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Effect of barn airspace temperature on composition and technological parameters of bulk milk produced by dairy cows of Czech Fleckvieh and Holstein breeds

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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 32 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 = 64) were recorded: barn airspace temperature (BAT) 12.29 °C; rennet coagulation time (RCT) 211 sec.; curd quality class (CQC) 1.55; titratable acidity (TA) 7.16 °SH; protein content (P) 3.46 %; fat content (F) 4.09 %; lactose content (L) 4.78 %; and solids non fat (SNF) 8.85 %. As compared with H, dairy cows of CF breed produced milk with statistically significantly higher (P < 0.01) contents of P (+0.28 %), SNF (+0.27 %) and statistically significant (P < 0.05) of TA. The remaining differences were statistically insignificant (P > 0.05): BAT; RCT; CQC; F and L. 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.

Key words: barn airspace temperature, composition of milk, technological parameters of milk, heat stress

Introduction

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 am 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 (Mitlöhner *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*. (1984) and Lacroix *et al*. (1996) reported that the percentage of fat, protein and casein was influenced by the seasonal variations. Hanuš *et al*. (2008) observed influence of summer period on milk composition particularly on protein and solids non fat which decreased. Also Dolejš *et al*. (1996) mentioned a decrease in protein and solid non fat content in milk with increase of air temperature. It is clear that influence of dairy cow milk yield level on fat content (Hanuš *et al*., 2007) is more intensive in Czech Fleckvieh but less intensive in Holstein (Janů *et al*., 2007) which is comparable to influence of environmental temperature variation on fat. Dolejš *et al*. (1996) found also the milk fat content depression with air temperature increase. 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 leads 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 17th 2010 to January 19th 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°36'14.809"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 32 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 alkaline 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 = 64), the average value of BAT was 12.29 °C and the standard deviation was 9.32 °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 13.25 °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 11.34 °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.

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

Parameter	Total				Farm A			Farm B			Signification
	$\bar{x}$	SD	min.	max.	$\bar{x}$	min.	max.	$\bar{x}$	min.	max.	
RCT (second)	211	16.5	160	240	213	185	240	209	160	240	**N.S.**
CQC (class)	1.55	0.50	1.00	2.00	1.56	1.00	2.00	1.53	1.00	2.00	**N.S.**
TA (°SH)	7.16	0.24	6.42	7.64	7.10	6.64	7.50	7.22	6.42	7.64	*****
P (%)	3.46	0.20	3.14	3.83	3.32	3.14	3.56	3.60	3.33	3.83	******
F (%)	4.09	0.21	3.64	4.48	4.08	3.64	4.48	4.11	3.67	4.41	**N.S.**
L (%)	4.78	0.06	4.61	4.86	4.79	4.62	4.86	4.77	4.61	4.86	**N.S.**
SNF (%)	8.85	0.20	8.44	9.24	8.72	8.44	8.91	8.99	8.77	9.24	******
BAT (C°)	12.29	9.32	−7.41	28.51	13.25	−3.96	28.51	11.34	−7.41	26.24	**N.S.**

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

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 3.32 % (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 4.08 % (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 and P, we can say that milk yield both breeds were higher than average in conditions of Czech Republic in comparison to data from the Milk Recording Scheme for the year 2010 according to Kvapilík et al. (2011). In the whole set of dairy cows and for the whole period under study, the average values of L and its standard deviation were 4.78 % and ± 0.06 %, respectively. On the farm A, the average value of L was 4.79 % (with the minimum and the maximum of 4.62 % and 4.86 %, respectively). On the farm B, the corresponding value was 4.77 % (with the minimum and the maximum of 4.61 % and 4.86 %, respectively). Also this difference between both farms was statistically non-significant ($P > 0.05$). In both herds and for the whole period under study, the average values of SNF and its standard deviation were 8.85 % and ± 0.20 %, respectively. On the farm A, the average value of SNF was 8.72 % (with the minimum and the maximum of 8.44 % and 8.91 %, respectively). On the farm B, the corresponding value was 8.99 % (with the minimum and the maximum of 8.77 % and 9.24 %, respectively). This difference between both farms statistically highly significant ($P < 0.01$).

For the whole period under study and both herds, the average values of RCT and its standard deviation were 211 sec and ± 16.5 sec. On farm A, the average value was 213 sec. (with the minimum and the maximum of 185 sec and 240 sec, respectively), while on the farm B it was 209 sec. (with the minimum and the maximum of 160 sec. and 240 sec, respectively). The difference between both farms was statistically non-significant ($P > 0.05$). As far as the values of CQC and its standard deviation for the whole study period were concerned, these were 1.55 ± 0.50, respectively. On the farm A, the average value of CQC was 1.56 class and on the farm B the corresponding value was 1.53 class. The minimum and the maximum values of QCQ (i.e. Class 1 and Class 2, respectively) were recorded in both herds. On the farm A, the average value of TA was 7.10 °SH and ranged from 6.64 to 7.50 °SH; on the farm B, the corresponding values were 7.22 and 6.42−7.64 °SH, respectively. In both herds, the average values of TA and its standard deviation were 7.16 °SH and ± 0.24, respectively. The difference between both farms was statistically significant ($P < 0.05$).

The correlation between milk content, technological parameters and barn airspace temperature on farms A and B are shown in Tab. II.

Table II: *Correlation between milk content, technological properties and barn airspace temperature on farm A and farm B*

		Farm A							
		RCT	**CQC**	**TA**	**P**	**F**	**L**	**SNF**	**BAT**
Farm B	**RCT**	**1**	-0.1597	0.1763	0.4187	0.5027	0.0539	0.4167	-0.4654
	CQC	-0.1977	**1**	-0.1697	-0.4003	-0.4279	0.0494	-0.3408	0.3790
	TA	0.0874	-0.2418	**1**	0.3363	0.0355	-0.5153	0.0950	-0.3953
	P	0.6610	-0.3447	0.4663	**1**	0.8071	-0.0937	0.9112	-0.8832
	F	0.5852	-0.3062	0.3282	0.8660	**1**	0.1596	0.8390	-0.7866
	L	-0.4985	0.1450	-0.2384	-0.6691	-0.5605	**1**	0.2863	0.0749
	SNF	0.6882	-0.3629	0.4403	0.9562	0.8509	-0.4586	**1**	-0.8013
	BAT	-0.5875	0.2820	-0.3838	-0.8886	-0.8889	0.6057	-0.8542	**1**

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

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 ($r = -0.46$ and $r = -0.59$, 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 (Falta *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 Jõudu *et al*. (2008); Ikonnen *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 = 0.38 and r = 0.28 on farms A and B, respectively; P < 0.01) while that of TA was correlated negatively (r = −0.39 and r = −0.38 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.

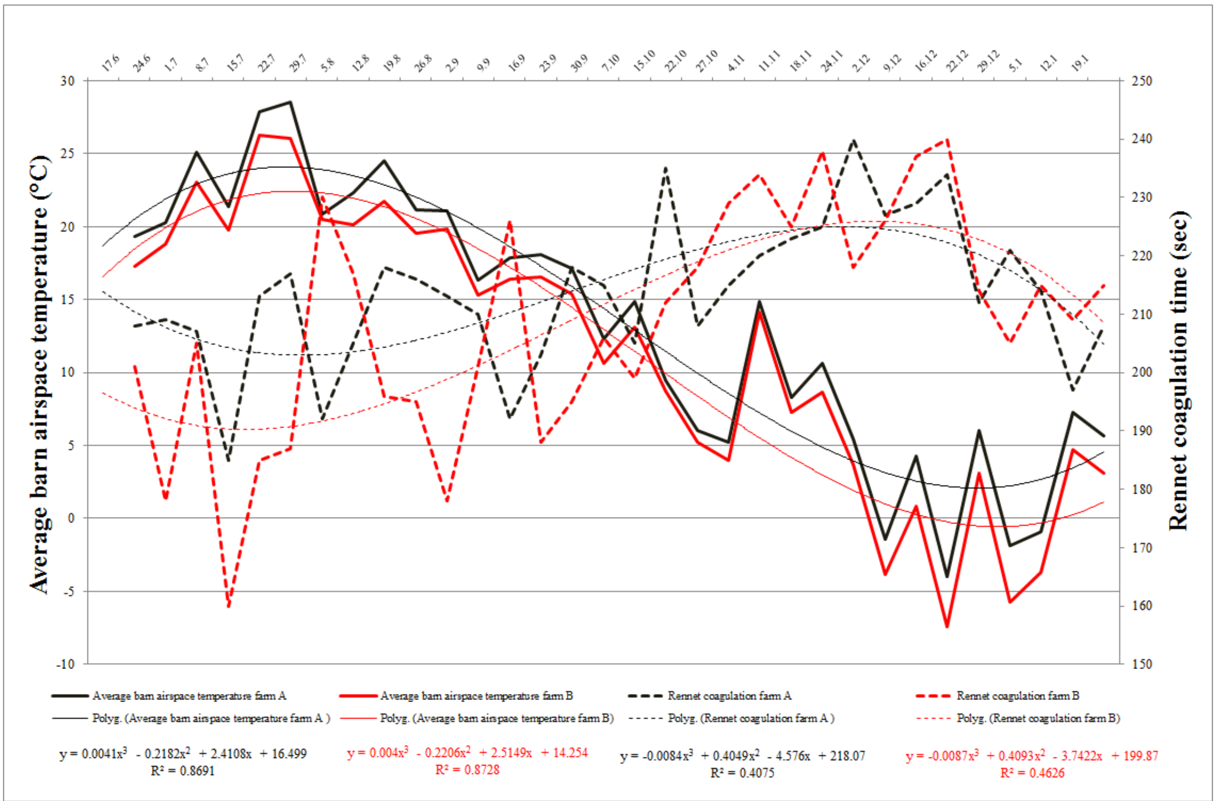

Figure 1*: Effect of barn airspace temperature on rennet coagulation time on farm A and B*

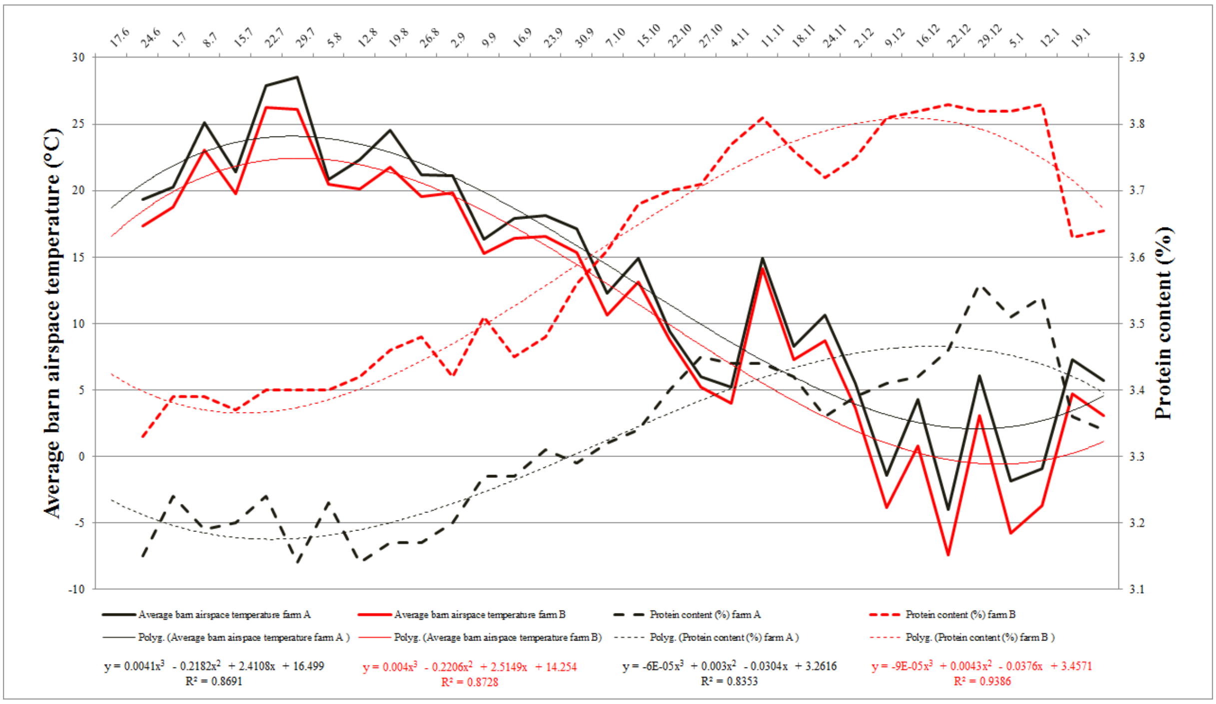

Figure 2: *Effect of barn airspace temperature on protein content on farm A and B*

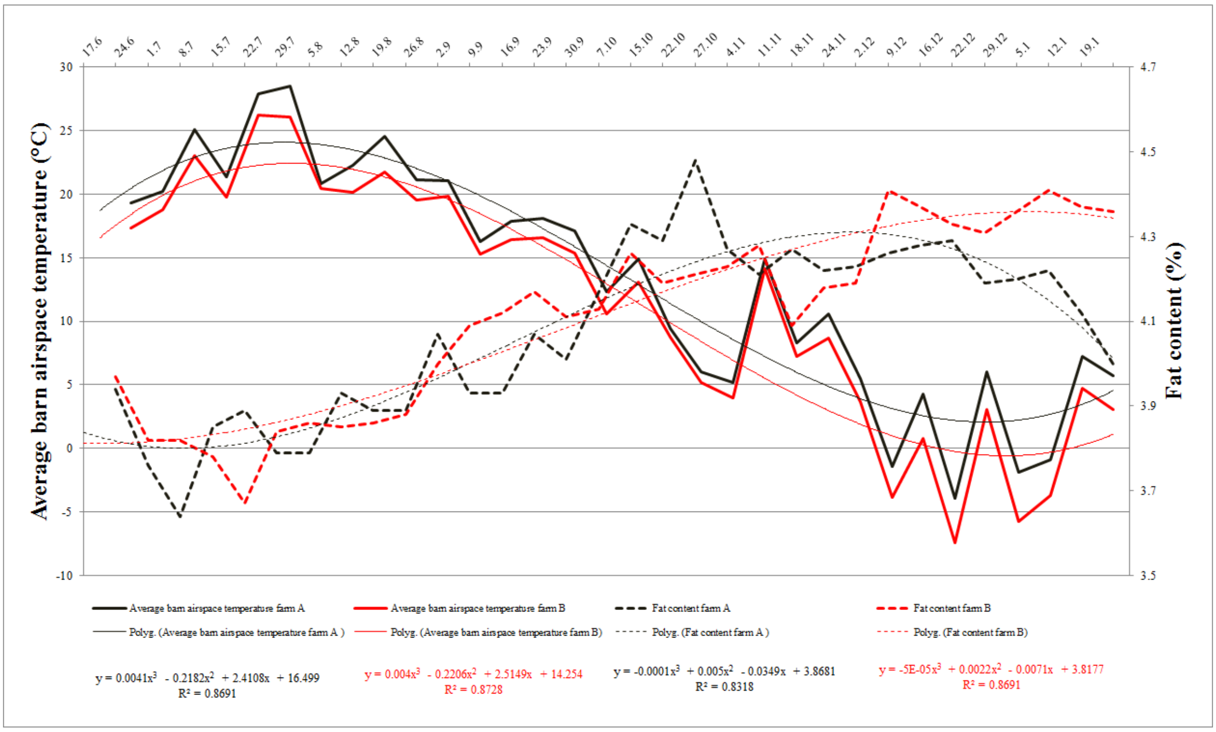

Figure 3: *Effect of barn airspace temperature on fat content on farm A and B*

As far as the effect of BAT on values of P was concerned, the highest negative correlation coefficient was found out on both farms ($r = -0.88$ 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 ($r = -0.79$ and $r = -0.89$ 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*., 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 $r = 0.81$ and $r = 0.87$. respectively; $P < 0.01$). Further it was found out that there was a positive correlation between BAT and L content on farms and B ($r = 0.07$; $P > 0.05$ and $r = 0.61$; $P < 0.01$, respectively). The result recorded on farm B differs from data published by Kadzere et al. (2001) who wrote that temperature 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 ($r = -0.8$ and $r = -0.85$ 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 *et al*. (2010), respectively. Chládek *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 does not corresponds with data published by Hanuš *et al*. (2011) who recorded them in a study with a different breed of cattle.

It is obvious that similar trends in the growth and decrease of temperatures were observed in the course of this study on both farms. However, it can be concluded that average daily temperatures were nearly identical on both farms and that the average difference was approximately 2 °C. This 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 +0.28 %), SNF (by +0.27 %) and statistically significant difference ($P < 0.05$) of TA (by – 0.12 °SH). The other differences were statistically non-significant ($P > 0.05$): BAT (−1.91 °C), RCT (−4 sec.), CQC (-0.03 class), F (+0.03 %) and L (−0.02 %).

Conclusion

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.

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Summary

Tato studie probíhala na dvou farmách (A, B) u dvou stád chovaných na území Jihomoravského kraje (Česká republika). Na farmě A bylo chováno stádo holštýnského skotu, na farmě B byly dojnice českého strakatého plemene. Celkem bylo odebráno 64 vzorků syrového kravského mléka v období od 17.června 2010 do 19.ledna 2011. Průměrné hodnoty technologických parametrů mléka byly zjištěny následovně: čas srážení 211 sekund, titrační kyselost 7,6 °SH, kvalita sýřeniny 1,55, obsah tuku 4,09%, obsah bílkovin 3,46%, obsah laktózy 4,78% a tukuprostá sušina 8,85%. Průměrná denní teplota byla 12,29 °C. Vliv sezóny byl statisticky průkazný u téměř všech sledovaných parametrů, jedinou výjimkou byl obsah laktózy na farmě A. Při porovnání výsledků získaných v průběhu roku byla zaznamenána nejnižší

hodnota času srážení v letním období, zatímco v zimě byla naměřena nejvyšší hodnota. V letním období byly zaznamenány nejnižší hodnoty u obsahu: tuku, bílkovin a tukuprosté sušiny. Na podzim byla naměřena nejnižší hodnota u obsahu laktózy, zatímco u obsahu tuku a bílkovin byla nejvyšší. Vliv plemene téměř ve všech případech byl statisticky neprůkazný, jedinou výjimkou byl obsah tuku a tukuprosté sušiny. Maximální rozdíly mezi oběma plemeny byly následující: čas srážení 80 sekund, titrační kyselost 1,22 °SH, kvalita sýřeniny 1, obsah tuku 0,84 g.100g-1, obsah bílkovin 0,69 g.100g-1, obsah laktózy 0,34 g.100g-1, obsah tukuprosté sušiny 0,8 SNF g.100g -1. Porovnáme-li průběh teplot v obou lokalitách, je možné konstatovat, že trend v růstu a poklesu teplot byl téměř stejný v průběhu sledovaného období, a že průměrný rozdíl teplot mezi chovy činil 2 °C. Tento rozdíl teplot byl dán jiným umístěním farem v regionu jižní Moravy. Je možné konstatovat, že nejnižší hodnoty času srážení byly shodně zaznamenány na obou farmách v průběhu letní sezóny.

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