EFFECT OF BARN AIRSPACE TEMPERATURE ON COMPOSITION AND TECHNOLOGICAL PARAMETERS OF BULK MILK PRODUCED BY DAIRY COWS OF CZECH FLECKVIEH AND HOLSTEIN BREEDS

O. Polák, D. Falta, O. Hanuš, G. Chládek

Received: August 31, 2011

Abstract


On two farms (A and B), samples of bulk milk produced by dairy cows of the Holstein (H) and Czech Fleckvieh (CF) breeds were collected every week on the same day within the time interval of 36 weeks. The aim of this sampling was to determine the effect of barn airspace temperature on milk composition and its technological parameters. The following average values of all bulk milk samples (n = 72) were recorded: barn airspace temperature (BAT) 12.08 °C; rennet coagulation time (RCT) 211 sec.; curd quality class (CQC) 1.53; titratable acidity (TA) 7.16 °SH; protein content (P) 3.46 %; fat content (F) 4.09 %; lactose content (L) 4.79 %; and solids non fat (SNF) 8.86 %. As compared with H, dairy cows of CF breed produced milk with statistically significantly higher (P < 0.01) contents of P (+0.27 %) and SNF (+0.26 %). The remaining differences were statistically insignificant (P > 0.05): BAT (−2 °C); RCT (−4 sec.); CQC (0 class); TA (+0.11 °SH); F (+0.05 %) and L (−0.03 %). As far as the effect of temperature was concerned, calculated correlation coefficients and plotted graphs indicated a marked effect of BAT on RCT; F and P. This effect was in all cases markedly negative: at lower BAT, F and P values were higher and RCT longer while at higher temperatures they were lower and shorter. These trends were similar in both breeds regardless to differences in average values of aforementioned parameters.

Although the milk cattle shows a high adaptability to a wide scale of climatic conditions, its performance can be influenced by great temperature fluctuations occurring within the year. Nowadays, effects of the heat stress represents a tropical problem also in Eastern and Central Europe. Summer climate causes the heat stress of dairy cows and the heat stress results in a depression in milk production. The heat stress occurs in situations when the ambient temperature is higher than that of the animal's thermal neutral zone (Novák et al., 2009). According to Vokřálková and Novák (2005), the thermoneutral zone of dairy cows ranges from −5 to +24 °C. Other authors reminded that in high-yielding (i.e. > 6,500 kg) and, especially, older cows, the thermal stress developed at temperatures > 21 °C (Novák et al., 2009; Vokřálková and Novák, 2005). The heat stress problem is getting worse as production levels continue to rise (Miltöhner et al., 2002; Beatty et al., 2006). The summer depression in production of milk causes significant economical losses in the dairy industry. The basic condition of dairy farm management depends on the knowledge of and understanding to factors affecting milk production at most, i.e. not only nutrition and health status of dairy cows but also the parity and calving season,
technological systems, and, above all, microclimatic conditions (Maust et al., 1972; Gader et al., 2007). Livestock performance is affected by heat stress mainly due to the fact that animals having problems with high temperatures and heat try to control their thermoregulation and heat production by reduced feed intake (Davis et al., 2003; Mader et al., 2004).

Within a species, the variation in milk composition and yield is dependent on many factors. Some of them are of genetic nature while others concern stage of lactation, daily variation, parity, type of feeding, udder health, and season (Haenlein, 2003). Climatic conditions are known as seasonal changes which influence the milk composition. There is a negative correlation between the environmental temperature on the one hand and amounts of milk fat and protein on the other. When the temperature is increasing the solids non fat tends to decrease (Ozrenk and Inci, 2008). Ng-Kwai-Hang et al. (2007) mentioned that in their experiments, milk protein content depression with air temperature increase. Also Sevi et al. (2001) found high ambient temperatures to adversely affect the yield and cheese-making parameters of milk by the clotting time and the rate of clot formation and decreasing clot firmness. The photoperiod (i.e. light-to-dark ratio) can also induce marked changes in milk yield and composition (Casati et al., 1998). In fact, a high light-to-dark ratio can lead to a reduction in fat and protein contents of milk, probably as a consequence of a greater secretion of prolactin whose concentration in plasma is higher in the summer than in the winter (Tucker, 1989). Lactation period moved forward progressing and when the environmental heat degree increased, the fat content decreased (Sekerden, 1999; Yetismeyen, 2000). Jõudu et al. (2008) concluded that an increase of protein content of milk has resulted in reducing rennet coagulation time of milk.

Marked environmental effects on milk composition and technological quality of milk also cannot be negligible. These effects are usually involved into such models as effect of breed, year or season. For example De Marchi et al. (2007) mentioned that in their experiments, milk producing by dairy cows of Holstein-Friesian breed showed the worst coagulation (including RCT) among all other breeds under study. In addition Hanuš et al. (2011) observed that herd, year, and season showed a significant effect on milk composition and its technological parameters (including RCT) of milk produced by dairy cows of the Czech Fleckvieh breed. Daviau et al. (2000) mentioned that shorter RCT was associated with a decrease in the content of protein, which usually associated also with a decrease in the content of casein. A significant effect of season and herd on rennet coagulation time and other parameters of milk technological quality in Holstein cows was observed also by Chládek et al. (2011).

The aim of this study was to determine the effect of barn airspace temperature on composition (i.e. contents of protein, fat, lactose and non fat solids) and technological parameters (titratable acidity, rennetability and curd quality) of bulk milk samples collected in herds of Czech Fleckvieh and Holstein breeds of cattle.

**MATERIAL AND METHODS**

The study was performed on two farms (A and B) in the South Moravian Region of the Czech Republic within the period from June 3rd 2010 to February 2nd 2011.

The herd on the first farm (A) consisted only from purebred Holstein (H) dairy cows (in average 350 head). In this herd, the average milk performance was 9,500 kg per lactation. The farm is situated in the village of Žabčice in a lowland area (GPS 49°0'51.786"N, 16°23'42.666"E) at the altitude of 179 m. All cows were kept together under identical conditions in a loose housing system with bedding and received a complete feeding ration ad libitum. Cows were milked twice a day at 4.00 and 16.00 h. This was the same barn as that used in experiments performed by Walterová et al. (2009).

On the other farm (B), only purebred dairy cows (in average 600 head) of the Czech Fleckvieh (CF) breed were raised. The average milk performance was 7,500 kg per lactation. The farm is situated in a lowland region in the village of Říčany, Moravia, Czech Republic (GPS 49°12'32.319"N, 16°23'42.666"E) in the altitude of 349 m. All animals were kept under identical conditions in a loose housing system with bedding and received also a complete feeding ration ad libitum. They were milked twice daily also at 4.00 and 16.00 h. This experiment took place in the same barn as that used by Erbez et al. (2010). On both farms were optimized diet according to Petrikovič and Sommer (2002). Feeding ration consisted from common used feeds in this region (corn silage, cereal meals, solvent oil meals, minerals and vitamins supplements).

Within a period of 36 weeks, bulk milk samples were collected in both herds once a week always on the same day. The samples represented a mixture of morning and evening milk. The average barn airspace temperature (BAT in °C) was measured on the day before milk sampling. Temperature measurements were performed every 15 minutes using three HOBO® data loggers (H08-007-02, Onset Computer Corporation), which were located...
approx. 1.40 m above the floor level in three different locations inside the barn to eliminate the effect of only one place of measuring.

On the next day, the average percentages of fat content (F), protein (P), lactate monohydrate (L), and solids non fat (SNF) were estimated in collected bulk milk samples together with values of titratable acidity (TA), rennetability (RCT), and curd quality (CQC). Milk rennetability was estimated using a “Nephelometric-turbidimetric test of milk coagulation” (Chládek and Čejna, 2005). The test was performed using the preparation Laktochym 1:5000 (Milcom Tábor) in the dose of 1 ml per 50 ml of milk (after the dilution of the renneting agent in the ratio 1:4). Curd quality (CQC) was evaluated after 60 minutes of incubation of 50 ml of renneted milk at 35 °C and compared with tabular values (Gajdůšek, 1999) using the scale from (1 = the best to 5 = the worst). TA was measured in a milk sample of 100 ml using an alkali solution up to light pink colour of the mixture (in ml of the 0.25 molx1−1 NaOHx100ml−1). The method was performed pursuant provisions of the standard CSN57 0530. Contents of P and F were estimated using the apparatus Milkoscope C5 (see the standard ČSN 57 0536).

For statistical analysis (by means of bi-factorial analysis of variance), programmes MS Excel and UNISTAT Version 5.1 were used. The analyses carried on, including abbreviations and units of measurement were as follows:

- \( H \) = Holstein
- \( CF \) = Czech Fleckvieh
- \( P \) = protein content (\%), g.100g\(^{-1}\)
- \( F \) = fat content (\%), g.100g\(^{-1}\)
- \( L \) = lactose (\%), g.100g\(^{-1}\)
- \( SNF \) = solid non fat (\%), g.100g\(^{-1}\)
- \( BAT \) = barn airspace temperature (°C)
- \( RCT \) = rennet coagulation time (in seconds)
- \( CQC \) = curd quality class
- \( TA \) = titratable acidity (°SH).

### RESULTS AND DISCUSSION

Values of mean, minimum, maximum and standard deviation (SD) of data from analysis of cow’s milk composition, technological parameters and barn airspace temperature are shown in Table I. On both farms (n = 72), the average value of BAT was 12.08 °C and the standard deviation was 9.3 °C. On the farm A, the average BATs ranged from a minimum of −3.96 °C to the maximum of 28.51°C; for the whole period under study, the average value of BAT was 13.08 °C. On the farm B, the corresponding values of BATs ranged from −7.41 °C to +26.24 °C; for the whole period under study, the average value of BAT was 11.08 °C. This means that in some periods the monitored dairy cows were exposed to a heat stress (above all if BATs approached to the limit of 26 °C). Many authors (e.g. Berman et al., 1985; Hahn, 1999 and West, 2003) reported that BATs above 23–26 °C were for dairy cattle critical and that caused a decrease in milk production. Some other authors, however, (e.g. Falta et al., 2008; Vokřálová and Novák, 2005) demonstrated that for high-yielding dairy cows BATs of only 21 °C were critical and triggered the heat stress.

In both herds, the average values of P and its standard deviation were 3.46 % and ± 0.20 %, respectively. On the farm A, the average value of P was 3.33 % (with the minimum and the maximum of 3.14 % and 3.56 %, respectively) while on the farm B it was 3.60 % (with the minimum and the maximum of 3.33 % and 3.83 %, respectively). The difference between farms A and B was statistically highly significant (\( P < 0.01 \)). The average values of F and its standard deviation for the whole period under study and both herds were 4.09 % and ± 0.21 %, respectively). On the farm A, the average F value was 4.06 % (with the minimum and the maximum of 3.64 % and 4.48 %, respectively) while on the farm B it was 4.11 % (with the minimum and the maximum of 3.67 % and 4.41 %, respectively). The difference between both farms was statistically non-significant (\( P > 0.05 \)). From our observed values F

### Table I: Mean, minimum, maximum and standard deviation of milk composition, technological properties and barn airspace temperature on both farms (A and B)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Total ( \bar{x} )</th>
<th>SD</th>
<th>min.</th>
<th>max.</th>
<th>Farm A ( \bar{x} )</th>
<th>min.</th>
<th>max.</th>
<th>Farm B ( \bar{x} )</th>
<th>min.</th>
<th>max.</th>
<th>Signification</th>
</tr>
</thead>
<tbody>
<tr>
<td>RCT (second)</td>
<td>211</td>
<td>15.69</td>
<td>160</td>
<td>240</td>
<td>213</td>
<td>185</td>
<td>240</td>
<td>209</td>
<td>160</td>
<td>240</td>
<td>N.S.</td>
</tr>
<tr>
<td>CQC (class)</td>
<td>1.53</td>
<td>0.50</td>
<td>1.00</td>
<td>2.00</td>
<td>1.53</td>
<td>1.00</td>
<td>2.00</td>
<td>1.53</td>
<td>1.00</td>
<td>2.00</td>
<td>N.S.</td>
</tr>
<tr>
<td>TA (°SH)</td>
<td>7.16</td>
<td>0.23</td>
<td>6.42</td>
<td>7.64</td>
<td>7.11</td>
<td>6.64</td>
<td>7.50</td>
<td>7.22</td>
<td>6.42</td>
<td>7.64</td>
<td>N.S.</td>
</tr>
<tr>
<td>P (%)</td>
<td>3.46</td>
<td>0.20</td>
<td>3.14</td>
<td>3.83</td>
<td>3.33</td>
<td>3.14</td>
<td>3.56</td>
<td>3.60</td>
<td>3.33</td>
<td>3.83</td>
<td>**</td>
</tr>
<tr>
<td>F (%)</td>
<td>4.09</td>
<td>0.21</td>
<td>3.64</td>
<td>4.48</td>
<td>4.06</td>
<td>3.64</td>
<td>4.48</td>
<td>4.11</td>
<td>3.67</td>
<td>4.41</td>
<td>N.S.</td>
</tr>
<tr>
<td>L (%)</td>
<td>4.79</td>
<td>0.06</td>
<td>4.61</td>
<td>4.95</td>
<td>4.80</td>
<td>4.62</td>
<td>4.95</td>
<td>4.77</td>
<td>4.61</td>
<td>4.86</td>
<td>N.S.</td>
</tr>
<tr>
<td>SNF (%)</td>
<td>8.86</td>
<td>0.20</td>
<td>8.44</td>
<td>9.24</td>
<td>8.73</td>
<td>8.44</td>
<td>9.20</td>
<td>8.99</td>
<td>8.77</td>
<td>9.24</td>
<td>**</td>
</tr>
<tr>
<td>BAT (°C)</td>
<td>12.08</td>
<td>9.30</td>
<td>−7.41</td>
<td>28.51</td>
<td>13.8</td>
<td>−3.96</td>
<td>28.51</td>
<td>11.08</td>
<td>−7.41</td>
<td>26.24</td>
<td>N.S.</td>
</tr>
</tbody>
</table>

Signification: N.S. – non significant (\( P > 0.05 \)); ** (\( P < 0.01 \))

RCT – rennet coagulation time; CQC – curd quality class; TA – titratable acidity; P – protein content; F – fat content; L – lactose content; SNF – solids non fat; BAT – barn airspace temperature, SD – standard deviation
The correlation between milk content, technological parameters and barn airspace temperature on farms A and B are shown in Tab. II. These data indicate a marked effect of BAT on all parameters of milk composition and technological quality on both farms; non-significant was only the effect of BAT on L content on the farm A. RCT was negatively correlated with BAT on both farms (r = −0.45 and r = −0.54, respectively; P < 0.01). This means that the higher the value of BAT, the shorter that of RCT. Average values of summer BAT indicated that during this season, the limit of heat stress could be trespassed on some days (Falá et al., 2008; Hanuš et al., 2008). As mentioned by Daviau et al. (2008), the shorter RCT was associated with a decrease in P content and also of casein. It was found out in this study that lower values of RCT were associated with a lower content of protein above all in the summer season; however, our results do not correspond with data published by Žoudu et al. (2008); Ikonen et al. (2004) and Sevi et al. (2001) who obtained opposite results. This could be partly explained on the base of high summer temperatures recorded in our study. This observation also corresponded with results published by Nájera et al. (2003). Regardless to differences existing between both farms, the value of CQC was positively correlated with BAT on both farms (r = 0.42 and r = 0.36 on farms A and B, respectively; P < 0.01) while that of TA was correlated negatively (r = −0.39 and r = −0.44 on farms A and B, respectively; P < 0.01). This effect of BAT on RTC on farms A and B is shown also in Fig. 1.

As far as the effect of BAT on values of P was concerned, the highest negative correlation coefficient was found out on both farms (r = −0.86 and r = −0.88 on farm A and B, respectively; P < 0.01). This effect of BAT on P content is obvious also in Fig. 2. Further, a negative coefficient of correlation was found out also between BAT and F content on both farms (r = −0.77 and r = −0.87 on farm A and B, respectively; P < 0.01). This effect of BAT on F content on farms A and B is illustrated also in Fig. 3. This trend in growth of P under conditions of decreasing temperatures was published by several authors (Hanuš et al., 2008; Dolejš et al.,

<table>
<thead>
<tr>
<th>Farm A</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>RCT</td>
<td>−0.1215</td>
<td>0.1200</td>
<td>0.3627</td>
<td>0.5469</td>
<td>−0.0199</td>
<td>0.2946</td>
<td>−0.4478</td>
</tr>
<tr>
<td>CQC</td>
<td>−0.1858</td>
<td>1</td>
<td>−0.4292</td>
<td>−0.3715</td>
<td>−0.0670</td>
<td>−0.4066</td>
<td>0.4198</td>
</tr>
<tr>
<td>TA</td>
<td>0.0806</td>
<td>−0.3225</td>
<td>1</td>
<td>−0.3601</td>
<td>−0.0047</td>
<td>−0.3365</td>
<td>0.1844</td>
</tr>
<tr>
<td>P</td>
<td>0.6277</td>
<td>−0.3922</td>
<td>0.5076</td>
<td>1</td>
<td>0.7107</td>
<td>−0.0220</td>
<td>0.8877</td>
</tr>
<tr>
<td>F</td>
<td>0.5771</td>
<td>−0.3301</td>
<td>0.3487</td>
<td>0.8584</td>
<td>1</td>
<td>0.0201</td>
<td>0.6249</td>
</tr>
<tr>
<td>L</td>
<td>−0.4731</td>
<td>0.1691</td>
<td>−0.2790</td>
<td>−0.6701</td>
<td>−0.5476</td>
<td>1</td>
<td>0.4028</td>
</tr>
<tr>
<td>SNF</td>
<td>0.6500</td>
<td>−0.4191</td>
<td>0.4920</td>
<td>0.9566</td>
<td>0.8446</td>
<td>−0.4672</td>
<td>1</td>
</tr>
<tr>
<td>BAT</td>
<td>−0.5410</td>
<td>0.3599</td>
<td>−0.4358</td>
<td>−0.8824</td>
<td>−0.8662</td>
<td>0.5699</td>
<td>−0.8556</td>
</tr>
</tbody>
</table>

RCT – rennet coagulation time; CQC – quality of curd; TA – titratable acidity; P – protein content; F – fat content; L – lactose content; SNF – solids non fat; BAT – barn airspace temperature
Effect of barn airspace temperature on composition and technological parameters of bulk milk produced by dairy cows (1996; Ng-Kwai-Hang et al., 1984; Lacroix et al., 1996). Kadzere et al. (2001) confirmed that during periods of warm weather, the percentage of milk protein decreased in all dairy cows. Moreover, McDowell et al. (1976) mentioned that if lactating dairy cows were transferred from a barn with air temperature of 18 to another with 30 °C, production of milk fat, solids non fat and milk protein decreased by 39.7; 18.9 and 16.9 %, respectively. Ozrenk and Inci (2008) also observed that contents of protein and fat of milk change along the year and that the percent of milk protein was positively correlated with that of milk fat. This observation was corroborated also in this study: it was found out that there was a positive correlation between contents of F and P (values of correlation coefficients on farms A and B were $r = 0.71$ and $r = 0.86$, respectively; $P < 0.01$). Further it was found out that there was a positive correlation between BAT and L content on farms and B ($r = 0.05; P > 0.05$ and $r = 0.57; P < 0.01$, respectively). The result recorded on farm B differs from data published by Kadzere et al. (2001) who wrote that temperature...
O. Polák, D. Falta, O. Hanuš, G. Chládek did not affect the lactose percentage. This marked difference can be partly explained by the fact that the breed of cattle was different. On both farms, the correlation between BAT and SNF was also very high \((r = -0.73\) and \(r = -0.86\) on farms A and B, respectively).

It can be therefore concluded that differences in RCT, as observed in our study (i.e. 13.5 %), were not the same as those recorded by Hanuš \textit{et al.} (2010), respectively. Chládek \textit{et al.} (2011) under different conditions and in different breeds (34.00 %, resp. 22.7 %). The existence of significant differences among individual breeds support the opinion that the parameter „breed” should be taken into account as one of factors that influence results of experiments focused on milk technological quality. An insignificant effect of breed on parameters of technological quality of milk observed in this study resulted above all from different localities, in which both farms were situated in the region of South Moravia. Thus, the differences in composition and technological parameters of milk resulted above all from different breeds: as compared with H dairy cows, those of CF breed produced statistically significantly \((P < 0.01)\) higher percentages of P (by +0.27 %) and SNF (by +0.26 %). The other differences were statistically non-significant \((P > 0.05)\): BAT \((-2 °C)\), RCT \((-4 sec.)\), CQC \((0)\), TA \((-0.11 °SH)\), F \((+0.05 %)\) and L \((-0.03 %)\). As far as the effect of temperature is concerned, the calculated values of correlation coefficients (and also the plotted graphs) indicate a marked effect of BAT on RCT, F and P. At lower temperatures, this effect was always markedly negative (i.e. higher in case of F, P and longer in case of RCT) while at high temperatures it was less pronounced (i.e. lower and shorter). It is also necessary to remember that, within the period under study, milk composition and its technological parameters were markedly influenced by the temperature (BAT), which could further deepen differences existing between individual breeds.

Regardless to differences in average values of parameters under study, these trends were similar in both breeds.

**SUMMARY**

This study was performed in two herds reared on two farms in the territory of South Moravian Region (Czech Republic). On farm A, there was a herd of Holstein cattle while on farm B the dairy cows were on CF breed. Altogether 72 samples of bulk milk were collected within the period beginning on 3 July 2010 and ending on 2 February 2011. Averages values of technological milk quality parameters were as follows: rennet coagulation time (RCT) 211 sec., titratable acidity (TA) 7.16 °SH, quality of curd (CQC)
Effect of barn airspace temperature on composition and technological parameters of bulk milk produced by dairy cows

1.53; fat content (F) 4.09 %, protein content (P) 3.46 %, lactose carbohydrate content (L) 4.79 % and solids non fat content (SNF) 8.86 %. The average daily temperature was 12.08 °C. The effect of season on nearly all parameters under study was significant (the only exception was L content on farm A). When comparing the results obtained during the year, the significantly shortest RCT value was recorded in summer while in winter it was the longest. In summer, values of F, P and SNF were the lowest. In the autumn, the lowest values of L were recorded while those of F and P were the highest. In winter, the values of SNF were the highest at all. The effect of breed on nearly all parameters under study was non-significant the only exception represented contents of P and SNF). Maximum differences between both breeds were as follows: RCT 80 sec, TA 1.22 °SH, QC 1, F 0.84 g.100g−1, P 0.69 g.100g−1, L 0.34 g.100g−1, SNF 0.8 g.100g−1. When comparing the course of temperatures in both localities, it is possible to conclude that trends in growth and decrease of temperatures was nearly the same during the study period and that it was equal to 2 °C. This resulted above all from different localities, in which both farms were situated in the region of South Moravia. It is also possible to concluded that the shortest values of RCT were recorded on both farms during the summer season.

Acknowledgements
This study was supported by the Research Project No. MSM6215648905 „Biological and technological aspects of sustainability of controlled ecosystems and their adaptability to climate change“, which was financed by the Ministry of Education, Youth and Sports (MŠMT) of the Czech Republic and by the project MŠMT Kontakt ME 09081.

REFERENCES


HANUŠ, O., FRELICh, J., JANŮ, L., MACEK, A., ZAJÍČKOVÁ, I., GENČUROVÁ, V., JEDELSKÁ,


SEKERDEN, O., 1999: Effects of calving season and lactation order on milk yield and milk components in Simmental cows. Turkish Journal of Veterinary and Animal Sciences, 23: 79–86. ISSN 1300-0128.


