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Effect of air temperature and humidity in a stable on basic physiological parameters in horses

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The aim of the study was to analyse selected air parameters in a stable (microclimate) and the basic physiological parameters of horses housed in the stable in different seasons of the year. The research material was 12 adult hot-blooded horses kept in a brick stable with stalls. Air parameters in the stable (temperature in the passageway, temperature in the stall at two points, relative humidity in the passageway, and relative humidity in the stall at two points) were determined four times in one year, in summer, autumn, winter and spring. Measurements were made with a Bluetooth BLE-LOGGER LB-518 battery-operated cordless thermo-hygrometer at 12 noon at five points in the stable located 300 cm apart. Physiological parameters of the horses, i.e. internal body temperature (Veterinär SC 12 veterinary thermometer), heart rate (Polar ELECTRO OY RS800CX with PolarProTrainer 5.0. software), and respiratory rate (with a manual stopwatch) were measured at 6 a.m. and 6 p.m. on each day of the study.
The season of the year was found to have a significant influence on the microclimate of the stable. To ensure optimal air humidity, airing of the stable should be limited only in winter and periodically in autumn. It is also worth emphasizing that the stable microclimate has a marked effect on the basic physiological parameters of horses. High temperature and relative humidity in the stable can cause unfavourable changes in the form of an increase in evening body temperature in the summer and a decrease in the winter. The remaining parameters, i.e. heart rate and respiratory rate, can also unfavourably increase, mainly in the summer. Horses should have fewer problems maintaining normal physiological parameters in winter, even fewer in autumn, and the fewest in spring.

KEYWORDS: horses, stable, air parameters, physiological parameters

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INTRODUCTION

Horses are herd animals that migrate over large areas (Goodwin, 2007). Their natural behaviours and needs should be taken into account in establishing optimal housing conditions (Mills and Clarke, 2007). These measures can ensure their good physical and mental health for many years (McGreevy et al., 1995). According to Harewood and McGowan (2005), housing conditions are also important because horses usually spend a large part of the day in the stable. This is due in part to the limited number and area of paddocks and pastures in urban areas, the specific character of training and sport competitions, disease, and owners' inadequate knowledge of the biology and welfare of equids (Goodwin, 2007).

Despite the positive aspects of housing horses in stables, e.g. the possibility of monitoring their feed and water intake and protection against unfavourable weather and insects (Mills and Clarke, 2007), the way horses are kept in stable conditions requires constant improvement (Minero and Canali, 2009). This will be possible owing to analysis of the effect of these conditions on the health and well-being of horses. Proper care of horses includes a balanced diet and therapeutic procedures, but also suitable stable conditions, i.e. the size of the stalls, natural and artificial lighting, air composition, including the concentration of chemical and microbiological contaminants, air temperature and humidity, means of ventilation, noise level, the opportunity for social contact, and many other factors (Clarke, 1993; Goodwin, 2007; Mills and Clarke, 2007).

The most important parameters determining the microclimate of the stable are considered to be air temperature and relative humidity (Bihuncová et al., 2013). Adult horses can tolerate large temperature differences, and thus it is believed that the temperature in the stable should range from 5 to 28°C. It should be remembered, however, that they fare better in low temperatures than in high ones (Janczarek et al., 2015). Unfortunately, some stable buildings heat up quickly, and if they cannot be safely ventilated, without causing draughts that are harmful to horses, the temperature cannot be lowered even at night (Webster et al., 1987). Another problem is inadequate cleaning of the stalls, which causes fermenting litter to heat up the building. Fermenting litter in combination with the air exhaled by the horses and their tendency to sweat not only causes changes in air composition and temperature, but also increases the relative humidity (Banhazi and Woodward, 2007). The relative humidity additionally depends on the weather outside.

Horses have low tolerance for high humidity, which detrimentally affects their well-being and increases their susceptibility to respiratory disease (Kohn et al., 1999). Proper humidity in the stable, which should not exceed 80%, depends on the amount of water vapour formed and on the ventilation system. An appropriate ventilation system also ensures acceptable concentrations of harmful gases, mainly carbon dioxide ($\leq$ 3.000 ppm), hydrogen sulphide ($\leq$ 5 ppm) and ammonia ($\leq$ 20 ppm).

Poor stable conditions negatively affect horses' immunity, overall vitality, willingness to work, and well-being. Problems with appetite or thermoregulation may appear as well (Janczarek et al., 2015; Hodgson et al., 1994). Therefore it is important above all to determine what temperature and humidity ranges in the stable can disturb the level of basic physiological parameters. Then it will be possible to at least partially improve the welfare of horses which for various reasons have limited access to paddocks and pastures.

We hypothesized that elevated temperature and humidity in the stable cause unfavourable changes in the physiological profile of horses. Therefore the aim of the study was to analyse selected air parameters in a stable and the basic physiological parameters of the horses kept in it in different seasons of the year.

MATERIAL AND METHODS

Horses

The research material was 12 hot-blooded horses of the Malopolski breed (four mares and eight geldings) that had been housed in a single stable building for at least one year. The age range of the horses was 7-15 years. The horses were used under saddle five days a week for about 90 min, for dressage or jumping. Every day they also spent 120-180 min in paddocks. Feed was administered three times a day. The standard feed ration consisted of meadow hay and oats with a vitamin supplement. The horses also had access to water and rock salt ad libitum.

Stable building

The horses were housed in a brick stable building with 0.1 m polystyrene foam insulation with a layer of plaster. The dimensions of the building were 24x11x3.5 m. The long axis of the building ran north to south, forming a passageway with metal double doors at each end. Along each side of the passageway there were six 3x3 m stalls separated by solid partition walls. Bars were placed in the front walls from a height of 1.2 m to allow the horses to put their heads out into the passageway. The standard equipment in the stalls included a plastic trough in the corner, an automatic drinker, a feeder, and a holder with a salt lick. The floor, which was covered with litter daily, was made of oak blocks. Each stall received sunlight through a window in a PCV frame that could be tilted open. The dimensions of each window were 1.6x1.0 m. The ceiling was made of wood with a natural ventilation system consisting of three vents. When the outdoor temperature was above 10ºC, the stable was ventilated continuously through one leaf of the double doors on each side of the passageway, left ajar.

RESEARCH METHODS

Determination of physical air parameters in the stable

The physical parameters of the air in the stable were determined four times during the year, in summer, autumn, winter and spring. The measurements were performed at 12 noon at five points in the stable that were 300 cm apart. The following measurements were made each time: 1) air temperature (ºC) in the passageway at a height of 150 cm, 2) air temperature (ºC) in a stall at a height of 50 cm, 3) air temperature (ºC) in a stall at a height of 150 cm, 4) relative humidity (%) in the passageway at a height of 150 cm, 5) relative humidity (%) in a stall at a height of 50 cm, 6) relative humidity (%) in a stall at a height of 150 cm. Measurements were made with a Bluetooth BLE-LOGGER LB-518 battery-operated cordless thermo-hygrometer. The Android STORE-LOGGER application, a cordless mobile system for monitoring the microclimate of warehouses, was used to read current and recorded data from the device.

Measurements of physiological parameters

Physiological parameters of the horses were measured twice each time the stable conditions were determined (first at 6 a.m. and again at 6 p.m.). The following measurements were made: internal body temperature (ºC), heart rate (beats/min), and respiratory rate (breaths/min).

Body temperature was measured rectally for 60 s using a Veterinär SC 12 veterinary thermometer. Heart rate (beats/min, also for 60 s) was measured using Polar ELECTRO OY RS800CX telemetric devices (Essner et al., 2013) consisting of a set of electrodes with a transmitter and a receiver with systematic data recording. The electrode was moistened with gel and fastened at the height of the horse's heart with rubber tape. Next the data were transferred to computer memory using an IrDA USB 2.0 Adapter. The data were analysed with PolarProTrainer 5.0. software. The respiratory rate was determined by observing and counting the movements of the abdomen in one minute using a manual stopwatch. The horses were accustomed to the performance of these measurements prior to the experiment.

Statistical methods

The results were tested for normality of distribution by the Shapiro-Wilk test, which confirmed the normal distribution of the data. Statistical analysis of the results was performed using the GLM procedure in the SAS package (SAS Institute Inc, 2003) with a statistical model including the horse as a random factor and the following fixed factors: sex of horse (n=2: mare, gelding), season (n=4: spring, summer, autumn, winter) and time of day (n=2: morning, evening). The interactions between factors were taken into account as well. Differences between levels of factors were tested by a post-hoc (Duncan's) test for least squares means. The level of significance was set at $P \leq 0.05$.

RESULTS AND DISCUSSION

The air temperature in the passageway of the stable and in the stall at a height of 150 cm above the passageway differed between seasons (Table 1). Beginning with the highest value, the sequence was summer, autumn, spring, winter. Significant differences were also found for temperature measured in the stall at a height of 50 cm in different seasons. The lowest and most similar values were noted in the winter and spring, while the value in summer was significantly higher than the others. Only in autumn were there no differences between means from different measurement points. In the remaining seasons, the lowest temperature was recorded in the passageway, and the highest at a height of 50 cm (summer and winter) or 150 cm (spring).

Significant differences were noted between means for relative humidity in the passageway of the stable at a height of 150 cm between seasons of the year (Table 2). This parameter was significantly lower in the spring and summer than in the autumn and winter. However, the two pairs of means were similar. Significant differences were also noted between means for relative humidity in the stall at heights of 50 and 150 cm. The mean was significantly lower in the summer and significantly higher in the autumn than in the other seasons. The two remaining means were similar. No differences were noted between means from different measurement points in any season.

The body temperature of the horses in most cases did not differ significantly between seasons of the year (Table 3). The morning temperature in winter was significantly lower than the temperature in summer, while each of them was similar to the temperature in autumn and spring. In the case of the evening measurements, the temperature was lowest in autumn and winter and highest in summer. Significant differences between the morning and evening values were only noted in summer. The mean for the evening measurements was significantly higher than the mean from the morning.

Table 1

Air temperature (ºC) in the stable during each season of the year

Measurement point		Season			
		Summer	Autumn	Winter	Spring
150 cm above passageway	LSM	22.15^{ax}	19.56^{bx}	7.13^{cx}	13.51^{dx}
	SE	4.27	3.11	3.76	3.38
50 cm above stall floor	LSM	26.45^{ayz}	20.45^{bx}	14.79^{cy}	16.04^{cxz}
	SE	3.21	3.33	2.19	3.26
150 cm above stall floor	LSM	24.77^{axz}	21.09^{bx}	12.79^{cy}	18.19^{dyz}
	SE	3.19	3.64	3.12	3.13

LSM – least squares mean, SE – standard error
Means with different superscript letters (a, b, c, d: in rows, x, y, z: in columns) are significantly different at $P \leq 0.05$.

Table 2

Relative humidity (%) of air in the stable in each season of the year

Measurement point		Season			
		Summer	Autumn	Winter	Spring
150 cm above passageway	LSM	34.45a	67.45b	54.87b	40.86a
	SE	12.45	11.05	10.96	21.18
50 cm above stall floor	LSM	39.92a	72.32b	58.44c	47.17c
	SE	12.17	11.28	11.06	11.23
150 cm above stall floor	LSM	37.81a	70.78b	57.37c	49.11c
	SE	12.03	11.65	11.27	11.47

LSM – least squares mean, SE – standard error
Means with different superscript letters (a, b, c: in rows; no significant differences in columns) are significantly different at $P \leq 0.05$.

The heart rate of the horses usually differed significantly between seasons (Table 3). For the morning measurement, the values recorded in the summer and autumn were significantly lower than in the winter and spring. In the case of evening measurements, all values differed significantly from one another. Beginning with the lowest value, the order was spring, winter, autumn, summer. Differences between morning and evening heart rate were noted only in autumn. The evening heart rate was significantly lower than the morning value.

Table 3

Physiological parameters of horses in each season

Parameter		Summer Morning	Summer Evening	Autumn Morning	Autumn Evening	Winter Morning	Winter Evening	Spring Morning	Spring Evening
Body temp. (°C)	LSM	37.82^{ax}	38.46^{ay}	37.44^{acx}	37.76^{bx}	37.27^{bcx}	37.53^{bx}	37.73^{acx}	38.05^{cx}
	SE	0.23	0.26	0.34	0.35	0.18	0.25	0.21	0.19
Heart rate (beats/ min)	LSM	34.67^{ax}	35.12^{ax}	34.67^{ax}	33.45^{by}	33.12^{bx}	32.45^{cx}	32.87^{bx}	31.76^{dx}
	SE	2.45	2.18	1.88	1.56	2.05	2.18	2.38	1.89
Respiratory rate (breaths/min)	LSM	14.34^{ax}	15.12^{ax}	14.62^{ax}	15.07^{ax}	15.33^{bcx}	15.23^{ax}	14.78^{acx}	14.26^{bx}
	SE	0.43	0.54	0.33	0.78	0.43	0.34	0.28	0.32

LSM – least squares mean, SE – standard error
Means with different superscript letters (a, b, c: between the same measurement in different seasons; x, y: between morning and evening measurement in the same season) are significantly different at $P \leq 0.05$.

The respiratory rate of the horses in most cases did not differ significantly between seasons (Table 3). The morning value was significantly higher in winter than in summer and autumn, and similar to the value noted in spring. In the case of the evening measurement, only the spring value was significantly lower than the others. No significant differences were found between means for the morning and evening measurements.

The air temperature at different points in the stable was found to depend on the season of the year. As could be expected, it was lowest in winter, followed by spring and then autumn, and finally highest in summer. It is worth noting, however, that the values were most similar in summer and autumn. This was particularly evident in the stalls just above the surface of the litter. Therefore it seems that intensive airing of the stable should be recommended not only in summer, but in autumn as well, when natural ventilation of the stable is often limited by partially closing the doors and windows. The necessity of year-round ventilation of the stable to lower the air temperature has been demonstrated by Bullone et al. (2016). The authors indicated that low air temperature in the stable has a positive effect by alleviating symptoms of airway obstruction during exacerbation of advanced equine asthma. They also stressed that air temperature was positively correlated with dust concentrations in the air, and further with increasing pulmonary pressure, pulmonary resistance and elasticity values.

The situation for relative humidity was somewhat different. The highest values were noted in the autumn and winter. Thus it seems that these two seasons can create the most difficulties in maintaining optimal microclimate conditions in housing for horses. Horses have low tolerance for high humidity (Clarke, 1987). It makes them more susceptible to respiratory disease (Bullone et al., 2016), and in old individuals exacerbated symptoms of chronic rheumatic disease may appear (Woods, 1993). Based on our results, we can once again stress the need for controlled ventilation in the stable in autumn and winter, as according to Bøe et al. (2017), when humidity is low and the air temperature in the stable is negative, horses can be kept in it without detriment to their health.

Despite the changes noted in selected air parameters in the stable, the differences in the internal body temperature of the horses that could have been associated with the season were minor, and their values were always consistent with reference ranges as well as research conducted in similar stable conditions (Green et al., 2005). This fact is undoubtedly influenced by the homeothermy of horses (Morgan, 1998) and the air parameters of the stable, which satisfied the minimal conditions for housing of horses (Bombik et al., 2011; Kwiatkowska-Stenzel et al., 2011). Significant differences in the horses' internal body temperature were noted only in comparing the summer with the winter. It is also worth noting that its value in summer rose during the course of the day, most likely because the building was heated by the sun (Trzaskowska, 2012). In winter, on the other hand, the horses' body temperature fell, reaching a significantly lower value in the evening compared to the morning. These results are not in agreement with research by Piccione et al. (2002). The authors report that this parameter progressed in successive hours of daylight in winter, suggesting that the internal body temperature of horses has a distinct diurnal rhythm. The discrepancies in the results may have been associated with how the stables were ventilated.

Thus based on the present study it is worth emphasizing that intensive airing of the building in spring is essential, while in winter it should be done less often, so as not to excessively increase humidity and not to disturb the diurnal rhythm of the horses' internal body temperature. This situation can result in hypothermia, as stressed by Brown et al. (2013).

It is also interesting that the heart rate of the horses was markedly different in different seasons. This may suggest that it is much more sensitive to microclimate conditions in the stable than is internal body temperature. The results indicate that heart rate was higher in the winter and spring than in the summer and autumn. However, it is unclear at this stage of research whether these differences were linked only to the conditions in the stable. It is possible that the increased heart rate may indeed have been caused by the need to warm up the body. In spring, on the other hand, it maybe have been determined by factors such as weakness associated with the rapid replacement of the hair coat (Stachurska et al., 2015).

The fewest significant differences between means were noted in the analysis of respiratory rate. However, the influence of the stable microclimate on this parameter should not be understated. This is indicated by the fact that when the humility was high and the air temperature was low, the respiratory rate was significantly higher than in the other seasons. This suggests that winter is the season in which it is most difficult to maintain conditions in the stable that can be considered favourable for horses (Bullone et al., 2016).

The seasonal differences in air parameters and the physiological parameters of the horses in the stable indicate the need for continued research on optimization of the means of maintaining a suitable microclimate in each season of the year. According to Janczarek et al. (2015) and Geor et al. (1995), this knowledge is important because both the overall climate and the microclimate of the stable can have an adverse effect on the physical condition and overall physical and mental health of horses.

CONCLUSIONS

The season of the year has a significant influence on the microclimate of the stable. To ensure optimal air humidity, only in winter and periodically in autumn should airing of the stable be limited. It is also worth emphasizing that the stable microclimate has a marked effect on the basic physiological parameters of horses. High temperature and relative humidity in the stable can cause unfavourable changes in the form of increased evening body temperature in the summer and a decrease in the winter. The remaining parameters, i.e. heart rate and respiratory rate, can also unfavourably increase, mainly in the summer. Horses should have fewer problems maintaining normal physiological parameters in winter, even fewer in autumn, and the fewest in spring.

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Wpływ temperatury i wilgotności powietrza w stajni na podstawowe parametry fizjologiczne koni

S t r e s z c z e n i e

Celem pracy była analiza wybranych parametrów technicznych powietrza w stajni (mikroklimat) i podstawowych parametrów fizjologicznymi koni utrzymywanych w tej stajni w różnych porach roku. Materiał badawczy stanowiło 12 dorosłych koni gorącokrwistych utrzymywanych w murowanej stajni boksowej. Parametry techniczne powietrza w stajni (temperatura na korytarzu, temperatura w boksie w dwóch punktach, wilgotność względna na korytarzu, wilgotność względna w boksie w dwóch punktach) określono w pierwszym dniu kalendarzowego lata, jesieni, zimy i wiosny tego samego roku. Pomiary za pomocą LB-518 – bezprzewodowego termohigrometru bateryjnego Bluetooth BLE-LOGGER były przeprowadzone o godzinie 12.00 w pięciu punktach stajni oddalonych od siebie o 300 cm. Pomiary parametrów fizjologicznych koni, czyli temperatury wewnętrznej ciała (termometr weterynaryjny Veterinär – Thermometer S.C. 12), częstości rytmu serca (mierniki Polar ELECTRO OY - RS800CX z programem PolarProTrainer 5.0.), częstości oddechów (stoper ręczny) przeprowadzono o godzinie 6.00 i 18.00 w każdym dniu badań.

Stwierdzono, że pora roku wywiera znaczący wpływ na kształtowanie mikroklimatu stajennego. Ze względu na utrzymanie optymalnego poziomu wilgotności względnej powietrza, jedynie zimą i okresowo jesienią powinno się ograniczać przewietrzanie stajni. Warto również podkreślić, że mikroklimat stajni wyraźnie oddziałuje na podstawowe parametry fizjologiczne koni. Wysoka temperatura i wilgotność względna powietrza stajni może spowodować niekorzystne zmiany w postaci wieczornego wzrostu temperatury wewnętrznej ciała koni w porze letniej i spadku w porze zimowej. Pozostałe parametry, czyli częstość rytmu serca i liczba oddechów może wówczas również niekorzystnie wzrosnąć, głównie w okresie letnim. Zimą, konie powinny mieć mniej problemów z utrzymaniem prawidłowego poziomu parametrów fizjologicznych, jeszcze mniej jesienią, a najmniej wiosną.

SŁOWA KLUCZOWE: konie, stajnia, parametry powietrza, parametry fizjologiczne