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THE FREEZING POINT OF BULK TANK MILK IN SLOVENIA [1]

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ABSTRACT

The purpose of this paper was to determine effects on freezing point of milk in bulk tank. The analysis included 90,579 milk bulk samples from Štajerska region between 2008 and 2013. The statistical model included milk purchaser, herd size, breed, interaction between pipeline material and milking system, calving interval, culling rate, milk cooling system, season, fat/protein ratio, production intensity and protein, lactose, and urea content as fixed effects. All effects significantly affected freezing point of bulk tank milk. The statistical model explained 32 % of the variance. The average value of freezing point was −0.5209 °C. The permissible value of −0,515 was exceeded by 5.7 % of the samples. In summer an increased freezing point and lower protein content was recorded. The estimated regression coefficient for protein was 0.0069 °C/%.

Key words: cattle, dairy cows, milk, freezing point, protein content, season effect

1 INTRODUCTION

The freezing point of milk is the temperature where milk changes from liquid to solid. It is rather constant and the freezing point of bulk tank milk is therefore used to determine whether water has been added. Milk has a lower freezing point than water and ranges from 0.520 °C to 0.560 °C. Higher freezing point of milk often demonstrate the falsification of milk with water. For example, 1 % of additional water increases the milk freezing point app. for 0.005 °C (Bajt *et al.*, 1998).

Nevertheless, higher freezing points can also occur on farms where no water was added, due to cow related factors like breed, stage of lactation, health (mastitis), due to environment like climate, seasonal as well as weather changes, and technological solutions as feeding regime, water intake, milking system, storage time, and milk temperature (Buchberger and Graml, 1988; Mitchell, 1989; Kirst *et al.*, 2000; Golc-Teger *et al.*, 2005; Henno *et al.*, 2008; Hanuš *et al.*, 2010; Hanuš *et al.*, 2011).

Several studies (Rohm *et al.*, 1991; Wiedemann *et al.*, 1993a; Elchner *et al.*, 1997; Golc-Teger *et al.*, 2005; Henno *et al.*, 2008; Sala *et al.*, 2010) reported more problems with freezing point in early summer caused by changes in temperature, increase in water intake, and transition from winter diet on fresh green fodder and grazing. Rohm *et al.* (1991) found that milk freezing point during winter was on average of 0.0008 °C lower than during summer. Furthermore, the freezing point can also depends on milk composition. Sala *et al.* (2010) presented that a decrease of protein for 0.1 % cause an increase of freezing point for 0.002 °C in cows aged up to six years.

Moreover, Hanuš *et al.* (2011) supported that milk freezing point was improved with higher protein content. Babnik *et al.* (2010) studied relationship between fat and

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protein ratio (F/P) and milk freezing point. Milk with F/P ratio below 1.1, reflecting a poor structured diet, has significantly higher freezing point while with F/B ratio above 1.5 has lower freezing point. Knowing effects on milk freezing point, farmers can avoid problems in delivering quality milk in terms of suitable freezing point (Babnik and Verbič, 2006; Buchberger, 2000).

Main goal of the research was to determine the most important effects on the freezing point of bulk tank milk on dairy farms in Štajerska region of Slovenia.

2 MATERIALS AND METHODS

Data on bulk milk samples from Štajerska region was obtained from the records of the quality control of milk delivered to the Dairies Celeia and Ljubljanske mlekarne between 2008 and 2013, and from Cattle Business Association (GPZ z.o.o.). Information about herd size, breed, calving interval, and culling rate were provided by Central cattle breeding database on the base of milk recording data. Information on the farming system were obtained from questionnaires filled out by respondents farmers. All together, 90,579 records from 608 farms were used in statistical analysis.

The statistical model includes milk purchaser (O_i), herd size (V_j), breed (B_k), interaction between pipeline material and milking system (CM_{lm}), calving interval (D_n), culling rate (Z_o), milk cooling system (H_p), season as year-month interaction (S_r), F/P ratio (R_s), milk production intensity (I_t), and protein ($x_{1ijklmnoprst}$), lactose ($x_{2ijklmnoprst}$), urea ($x_{3ijklmnoprst}$) content as fixed effects. Fat content and somatic cell count were not significant and therefore were not included in the model.

$$\begin{aligned} y_{ijklmnoprst} = \mu + O_i + V_j + B_k + CM_{lm} + D_n + Z_o + H_p + S_r \\ + R_s + I_t + b_1(x_{1ijklmnoprst} - \overline{x}_1) + b_{2i}(x_{2ijklmnoprst} - \overline{x}_2) \\ + b_3(x_{3ijklmnoprst} - \overline{x}_3) + e_{ijklmnoprst} \end{aligned}$$

Data were analyzed by GLM procedure with statistical package SAS® software (SAS Inst., Inc., 2011).

3 RESULTS AND DISCUSSION

Average freezing point of bulk tank milk was −0.5209 °C (Fig. 1) with standard deviation of 0.0046 °C and very close to reference value of −0.520 °C shown as solid line on Figure 1. Tolerance for freezing point of milk is set at −0.515 °C (dashed line). Whenever the freezing point is higher, milk price is reduced. In the present study, the freezing point exceeded tolerance value in 5.7 % of cases, 28.8 % of the samples were found between the reference value of 0.520 °C and a tolerance value of −0.515 °C. Two third (65.5 %) of milk samples could be considered as normal. The sharp drop in frequency at tolerance value of −0.515 °C can be a consequence of removed low quality milk in order to keep higher prices.

The statistical model used in this research, explained 32 % of total variance and all effects included in the model showed significant influence on freezing point.

Seasonal trends of protein content and freezing points of milk for all included years are presented in Figure 2. In summertime, freezing point increased and exceeded the average value of −0.5209 °C from May to October in almost all years. The highest average freezing point was found in July (0.5197 °C). The opposite trends were observed between freezing point and protein content. Protein content was low during summer and both results were related to environment temperature, feed and water intake as well as feed quality. Higher milk freezing point values during summer was also reported from Austria (Rohm *et al.*, 1991), previous researches from Slovenia (Golc-Teger *et al.*, 2005), Romania (Sala *et al.*, 2010), and Estonia (Henno *et al.*, 2008).

The highest freezing point of milk (Table 1) were

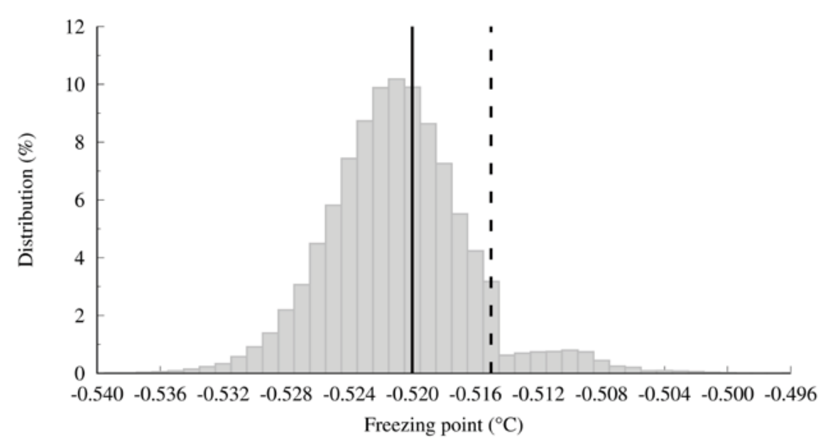

Figure 1: *Distribution of milk freezing point*

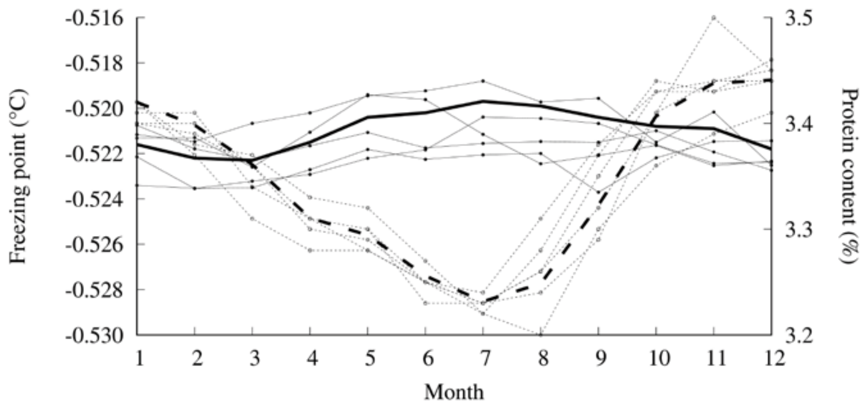

Figure 2: *Least square means for freezing points (solid lines) and averages for protein contents (dotted lines) of bulk milk samples by years*

observed by the purchaser 1 (−0.5199 °C). In smaller (1.0 to 15.9 cows) and larger herds (>26 cows), there is a slightly higher freezing point of milk (0.5212 °C). Also Wiedmann *et al.* (1993a, 1993b) indicate that the freezing point of milk in herds with 10 or fewer cows was higher (−0.511 °C).

It was found in our study that herds, with more than 70 % of Holstein Friesians cows, had the lowest freezing point which is just the opposite to other studies (Babnik *et al.*, 2010; Buchberger, 1986; Henno *et al.*, 2008). Possible explanation of this discrepancy in results might be in statistical model we used for analysing the influence of different parameters on freezing point, as milk components were include in the model. Herds with Holstein Friesians cows had lower freezing point of milk then other breeds probably as consequence of better feeding regime. Milk freezing point was the same in herds with Brown and Simmental cows, where herds were much smaller and cows were fed with less balanced feeding ratios. The worst results were obtained in mixed herds (with different breeds) where feed ratio for dairy cows were not well enough.

The milking system might cause deviation in milk freezing points (Table 1). Lower milk freezing point was obtained on farms with bucket milking systems. Milk from farms with pipeline milking system had better freezing point than milk obtained from farms with milking parlor. Higher freezing point of bulk milk was found in farms with milking robot. Kirst *et al.* (2000) explained that milk freezing point was gradually increasing when hand milking was replaced by milking machine, due to residual water in the equipment and pipelines. Rasmussen *et al.* (2002) and De Koning *et al.* (2003) agreed that the milk freezing point was increased by introduction of robot milking.

Health status of milking animals has a significant impact on the quality of milk. Sick animal can reduce feed intake which consequently affects the composition of milk and freezing point of milk (Babnik and Verbič, 2006). In our analysis herds which replaced more than

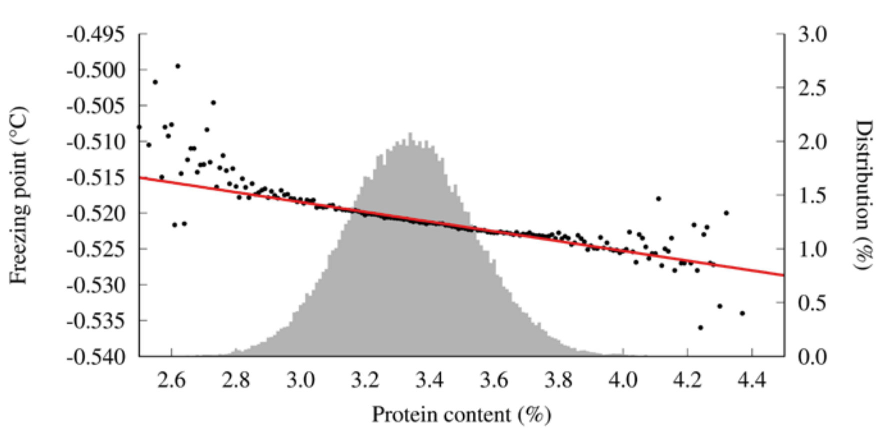

Figure 3: *A share of observations for milk protein content and the relation between the protein content and milk freezing point*

Table 1: *Least square means (LSM) and regression coefficient for freezing points with standard errors of estimates (SEE) for studied effects (except seasonal effect)*

Effects	Level	LSM	SEE
Milk purchaser	1	−0.5199	0.00006
	2	−0.5213	0.00009
	3	−0.5227	0.00007
Herd size	1–15.9	−0.5212	0.000066
	16–25.9	−0.5215	0.000068
	more 26	−0.5212	0.000069
Breed	Brown	−0.5213	0.000082
	Simmental	−0.5213	0.000081
	Holstein Friesian	−0.5216	0.000077
	Mixed herds	−0.5210	0.000077
Season	68 classes		
Interaction between pipeline material and milking system	1	−0.5223	0.000337
	2	−0.5224	0.000065
	3	−0.5208	0.000117
	4	−0.5215	0.000062
	5	−0.5204	0.000070
	6	−0.5225	0.000066
	7	−0.5216	0.000088
	8	−0.5212	0.000127
Calving interval (days)	340–400	−0.5213	0.000068
	401–420	−0.5215	0.000067
	421–440	−0.5216	0.000069
	441–460	−0.5210	0.000069
	< 461	−0.5211	0.000071
Culling rate	< 30 %	−0.5212	0.000070
	> 30 %	−0.5214	0.000062
Milk cooling system	Bulk tank	−0.5210	0.000066
	Tank	−0.5215	0.000062
	Other	−0.5215	0.000095
Fat/protein ratio	< 1.5	−0.5216	0.000130
	1.1–1.5	−0.5215	0.000048
	> 1.1	−0.5208	0.000093
Production intensity	Top 25 % herds	−0.5211	0.000067
	25 % good herds	−0.5217	0.000069
	25 % lower average	−0.5214	0.000068
	Bottom 25 % herds	−0.5210	0.000068
		Regression coefficient	SEE
Protein content		−0.0069	0.00009
Lactose content	Milk purchaser 1	−0.0122	0.00015
	Milk purchaser 2	−0.0196	0.00074
	Milk purchaser 3	−0.0150	0.00037
Urea content		−0.0002	0.00000

30 % of the animals had higher freezing point of milk (0.5212 °C).

We found higher freezing point values in milk of top 25 % and 25 % of the worst herds regarding milk yield. Slaghuis (2001) reported that a higher milk yield may contribute to increase freezing point of the milk. On the other hand, Wiedman *et al.* (1993b) reported that freezing point of milk more often increased in small herds with low milk yield per cow.

Protein content in bulk milk was on average 3.34 ± 0.20 % (Fig. 3) with most observations between 2.8 and 3.9 %. Results indicate that the freezing point decreases for 0.00069 °C (Fig. 3), when protein content increases by 0.1 %. The estimated regression coefficient of −0.00086 °C per 0.1 %, calculated by the Babnik *et al.* (2010) is in accordance with our results. By increasing the protein content of milk decreases milk freezing point, as expected. Buchberger (2000) indicated that reduction of protein content for 0.1 % leads to an increase of freezing point for 0.002 °C.

4 CONCLUSIONS

All fixed effects in the statistical model had significant effect on milk freezing point. In summer, milk freezing point was higher. The opposite trends were observed between freezing point and protein content. Protein content was low during summer. When protein content increased for 0.1 % the freezing point decreased for 0.00069 °C. For a more detailed analysis of the factors affecting the freezing point of milk, we would need data of individual cows.

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