Clayton, 1997) that can lead to excess UN, which can have a negative environmental impact (Kohn et al., 1997). It has been reported that protein efficiency (milk protein/feed protein consumed) of dairy cows can be improved by various feeding strategies and dietary manipulations (Baker et al., 1995; Vagnoni and Broderick, 1997; Mackle et al., 1999).

Jonker et al. (2002) found that 40% of Maryland and Virginia dairy farmers did not know what MUN was, and 89.5% did not routinely run the test. However, after participating in a field study, those farmers who participated found the MUN test to be useful and resulted in changed behaviors. The associations between MUN, nitrogen utilization efficiency (NUE), and milk variables would be important, from a practical aspect, in helping farmers understand how nutritional decisions can impact economic and environmental factors.

Several studies have evaluated the relationship between MUN and production variables in commercial dairy herds. Godden et al. (2000b) reported a positive relationship between herd-level average MUN and dietary variables such as CP, RDP, RUP and a negative association with nonfiber carbohydrates. In a related paper, Godden et al. (2000a) found a positive nonlinear association between cow-level MUN and milk yield and a negative nonlinear association between MUN and milk fat and protein percentage and a significant negative nonlinear association with somatic cell linear score. Other researchers have also found a positive relationship between MUN and milk yield (Carlsson et al., 1995), whereas others have found a negative relationship (Broderick and Clayton, 1997). Eicher et al. (1999) found the associations between MUN or milk protein percentage with respect to production factors such as parity, milk yield, and DIM varied consider-

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ably among herds. Carlsson and Bergström (1994) reported that increased milk fat percentage could have a negative effect on measured MUN.

Dairies in the Intermountain West utilize high protein legume forages in rations (Sannes, 2000) and the association between NUE and production variables, as measured by MUN, would be useful in helping minimize nitrogen losses while maintaining production.

The objective of this study was to characterize and investigate the association between MUN and milk yield, milk protein, milk fat, SCC, DIM, and parity in Holstein and Jersey cows using DHI records from commercial dairies located in the Intermountain West.

MATERIALS AND METHODS

A retrospective, observational study was conducted by analyzing individual cow records from monthly DHI tests collected by the Rocky Mountain DHI affiliate (Logan, UT). Forty-one herds (75.5% of cows) were from Utah, 6 (12.4% of cows) from Idaho, and 7 (12.1% of cows) from Montana. Monthly herd milk tests beginning January 1999 and ending December 2000, that included a MUN test, were combined into a dataset that included herd code, date of test, breed of cow, milk weight, milk fat percentage, milk protein percentage, SCC, MUN, parity, DIM, breeding date and pregnancy status. A total of 49 Holstein and 5 Jersey herds were included, with each herd being represented by 3 to 19 monthly tests during the 24-mo period. Herd sizes ranged from 40 to 550 cows. Open free-stall housing and TMR feeding were the most common management practices on these farms, but no distinction was made for management style or feeding scheme in the data set. Missing values were coded as such in the database and each production variable was screened for outliers. Milk urea N concentrations <1 or greater than 40 mg/dl were excluded from the analysis to remove outliers and because there were too few values. Cows with milk production greater than 84 kg were also excluded. The complete dataset consisted of 69,724 Holstein and 6136 Jersey individual cow-month records.

The milk sample used for component analysis was from either one or two milkings and no distinction was made in the database regarding milk sampling because most herds were fed TMR. For herds where only one sample was taken each month, a.m. and p.m. samplings were normally alternated each month so that the MUN analysis probably wasn't biased in any particular direction. Milk was analyzed for milk fat and protein percentage and SCC using the infrared method (Bentley 2000; Bentley Instruments, Chaska, MN). Concentrations of MUN were determined using

the Bentley Instruments Chemspec 150 Urea analyzer (Chaska, MN) for milk. This machine uses a chemical reaction to determine MUN concentrations rather than the NIR method. Urea was measured by an enzymatic reaction (modified Berthelot reaction) that splits urea to ammonia that is quantified colorimetrically.

Statistical Analyses

Categories. Days in milk were grouped into 30-d increments, with those greater than 420 d grouped into one category. Milk urea N was grouped by increments of 2 mg/dl with those less than or equal to 6 mg/dl grouped into one category, and equal to or greater than 24 mg/dl as a category. Milk production was grouped by increments of 9.1 kg/d (20 lb/d) with the upper grouping for Jersey cows of 45.5 kg and greater and 63.6 kg and greater for Holstein cows.

Milk protein percentages were grouped into categories in two different ways. In the first, milk protein percentage was categorized into increments of 0.2% beginning with $\leq 2.2\%$ and ending with $\geq 4.8\%$. In the second set, milk protein categories were created based on the groupings in Nelson, 1996. For Holsteins, the categories were $\leq 3.0\%$, 3.01 to 3.2%, and $> 3.2\%$ milk protein. Although no breakdown has been suggested for Jersey cows, we categorized them in a similar manner using the following groupings: $\leq 3.5\%$, 3.51 to 3.7%, and $> 3.7\%$ milk protein.

Descriptive statistics. Descriptive statistics were computed for DIM, milk yield, MUN, milk protein and fat percentage, SCC and parity, by breed of cow, using the Proc Freq procedure of SAS (SAS, 1996).

Simple correlation coefficients and principal component analyses were calculated to determine collinearity (SAS, 1996). Variables correlated at $r > 0.5$ were not included in the same model. Least squares means were determined for MUN concentration and milk yield by DIM categories for Holstein and Jersey cows using the Proc Mixed procedure in SAS (SAS, 1996). Parity, DIM, and test month within test year were added to the model as covariates. Cow within herd was included in the random statement to control for repeated measures within herd on different test days.

Association between MUN categories and production variables. Multivariate mixed linear regression models using the Proc Mixed procedure in SAS (SAS, 1996) were used to determine the association between milk yield, milk fat and protein percentage, SCC, linear SCC, pounds of fat and protein per day (dependent variables) and MUN categories (independent variable). Parity, DIM, and month of test within year of test were added to the model as covariates. Test month within test year was added to make allow-

ance for the change from total milk protein to true milk protein during the time period of data collection. The reported values are primarily true protein. Least-squares means were determined for Holstein and Jersey breeds of cow. Cow within herd was included in the random statement to control for repeated measures within herd on different test days.

Association between MUN concentrations and DIM and parity. Multivariate mixed linear regression models using the Proc Mixed procedure in SAS (SAS, 1996) was used to determine the association between MUN (dependent variable) and DIM and parity categories (independent variables). Test month within test year was added to the model as a covariate. Least squares means were calculated by breed of cow. Multiple comparisons were made with *P*-values adjusted using Tukey's procedure. Cow within herd was added to the random statement to control for repeated measures within herd on different test days.

Association between MUN and milk protein and fat percentage. A mixed multivariate regression model (Proc Mixed procedure in SAS, 1996) was developed to determine the association between MUN (dependent variable) and either milk fat or protein (independent variables). Parity, DIM, and test month within test year were added to the model as covariates. Cow within herd was added to the random statement to control for repeated measures within herd on different test days. Quadratic and cubic terms were added and remained in the model if significant ($P < 0.05$). The resulting regression equation was used to plot MUN concentration, by breed, based on a range of milk fat and protein percentages. Fat percentages greater than 5.4% for Holstein cows and less than 2.8% for Jersey cows were retained for completeness even though they are probably at the extreme ends of the range of normal values for these breeds.

Association between MUN and combinations of milk yield and milk protein percentage categories. Multivariate mixed linear regression models using the Proc Mixed procedure in SAS (SAS, 1996) was used to determine the association between MUN (dependent variable) and milk yield and protein categories (Nelson, 1996)(independent variables). Parity, DIM (not significant) and test month within test year were added to the model as covariates. Cow within herd was added to the random statement to control for repeated measures within herd on different test days. Least squares means were calculated by breed of cow. Multiple comparisons were made with *P*-values adjusted using Tukey's procedure.

RESULTS AND DISCUSSION

Characterization of Database

Descriptive statistics for DHI variables are listed, by breed, in Table 1. Mean DIM was 194 for Holsteins

Table 1. Least squares means and SD of DHI variables for Holstein (n = 69,717 cow-months) and Jersey cows (n = 6138 cow-months).

	Holstein cows		Jersey cows	
	LS mean	SD	LS mean	SD
DIM	194	129.0	180	130.3
Milk, kg	33.8	10.73	22.4	7.2
MUN, mg/dl	15.5	3.73	14.1	3.20
Protein, %	3.19	0.379	3.70	0.447
Fat, %	3.56	0.757	4.62	0.839
SCC, $\times 1000$	270	741.0	336	909.0
Linear score	2.57	2.11	2.88	2.11
Parity	2.46	1.60	2.41	1.66

and 180 for Jerseys and was higher than reported in other studies (Jonker et al., 1998; Godden et al., 2001a). Milk yield for Holsteins, 33.8 kg, was higher than has been reported in other MUN studies (Carlsson et al., 1995; Godden et al., 2001a, 2001b). Overall, average cow-level MUN concentrations were similar to values reported in other studies (Broderick and Clayton, 1997; Jonker et al., 1998; Godden et al., 2001a; Rajala-Schultz et al., 2001).

Mean milk fat and protein percentages for Holsteins were 3.56 and 3.19%, respectively, and were similar to values reported by Jonker et al. (1998) and Oltner and Wiktorsson (1983), but lower than those reported by Godden et al. (2001a). Mean milk fat and protein percentages were 4.62 and 3.70% for Jersey cows. As expected, mean milk yield was higher for Holstein cows ($P < 0.001$) than for Jersey cows, and both mean milk protein and fat percentages were higher in Jersey cows ($P < 0.001$). The mean parity for both breeds was 2.4 lactations and is similar to what was reported by Godden et al. (2001a).

Associations Between MUN and DIM

Mean milk yield and MUN concentrations, by DIM categories, demonstrated curvilinear, parallel relationships (Figures 1 and 2; Tables 2 and 3). The concentration of MUN was lower ($P < 0.0001$) during the first 30 DIM category compared with all other DIM categories. Others have shown this same association (Carlsson et al., 1995; Eicher et al., 1999; Godden et al., 2001a). Although it can be speculated that the lower MUN concentrations might be related to lower DMI or possibly consumption of a ration with a different composition than after 30 DIM, further work to determine the cause of the lower MUN during this time period would be helpful when using MUN concentrations as a management tool.

Carlsson et al. (1995) observed higher urea concentrations at peak lactation than in later lactation, similar to this study. Jonker et al. (1999) modeled expected

Figure 1. Least squares means of MUN concentration and milk yield by 30-d DIM categories for Holstein cows.

Figure 2. Least squares means of MUN concentration and milk yield by 30-d DIM categories for Jersey cows.

MUN concentrations for an entire lactation and showed that MUN concentrations resembled a lactation curve. Schepers and Meijer (1998) found that DIM had no effect on mean MUN. However, the authors stated that because the nutritional variables they looked at were not statistically independent, the effect of DIM was probably included indirectly through the nutritional factors.

In later lactation, as milk production declines, the protein requirement decreases, and we suggest that MUN should also decline. We observed that as milk declined, some of the herd MUN concentrations did not decline at the same rate (data not shown). This suggests the possibility that for those herds, protein may have been overfed in late lactation or the ration contained a different amount of rumen degradable protein than earlier in lactation.

Godden et al. (2001a) and, to a lesser extent, Carlsson et al. (1995), showed a positive relationship between milk yield and MUN. We saw the same relationship in our data. The question then becomes one of whether changes in MUN concentrations during lactation are a function of DMI or directly associated in some manner with milk yield (Figures 1 and 2). Jonker et al. (1999) suggested that milk production drives the requirement for N in lactating cows fed according to NRC requirements (NRC, 2001) and that changes in total protein intake (Broderick and Clayton, 1997; Godden et al., 2001b), coupled with DMI, drive changes in MUN concentrations.

Association Between MUN and Parity

Mean MUN concentration, by DIM categories and parity, are shown for Holstein and Jersey cows in Ta-

Table 2. Least squares means of MUN concentration by DIM categories and parity for Holstein cows.

DIM category	Lactation 1		Lactation 2		Lactation 3+		All	
	N	Mean	N	Mean	N	Mean	N	Mean
≤30	1809	13.6 ^b	1435	15.0 ^a	2137	13.9 ^b	5381	14.2
31–60	2047	15.6 ^b	1669	16.4 ^a	2478	15.7 ^b	6194	15.9
61–90	1893	16.2 ^f	1591	16.6 ^e	2402	16.1 ^f	5886	16.3
91–120	2060	16.3	1576	16.4	2313	16.2	5949	16.3
121–150	2002	16.1	1603	16.2	2258	16.0	5863	16.1
151–180	2032	16.2	1498	16.1	2193	15.9	5723	16.1
181–210	1997	16.0	1484	15.7	2142	15.7	5623	15.8
211–240	1968	15.7	1444	15.5	2079	15.4	5491	15.5
241–270	1896	15.6 ^e	1393	15.2 ^f	2007	15.3 ^{ef}	5296	15.3
271–300	1637	15.5	1219	15.2	1811	15.2	4667	15.3
30–330	1437	15.4	941	14.9	1392	15.0	3770	15.1
331–360	1064	15.3	743	14.8	1065	14.9	2872	15.0
361–390	745	15.2	527	14.8	763	14.8	2035	14.9
391–420	559	15.2	355	14.6	526	14.6	1440	14.8
>420	1512	14.8	701	14.3	1314	14.6	3527	14.6
Total/avg.	24,658	15.5 ^c	18,179	15.4 ^f	26,880	15.3 ^a	69,717	

^{a,b,c}Least square means within the same row with different superscripts differ at $P < 0.0001$.

^{e,f,g}Least square means within the same row with different superscripts differ at $P < 0.05$.

Table 3. Least squares means of MUN concentrations by DIM categories and parity for Jersey cows.

DIM category	Lactation 1		Lactation 2		Lactation 3+		All	
	N	Mean	N	Mean	N	Mean	N	Mean
≤30	312	12.8 ^{ab}	140	13.5 ^a	177	12.1 ^b	629	12.8
31–60	280	14.1	170	14.4	219	13.9	669	14.2
61–90	227	14.8	140	14.9	237	14.3	604	14.7
91–120	203	13.8	139	14.4	208	14.6	550	14.3
121–150	189	14.1	113	14.6	185	14.3	487	14.3
151–180	142	14.1	131	14.5	193	14.2	466	14.3
181–210	146	14.0	108	14.3	181	14.2	435	14.2
211–240	153	13.5	114	14.1	175	14.1	442	13.9
241–270	132	14.5	101	14.2	153	13.9	386	14.2
271–300	144	14.2	74	13.3	136	13.9	354	13.8
301–330	125	13.9	83	13.4	113	13.2	321	13.5
331–360	111	14.2	42	13.8	85	13.9	238	14.0
361–390	85	13.9	27	14.3	49	13.5	161	13.9
391–420	63	13.0	31	13.7	31	13.1	125	13.2
>420	116	13.0	52	12.8	103	13.1	271	13.0
	2428	13.9 ^{ab}	1465	14.0 ^a	2245	13.8 ^b		

^{a,b,c}Least square means within the same row with different superscripts differ at $P < 0.0001$.

^{e,f,g}Least square means within the same row with different superscripts differ at $P < 0.05$.

bles 2 and 3. For Holsteins, the overall mean for the second-parity group was higher ($P < 0.0001$) than first or third and greater parity, even though the difference was only 0.2 mg/dl. Overall mean MUN concentration of Jersey cows in third and greater lactation was lower ($P < 0.0001$) than first or second lactation. The overall differences are small, and the biological significance of this observation is questionable.

Godden et al. (2001a) found significant changes, similar to our results, in MUN concentrations by parity, which were also numerically small. In a study by Carlsson et al. (1995), multiparous cows had higher MUN (14.4 mg/dl) than primiparous cows only when cows were in confinement housing rather than on pasture. Jonker et al. (1998) used models to predict changes in MUN due to parity and suggested that first lactation animals would have a higher MUN than mature animals. In another study by Jonker et al.

(1999), target MUN concentrations averaged 16.3 mg/dl for first lactation, 16.8 for second lactation, and 16.2 for third lactation.

In the current data, differences due to parity were only found for DIM categories of < 90 DIM (Tables 2 and 3). Most studies have looked only at primiparous compared with multiparous cows (Carlsson et al., 1995; Jonker, 1998; Godden et al., 2001a). We do not have an explanation for the differences between second and older lactation cows.

Association Between MUN and Milk Protein Percentage

Descriptive information about protein percentage, stratified by MUN category, and breed are summarized in Tables 4 and 5. The results of a mixed multivariate regression model of MUN against selected lev-

Table 4. Least squares means and SE for milk yield, protein, and fat percentage and SCC by MUN concentration categories for Holstein cows.

Mun categories, mg/dl	N	Milk		Protein, %		Fat, %		SCC		Linear score		Fat, kg		Protein, kg	
		Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
≤6.0	190	30.2	0.67	3.34	0.024	3.85	0.055	468	53.8	3.26	0.146	1.11	0.023	0.98	0.020
6.01–8	745	29.0	0.35	3.40	0.012	3.88	0.028	550	27.5	3.51	0.074	1.08	0.013	0.97	0.010
8.01–10	3219	31.4	0.17	3.33	0.006	3.72	0.014	461	13.8	3.16	0.038	1.12	0.007	1.03	0.005
10.01–12	8163	32.3	0.12	3.28	0.004	3.61	0.009	381	9.3	2.91	0.025	1.12	0.005	1.04	0.004
12.01–14	13,083	33.1	0.10	3.25	0.003	3.57	0.008	302	7.7	2.72	0.021	1.14	0.004	1.06	0.003
14.01–16	15,126	33.8	0.09	3.21	0.003	3.53	0.007	255	7.3	2.55	0.020	1.16	0.004	1.07	0.003
16.01–18	12,726	34.6	0.10	3.18	0.003	3.50	0.008	217	7.7	2.38	0.021	1.18	0.004	1.08	0.003
18.01–20	8616	35.8	0.11	3.15	0.004	3.48	0.009	182	9.0	2.21	0.024	1.22	0.004	1.11	0.003
20.01–22	4535	36.9	0.15	3.10	0.005	3.44	0.012	172	11.9	2.12	0.032	1.24	0.006	1.13	0.005
22.01–24	2017	37.7	0.22	3.07	0.008	3.45	0.017	147	17.3	1.97	0.047	1.28	0.008	1.14	0.006
>24	1304	37.5	0.27	3.03	0.009	3.49	0.022	124	21.5	1.96	0.058	1.30	0.010	1.11	0.008

Table 5. Least squares means and SE for milk yield, protein, and fat percentage and SCC by MUN concentration categories for Jersey cows.

Mun categories, mg/dl	N	Milk		Protein, %		Fat, %		SCC		Linear score		Fat, kg		Protein, kg	
		Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
≤6.0	21	18.8	1.43	3.79	0.082	5.12	0.168	216	198.1	3.42	0.447	0.94	0.069	0.72	0.050
6.01–8	80	18.2	0.75	3.91	0.042	4.79	0.087	738	102.7	3.98	0.232	0.88	0.036	0.71	0.026
8.01–10	366	20.5	0.35	3.85	0.020	4.87	0.041	522	48.2	3.57	0.110	0.98	0.017	0.77	0.012
10.01–12	1183	21.2	0.20	3.82	0.012	4.78	0.024	460	27.6	3.34	0.064	1.00	0.010	0.80	0.007
12.01–14	1581	22.0	0.18	3.76	0.010	4.62	0.021	324	24.2	2.99	0.056	1.00	0.009	0.82	0.006
14.01–16	1405	22.3	0.19	3.73	0.011	4.54	0.022	255	26.0	2.80	0.060	1.00	0.009	0.82	0.007
16.01–18	838	22.7	0.24	3.70	0.014	4.58	0.028	236	32.8	2.55	0.076	1.02	0.012	0.82	0.008
18.01–20	426	23.0	0.33	3.61	0.019	4.52	0.039	199	45.3	2.39	0.104	1.03	0.016	0.82	0.012
20.01–22	146	23.6	0.56	3.59	0.032	4.53	0.066	128	77.1	2.19	0.175	1.05	0.027	0.83	0.020
22.01–24	57	23.9	0.88	3.61	0.050	4.64	0.103	329	121.4	2.66	0.275	1.08	0.042	0.85	0.031
>24	36	21.5	1.12	3.61	0.063	4.77	0.129	241	151.6	2.09	0.343	0.96	0.054	0.76	0.039

els of milk protein is shown in Figure 3 for Holstein and Jersey cows. The data suggest that as milk protein percentage increased, MUN concentration decreased. Because of the inverse relationship between MUN and milk protein percentage, lower MUN may be associated with a greater use of dietary CP, leading to improved NUE. Other reports have shown either no relationship between milk protein percentage and MUN (Broderick and Clayton, 1997; multiple regression model) or a negative, nonlinear association (Godden et al., 2001a). Equations in the current study also suggest that the relationship between milk protein percentage and MUN differs between Holstein and Jersey cows at lower milk protein percentages, but follows a similar relationship at higher milk protein percentages (Figure 3).

The concentrations of MUN categorized by milk yield and milk protein categories of ≤ 3.0%, 3.01 to 3.2%, and >3.2% are shown in Table 6 for Holstein cows. Categories of ≤9.1 and >63.6 kg of milk were considered extreme in this dataset for Holstein cows and are not shown. In Holstein cows, MUN was lower ($P < 0.0002$) when milk protein was >3.2% (vs. < 3.0%) for milk yields ranging from 27.31 to 63.6 kg. Also, MUN was lower for cows with milk protein > 3.2% than the grouping of 3.01 to 3.2% milk protein for milk yields ranging from 27.3 to 54.5 kg/d. Approximately

27.3 kg/cow per day of milk was the minimal production level before MUN differed across milk protein levels (Table 6). Because of these relationships, perhaps milk protein percentage should be considered in addition to MUN concentration as a management tool for determining if rations are properly balanced for production. The association was not seen between MUN and milk protein categories for Jersey cows, suggesting need for research to investigate why the relationship between MUN and milk protein percentage might differ for Jersey compared with Holstein cows. Because the Jersey cows in the current study were in different herds than were the Holstein cows, herd differences in feeding regimens may account for some of the breed differences.

As listed in Nelson (1996), herd-level groupings of low, average, and high milk protein percentages in combination with three levels of MUN (< 12, 12 to 16, and > 16 mg/dl), may give an indication of an imbalance of protein and energy in the ration. He suggested that when milk protein was 3.0 to 3.2% and MUN concentration was 12 to 16 mg/dl, protein degradability fractions and net energy were most likely balanced. In this study (Table 6), cow-level mean MUN (meant to simulate a herd-level mean) for each category of milk protein percentage and milk yield was within this range for Holsteins, except when milk production was

Table 6. Least squares means and SE of MUN concentration by milk yield and protein percentage categories for Holstein cows.

Milk categories, kg	≤3.00%			3.01–3.20%			>3.20%		
	N	MUN, mg/dl	SE	N	MUN, mg/dl	SE	N	MUN, mg/dl	SE
9.1–18.2	460	14.7 ^a	0.143	544	14.8 ^a	0.132	3138	14.6 ^a	0.060
18.21–27.3	1848	15.2 ^a	0.074	2288	15.1 ^a	0.067	8795	14.8 ^b	0.039
27.31–36.4	5340	15.9 ^a	0.047	5442	15.6 ^b	0.046	11,171	15.0 ^c	0.035
36.41–45.5	6922	16.5 ^a	0.042	4791	16.0 ^b	0.048	5548	15.3 ^c	0.045
45.51–54.5	4284	17.1 ^a	0.052	1879	16.3 ^b	0.073	1265	15.4 ^c	0.088
54.51–63.6	1223	17.7 ^a	0.091	278	16.6 ^b	0.183	121	15.8 ^b	0.277

^{a,b,c}Different within row $P < 0.0002$.

Figure 3. Graphs of the results from univariate regression models developed for the association between milk fat and protein percentage on MUN concentration for Holstein and Jersey cows (HP = milk protein percentage for Holstein cows; JP = milk protein percentage for Jersey cows; HF = milk fat percentage for Holstein cows; and JF = milk fat percentage for Jersey cows).

very high, then MUN concentrations were higher. Kohn et al. (2002) suggested that herd-level means of 12 to 16 mg/dl may be too high. If so, then dairy farmers in the Intermountain West are possibly overfeeding protein or underestimating protein degradability of the high quality alfalfa being fed.

Association Between MUN and Milk Fat Percentage

An inverse relationship between MUN categories and milk fat percentage was observed in these data for both Holstein (Table 4) and Jersey cows (Table 5). The result of a mixed multivariate regression model of MUN against selected levels of milk fat percentage is shown in Figure 3 for Holstein and Jersey cows. Within the normal physiological range of milk fat percentages for each breed, MUN concentration change was very small, but as milk fat percentage increased MUN concentration decreased.

Godden et al. (2001a) reported a negative, nonlinear association between milk fat and MUN when cow-level analysis was performed, but when herd-level means were used (2001b), reported a positive relationship between milk fat percentage and MUN. Broderick and Clayton (1997) also reported a negative relationship between MUN and milk fat. Jonker et al. (1998) predicted that a change in milk fat of ± 0.5 percentage units would change the estimated mean lactation MUN concentration by approximately ± 1.70 mg/dl. The relationship between milk fat and MUN may be an indirect result of nutritional variables or a direct

negative effect of milk fat on MUN (Carlsson and Bergström, 1994).

Association Between MUN and SCC

A mixed multivariate regression model of MUN with SCC showed a significant negative linear effect for both Holstein and Jersey cows (Tables 4 and 5). Godden (2001a) also reported a slightly negative relationship between MUN and linear score. Eicher et al. (1999) reported no significant association of SCC on MUN.

Association Between MUN and Breed Effect

Kauffman and St-Pierre (2001) studied the relationship between UN excretion and MUN with limited numbers of Holstein and Jersey cows. The relationship of UN to MUN was linear for both breeds, but the slopes for each breed were significantly different. It was found that the breed effect in the relationship of UN to MUN was completely eliminated when BW was included in the equation.

Jonker et al. (1998), later modified by Kohn et al. (2002), also reported a breed effect based on BW. They predicted that BW was negatively correlated with MUN concentration in lactating dairy cows. A larger cow would have a lower MUN concentration, and a smaller cow a higher MUN concentration. In this study, when breed was added to the analysis as a variable, there was a significant difference due to breed, with Jersey cows having a lower MUN concentration than the larger Holsteins (data not shown). Kauffman and St-Pierre (2001) reported no difference between Holstein and Jersey MUN concentrations (9.44 and 9.47 mg/dl, respectively).

The results of the current study have shown differences within and between breeds of cows relative to MUN and other production variables. It is not clear from this dataset what caused these differences, but differing milk production and composition, different N utilization between the breeds, or different feeding and management strategies across herds may be included. Few other researchers have examined the differences between Holsteins and Jerseys as they relate to MUN, and this appears to be an area that needs further study.

CONCLUSIONS

In these data, MUN concentrations were positively associated with milk yield and negatively associated with milk protein and fat percentage. Milk urea N concentration appeared to have an inverse association

with SCC. Our results suggest that MUN concentrations should be evaluated in association with breed, DIM, milk yield, and protein percentage when determining the efficiency of N utilization. Additional research on the association between production values and MUN concentration for Jersey cows is needed.

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