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EVALUATION OF SELECTED PHYSICAL AND MICROBIOLOGICAL PARAMETERS OF AIR IN A BOX-STALL STABLE

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Abstract. The aim of the study was to evaluate selected physical and microbiological air parameters. The analysis was conducted during the spring, summer, fall and winter in a box-stall stable with Wielkopolski horses. The physical air parameters were measured according to generally established methods used in livestock science. The air was evaluated for microbial contamination by the impaction method; 12 samplings were carried out using a SAS 100 sampler located in three sampling sites of the stable: the initial, middle, and end part of the building. The numbers of the following microbes were determined in the analyzed air: total bacteria, *Enterobacteriaceae* cells, streptococci, mannitol positive staphylococci, hemolytic bacteria, actinomycetes and total molds and yeast-like fungi. Measurements of temperature and humidity parameters showed that the average air temperature in the stables was lowest in the winter, 8.2°C with humidity 76.2%, whereas the highest average air temperatures, which averaged 21.2°C with the lowest relative humidity of 60.2%, were recorded in the summer. The other air physical parameters corresponded to the minimum requirements for horses. Microbiological analyses of air samples revealed the presence of bacteria belonging to the *Enterobacteriaceae* family, staphylococci, streptococci, as well as fungi that can adversely affect the health of horses and people in the stables. We the found air microbial contamination above the standard level, and it depended on microclimate conditions and the season.

Key words: stable, air, physical parameters, microbiological contamination

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INTRODUCTION

In relation to other livestock animals, horses are characterized by higher requirements of environment quality, particularly in terms of air physical characteristics. The most important indicators of the internal microclimate in the stable include temperature, relative humidity, air speed, lighting, cooling and the concentration of harmful gases [Fiedorowicz and Łochowski 2008]. The main factors that negatively affect the microclimate in the stable include facility design flaws, improperly functioning ventilation and overcrowding [Schatzmann 1998]. Physical air parameters that exceed the optimum standards may negatively impact the health of the horses, including their physical and mental condition [Kolbuszewski and Bombik 1989]. However, horses housed at low temperatures may adapt and tolerate critically low temperatures, i.e. –15°C [McBride et al. 1983, Cymbaluk 1994].

Microbial contamination of the air inside livestock animal facilities is an important factor that affects the welfare of the animals. This environment promotes the proliferation and growth of many microorganisms including bacteria, viruses, mold- and yeast-like fungi [Karwowska 2005]. The amounts of microorganisms in the air inside livestock buildings depend on the species, their health status, the surface-to-volume ratio of the building, housing and nutrition system, and physical parameters of air [Duchaine et al. 2000, Chang et al. 2001, Budzińska and Jurek 2006]. The risk of contamination of the air, walls, floors and bedding in livestock facilities is increased when the farming environment is the source of a humid and warm microclimate, in which both bacteria and fungi proliferate particularly easily. According to Zucker et al. [2000], the air of animal housing facilities is dominated by three families of bacteria: *Enterobacteriaceae*, *Pseudomonadaceae* and *Neisseriaceae*. The authors indicate that the most commonly isolated *Enterobacteriaceae* strains are *Enterobacter agglomerans* and *Escherichia coli*; the bedding and feeds are the sources of the former strain, whereas the latter come mainly from the manure. The airborne infectious and opportunistically infectious bacteria include *Mycoplasma hyopneumoniae*, *Pasteurella haemolytica*, *Salmonella typhimurium* and *Staphylococcus aureus*. It has been shown that dust particles suspended in the air in stables contain high levels of bacterial endotoxins, which contribute to the incidence of allergic diseases and other equine chronic diseases [Elfman et al. 2009]. Moreover, recurrent airway obstruction (RAO) has often been diagnosed in horses. This disease results from inhaling the air containing organic dust particles, mostly coming from hay and the bedding. Air dust has revealed pathogenic fungi such as *Feania rectivirgula*, *Aspergillus fumigatus* and *Thermoactinomyces vulgaris*, which can cause inflammation of the lower respiratory tract [Niedźwiedź et al. 2006].

The aim of the study was to evaluate selected physical and microbiological air parameters in a box-stall stable that housed horses.

MATERIAL AND METHODS

The study was carried out in a stable in an agritourism farm, which housed 17 Wielkopolski horses. The horses were housed in individual box stalls, on a deep bedding. The surface are of a single box stall was 9 m^2. Manure was removed once a week, whereas disinfection of the building was carried out once a year by liming the walls and floors. The building was equipped with a gravity ventilation. At designated places inside the stable, we measured the following physical parameters: temperature, air relative humidity and air speed, which was measured using a microclimate analyzer MM-01. For the measurement of air dustiness, we applied the calculation method using the Zeiss conimeter, and natural light measurement was performed using a light meter type L-51. Measurements of these air parameters were performed according to the methods specified by Kośla [2011].

Air samples for microbial contamination analysis were collected in the spring, summer, fall, and winter by the impaction method using a SAS 100 sampler. Three measuring sites were designated inside the stable: P1 – in the initial part, P2 – in the middle, and P3 – at the end of the building Tripods with the analytical equipment were placed at a height of 1.50 m. Each air sample was collected in three replications. The numbers of the following microbes were determined in the analyzed air: total bacteria, *Enterobacteriaceae* bacteria, streptococci, mannitol-positive staphylococci, hemolytic bacteria, actinomycetes and total mold- and yeast-like fungi. The following culture media were used in the study: nutrient agar, MacConkey's agar, Streptococcus-selective agar, Chapman mannitol agar, blood agar, Pochon medium, Sabouraud agar with chloramphenicol and agar with Rose Bengal chloramphenicol (RBC). Species composition of the mold-like fungi was determined by culture on agar blocks from which slides were made and stained with lactophenol cotton blue. Macroscopic features of the colonies were defined and microscopic observations were carried out. Taxonomy was determined using available systematics sources. Yeast-like fungi were identified using the Api 20 C AUX diagnostic kit.

RESULTS AND DISCUSSION

The measurements of temperature and humidity showed that the average air temperature in the stable was lowest in the winter, 8.2°C, at the humidity 76.2% (Table 1). In the summer the highest air temperatures were recorded, averaging 21.2°C, accompanied by the lowest relative humidity of 60.2%. Thermal and hu-

midity factors are important for the welfare and health status of horses. It should be noted that adult horses have a higher tolerance to low temperatures and better tolerate lower temperature ranges, although the conditions in the studied stable were in conformity with the standards specified in the Ordinance of the Minister of Agriculture and Rural Development of 28 June 2010 [DzU nr 116, poz. 778]. The microclimate parameters in livestock facilities are an important factor affecting the welfare of animals [Kołacz and Dobrzański 2006, Kośla 2011, Kośla and Porowska 2013]. The minimum standards for welfare of horses state that air temperature in the stables should not be lower than 4–6°C for adult horses [Kośla 2011], while Morgan [1998] proposed the thermo-neutral range for horses to be 5 to 25°C. According to Kośla and Porowska [2013], air temperatures in older-type buildings during the winter months ranging on average 5.1 to 5.6°C, while the highest temperatures were found in the summer, remaining in the range 22.2–26.0°C. Witkowska et al. [2012] report – based on measurements conducted throughout the year – that temperatures were slightly higher inside the stable than outside of the building, and this difference ranged from 0.7 to 2.6°C. In turn, the winter relative humidity inside the stable was higher than the outside of it by about 20%. The authors found that the factors that shape thermal and humidity parameters in the stable may include the design of the building and the quality of thermal insulation. Microclimate studies carried out by Karwowska [2005] in livestock buildings demonstrated that relative humidity at low air temperatures, in the range of 10–13°C, remained in the range 80–90%. On the other hand, Sowińska et al. [2015] reported relative humidity inside horse-housing facilities ranged from 85.14 to 92.26%, at a temperature of from 5.09 to 7.79°C. In the analyzed building, average air speed was 0.23 $m \cdot s^{-1}$ during the winter, which is consistent with the standard recommendations for the facilities for horses (0.3 $m \cdot s^{-1}$). Łojek et al. [2009] obtained similar results of studies in the winter. In other seasons, we found that the minimum standard was exceeded by 0.07 $m \cdot s^{-1}$ in the spring, 0.13 $m \cdot s^{-1}$ in the summer, and about 0.34 $m \cdot s^{-1}$ in the fall. Similar to our findings, Kośla and Porowska [2013] point out that in the autumn the speed of air movement can be exceeded, especially in old stables. On the other hand, Bombik et al. [2009] reported a slight excess in the speed above the standard values for air movement, as the average remained in the range of 0.31 $m \cdot s^{-1}$, in a box-stall stable, to 0.44 $m \cdot s^{-1}$, in a tie-stall stable. In our stable, the natural lighting was supported with artificial lighting, with daylight illumination provided by 1:15 window-to-floor area, which complies with the standards for premises where horses are kept [Fiedorowicz 2007]. According to Houpt and Houpt [1988] horses prefer living in a place with a high level of solar illumination. The illumination in the analyzed stable remained at an average level of 41 to 75 lx. Fiedorowicz and Łochowski [2008] report that in accordance with the technological standards

of housing systems for horses the internal illumination should be in the range of 25 to 100 lx. Bombik et al. [2009] found lower light intensities in tie-stall and box-stall stables, which were 31.5 and 19.2 lx, respectively. On the other hand, those carried out in box-stall stables alone revealed a higher value of lighting, in the range 50.0 to 59.4 lx [Bombik et al. 2011]. Kośla and Porowska [2013] report that the intensity of natural lighting in the stables was dependent on the season of year, stall types and location of the building.

Table 1. Average microclimate parameters in the air of the stable

Tabela 1. Średnie wartości parametrów mikroklimatu w powietrzu stajni

Experimental period Okres badań	Air temperature, °C Temperatura powietrza, °C	Relative humidity, % Wilgotność względna powietrza, %	Air movement speed, $m \cdot s^{-1}$ Prędkość ruchu powietrza, $m \cdot s^{-1}$	Lighting intensity, lx Natężenie oświetlenia, lx	Dustiness of air, part. $\cdot cm^{-3}$ Zapylenie powietrza, szt. $\cdot cm^{-3}$
Spring – Wiosna	12.4	65.4	0.37	55	183
Summer – Lato	21.2	60.2	0.43	75	319
Autumn – Jesień	12.6	74.6	0.64	44	182
Winter – Zima	8.20	76.2	0.23	41	151

Our studies revealed that air-suspended dustiness was highest in the summer, 319 particles in 1 cm^3, whereas in the other seasons, the number of particles did not exceed 200 particles in 1 cm^3, which – according to the Kovacs scale – classified the air as moderately polluted [Kołacz and Dobrzański 2006]. The number of dust particles in the air inside livestock facilities should not exceed 400 per 1 cm^3 [Kośla 2011].

Table 2 and Figures 1–4 present the quantitative composition of microorganisms isolated from the air in the studied stable. The air in the stable was characterized by a strong microbial contamination. The lowest total number of bacteria was recorded during the winter, at a level of 3.74 to 5.92×10^4 CFU $\cdot$ m^{-3}. In the other studied periods, the number of microorganisms ranged from 1.04×10^5 to 5.90×10^5 CFU $\cdot$ m^{-3}. Comparing the results to those proposed as standard for this type of buildings (5.0×10^4 CFU $\cdot$ m^{-3}) by Krzysztofik [1992], it must be assumed that the air was contaminated, since the total number of bacteria calculated from the individual measuring points exceeded the recommended standards. The results obtained here are similar to those reported by Witkowska et al. [2012]. On the other hand Samadi et al. [2009] reported the total number of bacteria in the air of a stable in the range of 1.22 to 7.82×10^3 CFU $\cdot$ m^{-3}. In the air of the studied stable, a significant number of bacteria belonging to the *Enterobacteriaceae* family, 2–3 log CFU $\cdot$ m^{-3}, was found throughout the study period. From the sanitary-epidemiological point of view, the presence of pathogenic microorganisms and

potentially pathogenic in the air constitute a health hazard to humans and animals [Machnicka and Żelazny 2005].

Table 2. Number of microorganisms (CFU · m^{-3}) in the air of the stable house

Tabela 2. Liczba mikroorganizmów (jtk · m^{-3}) w powietrzu stajni

Specification Wyszczególnienie	Dumping samples Punkty poboru	Experimental period – Okres badań			
		Spring Wiosna	Summer Lato	Autumn Jesień	Winter Zima
Total number of mesophilic bacteria Ogólna liczba bakterii mezofilnych	P1	1.92×10^5	4.81×10^5	2.62×10^5	4.87×10^4
	P2	4.20×10^5	5.90×10^5	3.78×10^5	5.92×10^4
	P3	2.45×10^5	3.15×10^5	1.04×10^5	3.74×10^4
Bacteria of the family *Enterobacteriaceae* Bakterie z rodziny *Enterobacteriaceae*	P1	5.75×10^2	9.99×10^2	8.28×10^2	2.40×10^2
	P2	6.86×10^2	1.02×10^3	9.30×10^2	3.42×10^2
	P3	4.69×10^2	8.89×10^2	7.22×10^2	1.38×10^2
Streptococci Paciorkowce	P1	2.32×10^3	1.60×10^3	2.01×10^3	8.13×10^2
	P2	3.40×10^3	2.83×10^3	3.13×10^3	9.25×10^2
	P3	1.25×10^3	5.40×10^2	9.90×10^2	7.06×10^2
Staphylococci mannitolpositive Gronkowce mannitolododatnie	P1	2.26×10^1	2.92×10^1	2.42×10^1	1.52×10^1
	P2	3.48×10^1	3.94×10^1	3.44×10^1	2.56×10^1
	P3	1.12×10^1	1.60×10^1	1.40×10^1	0.52×10^1
Staphylococci hemolytic Gronkowce hemolizujące	P1	1.46×10^1	7.61×10^2	6.02×10^2	3.22×10^1
	P2	2.48×10^1	8.62×10^2	7.10×10^2	4.25×10^1
	P3	0.43×10^1	6.59×10^2	4.90×10^2	2.12×10^1
Actinomycetes Promieniowce	P1	4.67×10^3	4.03×10^3	3.99×10^3	6.71×10^3
	P2	9.03×10^3	4.29×10^3	6.54×10^3	7.56×10^3
	P3	4.01×10^3	3.52×10^3	3.57×10^3	6.50×10^3
Number of moulds Liczba grzybów pleśniowych	P1	2.10×10^3	1.91×10^3	2.87×10^3	2.48×10^3
	P2	1.53×10^3	2.80×10^3	4.78×10^3	4.46×10^3
	P3	1.85×10^3	3.12×10^3	2.48×10^3	1.27×10^3
Number of yeast Liczba grzybów drożdżoidalnych	P1	6.37×10^2	1.91×10^3	1.08×10^3	5.10×10^2
	P2	2.50×10^2	2.55×10^3	1.08×10^3	3.18×10^2
	P3	5.10×10^2	2.93×10^3	1.02×10^3	7.01×10^2

P1 – beginning of stable, P2 – middle of stable, P3 – end of stable.
P1 – początek stajni, P2 – środek stajni, P3 – koniec stajni.

Our results showed a high degree of air contamination by streptococcus, the number of which ranged from 7.06×10^2 (winter) to 3.40×10^3 CFU · m^{-3} (spring). Among the isolated streptococcus, there is a high probability of pathogenic bacteria or opportunistic bacterial pathogens. Czernomysy-Furowicz et al. [2010] report that the species *Streptococcus equi* can cause acute or chronic inflammation of the lymph nodes of the head and neck. In horses, these microorganisms cause an epidemic disease-scrofula. In our study, the analysis were on the presence of potentially pathogenic staphylococci, mannitol-positive and hemolytic,

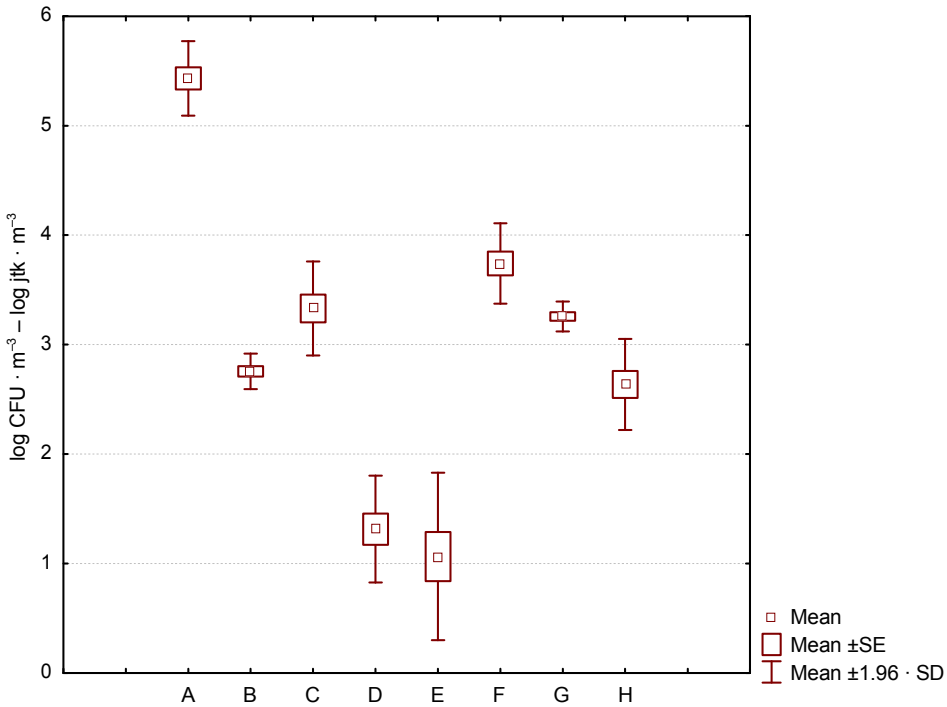

Fig. 1. Average number of microorganisms (log CFU · m^{-3}) in the air of the stable in the spring; A – total number of mesophilic bacteria, B – bacteria of the family *Enterobacteriaceae*, C – Streptococci, D – mannitol-positive Staphylococci, E – hemolytic bacteria, F – Actinomycetes, G – number of molds, H – number of yeast, SE – standard error, SD – standard deviation

Rys. 1. Średnia liczba mikroorganizmów (log jtk · m^{-3}) w powietrzu stajni w okresie wiosennym; A – ogólna liczba bakterii mezofilnych, B – bakterie z rodziny *Enterobacteriaceae*, C – paciorkowce, D – gronkowce mannitolododatnie, E – bakterie hemolizujące, F – promieniowce, G – liczba grzybów pleśniowych, H – liczba grzybów drożdżoidalnych, Mean – średnia, SE – błąd standardowy, SD – odchylenie standardowe

whose number was varied in different periods of the study. The lowest number of these microorganisms were found in winter and spring, which ranged from 1 to 2 log CFU · m^{-3}. On the other hand, summer and autumn levels of hemolytic staphylococci in the air of the stable were within 3 log units (Figs. 1–4). According to the recommendations given by Krzysztofik [1992], the number of hemolytic bacteria in the air in a barn should not exceed 5×10^2 CFU in 1 m^3. Our study showed that in the summer and autumn, the number of hemolytic staphylococci exceeded the recommended level. According to Kluczek [2000], the most often isolated microorganisms in the air in livestock facilities were staphylococci, reaching

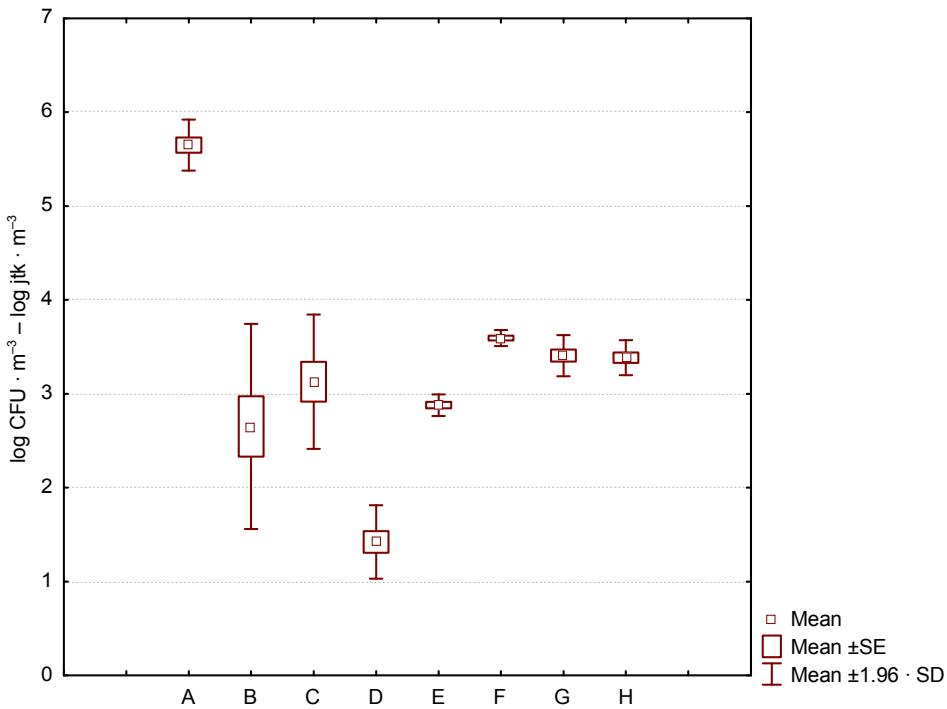

Fig. 2. Average number of microorganisms (log CFU · m^{-3}) in the air of the stable during the summer; for explanations see Fig. 1

Rys. 2. Średnia liczba mikroorganizmów (log jtk · m^{-3}) w powietrzu stajni w okresie letnim; oznaczenia jak na rys. 1

30–40%. Other more common pathogens were *Enterobacteriaceae*, Enterococci, *Pseudomonas*, and *Candida* yeast. In turn, the study by Martin et al. [1996] found that the most frequently identified bacteria in livestock facilities were: *Aerococcus viridians*, *Enterococcus durans*, *Micrococcus* spp. *Staphylococcus hominis*, *S. sciuri*, *S. simulans*, *Bacillus* spp., *Cornynebacterium* spp., *Acinetobacter calcoaceticus*, *Enterobacter agglomerans*, *Pasteurella* spp.

In our study, a large group of bacteria isolated from stable air samples were actinomycetes, the number of which oscillated within the range 3.52×10^3 to 9.03×10^3 colonies in 1 m^3. Elfman et al. [2009] confirms the dominance of actinomycetes in the horse-stable air, while pointing out that the highest numbers of actinomycetes occurred in February and March, with *Streptomyces* spp. being the most commonly identified species. These microorganisms are commonly isolated from different backgrounds, but most primary place of isolation is the soil, while the most common source of these bacteria in livestock facilities is the bedding and

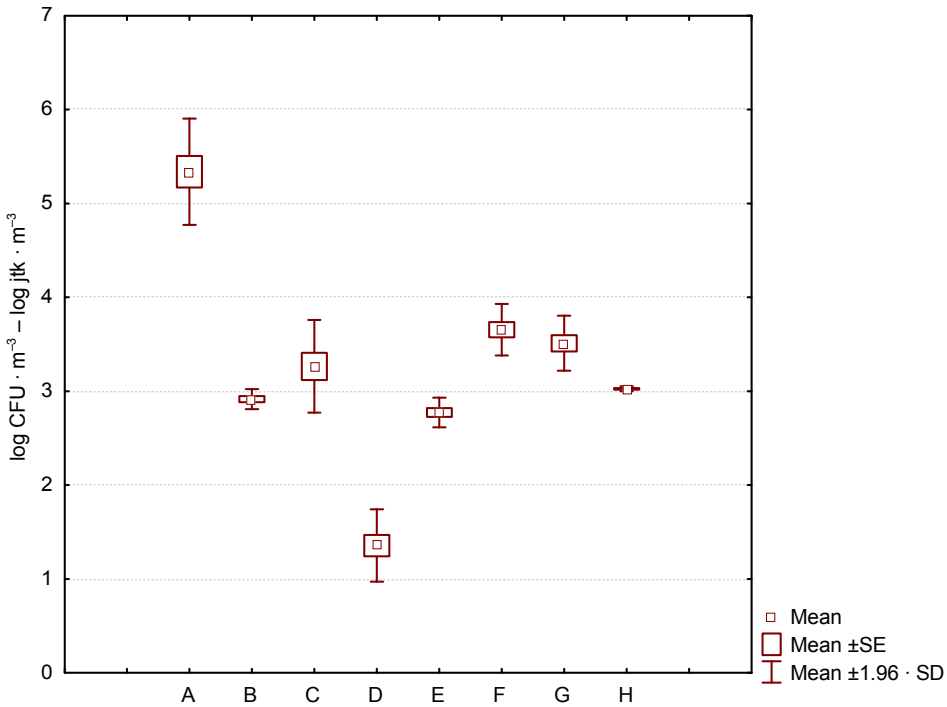

Fig. 3. Average number of microorganisms (log CFU · m^{-3}) in the air of the stable during the fall; for explanations see Fig. 1

Rys. 3. Średnia liczba mikroorganizmów (log jtk · m^{-3}) w powietrzu stajni w okresie jesiennym; oznaczenia jak na rys. 1

feed [Solecka et al. 2013]. Elfman et al. [2009] and Samadi et al. [2009] reported that actinomycetes in livestock houses, which are associated with particles of dust and organic dusts, may adversely affect the respiratory system of humans and animals.

Filamentous fungi are very abundant in the air of livestock premises. The count of these microorganisms in the air depends on many factors, the most important being the season of year, air temperature, stocking density, the system of ventilation, and the hygienic state of the premises [Kiliszczyk et al. 2013]. The bioaerosol particles comprises fungi and their spores, as well as mycotoxins produced by toxigenic fungi [Kaźmierczuk et al. 2004]. Our analysis of air samples revealed mold-like fungi at the level of 1.53×10^3 to 4.78×10^3 CFU · m^{-3}, and yeast-like fungi from 2.50×10^2 to 2.93×10^3 CFU · m^{-3}. Nardoni et al. [2005] also noted a high concentration of microscopic fungi in the air of horse stables,

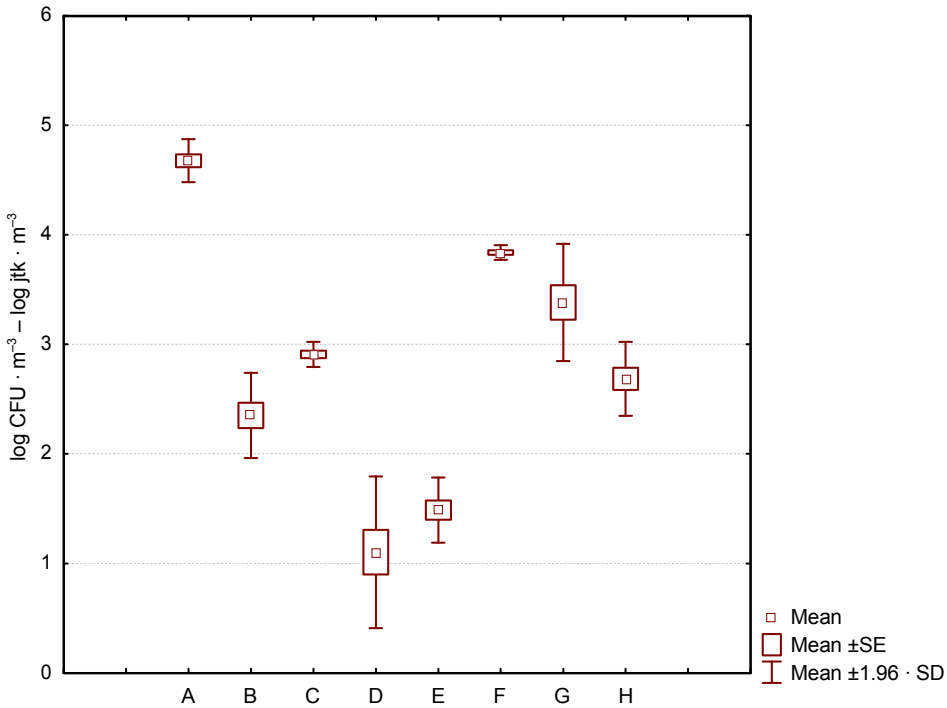

Fig. 4. Average number of microorganisms (log CFU · m^{-3}) in the air of the stable during the winter; for explanations see Fig. 1

Rys. 4. Średnia liczba mikroorganizmów (log jtk · m^{-3}) w powietrzu stajni w okresie zimowym; oznaczenia jak na rys. 1

which ranged from 1750 to 3000 CFU · m^{-3}. A similar degree of mycological pollution of the air in facilities for horses was reported by Witkowska et al. [2012].

In our study of air samples isolated species of fungi of the genera *Aspergillus*, *Penicillium*, *Mucor*, *Cladosporium* and *Rhizopus*, as well as yeast-like fungi: *Candida*, *Cryptococcus*, *Rhodotorula* (Table 3). Elfman et al. [2009] most frequently identified in horse-stable air samples such fungi as *Cladosporium* spp., *Alternaria* spp. and *Aspergillus fumigatus*. Fungi present in the air of livestock facilities can have a negative effect on animals and humans. According to Breitenbach and Simon-Noble [2002], spores of *Alternaria*, *Cladosporium*, *Fusarium*, *Mucor* and *Aspergillus* may cause inhalant allergies. Furthermore, in humans with impaired immune, fungi can cause superficial and systemic fungal infections. It was found that some species of fungi that produce mycotoxins can be inhaled into the body or introduced with food and cause mutagenic, carcinogenic and immunotoxic consequences [Pitt 2000]. In the analyzed air, potentially toxigenic fungi have been

Table 3. The most frequently isolated fungi species in the air of the stable

Tabela 3. Najczęściej izolowane gatunki grzybów w powietrzu stajni

Specification Wyszczególnienie	Spring Wiosna	Summer Lato	Autumn Jesień	Winter Zima
Aspergillus niger	+++	+++	+	+++
Aspergillus flavus	++	–	++	–
Penicillium notatum	++	–	++	–
Penicillium digitatum	+	+	++	–
Mucor mucedo	–	+++	++	–
Mucor hiemalis	++	++	–	++
Cladosporium herbarum	–	–	++	++
Rhizopus nigricans	++	++	++	++
Candida krusei	+	++	++	+
Candida albidus	++	++	++	+
Cryptococcus terreus	+	+	+	+
Rhodotorula mucilginosa	+	+	–	–

+++ very often, ++ often, + rarely, – not isolated.
+++ bardzo często, ++ często, + rzadko, – nie wyizolowano.

found, with the particular concerning presence of *Aspergillus flavus*. Accordingly, there is a need for continuous monitoring of microbiological contamination of the air in facilities for horses and carrying out disinfections, since under adverse environmental conditions and reduced immunity of the horses, the identified species of microorganisms can cause a variety of diseases including respiratory disorders.

CONCLUSIONS

The study showed that the air in the analyzed stable for horses was characterized by appropriate physical parameters not deviating from the recommended standards for animals. However, we found significant microbiological contamination, which depended on the microclimate conditions and the season of the year. We have found the number of microbes above the acceptable standards and microorganisms which may adversely affect the health of horses and people present in the stable. The analyzed air samples were found to contain bacteria belonging to the family *Enterobacteriaceae*, staphylococci, streptococci and fungi that under impaired immunity of the horses can cause respiratory diseases.

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OCENA WYBRANYCH PARAMETRÓW FIZYCZNYCH I MIKROBIOLOGICZNYCH POWIETRZA W STAJNI BOKSOWEJ

Streszczenie. Celem pracy była ocena wybranych parametrów fizycznych i mikrobiologicznych powietrza, którą przeprowadzono w okresie wiosennym, letnim, jesiennym i zimowym w stajni boksowej, w której utrzymywano konie rasy wielkopolskiej. Badania parametrów fizycznych powietrza przeprowadzono zgodnie z ogólnie przyjętymi metodami zoohigienicznymi. Próbki powietrza w celu oceny stopnia zanieczyszczenia mikrobiologicznego pobierano 12-krotnie metodą zderzeniową za pomocą próbnika Sas 100 w trzech punktach pomiarowych: początkowej, środkowej i końcowej części budynku. W analizowanym powietrzu oznaczono ogólną liczbę bakterii, bakterie z rodziny *Enterobacteriaceae*, paciorkowce, gronkowce mannitolododatnie, bakterie hemolizujące, promieniowce oraz ogólną liczbę grzybów pleśniowych i drożdżopodobnych. Pomiary parametrów termiczno-wilgotnościowych wykazały, że średnia temperatura powietrza w stajni była najniższa w okresie zimowym i wynosiła 8,2°C przy wilgotności 76,2%, natomiast w miesiącach letnich odnotowano najwyższe średnie temperatury powietrza utrzymujące się na poziomie 21,2°C przy najniższej wilgotności względnej wynoszącej 60,2%. Pozostałe parametry fizyczne powietrza były zgodne z minimalnymi wymaganiami dla koni. Przeprowadzone badania mikrobiologiczne wykazały, że w analizowanych próbach powietrza stwierdzano występowanie bakterii należących do rodziny *Enterobacteriaceae*, gronkowców, paciorkowców i grzybów, które mogą negatywnie wpływać na zdrowie koni i ludzi przebywających w stajni. Ustalono ponadnormatywne występowanie badanych mikroorganizmów, które zależało od warunków mikroklimatycznych i pory roku.

Słowa kluczowe: stajnia, powietrze, parametry fizyczne, zanieczyszczenie mikrobiologiczne

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