Bulgarian Journal of Agricultural Science, 20 (No 1) 2014, 215-219
Agricultural Academy

THE EFFECT OF AIR TEMPERATURE AND BREED ON BOVINE MILK COMPOSITION AND ITS PROCESSING QUALITY

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Abstract

FALTA, D., M. ADAMSKI, V. CEJNA, O. HANUS, F. LATEGAN, R. KUPCZYNSKI, G. CHLADEK, R. FILIPCIK and L. MACHAL, 2014. The effect of air temperature and breed on bovine milk composition and its processing quality. *Bulg. J. Agric. Sci.,* 20: 215-219

A total number of 480 bulk milk samples were collected in ten dairy herds over the period of 48 consecutive weeks with the objective to assess the effect of air temperature and cattle breed on milk composition and processing quality. The samples were allotted into five temperature-based groups, namely: -5.0 to 0.0°C; 0.1 to 5.0°C; 5.1 to 10.0°C; 10.1 to 15.0°C; 15.1 to 20.0°C. The sample cow breeds consisted of Czech Fleckvieh (C), Holstein (H) breeds or their crosses (CH). The following mean values of milk composition and processing quality parameters were found (n = 480): fat content (F) 3.95 $g.100g^{-1}$, protein content (CP) 3.36 $g.100g^{-1}$, lactose content (L) 4.71 $g.100g^{-1}$, solids non-fat (SNF) 8.96 $g.100g^{-1}$, rennet coagulation time (RCT) 264.1s, titratable acidity (TA) 6.49°SH, active acidity (AA) 6.72, specific density (SD) 1.0279 $kg.l^{-1}$, amount of milk produced on a sampling day (Q) 4 859 kg and air temperature (T) 7.61°C.

Increasing air temperature was associated with a shorter ($p<0.05$) RCT and a lower F, CP, SNF and AA, TA and Q remained unchanged; SD and L were higher. C cows had a shorter RCT (- 17.3 s), a significantly higher F (+0.42 $g.100g^{-1}$), CP (+0.25 $g.100g^{-1}$), SNF (+ 0.24 $g.100g^{-1}$) and TA (+0.33°SH), a significantly lower AA (- 0.02 pH) and SD (-0.0004 $kg.l^{-1}$) and non-significantly lower L (- 0.02 $g.100g^{-1}$) compared to H cows. No interactions were found between the effects of air temperature and breed for any of the observed milk parameters, e.g. RCT was shorter at higher temperatures in all breed groups.

Key words: milk, cows, milk composition, processing quality, air temperature, Czech Fleckvieh, Holstein

Introduction

Milk processing quality is determined by a number of factors, including fat content, protein content (both crude and true), casein content, lactose content, non-fat solids content, somatic cell count and processing properties, such as titratable acidity, active acidity, alcohol stability, fermentation ability of milk, rennet coagulation time (RCT or CAS) and the volume of whey separated in the process of rennet coagulation (Hanuš et al., 2007, 2010; Janů et al., 2007).

Processing properties are already set in fresh raw milk and are determined by the cow's individual characteristics, genotype or breed (Bayram et al., 2009; Matějíček et al., 2008). They can however be affected by the number and stage of lactation (Summer et al., 2003). Feed ration is also an important factor since it can influence protein content and thus solids non-fat content (Davis and White, 1958). Cimen et al. (2010) studied seasonal variations of biochemical taste parameters in milk. The processing properties of milk are also influenced by a cow's health status (Varlyakov et al., 2012).

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The rennet coagulation time (RCT) affects the processing quality of milk and consequently the process of cheese-making, cheese yield and its quality (Johnson et al., 2001) and is an essential aspect of the cheese making process (Cassandro et al., 2008). According to Daviau et al. (2000), it is well known that reducing the pH of milk from 6.7 to 5.8 leads to a faster rennet coagulation time. Reduced concentrations of casein also led to a reduction of RCT. Jõudu et al. (2008) presented that an increase in milk protein, casein, casein fractions, and casein number resulted in decreased RCT of milk. However, Polák et al. (2011) found no differences in RCT between Holstein and Czech Fleckvieh cows with significantly different milk protein content. Nájera et al. (2003) discovered that a growing temperature shortened RCT while a growing active acidity lengthened RCT.

A phenotypic correlation between rennet coagulation time and protein content was 0.02 and genotypic 0.22 (Ikonen et al., 2004) or according to Comin et al. (2005) -0.041 and 0.128, respectively.

Material and Methods

A total number of 480 bulk milk samples were collected in 10 dairy herds over the period of 48 consecutive weeks. The bulk samples represented a mixture of evening and morning milking. The samples were collected once a week on the same day. They were analysed in the dairy immediately after their delivery. The observed 10 herds were identical throughout the experiment and the amount of milk they produced varied (up to 20 000 l per day). The cows were of the Czech Fleckvieh, Holstein or their cross breeds and the breed ratio in herds remained stable throughout the experiment. The following parameters of milk composition and processing quality were observed:

Milk composition – fat (F; g.100g^{-1}), crude protein (P; g.100g^{-1}), lactose (L; lactose monohydrate; g.100g^{-1}) and solids non-fat (SNF; g.100g^{-1}) using NIR analyzer MilkoScan S50.

Milk amount – measured when handed over to the dairy tanker on the sampling day.

Rennet coagulation time (RCT) was determined by a turbidimetric detector of milk coagulation. The optical sensor of the turbidimeter converts the intensity of transmitted light into the electric signal and the output voltage is a function of the input light intensity. During coagulation, the transmitted light loses its intensity, which leads to a decrease of the output voltage. This course is immediately derived and the final para–casein clotting corresponds with the minimum value of the derivative curve.

Active acidity – measured by a pH-meter WTW YpH 197.

Titratable acidity – measured in a 100 ml milk sample using an alkaline solution (ml 0.25mol.l^{-1} NaOH) up to a light pink colour of the sample.

Specific density – measured by a densimeter.

Air temperature – calculated as the arithmetic mean of values measured at 7.00, 14.00 and 2x21.00 on the sampling day. The samples were recorded into five temperature-based categories: -5.0 to 0.0°C; 0.1 to 5.0°C; 5.1 to 10.0°C; 10.1 to 15.0°C; 15.1 to 20.0°C. The data were tested using the analysis of variance method with the air temperature and breed as factors and the sampling week as replication (Unistat 5.1).

Results and Discussion

The effect of air temperature on milk composition and processing quality is described in Table 1. The number of

Table 1
The effect of air temperature on milk composition and processing quality

Milk parameter	Units	Mean	Mean temperature range				
			- 5 to 0°C	0.1 to 5°C	5.1 to 10°C	10.1 to 15°C	15.1 to 20°C
Number		480	79	108	96	109	88
Air temperature (T)	°C	7.61	- 2.26 ^{a}	1.89 ^{b}	7.26 ^{c}	12.03 ^{d}	18.43 ^{e}
Rennet coagulation time (RCT)	sec.	264.1	273.6 ^{c}	274.0 ^{c}	269.1 ^{bc}	258.8 ^{b}	244.3 ^{a}
Titratable acidity (TA)	°SH	6.49	6.51 ^{a}	6.47 ^{a}	6.53 ^{a}	6.47 ^{a}	6.47 ^{a}
Active acidity (AA)	pH	6.72	6.73 ^{b}	6.72 ^{ab}	6.72 ^{ab}	6.71 ^{ab}	6.71 ^{a}
Density (SD)	kg.l^{-1}	1.0279	1.0278 ^{b}	1.0278 ^{b}	1.0280 ^{ab}	1.0280 ^{ab}	1.0281 ^{a}
Fat content (F)	g.100g^{-1}	3.95	4.05 ^{bc}	4.07 ^{c}	3.94 ^{b}	3.94 ^{b}	3.78 ^{a}
Protein content (CP)	g.100g^{-1}	3.36	3.42 ^{c}	3.43 ^{c}	3.38 ^{bc}	3.32 ^{b}	3.23 ^{a}
Lactose (L)	g.100g^{-1}	4.71	4.71 ^{b}	4.67 ^{a}	4.71 ^{b}	4.72 ^{b}	4.74 ^{b}
Solids non-fat (SNF)	g.100g^{-1}	8.96	9.04 ^{c}	9.02 ^{c}	8.99 ^{c}	8.91 ^{b}	8.83 ^{a}
Volume (Q)	kg	4 970	4 859 ^{a}	4 920 ^{a}	5 010 ^{a}	4 952 ^{a}	5 108 ^{a}

a-e values within one row marked with different letters differ ($P \leq 0.05$)

samples varied between 79 (temperature range -5 to 0°C) to 109 (temperature range 10.1 to 15°C). The mean daily temperature obviously increased (– 2.26°C to 18.43°C) with increasing temperature range (from -5 - 0°C to 15.1 - 20°C).

The RCT was shortest (244.3s) and the active acidity lowest (6.71 pH) in the highest temperature group (15.1 to 20°C). On the contrary, the values of these two parameters (274s and 6.72 pH) were greatest at the temperature range 0.1 to 5°C and -5 to 0°C, respectively. The milk density was lowest (1.0278 kg.l^{-1}) during cold days (0.1 to 5°C and -5 to 0°C) and highest (1.0281 kg.l^{-1}) during warm days (15.1 to 20°C).

The titratable acidity did not vary with changing temperature; the maximum difference of 0.16°SH was not statistically significant. The amount of milk produced on a sampling day was also independent of temperature (max. differences 3 %, non-significant). Fat (4.07 g.100g^{-1}), protein (3.43 g.100g^{-1}) and solids non-fat content (9.02 g.100g^{-1}) were greatest and lactose content smallest (4.67 g.100g^{-1}) at temperatures between 0.1 and 5°C. Vice versa, fat (3.78 g.100g^{-1}), protein (3.23 g.100g^{-1}) and solids non-fat content (8.83 g.100g^{-1}) were greatest and lactose content smallest (4.74 g.100g^{-1}) at temperatures between 15.1 and 20°C.

The study covered most of the important milk processing quality parameters described by dairy experts in their works (Hanuš et al., 2007, 2010). Even the authors who do not particularly specialize in milk processing quality thought it necessary to include milk coagulation properties into the methods of their dairy cattle experiments (Marchesini et al., 2009; Masoero et al., 2009). Similarly, to Davis and White (1958) a drop in solids non-fat with decreasing protein content in milk was recorded. The decreased protein content was linked with a lower fat content and the greater lactose content, thus confirming the generally known relationships between milk components.

A shorter RCT was associated with a slightly (but statistically significant) lower active acidity; a similar (only a somewhat greater) change in active acidity was described by Davidu et al. (2000). The coagulation time was also shorter in milk with the lower protein content. However, a number of authors found quite opposite results (Jõudu et al., 2008), or even a positive correlation between the two parameters (Ikonen et al., 2004; Comin et al., 2005). Some authors associated a shorter RCT with a higher temperature (Nájera et al., 2003 or Polák et al., 2011). Our range of values was similar to that found by Chládek (2011) but their maximum RCT was considerably longer.

The effect of breed on milk composition and its processing quality is described in Table 2. A number of bulk samples varied among breed groups – from 96 (Czech Fleckvieh) to 239 (Holstein). The Czech Fleckvieh cows had a significantly shorter RCT (by - 17.3s), lower active acidity (- 0.02 pH), density (-0.0004 kg.l^{-1}) and amount of tank milk on a sampling day (- 1576 kg) than the Holstein cows; the lactose content was insignificantly lower (-0.02 g.100g^{-1}). The titratable acidity (+0.33°SH), fat content (+0.42 g.100g^{-1}), protein content (+0.25 g.100g^{-1}) solids non-fat (+ 0.24 g.100g^{-1}) and air temperature (non-significant, +0.12°C) were higher in the Czech Fleckvieh cows. The crossbreds' milk parameters ranged between the Holstein and Czech Fleckvieh values; only their RCT was similar to Holstein.

A negative correlation between air temperature and RCT was confirmed in both breeds and crosses although there was

Table 2
The effect of breed (crossbreed) on milk composition and processing quality

Milk parameter	Units	Mean	Breed (crossbred)		
			C	H	C x H
Number		480	96	240	144
Air temperature (T)	°C	7.61	7.72 ^{a}	7.6 ^{a}	7.54 ^{a}
Rennet coagulation time (RCT)	sec.	264.1	249.1 ^{a}	266.4 ^{b}	269.5 ^{b}
Titratable acidity (TA)	°SH	6.49	6.73 ^{a}	6.4 ^{b}	6.47 ^{c}
Active acidity (AA)	pH	6.72	6.7 ^{a}	6.72 ^{b}	6.72 ^{b}
Density (SD)	kg.l^{-1}	1.0279	1.0277 ^{a}	1.0281 ^{b}	1.0279 ^{c}
Fat content (F)	g.100g^{-1}	3.95	4.23 ^{a}	3.81 ^{b}	4.01 ^{c}
Protein content (CP)	g.100g^{-1}	3.36	3.54 ^{a}	3.29 ^{b}	3.35 ^{c}
Lactose (L)	g.100g^{-1}	4.71	4.7 ^{a}	4.72 ^{a}	4.71 ^{a}
Solids non-fat (SNF)	g.100g^{-1}	8.96	9.14 ^{a}	8.9 ^{b}	8.95 ^{c}
Volume (Q)	kg	4 970	4514 ^{a}	6090 ^{b}	3407 ^{c}

a-e values within one row marked with different letters differ ($P \leq 0.05$) C - Czech Fleckvieh, H - Holstein, CH - Crossbred (Czech Fleckvieh and Holstein) a significant difference in RCT between the breeds. This is graphically described in Figure 1, together with regression equations with high coefficients of determination (R^2).

A considerable effect of breed on milk processing quality was discovered by numerous authors, e.g. Malacarne et al. (2005) and Bayram et al. (2009), who found significant differences between Holstein and Brown cattle or Hanuš et al. (2010) who compared Czech Fleckvieh and Holstein. They also found a shorter RCT in Czech Fleckvieh. The seasonal (based on air temperature) changes in RCT followed a similar pattern in all the observed breeds (and crosses) independently of the breed differences in protein content. This corresponded with the results of Polák et al. (2011).

No statistically significant interactions between the effects of air temperature and breed in any of the observed milk parameters (Figure 1) were recorded. For example, RCT was shorter at higher temperatures in all Holstein (H), Czech Fleckvieh (CF) and crossbred (CH) cows, despite the breed differences in absolute RCT values. This finding corresponds with results reported by Chládek et al. (2011).

Conclusions

The analysis of 480 bulk milk samples revealed that increased air temperature was associated with a shorter RCT and decreased fat, protein and solids non-fat content and active acidity, and, on the contrary, the milk density and lactose content tended to increase. The Czech Fleckvieh cows had a significantly shorter RCT and a lower active acidity, density and milk volume and non-significantly lower lactose content compared to Holstein cows. The titratable acidity, fat content and solids non-fat were significantly higher.

No statistically significant interactions between the effects of air temperature and breed in any of the observed milk parameters were recorded.

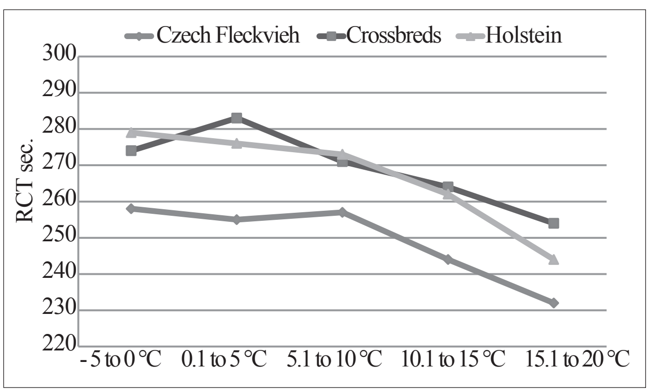

Fig. 1. Rennet coagulation time (RCT in the observed breeds (crossbreed) at different air temperatures

Acknowledgements

The study was supported by project CZ.1.07/2.3.00/20.005 The excellence of Ph.D. studies at FA MENDELU for the following scientific European career, IGA FA MENDELU **TP 5/2014** and RO0511 from February 28th 2011.

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Received April, 27, 2013; accepted for printing December, 2, 2013.