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Spatial-time correlation between milk urea with milk components and somatic cell score of bulk milk samples from farms supplying milk for cheese and milk powder manufacturing

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Abstract

Milk urea nitrogen (MUN) has been used to indicate the dietary protein/energy balance for the dairy cow, and may be negatively associated with the content of valuable milk components for the manufacture of dairy products. The objective of the study was to model the temporal pattern of the correlation between MUN and the percentages of fat (FP), protein (PP), lactose (LP) and total milk solids (MSP), and somatic cell score (SCS) ($\log_2$ somatic cell count) of bulk milk samples from farms supplying milk for the manufacture of cheese and milk powder. Daily records of milk delivery dates, the composition of bulk milk samples for FP, PP, LP, MSP, SCS and MUN from 28 seasonal supply dairy farms were analysed. The results show there is a negative association between MUN and milk components. The concentration of MUN in milk of New Zealand cows is high compared with that of milk from cows fed a total-mixed-ration, due to the high crude protein content in the pasture fed to dairy cows in New Zealand.

Keywords: milk urea; milk components; spatial-time correlation

Introduction

The current herd testing system in New Zealand provides dairy farmers information for individual cows comprising percentages of fat (FP), protein (PP), total milk solids (MS) and somatic cell count (SCC). Dairy companies like Open Country Dairy Ltd. are producing the same milk composition parameters for daily samples of bulk milk from their suppliers as well as milk urea (MU). The content of MUN from bulk milk samples can be used to monitor MUN changes of cows in a herd because there is a good agreement between MUN from bulk tank milk samples and individual cow MUN determinations (Arunvipas et al. 2004).

The amount of urea a cow excretes in the urine is directly proportional to the concentration of urea in the blood. This amount is proportional to the concentration of MUN. Milk urea is the main non-protein source of nitrogen in milk, and as such it reflects the efficiency of nitrogen utilization by the cow and the amount of nitrogen being excreted in the environment. Therefore, MUN could be a good predictor of urinary N excretion by dairy cows and a way to monitor the efficiency of protein utilization in dairy herds (Kohn et al. 2002). According to some reports, MUN is negatively related to both PP (Trevaskis & Fulkerson 1999; Godden et al. 2001) and SCC (Godden et al. 2001) at the individual cow level. The negative associations of MUN with PP might have a negative effect on the yield of products manufactured with this milk, and therefore, uncovering the size and nature of the relationship between MUN and other economically important milk components during the milking season should be undertaken.

The objective of the study was to model the seasonal pattern of the correlation between MUN, FP, PP, lactose percentage (LP), MSP (FP + PP + LP) and SCC of bulk milk samples from 28 New Zealand seasonal dairy farms supplying milk for the manufacture of cheese and milk powder.

Materials and methods

Data

Data on composition of daily bulk milk samples of 28 seasonal dairy farms from the upper North Island in New Zealand supplying milk to Open Country Dairy Ltd were available from December 2010 to June 2011 inclusive. The herds of these farms were all subscribers to the milk recording service provided by Livestock Improvement Corporation.

For all the farms, starting from about Day 90 of the milking season, daily records of FP (%), PP (%), LP (%),MSP (%), SCC (cells/mLof milk) and MUN (mg/dL of milk) from bulk milk samples representing the composition of the morning and evening milkings were available for analysis. Somatic cell score (SCS) was calculated as the $\log_2$ of SCC. Additionally, to explore seasonal trends in the data, the days after the farm's first milk pick-up in the season were generated for all farms contributing information.

The data file was edited and only records with non-missing values for MUN were included in the analysis. The MUN records were paired up with the corresponding records for FP, PP, LP, MSP, SCC, and SCS. With the exception of SCC or SCS, for which the number of records was 2,684, the number of records for the milk composition variables FP, PP, LP, and MSP was 2,686 (Table 1).

For comparison purposes with the present study, the range of values of treatment means for crude protein (CP) content of the diet, the concentration of

Table 1 Descriptive statistics for milk composition, content of milk urea nitrogen, somatic cell count and somatic cell score of bulk milk samples from 28 seasonal supply dairy farms supplying milk to Open Country Dairy Ltd during 2010-11 for the manufacture of cheese and milk powder. Somatic cell score = $\log_2$ Somatic cell count.

Variable	N	Mean	Minimum	Maximum	Standard deviation
Fat (%)	2,686	5.2	3.8	9.0	0.6
Protein (%)	2,686	3.8	3.1	6.0	0.4
Lactose (%)	2,686	4.8	4.0	5.1	0.1
Total milk solids (%)	2,686	14.4	12.4	20.0	0.9
Milk urea nitrogen (mg/dL of bulk milk)	2,686	16	6	28	3
Somatic cell count (cells/mL x 1,000)	2,684	240	32	1,062	102
Somatic cell score (units)	2,684	7.8	5.0	10.0	0.6

Table 2 Range of values reported in the literature for the mean of crude protein (CP) content of a diet, milk urea nitrogen (MUN) concentration, and the overall mean of the percentage of fat and protein in the milk, for dairy cows fed either a total-mixed-ration (TMR) or pasture.

Feeding system	Parameters				Source	Country
	Range in dietary crude protein (%)	Range in milk urea nitrogen (mg/dL)	Mean fat (%)	Mean protein (%)		
TMR	14.3–17.5	15.1–23.4	3.8	3.2	Baker et al. (1995)	USA
	14.3–17.5	15.1–23.4	4.1	2.9	Burgos et al. (2007)	USA
	15.2–19.1	12.0–21.0	3.8	3.2	Rius et al. (2010)	USA
Pasture	17.5–16.2	14.0–16.5	3.9	3.1	Tas et al. (2006)	Netherlands
	15.1–16.2	16.7–20.5	4.1	3.4	Taweel et al. (2005)	Netherlands
	19.8–19.8	15.1–16.2	4.5	3.3	Kolver & Aspin (2006)	New Zealand
	19.5–24.7	18.21–19.3	4.7	-	Higgs et al. (2009)	New Zealand
	17.8–28.0	15.4–50.1	-	-	Pacheco et al. (2009)	New Zealand
	17.1–18.7	12.3–15.8	5.3	3.8	Bryant et al. (2010)	New Zealand
	21.7–24.1	34.2–49.8	-	3.9	Pacheco et al. (2010)	New Zealand
	23.0–28.1	14.3–20.3	4.3	3.3	Higgs et al. (2013)	New Zealand
	23.7–26.3	26.6–33.9	5.7	4.1	Totty et al. (2013)	New Zealand

MUN in milk samples, and the average of the experiment for the percentages of fat and protein for dairy cows fed on total-mixed-ration (TMR) or at pasture, are summarised from selected references in Table 2.

Statistical analysis

The relationship between the time after a farm's first milk pick-up and MUN, FP, PP, LP, MSP, and SCS was modelled by fitting the n-degree Legendre polynomial of best fit using random regression analysis with the MIXED procedure of SAS (SAS 2011). Farms were regarded as subjects, and Legendre polynomials from first up to the fourth degree were fitted to each of the variables analysed. Model fitting ended whenever the parameter of an extra term added to the random regression model had no significant effect. For each variable analysed, the model of best fit was chosen comparing the corresponding nested models using a likelihood ratio test (McArdle 2012).

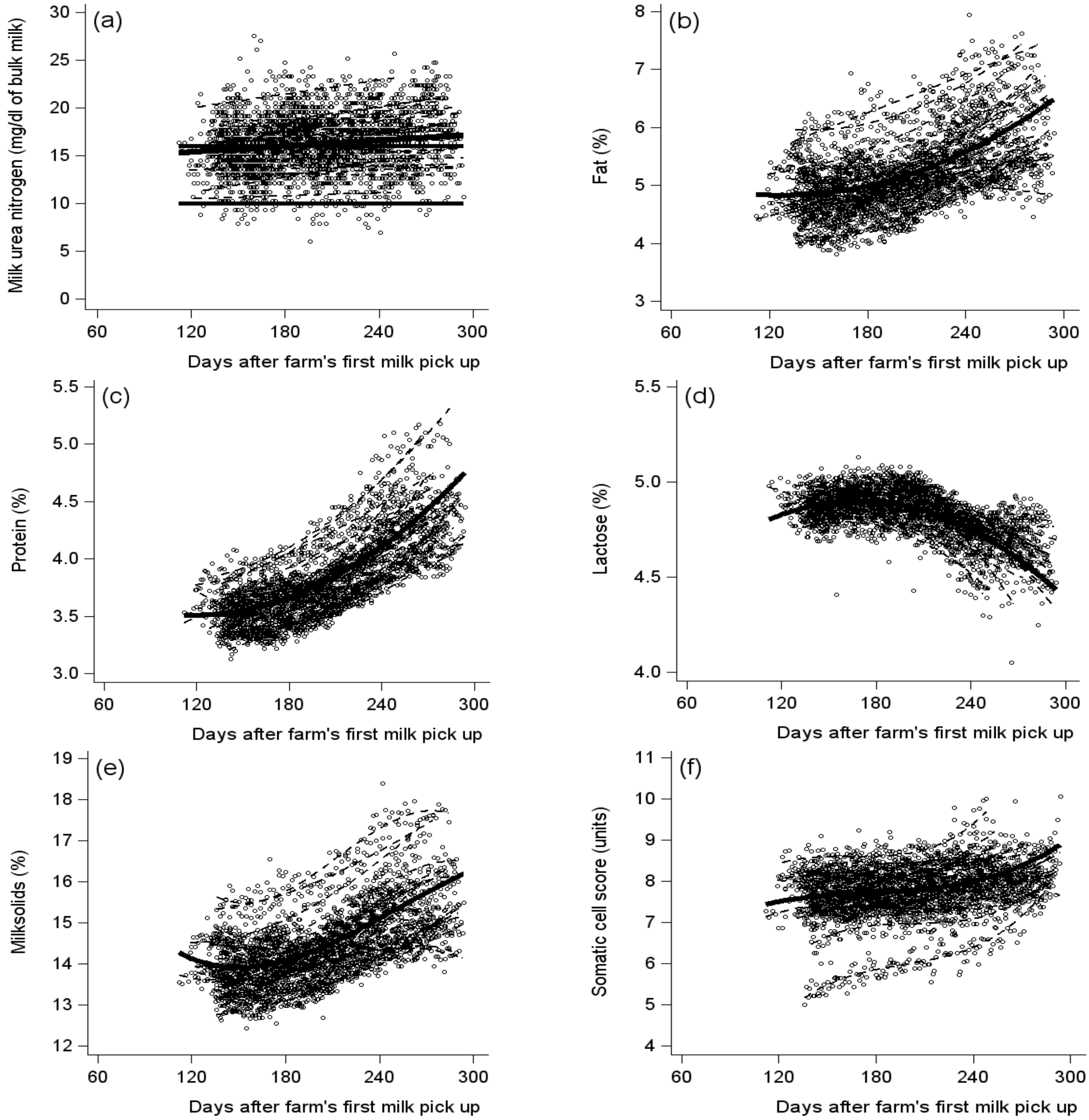
Product-moment Pearson correlation coefficients (r) between MUN and FP ($r_{MU,FP}$), MUN and PP ($r_{MU,PP}$), MUN and LP ($r_{MU,LP}$), MUN and total milksolids ($r_{MU,MSP}$), and MUN and SCS ($r_{MU,SCS}$) were obtained for each day of milk supply using the CORR procedure of SAS (SAS, 2011). An output file with the size and significance of the corresponding correlation coefficients was obtained and used along with the days after the farm's first milk pick-up in the season, to generate scatter plots for each variable paired up with MUN.

Results and discussion

Descriptive statistics for the variables analysed are presented in Table 1. Average values for the milk composition variables were 5.2%, 3.8%, 4.8%, and 14.4% for the percentages of fat, protein, lactose and total milksolids, respectively. The average concentration of MUN was 16.3 mg/dL and ranged from a minimum of 6.1 mg/dL to a maximum of 27.5 mg/dL of bulk milk. The average SCC was just over 240,000, with a range of 32,000 to just over one million. The corresponding values for the SCS were an average of 7.8 units and a range of 5 units to 10 units.

The concentration of MUN in the days following the farm's first milk pick-up showed an overall slight linear increase toward the end of the season, as described by the first degree Legendre polynomial that best fitted the data with the majority of the data points

Figure 1 Scatter plots, overall fixed regression (solid thicker line) and individual random farm regressions (broken lines) predicted by fitting a Legendre polynomial of first (a), second (b, c, d) or third (e, f) degree to the composition of bulk milk samples collected from 28 New Zealand seasonal dairy farms supplying milk to Open Country Dairy Ltd for the manufacturing of cheese and milk powder. Parallel black solid lines in (a) are the recommended upper and lower limits of milk urea nitrogen for dairy cattle.



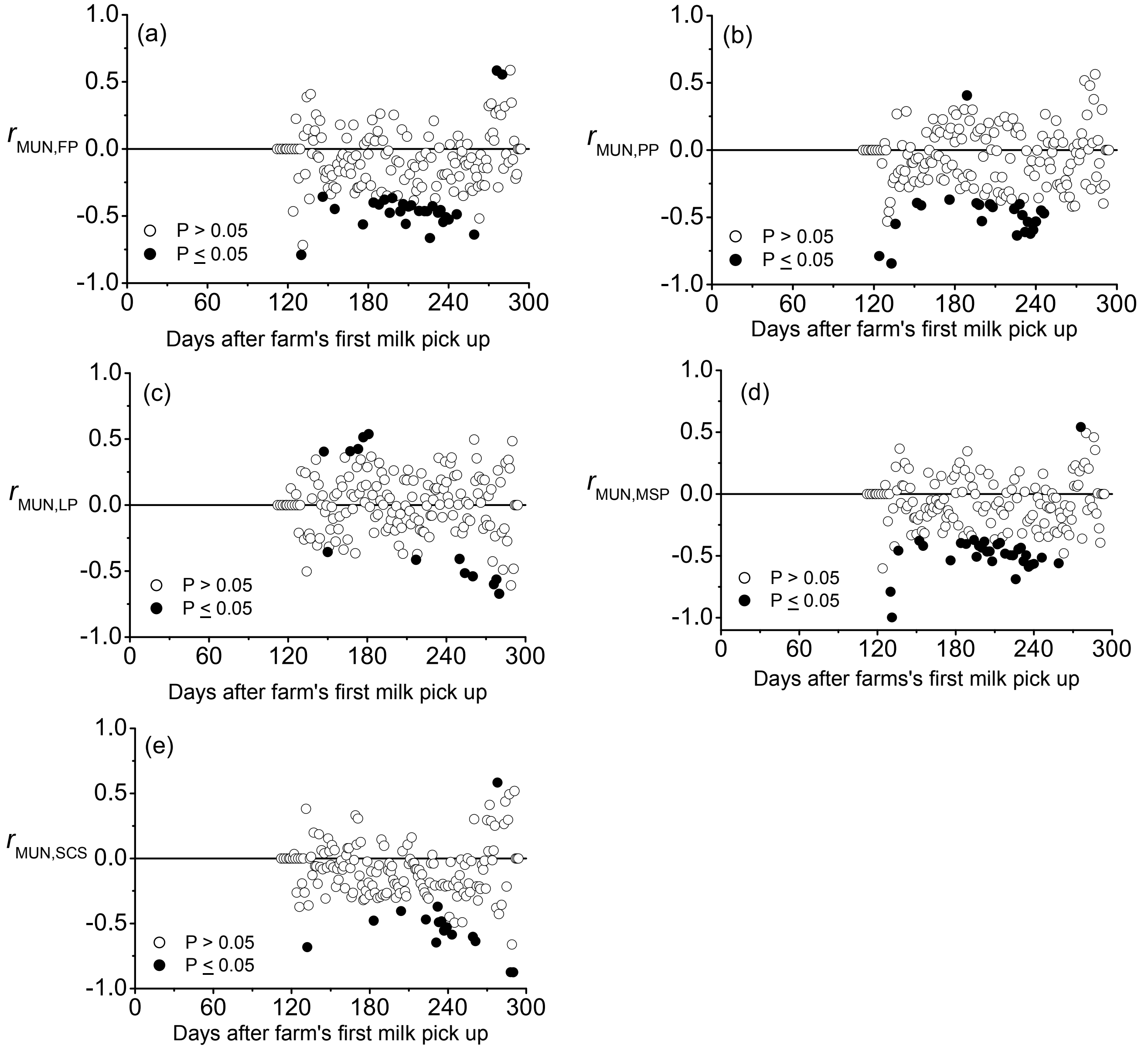
falling outside the interval of 10 mg/dL to 16 mg.dL as represented by the horizontal parallel lines in Figure 1. The scatter plots and respective predicted overall fixed and random farm regression lines for FP, PP, LP, MSP and SCS are also presented in Figure 1. A second degree Legendre polynomial provided the best fit for FP, PP, and MSP, whereas for LP and SCS a third degree Legendre polynomial was required to obtain the best fit (Figure 1).

The patterns of the spatial-time correlation between MUN and FP, PP, MSP, LP and SCS are shown in Figure 2. The estimated correlation coefficients between MUN with FP, PP, MSP, SCS, and their significance levels followed a similar pattern across the days of milk collection. In the interval from Day 130 to about Day 250 of the milk collection period the presence of significant negative association between MUN and the variables referred to above was noticeable. A similar pattern, but with a lower presence of significant negative correlation coefficients was found for LP, in the interval from Day 150 to Day 280 of the milking season (Figure 2).

Discussion

The concentration of components in the milk from the 28 farms provided information that is typical of New Zealand milk collected from seasonal supply

Figure 2 Scatter plots of the spatial-time correlation (r) between milk urea nitrogen (MUN, mg/dL of bulk milk) and the percentages of fat [(a) $r_{MUN,FP}$], protein [(b) $r_{MUN,PP}$], lactose [(c) $r_{MUN,LP}$], total milksolids [(d) $r_{MUN,TMSP}$], and somatic cell score [(e) $r_{MUN,SCS}$] by day of milk collection of 28 New Zealand seasonal dairy farms supplying milk to Open Country Dairy Ltd for the manufacture of cheese and milk powder.



dairy farms (Livestock Improvement Corporation 2012) or milk from New Zealand dairy cows in late lactation fed solely on grazed pasture (Totty et al. 2013). The slightly higher averages of 5.18% fat and 3.81% protein for the farms in the study, compared with the national averages of 4.73% fat and 3.75% protein, for the 2010-2011 season (Livestock Improvement Corporation 2012), might have been due to the cows on the study farms being in the second trimester of their lactation. No MUN was recorded during the first 93 days of the milking season.

A large variability for MUN was observed in the data analysed, with the majority of the data points falling outside the range of 10 to 16 mg of MUN/dL of milk, generally regarded as optimum (Jonker et al. 1999) for dairy cattle fed indoors with total-mixed-rations (Table 2). The average MUN of 16.3 mg/dL obtained for this study falls within the range of the response of both the TMR and the pasture fed experiments from Table 2. However, the higher values for the range of the response from 6.1 to 27.5 mg of MUN/dL of milk are more in line with the range of the response of the pasture fed experiments from Table 2. The range of CP from 14.3 to 19.1% for the diets used in the TMR experiments summarised in Table 2 (Baker et al. 1995; Burgos et al. 2007; Rius et al. 2010), covers the recommended theoretical optimum of 16.5 to 16.7 % of CP in the diet for maximum yield of milk and milk protein (Broderick 2003; Olmos Colmenero & Broderick 2006). In contrast, with the exception of the experiment of Taweel et al. (2005), all the experiments summarised in Table 2, in which the cows were fed mainly fresh pasture, the crude protein content of the feed on offer was considerably higher than the optimum CP% for the yield of milk and milk protein referred to above. The response in MUN for the TMR experiments, which ranged from 12.0 mg/dL of milk to 23.4 mg/dL of of milk, was less variable than that in the pasture fed experiments which ranged from 12.3 mg/dL of milk to 49.8 mg/dL of milk. Of the pasture fed experiments from Table 2, only those reported by Tas et al. (2006), Kolver and Aspin (2006), and Bryant et al. (2010) fell within the recommended MUN range of 10 to 16 mg/dL of milk.

The significant negative estimators of the correlation coefficient indicate that, for this range of days after the farms' first milk pick-up of the season, high values of MUN are associated with low values of FP, PP, MSP, and SCS. Studies of individual cow milk samples, have shown an inverse relationship between MUN and FP in both Holstein and Jersey cows (Johnson & Young 2003). Similar results for Holstein cows fed indoors with total mixed rations from several studies were reported by Broderick & Clayton (1997), Carlsson et al. (1995), and Fatehi et al. (2012).

According to some reports, MUN is negatively related to milk protein content (Trevaskis & Fulkerson 1999; Godden et al. 2001). Johnson & Young (2003) working with milk records from individual Holstein or Jersey cows found that as PP increased, MUN concentration decreased. Similar results were found by Fatehi et al. (2012) with Holstein cows fed indoors with a total mixed ration that had little variation in composition throughout the year. However, other reports have shown either no relationship between PP and MUN (Broderick & Clayton 1997) or a negative nonlinear association (Godden et al. 2001).

A negative association between MUN and SCS was also reported for Holstein or Jersey cows by Johnson & Young (2003). Godden et al. (2001) also reported a slightly negative relationship between MUN and somatic cell linear score, whereas Eicher et al. (1999) reported no association between SCC and MUN.

Bulk tank MUN can be used as a simple and non-invasive indicator of the protein status of the feed and the nitrogen utilization efficiency in lactating dairy cattle. Routine monitoring of bulk tank MUN may allow dairy farmers to adjust dietary protein levels to better match protein requirements of their cows and potentially increase profitability by reducing feed costs, while at the same time reducing the excretion of nitrogen to the environment (Burgos 2007).

The results of this study show there is a negative association between MUN and milk components, and the concentration of MUN in milk of New Zealand cows is high compared with that on milk of total-mixed-ration fed cows, due to the high crude protein content of the pasture consumed by dairy cows in New Zealand.

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