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THE EFFECT OF OUTSIDE AIR TEMPERATURE ON TRANSPORTATION TEMPERATURES AND PROCESSING QUALITY OF COW'S MILK

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Abstract

The objective of this study was to assess the effect of outside air temperature on the transportation temperature and processing quality of cow's milk. The data used in the analyses (208 bulk samples) were collected on four farms over a period of 52 consecutive weeks. The samples were grouped into four outside air temperature-based groups, namely: below 1.0 °C; from 1.1 to 8.0 °C; from 8.1 to 15.0 °C; above 15.1 °C. Mean values of the observed characteristics were as follows: average outside air temperature 7.40 °C, milk temperature on dairy farms 5.19 °C (at collection) and milk temperature on arrival at the dairy factory 5.60 °C. The average duration of transport was 211 minutes, milk volume in the tanker 12,885 l, fat content 4.13 %, protein content 3.40 %, lactose content 4.89 %, casein content 2.97 %, titratable acidity 6.31 SH, active acidity 6.75 (pH), rennet coagulation time (RCT) 201 sec., curd class 1.11 (on five-point scale) and 1.49 (on ten-point scale). Increasing outside air temperature was closely correlated ($p < 0.01$) with an increase in milk temperature at the dairy factory (at delivery). A significant ($p < 0.01$) increased difference between the temperatures on the farm (at collection) and at delivery in the dairy factory was also recorded. The titratable acidity decreased and so did the curd class on the ten-point scale. Milk temperature on the farm (at point of entering transportation tank) also increased significantly ($p < 0.01$) with outside air temperature. Other differences were not significant ($p > 0.05$). Findings of this study suggest that outside air temperature influences the properties and processing quality of the transported milk, even though the temperature differences of the milk itself ranged within the acceptable limits. It therefore stands to reason that, when the temperature of milk on load is close to the recommended temperature limits it can exceed this limit during transportation to the dairy factory and cause significant damage to the processing quality of the transported milk.

Keywords: milk composition, processing quality, outside air temperature, milk transportation

INTRODUCTION

Milk processing quality is determined by a number of factors including the fat content, protein content (both crude and true), casein content, lactose content, non-fat solids content, somatic cell count and processing quality, such as titratable acidity, active acidity, alcohol stability, fermentation ability of milk, rennet coagulation time (RCT) and the volume of whey separated in the process of rennet coagulation (Hanuš *et al.*, 2007, 2010; Janů *et al.*, 2007). Also, composition of casein is important for proper coagulation of milk (Bonfatti *et al.*, 2013). Processing quality is already established in fresh raw milk and is determined by the cow's individual characteristics, genotype or breed (Bayram *et al.*, 2009; Matějíček *et al.*, 2008). They can also be affected by parity and stage of lactation (Summer *et al.*, 2003). The feed ration is also an important factor since it can influence protein content and consequently solids non-fat content (Davis and White, 1958). A study by Cimen *et al.*, (2010) suggested seasonal variations of biochemical characteristics of milk. The processing quality of milk is also influenced by the cow's health condition and heat stress (Hanuš *et al.*, 2008; Varlyakov *et al.*, 2012). Other factors like somatic cell count could also be affected by season (Pašić *et al.*, 2016).

The RCT is significantly ($p < 0.01$) associated with the processing quality of milk and influences the process of cheese making, cheese yield and cheese quality (Johnson *et al.*, 2001). RCT is therefore an essential aspect of the cheese making process (Cassandro *et al.*, 2008). It is generally known, that reducing the pH of milk from 6.7 to 5.8 leads to shorter RCT and that lower casein content also reduces RCT (Daviau *et al.*, 2000). Jõudu *et al.* (2008) reported that an increase in milk protein, casein, casein fractions, and casein number resulted in reduced RCT of milk. Nájera *et al.* (2003) found that increasing temperature reduced RCT while increasing active acidity prolonged it.

Milk temperature plays an important role in milk processing (Riddell-Lawrence and Hicks, 1989; Tyrisevä *et al.*, 2004). Usually, in state norms of EU states, there is recommended that milk should be kept within the temperature limits between 4 and 6 °C. Higher temperatures are generally known to have a negative impact on milk quality, but detrimental effects have also been recorded at temperatures below the generally accepted limits (Legraët and Brulé, 1993; Kirin, 2001). Both dairy farms and dairy factories keep milk in cooling tanks equipped with efficient cooling devices to keep the milk temperature within the limits. However, milk processing can be jeopardised during transportation from the dairy farm to the dairy factory. The tankers transporting milk do not usually have an active cooling system, but only insulation. This could have serious consequences, especially in summer, because milk may be transported over long distances and subject to drastic changes in temperature – often outside the recommended limits. Therefore, it is necessary to determine the effect of outside air temperature on milk temperature and consequently on the processing quality of the transported milk.

MATERIALS AND METHODS

A total number of 208 bulk milk samples were collected on four dairy farms over a period of 52 consecutive weeks (during the season 7/2012–7/2013), representing a mix of the evening and morning milkings. The samples were collected once a week on the same day at all dairy farms. They were analysed at the collection point on the dairy farm and then again immediately after delivery at the dairy factory.

The following milk characteristics and processing qualities were recorded:

- Milk composition – fat (F; %), crude protein (P; %), lactose (L; lactose monohydrate; %) and casein (C; %) were recorded using Lactoscope FTIR Advanced after its regular calibration according to relevant reference method results.
- Milk volume in the tanker – measured when collected by the tanker on the sampling day.
- Rennet coagulation time (RCT) was determined by a turbi-dimetric detector of milk coagulation described by Chládek *et al.*, 2011.
- Active acidity (pH) – measured by a pH-meter WTW 197i.
- Titratable acidity (SH) – measured in a 100 ml milk sample using an alkaline solution (0.25mol.l-1NaOH) up to a light pink colour of the sample.
- Air temperature – the average outside air temperature values were provided by the Czech Hydro-meteorological Institute, and were measured at the weather station in Pribyslav (CZ). The samples were allotted into four temperature-based categories: to 1.0 °C; from 1.1 to 8.0 °C; from 8.1 to 15.0 °C; above 15.1 °C. The data were tested using the analysis of variance method with the outside air temperature as independent factor and the sampling week as replication.
- Milk temperature and the duration of transportation – using the system MAK 3002 implemented in tankers. It was automatically measured during the tank filling on the farm and delivery of milk in dairy.
- Curd quality – was evaluated when the curd had set by assessing visual aspects of the curd and whey. The classification scale distinguished either 5 classes (class 1 = the best – firm curd, pure whey; class 5 = the worst – no solid structure) or 10 classes (1 = the best, 10 = the worst) (methods according Gajdůšek, 1997).

RESULTS AND DISCUSSION

Milk temperature, milk volume and duration of transportation within the observed outside air temperature range are described in Tab. I. The number of samples in each temperature based class varied between 44 and 56. The average outside air temperature ranged from −3.48 °C to 18.07 °C. The milk temperature at dairy farms ranged between 4.98 °C and 5.57 °C. Interclass comparisons suggested that the intra-class variation in milk temperature difference between the dairy farm and the factory is most significant ($p < 0.01$) below 1 °C.

Irrespective of the outside air temperature, the average difference in milk temperature at collection on the dairy farm during the observation period never exceeded 0.59 °C. The milk temperature on arrival at the dairy factory ranged between 5.14 °C and 6.14 °C. This fell well within the recommended limits of 4–6 °C. Interclass comparisons in the variations of milk delivery temperatures at the dairy factory are indicated in Tab. I. The recommended limit was slightly exceeded (by 0.14 °C) only in the class with the highest average outside air temperature (above 15.1 °C). In the class with outside air temperatures below 1 °C the difference was only 0.07 °C, but in the group with outside air temperatures above 15.1 °C it was 0.57 °C. The value 0.07 °C was significantly ($p < 0.01$) lower than all other values. The duration of transport and volume of milk in the tanker did not vary significantly and stayed within the interval between 210 to 212 minutes traveling time, while milk volumes ranged between 12,599 kg to 13,172 kg.

Milk composition at the observed outside air temperatures is presented in Tab. II. The average fat content was greatest (4.13 %) in the class with outside air temperatures below 1 °C (4.27 %) and lowest in the group with temperatures above 15.1 °C (4.03 %). Chládek *et al.* (2011) recorded comparable results – an average fat content 3.81 % (ranging from 3.69 to 3.89 %) associated with seasonal changes. Polák *et al.* (2011) recorded fat contents in cow's milk between 3.67 % and 4.41 % with the average 4.11 %.

The average protein content (3.40 %) copied the trend of the fat content and decreased with the growing outside air temperature from 3.47 % (the class with outside air temperatures below 1 °C) to 3.28 % (the class with outside air temperatures above 15.1 °C). This corresponds with findings recorded by Čejna *et al.* (2006) or Kuczaj (2001). The average lactose content (4.89 %) was growing with the increasing outside air temperature from 4.84 % (in the group with outside air temperature below 1 °C) to 4.94 % (outside air temperatures above 15.1 °C). A similar trend was recorded by Polák *et al.* (2011) with average lactose content 4.80 %, the minimum 4.62 % and the maximum 4.95 %. The casein content was almost constant, the changes were only minor (not significant).

Milk processing quality at the observed outside air temperature classes is described in Tab. III. The average titratable acidity was 6.31 SH with the maximum of 6.39 SH in the group with outside air temperature below 1 °C and the minimum of 6.26 SH at temperatures above 15.1 °C. Slightly higher values of titratable acidity were recorded

I: *Milk temperature, volume and duration of transport within the observed outside air temperature range*

Characteristics	Mean n = 208	Units	Outside air temperature-based classes			
			Below 1 °C	1.1 to 8 °C	8.1to 15 °C	Above 15.1 °C
			n = 52	n = 56	n = 56	n = 44
Average outside air temperature	7.40	[°C]	–3.48A	4.47B	12.06C	18.07D
Milk temperature – dairy farms	5.19	[°C]	5.07a	4.98a	5.23ab	5.57b
Milk temperature – dairy factory	5.60	[°C]	5.14A	5.38AB	5.83BC	6.14C
Temperature difference between farm and factory	0.41	[°C]	0.07A	0.41B	0.60B	0.57B
Duration of transport	211	Minutes	210	212	212	210
Milk volume in tanker	12,885	[kg]	12,599	12,782	13,027	13,172

Values in the same line marked with different symbols (a to d, or A to D, respectively) are different ($P < 0.05$ or $P < 0.01$, respectively)

II: *Milk composition within the observed outside air temperature classes*

Characteristic	Air temperature-based classes					
	Mean n = 208	Unit	Below 1 °C n = 52	1 to 8 °C n = 56	8 to 15 °C n = 56	Above 15 °C n = 44
Fat	4.13	%	4.27A	4.15B	4.07C	4.03C
Protein	3.40	%	3.47A	3.47A	3.35B	3.28C
Lactose	4.89	%	4.84A	4.88AB	4.90BC	4.94C
Casein	2.97	%	2.97	2.96	2.96	2.99

Values in the same line marked with different symbols (a to d, or A to D, respectively) are different ($P < 0.05$ or $P < 0.01$, respectively).

by Chládek *et al.* (2011) and Polák *et al.* (2011) – on average 7.16 SH, minimum 6.42 SH and maximum 7.64 SH. The greatest difference (0.09 SH) was found between the groups with temperatures below 1 °C and 1.1 to 8 °C. Falta *et al.* (2014) reported an almost identical difference (0.16 SH) which was insignificant in their study.

RCT was shortest in the group with temperatures above 15.1 °C (194 s) and longest (209 s) in the group with temperatures between 1.1 and 8 °C. Variability (16.25 %) was comparable to the values reported by Polák *et al.* (2011) or Čejna, (2008). The average RCT was 201s. Somewhat greater values were reported by Falta *et al.* (2014), and that was 244.3s during the season with the highest outside air temperatures.

Active acidity values remained constant throughout the observation (in average 6.75 pH).

Considering our previous experience with the visual evaluation of curd we extended the original 5-point system to a 10-point system in order to refine the evaluation and describe minute differences in curd quality. Although the quality of curd was best on both the 5-point and 10-points scale in classes with the highest temperatures (8.1 to 15 °C and above 15.1 °C), findings suggest no significant interclass relationships at various intra-class scale differences.

III: *Processing quality of milk within the observed outside air temperature classes range*

Property	Mean n = 208	Unit	Outside air temperature classes			
			Below 1 °C	1 to 8 °C	8 to 15 °C	Above 15 °C
			n = 52	n = 56	n = 56	n = 44
Titratable acidity	6.31	SH	6.39A	6.30B	6.27B	6.26B
Active acidity	6.75	pH	6.75	6.75	6.76	6.75
RCT	201	Sec.	202	209	199	194
Curd class (5)	1.11	1 to 5	1.12	1.20	1.05	1.05
Curd class (10)	1.49	1 to 10	1.52AB	1.77B	1.25A	1.41A

Values in the same line marked with different symbols (a to d, or A to D, respectively) are different (P < 0.05 or P < 0.01, respectively).

CONCLUSIONS

This study analysed the impact of outside air temperature during transport on the processing characteristics of milk and milk composition

In this study the analysis of data on 208 bulk samples of cow's milk suggest that the temperature of transported milk (on farm, at dairy and difference between them) increased with increasing outside air temperature.

In contrast the milk protein and fat content were decreasing with increasing outside air temperature. On the contrary, lactose content significantly increased and, the quality of curd and RCT was also better at higher temperatures. Our results further suggest that outside air temperature during transportation significantly influences the processing quality of the transported milk although the changes in the temperature of milk itself remains within the recommended limits (4-6 °C). It therefore stands to reason, that when the temperature of milk on load is close to the recommended temperature limit it can exceed this limit during transportation to the dairy factory.

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