The effect of stable microclimate on composition of bulk milk samples from Holstein cows

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Abstract: The aim of this study was to determine the effect of stable microclimate on the composition of bulk milk samples from Holstein cows. The study lasted 25 weeks (milk samples were sampled daily and analysed weekly) from April 2013 to September 2013. Data and milk samples come from University farm in Žabčice (49° 0′ 43″ N, 16° 36′ 8″ W; 182 m.a.s.l.). Measured stable parameters were: cooling power, air velocity, light intensity, air temperature and relative humidity. In the samples of milk were monitored: content of fat, protein, lactose and minerals (calcium, magnesium, and chloride). Based on the correlation of milk composition and stable microclimate was found with increasing air temperature decreased cooling power ($r = -0.77$, $P < 0.001$). Furthermore, results indicated that with increasing air velocity decreased cooling power ($r = -0.52$, $P < 0.01$). With increasing lactose content increased fat content ($r = 0.64$, $P < 0.01$) and protein content ($r = 0.57$, $P < 0.05$). Had also been found negative correlation between calcium content and magnesium content ($r = -0.41$, $P < 0.05$). Air temperature had a statistically significant effect on magnesium content ($r = 0.42$, $P < 0.05$) and protein content. ($r = -0.49$, $P < 0.05$). Positive correlation was found between the cooling power and the protein content ($r = 0.48$, $P < 0.05$) and a negative correlation was found between the relative humidity and the magnesium content ($r = -0.45$, $P < 0.05$) in the milk samples.

Key-Words: stable microclimate, composition of milk, Holstein cows

Introduction

The main function of a livestock building is to protect farm animals against adverse and variable atmospheric conditions and to raise them in a way that ensures herd health and welfare as well as profitability of production. This is possible when the building is equipped with technological, functional and structural solutions that largely determine indoor microclimate conditions [1]. One of the most important challenges in modern stables is to maintain appropriate microclimate, i.e. sufficient air temperature, humidity, air flow velocity, low pollution and low content of gases [2].

Air temperature - cows are the homoioterm animals, which mean that the animals keep a constant body temperature. Physiological functions of cattle work relatively independently of environment temperature. This stability is relative, because the enormous decrease or increase of environmental temperature can induce undercooling or overheating of the organism [3]. Cattle tolerate low temperatures better than high ambient temperature [4]. High environmental temperature causes lower feed intake and lower milk yield [3].

Relative air humidity is another main indicator of the quality of stable microclimate immediately after air temperature [5]. Seasonal and daily changes of relative air humidity values are suppressed owing to production of heat and water vapor from animals and air ventilation in stable [6]. The amount of evaporation depends mainly on the air temperature, degree of water vapor saturation and air flow. High relative humidity has a negative impact on the welfare and milk production of dairy cows [5].

Cooling power (refrigeration) is physiologically significant factor that results from the simultaneous action of air temperature, relative air humidity and air velocity. Cooling power expresses the loss of heat from the surface of the organism and also the thermal comfort of the animal. This is the amount of heat that is released from the unit body surface for a certain time period [7].

Air velocity (air flow) – wind is the basic meteorological element, which describes the air flow in a particular location of the atmosphere at any given time with regard to Earth. Air flow around animals can have either positive or negative effects. Air flow takes heat and water vapor and supports thermoregulation, or it causes unpleasant draught [8].

Light intensity – light is visible part of the spectrum of solar radiation in the wavelength range (about 260-760 nm). Cattle are sensitive to light intensity. In the stable should be for light (intensity of 150-200 lux) a period of 16-18 hours. Exceeding this time has a negative effect on physiological function of cattle [8].

Factors that influence milk composition include two aspects: external factors (e.g. season, feeding system and milking frequency) and internal factors (e.g. gene, parity, and stage of lactation) [9]. Some studies have shown that seasonal variation affects milk composition through several aspects, such as ingestible diets, photoperiod, and temperature [10]. Monitoring of milk components is evident in the whole world [11]. Minerals found in milk such as Se, Ca, K, Zn, Mg, and P, contribute to several vital physiological processes (e.g. Ca and P play an important role in bone metabolism; Ca, K, and Mg in the regulation of blood pressure [12]. Minerals represent a small fraction of solids, but play an important role in the structure and stability of casein micelles [13].

The aim of this work was to assess the effect of stable microclimate on the composition of bulk milk samples from Holstein cows.

Material and Methods

Characterization of animals, housing and feeding

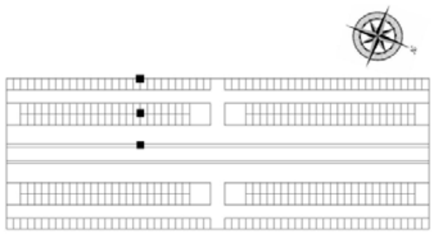
The observation was carried out on the University farm in Žabčice (49° 0′ 43″ N, 16° 36′ 8″ W; 182 m.a.s.l.) where are reared Holstein dairy cows. During the period (from April 2013 to September 2013) were collected data and milk samples (n = 25) after the morning milking. All cows were milked twice a day, but this study does not deal with afternoon milk yield. Cows were housed in free-stall stable bedded stalls and they were fed a TMR ("total mix ratio"). During the study were all cows healthy, untreated and milked (average 401) and were in various stages (average 191 days) and in a different number (average 2.34) of lactation.

Analysis of stable microclimate

Stable microclimate was measured one a day before the control day.

Air temperature represents the average of daily temperatures. It was measured every 15 minutes by 3 sensors with HOBO data logger (Onset Computer). The sensors were stationed in a stable (in height at the withers) (Figure 1).

Fig. 1 Location of sensors in the main stable of production



Relative humidity in stable was recorded by the same sensors and in the same intervals like air temperature.

Hill's kata thermometer was immersed in hot water to heat up to more than 38 °C. Refrigeration was measured at three locations in a stable (near the HOBO sensors) and then averaged into a single value. Refrigeration was detected by using kata thermometer (F = 24,751.82 W/m^2). Kata value was calculated according to the formula [7]: K = F/t
(F - kata thermometer factor (W/m^2) – a constant amount of heat loses 1 cm^2 flask of kata thermometer when cooled from 38 °C to 35 °C; t - time (s) decrease in alcohol column of kata thermometer from 38 °C to 35 °C).

Air velocity (air flow) was measured by an anemometer Testo 405-V1. Air velocity was measured near HOBO sensors (i.e. at three places in the stable). Data were averaged.

Light intensity was measured by lux meter Testo 540. Measurement was carried out at three locations in the stable (near the HOBO sensors - the height at the withers of cows). Data were averaged.

Analysis of milk samples

Milk sample were taken in control day. Analyses of samples were carried out the day after sampling in the laboratory at the Department of Animal Breeding at Mendel University in Brno.

Measured milk compositions were: fat content (g.100g^{-1}), lactose (lactose monohydrate; g.100g^{-1}) and proteins (g.100g^{-1}). Milk composition was measured on instrument Julie C5 Automatic (Scope Electric) working on the principle of thermo analysis. Chloride content in milk was determined after the addition of nitric acid by titration argentometric. Chlorides were precipitated by excess silver nitrate solution and for reverse titration was used a solution of ammonium thiocyanate. For the determination of calcium content was used complexometric titration with EDTA, 2Na.

Magnesium content was observed by titration of a mixture of milk with an ammoniacal buffer solution (pH 10) with 2Na.

Statistical analysis
Milk production was obtained from the computer database of university farm in Žabčice. MS Office Excel 2010 was used to evaluate of data. Statistical evaluation of the data was carried out in STATISTICA 10.0.

Results and Discussion

Characteristic of stable microclimate
Basic characteristics (mean, standard deviation, range) and optimal values of each parameter stable environment are described in Table 1. Some values of stable microclimate were not found in their optimal range. Thermo neutral zone for cows (with milk yield over 22 kg) is from 4 °C to 10 °C. At high air temperatures intake of feed is reduced, deficit in the body occurs and milk yield is reduced [8]. Relative humidity is the second major indicator of the quality of stable environment [5]. In the stable should be relative humidity in the range of 40–80 % and it should not exceed 85 % [8].

Table 1 Basic characteristic of stable microclimate parameters

Parameters of stable microclimate	**Unit**	**Mean ± SD**	**Range**	**Optimum values** [8]
Cooling power	W/m	468.68±110.91	185.21–614.30	170–500
Air velocity	m/s	0.41±0.27	0.08–1.15	0.1–0.3*
Light intensity	Lx	1270.89±1162.94	341.33–6654.33	150–200
Air temperature	°C	18.63±4.50	9.32–28.07	4–10
Relative air humidity	%	54.81±11.99	33.44–8.90	40–80

** - at high air temperature 0.5 – 1.5 m/s; SD – standard deviation*

Table 2 shows the relationship between the parameters of stable environment.

With increasing air temperature decreased cooling power ($r = -0.77$, $P < 0.001$). These results confirm Zejdová et al. [8] and they add that lower values (less than 170 W/m^2) are typical for very hot weather and negative relationship of cooling power and air temperature was caused by method of measuring.

With increasing air velocity decreased cooling power ($r = -0.52$, $P < 0.01$). The optimal value of air velocity has a beneficial effect on blood circulation and metabolism. At higher speeds and at low temperature environment occurs over cooling. Adverse air flow is known as the draught. [14]. Inadequate air ventilation increases the risk of disease of animals [15].

Insignificant correlations ($P < 0.05$) were found for relative humidity, light intensity among other microclimatic parameters. The relative humidity depends mainly on the air temperature, degree of saturation with water vapor and air flow [5].

Table 2 Relationship among stable microclimate

Correlations among stable microclimate	Cooling power	Air velocity	Light intensity	Air temperature	Relative air humidity
Cooling power	-	-0.52**	-0.07	-0.77***	0.15
Air velocity	-0.52**	-	0.31	0.29	-0.14
Light intensity	-0.07	0.31	-	0.17	-0.24
Air temperature	-0.77***	0.29	0.17	-	-0.28
Relative air humidity	0.15	-0.14	-0.24	-0.28	-

***- $P > 0.01$; *** - $P > 0.001$; unmarked - $P < 0.05$*

Characteristic of milk composition
Basic characteristics (mean, standard deviation, range) of each milk components are described in Table 3. Some values of minerals content were not found in their optimal range (calcium content: 0.9–1.4 $g.l^{-1}$; content of magnesium: 0.05–0.24 $g.l^{-1}$; content of chlorides 0.8–1.4 $g.l^{-1}$) [16].

Relationships among milk composition are described in Table 4. With increasing lactose content increased fat content ($r = 0.64$, $P < 0.01$) and protein content ($r = 0.57$, $P < 0.05$). Had also been found negative correlation between calcium content and magnesium content ($r = -0.41$, $P < 0.05$).

The composition and functional properties of cow's milk are very important [17].

Table 3 Basic characteristic of milk composition

Parameters of milk composition	Unit	Mean ± SD	Range
Content of calcium	$g.l^{-1}$	0.99±0.11	0.77–1.18
Content of magnesium	$g.l^{-1}$	0.34±0.09	0.17–0.61
Content of chlorides	$g.l^{-1}$	0.88±0.05	0.78–0.99
Content of fat	$g.100g^{-1}$	3.79±0.24	3.34–4.31
Content of protein	$g.100g^{-1}$	3.09±0.08	2.93–3.24
Content of lactose	$g.100g^{-1}$	4.64±0.11	4.38–4.85

SD – standard deviation

Table 4 Relationship among milk composition

Correlations among milk composition	Content of calcium	Content of magnesium	Content of chlorides	Content of fat	Content of protein	Content of lactose
Content of calcium	-	-0.41*	-0.03	-0.20	-0.03	0.04
Content of magnesium	-0.41*	-	-0.01	-0.09	-0.28	-0.12
Content of chlorides	-0.03	-0.01	-	-0.06	-0.09	-0.17
Content of fat	-0.20	-0.09	-0.06	-	0.32	0.64**
Content of protein	-0.03	-0.28	-0.09	0.32	-	0.57*
Content of lactose	0.04	-0.12	-0.17	0.64**	0.57*	-

** - P > 0.05; ** - P > 0.01; unmarked - P < 0.05*

Relationship between stable microclimate and milk composition

Table 5 presents relationship between stable microclimate and milk components content. Air temperature had a statistically significant effect on magnesium content ($r = 0.42$, $P < 0.05$) and protein content. ($r = -0.49$, $P < 0.05$). Positive correlation was found between the cooling power and the protein content ($r = 0.48$, $P < 0.05$) and a negative correlation was found between the relative humidity and the magnesium content ($r = -0.45$, $P < 0.05$) in the milk samples.

Season have a great impact on composition of bulk tank milk samples. Content of protein, fat, lactose, calcium and chlorides were the lowest in summer and the highest in winter, with intermediate values in spring and autumn [18, 19]. Some studies have shown that seasonal variation affects milk composition through several aspects, such as diets, photoperiod, and temperature [10]. High values of relative humidity have a negative effect on milk production of dairy cows [5].

Table 5 Correlations between stable microclimate and milk composition

Correlations	Content of calcium	Content of magnesium	Content of chlorides	Content of fat	Content of protein	Content of lactose
Cooling power	-0.03	-0.37	-0.01	0.23	0.48*	0.21
Air velocity	-0.07	0.02	0.00	0.25	0.10	0.29
Light intensity	-0.03	-0.17	-0.31	0.18	0.26	0.24
Air temperature	-0.17	0.42*	-0.17	-0.06	-0.49*	-0.18
Relative air humidity	0.23	-0.45*	-0.16	-0.17	-0.09	-0.35

** - P > 0.05; unmarked - P < 0.05*

Conclusion

The aim of this study was evaluated the effect of stable microclimate on composition of bulk milk samples from Holstein cows. Measured parameters were stable microclimate (cooling power, air velocity, light intensity, air temperature and relative air humidity) and milk composition (content of calcium, magnesium, chlorides, fat, protein and lactose). The research has shown that high values of air temperatures and low values of cooling power negatively affected composition of milk.

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