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Diurnal Variations in Milk Macro-Mineral Concentrations in Holstein Dairy Cows in Urmia, Iran

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A total of 1064 milk samples were collected from 40 high yielding and 36 moderate yielding cows during the morning and afternoon milking consecutively for seven days cows, to determine the diurnal variations in macro-mineral concentrations. Milk macro-mineral concentrations in the morning milking and in low producers were greater than in the afternoon and in high producers, respectively. The daily mean milk macro-minerals for Ca, IP, Mg, Na and K concentrations were 13.25, 10.76, 3.84, 76.2 and 17.1 mmol/l, respectively. The highest and lowest concentrations were observed in Na and Mg, respectively. Mean comparison of milk values (ANOVA) between low and high producers in the morning, afternoon and daily milking times were all significantly different (P<0.01). Significant and positive correlations were found among all macro-minerals except for Na and K, in which there was a significant negative correlation. The highest and lowest correlations were found between Ca & IP (r=0.37, P<0.01) and Na & IP (r=0.10, P<0.01), respectively. It is concluded that the milk macro-mineral concentrations varied according to milk production of cows and milking times. Thus, by balancing the macro-minerals in animals' diets, it may be possible to achieve the highest milk quality and quantity yield.

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KEYWORDS
Milk, cows, milking time, Holstein, macro-minerals.

INTRODUCTION

Cow milk contains 8 to 9 g/l macro and trace minerals (Gaucheron 2005). Over 80% of macro-minerals are soluble in milk serum, which are easy to measure, and other 20% are conjugated by milk casein and not considered as part of the macro-mineral values for laboratory evaluation. The concentration of Mg in milk is lower than other macro-minerals. Macro-minerals Ca and Mg present in milk play major role in bone growth and weight gain in young animals, casein denaturizing in abomasum, and the prevention of metabolic and nutritional disorders among both young and old animals (Bomba et al., 1993, Radostits et al., 2007).

The variation in macro-mineral concentration has been studied in blood serum (Hu and Kung 2009), the musculoskeletal system (Schaefer et al., 1990), CSF (Radostits et al., 2007) and urine (Michelini et al., 1999), but meager information is available on variation in macro-mineral concentration in milk. Gaucheron (2005) reported the probable partial correlations among milk macro-minerals. Bomba et al., (1993) observed that absorption of Ca from milk in gut and the occurrence of calf hypomagnesaemia is directly dependent on the amount of milk Mg. Gabris and Bajan (1983) reported correlations between milk Ca, K and Na only in high yielding cows.

The macro-mineral concentration in milk is influenced by many factors such as the amount of milk yield, milking times, breed, season, and diet.

Present trial was conducted with following objectives

- To understand the effects of milk volume and milking times on macro-minerals.
- To determine the variations in milk macro-minerals in morning and afternoon milking.
- To compare the diurnal variations of milk parameters in moderate and high producer cows.
- To present the relationships among milk macro-minerals in dairy cows.

MATERIALS AND METHODS

Seventy six lactating Holstein cows, including 36 moderate yielders (up to 20 kg/day) and 40 high yielders (up to 40 kg/day) were selected from the northwest of Iran. The average milk yield in the selected dairy herd was from 29 to 32 kg/day. The high producer cows were all in the first half of lactation and the majority of moderate producers were in the second half of lactation. Ten ml milk samples were collected from each cow during the morning and afternoon milking for seven consecutive days. 1064 milk samples thus collected were evaluated. Age, pregnancy, number of parity and daily milk yield were recorded for further studies. Cows were fed ad libitum diet containing Lucerne, pulp, concentrate and silage, four times per day. During the study mastitis and other clinical diseases were assessed and the cows were all found to be in good health.

Milk samples were first defatted by placing them in a cool area (4C°) and/or centrifugation at 3000g for 5 minutes. Milk casein was separated by 0.1 N HCl in pH 3.6. The remaining milk serum was used to determine the macro-mineral concentrations. Calcium, IP and Mg concentrations were measured using appropriate kits (Pars Azmon, IR) in an auto-analyzer (RA-1000, Pharmacia, LKB, Novaspec, USA). Milk Na and K concentrations were assessed by a flame photometer (Jenway, Clinical PFP7, UK) using standard Na and K (Ziest-Chimi, Iran).

Data were analyzed by SPSS13 statistical program and Mean±SEM were determined for milk parameters in the morning, afternoon, daily and overall milking yield. Student t-test and one way ANOVA were carried out to find out the differences in the parameters under study for each milking yield. Pearson correlation tests were used to evaluate the relationship among parameters in different milking yields.

RESULTS

Mean macro-mineral concentrations, (except for Na in high yielders) were greater in the morning than in the afternoon milking in both moderate as well as high producers (Table 1). Mean milk macro-mineral concentrations in the moderate yielders were greater than in the high producer cows. Mean daily macro-mineral concentrations were 13.25, 10.76, 3.84, 76.2 and 17.1, for calcium, phosphorus magnesium, sodium and potassium respectively (Table 1).

The diurnal comparison of mean macro-minerals (ANOVA) in the moderate and high producers in the morning, afternoon and daily milking yield revealed significant differences ($P<0.01$) among macro-minerals (Table 2). Significant differences ($P<0.01$) were also observed in individual investigation among macro-minerals in all groups and milking times.

There were significant positive correlations ($P<0.01$) between the macro-minerals in both groups except for milk Na and K, in which the relationship was negative. The strongest correlation ($r=0.37$, $P<0.01$) was observed between Ca and IP, while the weakest was between IP and Na ($r=0.10$, $P<0.01$).

DISCUSSION

Scientific husbandry practices have emphasized upon macro-mineral administration in animal diet during the growth phase, pregnancy and lactation periods. The level of Ca in milk has been recorded as high as 15 times that of blood (Guzman and Gongora, 1992). However, Ca concentration in milk varies monthly and seasonally (Kubarsepp et al., 2002 and Ramin et al., 2007).

In this study the mean daily milk Ca and IP were 6 and 8 fold that of blood respectively, which was less than (22 and 17 folds that of blood) recorded earlier by Ramin et al., (2007) and Guzman and Gongora (1992). The concentrations of milk minerals are not stable and vary depending on nutrition (Frank and Swensson, 2002), breed (Van Hulzen et al., 2009), lactation period, milk protein, urea and milk yield (Wu et al., 2001 and, Closa et al., 2003). Gabris and Bajan (1983) reported higher concentration of Milk Ca in high producers than in moderate ones; these observations were contradictory to our findings

Milk Na and K concentrations in present study were recorded to be 76.2 and 17.1 mmol/l respectively. These values were not in agreement with those recorded by Ramin et al., (2005, 2007). The variations recorded for these minerals between the morning and afternoon milking were not significant. In this study the concentration of Na in milk was higher than K. There is no reports to show the side effects of low milk K or low absorption from the gut, but milk K and salts increase following mastitis (Ragheb et al., 1998), while milk Na decreases in cows estrus.

Milk Mg in this study was 3.84 mmol/l and it was lower than the values reported by Guzman & Gongora (1992) and Ramin et al. (2005). During the present study Milk Mg concentration in the morning milking and moderate yielders was higher than that the afternoon milking and high yielders. The reason could be related to the resting time between the two milkings', and the high milk solids in moderate yielders in comparison with high yielders. Similar findings were reported by Gabris and Bajan (1983) in low and high producer cows. Low milk Mg was reported following high milk yield (Gabris & Bajan, 1983), heat stress and season (Kume, 1992), mastitis (Ragheb et al., 1998) and bovine viral leukemia (Madej et al., 1994), Milk with high Mg augurs high quality of milk, increased milk Ca absorption in gut, and the prevention of calf milk tetany (Bomba et al.,1993).

Mean milk macro-minerals in the morning, afternoon and daily milking (Table 2) were significantly different and observations were in agreement with reports of Gabris and Bajan (1983). The reason for the differences between milking times could be related to the variations in the amounts of feed consumption between cows and milk volume as well. These variations involve all macro-minerals including Ca, IP, Mg, Na and K (Kubarsepp et al., 2002), but the importance of Ca and Mg is more apparent than other minerals.

The presence of significant positive correlations between milk macro-minerals in the morning, afternoon and daily milk yield indicates their appropriate balances in milk production among healthy animals. The strong relationships between Ca/IP (r=0.88), Ca/Mg (r=0.88) and Na/K (r=0.88) reported in this study indicate that the proportion of these minerals in the diet could be vital for milk yield. Gabris and Bajan (1983) studied the correlations between Ca, Na and K only in high producer cows.

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Table 1: Comparison of mean ± SE of the milk micro-mineral concentrations (mmol/l) in the morning (n=495), afternoon (n=512) and daily milk (n=1007) in the moderate and high producer cows.

Parameters	**Calcium**	**Phosphorus**	**Magnesium**	**Sodium**	**Potassium**
Moderate producers (morning milking)	13.49±0.15 a	11.21±0.22 a	3.99±0.06 a	77.1±2.34 a	17.28±0.33 a
High producers (morning milking)	13.37±0.17 a	11.27±0.23 a	3.81±0.06 a	67.8±2.11 c	17.16±0.36 ac
Moderate producers (afternoon milking)	13.43±0.15a	9.91±0.21 b	3.88±0.06 a	87.9±2.55 b	16.98±0.33 ac
High producers (afternoon milking)	12.79±0.15 b	10.27±0.19 b	2.64±0.05 b	72.3±2.28 a	16.77±0.3 bc
Morning milking yield	13.43±0.11 a	11.24±0.16 a	3.9±0.05ac	72.6±1.53 ac	17.04±0.24 ab
Afternoon milking yield	13.07±0.11 ab	10.12±0.14 b	3.74±0.04 a	72.3±1.92 ac	17.01±0.21 ab
Daily milking yield	13.25±0.08 a	10.67±0.1 a	3.84±0.04 a	76.2±1.17 a	17.07±0.15 ab

Different letters in each column were significant different (P<0.05)

Table 2: Mean diurnal comparison (ANOVA) of milk macro-minerals in the moderate and high producer cows in the morning, afternoon and dairy milk yields.

Parameters	Calcium		Phosphorus		Magnesium		Sodium		Potassium	
	df	F	df	F	df	F	df	F	df	F
Moderate producers (morning milking)	6 (234)	17.6**	6 (236)	16.8**	6 (239)	10.6**	6(233)	3.6**	6(239)	7.2**
Moderate producers (afternoon milking)	6 (234)	17.9**	6 (236)	13.8**	6 (239)	17.6**	6(234)	70**	6(234)	11.1**
High producers (morning milking)	6 (249)	30.3**	6(49)	36.9**	6 (239)	31.2**	6(239)	10.6**	6(216)	11.0**
High producers (afternoon milking)	6 (264)	14.1**	6 (262)	25.5**	6 (254)	11.3**	6(252)	5.1**	6(264)	9.5**
Morning milking yield	6 (484)	31.1**	6 (485)	52.7**	6 (502)	39.1**	6(489)	6.1**	6(491)	22.4**
Afternoon milking yield	6 (502)	30.0**	6 (502)	64.8**	6 (494)	25.5**	6(502)	47.4**	507)	14.2**
Daily milking yield	6 (988)	55.7**	6 (988)	104.3**	6 (1003)	42.7**	6(985)	13.9**	6(990)	16.8**
Overall	13 (988)	55.7**	13 (988)	60.9**	13 (1003)	29.8**	13(985)	7.8**	13(990)	32.3**

***=P<0.01*

Table 3: Correlations among milk macro-minerals concentrations in the morning, afternoon and daily milking in cows.

Parameters	**Phosphorus**		**Magnesium**		**Sodium**		**Potassium**	
	df	r	df	r	df	r	df	r
Afternoon milking								
Ca	502	0.68**	503	0.53**	476	0.19**	480	0.21**
IP			503	0.45**	475	0.14**	480	0.22**
Mg					484	0.20**	489	0.11*
K							501	0.17**
Morning milking								
Ca	452	0.45**	459	0.30**	447	0.05	449	0.24**
IP			462	0.44**	452	0.12*	454	0.23**
Mg					482	0.25**	481	0.43*
K							489	-0.19**
Daily milking								
Ca	928	0.37**	942	0.24**	925	0.11**	929	0.26**
IP			942	0.30**	924	0.10**	928	0.26**
Mg					980	0.21**	983	0.32*
K							990	-0.33**

***=P<0.01 ، *=P<0.05*