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The Air Quality in Transylvanian Dairy Barns with Tie-Stalls

POPESCU Silvana*, C. BORDA, Cristina I. HEGEDUS, Marina SPINU, R. STEFAN, Eva A. DIUGAN

University of Agricultural Sciences and Veterinary Medicine Cluj - Napoca, Mănăştur St., No. 3 - 5, 400372 Cluj-Napoca, Romania

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Abstract

The aim of this work was to assess the quality of the air in dairy barns with tie-stalls, based on the total number of mesophilic bacteria and on the concentrations of noxious gases (ammonia, carbon dioxide and hydrogen sulphide). We also studied the correlations between the main indicators of the air quality and the parameters of the microclimate (temperature, relative humidity and air flow velocity). Forty dairy cow barns were investigated in Transylvania in the cold season. The parameters were tested using specific methods. The numbers of the total mesophilic bacteria in the air varied between 2.50 x 10^4 cfu/m^3 and 3.36 x 10^5 cfu/m^3, with a main value of 1.52 x 10^5 cfu/m^3. The ammonia was present in all of the barns, having concentrations from 3.00 ppm to 37.00 ppm, with a mean value of 22.47 ppm. Ammonia exceeded the threshold limit in 57.5% of the investigated barns. The carbon dioxide was below the threshold limit in all of the barns and no hydrogen sulphide was found. Positive correlations were demonstrated between the ammonia concentration and the air temperature (Spearman r = 0.451, $p < 0.05$) and between the ammonia and the relative humidity of the air (Spearman r = 0.634, $p < 0.05$). The air quality was low in more than a half of the investigated barns due the high concentration of the ammonia.

Keywords: indoor air, mesophilic bacteria, ammonia, carbon dioxide, air temperature, relative humidity

1. Introduction

Providing good air quality in farm animal housing is important for the health and welfare of farm animals and staff and for the outdoor environment of farming enterprises [18]. The air in livestock buildings contains a large variety of different gases, microorganisms and considerable amounts of dust. The indoor concentrations of many of these contaminants may be proximal to or exceed threshold levels suggested for housed animals and human employees.

Strong epidemiological evidence suggests that dust associated with bacteria can directly cause infectious and allergic diseases in animals and farm workers [10]. High concentrations of noxious gases in animal shelters affect the welfare of animals, the health of human workers and the resistance of the buildings themselves [3, 4, 18, 22]. Major quantities of these compounds are emitted in the environment where the health of nearby residents may be harmed by regular exposure and where the small particulates may contribute to atmospheric pollution and global dimming [15].

Reducing air pollutants in animal houses is an urgent requirement for the development of future animal production. It will provide a safer and healthier work environment for employees and a

* Corresponding author.
Tel.: 0264596384; Fax: 0264593792
e-mail: popescusilvana@yahoo.com

better atmosphere for the animals – by improving their health, welfare and performance.

The aim of this study was to assess the quality of the air in dairy barns with tie stalls, based on the number of bacteria and fungi and on the concentration of noxious gases (ammonia, carbon dioxide, hydrogen sulphide). Furthermore, the correlation of airborne bacteria and ammonia with the environmental parameters (relative humidity, air temperature and air flow velocity) was investigated.

The role of microorganisms consists in the genesis of oil deposits and microbiological biodegradation of hydrocarbon residues [5] from different habitats (soil, water, etc.).

Microorganisms have a special ecological importance because they can be used in the remediation of soils contaminated with hydrocarbons. In this regard it was noted that many microorganisms have the ability to use gaseous hydrocarbons, liquid and solid aliphatic and aromatic series and asphalt as carbon and energy source [20].

The process of remediation of hydrocarbons contaminated soils by biological processes is known as bioremediation. The bioremediation is realized by indigenous or especially created microorganisms which are introduced into polluted soil [15].

2. Materials and Methods

This study was conducted on 40 dairy cattle tie-stall barns (32-200 dairy cows/barn), in Transylvania during the period of December 2009 – January 2010. All barns were closed, with solid flooring. The cattle houses had only natural ventilation systems.

The cows were kept tied in the barns during the cold season (pasturing in the rest of the year, in daytime) or permanently (without pasturing). Each barn was visited once for the study. The sampling and measurements were done in the morning in three different locations of the barns.

The mean values of the determined parameters were calculated for each barn. Air samples were taken using a MAS-100 air sampler (Merck, Germany) based on the principle of the Andersen air sampler. Bacteria was collected and grown in Petri dishes on Columbia agar. Air was sampled in a volume of 10 L because preliminary studies showed it to be optimal for the subsequent plate analysis and type of agar. Plates with the usual bacterial nutrient Columbia agar were then incubated for 24 h in an incubator at a working temperature of 37°C. The grown colonies were calculated by a mechanical optic colony counter and results were corrected using the conversion formula devised by Feller [7]. The average number of bacteria was calculated as colony-forming units in one cubic meter (cfu/m^3). Ammonia, carbon dioxide and hydrogen sulphide concentrations were determined by air sampling with Dräger – Multiwarn II (Dräger Safety, Germany) device. Air temperature (ºC), relative humidity (%) and air flow velocity (m/s) in the barns were determined simultaneously using a Testo 400 device (Testo Inc., Germany). The obtained data were statistically processed with the SPSS version 17 software. The descriptive statistical indicators were calculated (mean, standard deviation, median, minimum and maximum) for the measured parameters. The correlation coefficient (Spearman r) between airborne bacteria and ammonia concentration with air temperature, relative humidity and air flow velocity were also calculated.

3. Results and Discussion

The descriptive statistic analysis (mean, standard deviation, median, minimum and maximum) for investigated parameters (mesophilic bacteria, ammonia, carbon dioxide, hydrogen sulphide, air temperature, relative humidity and air flow velocity) in the 40 dairy cattle barns with tie-stalls are shown in table 1.

Table 1. Descriptive statistic analysis for the investigated parameters in the 40 dairy cattle barns

Parameter	n	Mean	SD	Median	Minimum	Maximum	95% C I	
							From	To
Mesophilic bacteria (cfu/m^3)	40	1.52×10^5	7.49×10^4	1.66×10^5	2.50×10^4	3.36×10^5	1.28×10^5	1.76×10^5
Ammonia (ppm)	40	22.47	9.82	27.00	3.00	37.00	19.33	25.61
Carbon dioxide (ppm)	40	1112.5	833.65	1000.0	100.00	2500.0	845.83	1379.2
Hydrogen sulphide (ppm)	40	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Temperature (°C)	40	12.05	4.32	11.0	6.40	19.70	10.66	13.43
Relative humidity (%)	40	83.48	10.54	85.40	59.20	98.65	80.10	86.85
Air flow velocity (m/s)	40	0.34	0.038	0.34	0.29	0.40	0.33	0.35

n = number of barns; SD = standard deviation; CI = confidence interval

Table 2 presents the correlations between the total number of mesophilic bacteria, the ammonia concentration and the microclimatic parameters (air temperature, relative humidity and air flow velocity). Statistically significant correlations were determined only between ammonia and air temperature and ammonia and relative humidity of the air.

Table 2. Relationship between total mesophilic bacteria and ammonia with microclimate parameters (temperature, relative humidity and air velocity)

Parameter	Temperature	Relative humidity	Air flow velocity
Mesophilic bacteria	-0.019 ns (p = 0.907)	-0.007 ns (p = 0.960)	-0.093 ns (p = 0.566)
Ammonia	0.451** (p = 0.003)	0.634*** (p = 0.0001)	0.270ns (p = 0.091)

ns - $p > 0.05$; ** - $p < 0.01$; *** - $p < 0.001$

The total number of mesophilic bacteria were different in the 40 assessed barns; the determined values were similar to those in the scientific literature. Several researches showed that the total number of mesophilic bacteria in cattle houses ranges from 10^4 to 10^6 cfu/m^3 [6, 10, 20]. More recent studies showed that the mean values of the total bacterial count in the dairy cows' barns ranged from 1.7 x 10^3 to 8.8 x 10^4 cfu/m^3 [11] or from 2.82 x 10^4 cfu/m^3 to 7.76 x 10^4 cfu/m^3 as it was found by Matković et al. [14] in their research. The great variability of the mesophilic bacterial count in the air of the barns is the reason for which a compulsory hygienic standard for the acceptable number of airborne bacteria is not yet established on an international level.

However, the recommendation of most of the authors, applicable in our country as well, is that the total number of mesophilic bacteria should not exceed 2.5 x 10^5/m^3 [5] in the air of the farm animals' barns. In our study this value was exceeded in only one barn. The total number of mesophilic bacteria constitutes the basic assessment criteria of the air hygiene quality.

The microbial loading of the air indicated through the total number of mesophilic bacteria is influenced by several factors, such as the number of housed animals, the breeding technologies, the flooring type, the bedding materials, the quality of microclimate, the concentration of dusts, the ventilation level and so one. High air contamination levels Lange [12] indicated an improper functioning of the ventilation systems, storage moisture of feed rations, kinds of work practice and climatic conditions.

Ammonia was found in each of the investigated barns (table 1). Its concentration is higher than those described in scientific literature (6-10 ppm) [9, 19]. Clark and McQuitty [2] studied the air quality in six Alberta commercial dairy barns and found that the NH_3 was present in all six barns and the overall mean values ranged from 7 to 20 ppm. Groot Koerkamp et al. [9] investigated concentrations and emissions of ammonia in different livestock buildings in England, the Netherlands, Denmark and Germany. The highest ammonia concentration in cattle houses was found in Germany (22.7 ppm), with mean values in different countries varying between 0.9 ppm and 7.1 ppm. Another investigation of ammonia concentrations in livestock buildings in Germany found a mean value of 6.4 ppm in cow houses [19]. In a more recent study conducted in dairy cow barns in Finland and Estonia, the ammonia concentrations varied between 0 and 64 ppm [21].

The maximal reported value was higher than our study's highest value (37 ppm). High ammonia concentrations are usually found in closed buildings. The indoor ammonia concentration depends on the flooring type, bedding material, animals' age, microclimate factors, type of manure evacuating system, frequency of cleaning and on the animals' diet [9]. In our study, the barns with high ammonia concentrations were poorly ventilated and dirty. In 57.5% of the investigated barns the ammonia concentration exceeded the admitted threshold value of our country (26 ppm).

Ammonia levels in animal houses can exceed 25 ppm when lower winter ventilation rates are used and can reach 40 ppm in poorly ventilated buildings [9]. Ammonia is considered the most significant pollutant in the air of the cattle barns, due its irritating effect on respiratory epithelium [13]. Ammonia generated in animal houses is also a polluting factor for the outside environment.

Ammonia is known to cause acid deposition and eutrophication when suspended NH_3 from dairy and other animal production facilities is deposited on land and in bodies of water [1]. In conformity with the obtained results it is possible for dairy cows to represent an important source of airborne ammonia, as it is stated in scientific literature [8]. In all of the barns the carbon dioxide concentration was below the maximal admitted limit value for dairy cattle houses. The average concentration of CO_2 in dairy buildings is 1900 ppm [17].

We did not find hydrogen sulphide in the air of any of the investigated barns (Table 1).

Temperature had a mean value of 12.05 °C in accordance with the recommendation for dairy cattle barns. Yet the maximal recorded value was higher than the recommended optimal temperature.

Various recommendations for temperature conditions for keeping dairy cows appear in the literature [20, 21]. In Romania the recommended optimal temperature for dairy cows ranges between 10 and 14 C° [16]. Temperature is an environmental parameter that can affect the health, welfare, and production efficiency of dairy cows, and thus the profitability of dairy production. The measured relative humidity had a mean value of 83.48%, exceeding the optimal value for dairy cattle barns. In a study realised by Teye et al. [21] in dairy cows' barns in Finland and Estonia, the relative humidity varied from 38% to 92%. In our study the relative humidity varied from 59.20% to 98.65% (table 1).

Relative humidity in the dairy buildings exceeded the recommended values when the ventilation was inadequate.

High relative humidity during the cold seasons is a major problem in most of the dairy buildings. A well-insulated roof is needed in naturally ventilated dairy buildings.

Adequate roof insulation can not only prevent the condensation of moisture at roof level, which leads to rust and mould in dairy buildings, but also improve the exchange of air in the building.

The velocity of the air flow had a mean value of 0.34 m/s, corresponding to the recommendations for dairy cattle barns. The maximal recorded values were slightly higher (0.4 m/s). The results are in conformity with those obtained by other researchers in their studies [21].

The production and emission of ammonia are usually influenced through the microclimate parameters as temperature, relative humidity of the air and air flow velocity.

These assumptions are confirmed by the significant correlation between indoor temperature and ammonia (Spearman $r = 0.451$, $p = 0.003$) and relative humidity and ammonia (Spearman $r = 0.634$, $p = 0.0001$) in the barns we investigated (table 2). In the study conducted by Seedorf and Hartung [19] none of these significant interactions were observed in the cattle houses, but in the poultry houses these correlations were demonstrated.

4. Conclusions

In more than half of the investigated barns the quality of the air was low due to the presence of ammonia concentrations exceeding the maximal admitted limit, indicating a need for improved housing conditions in the future. The results showed that temperature and humidity represent two of the factors influencing the ammonia concentration in the air of dairy cattle barns with tie stalls in Transylvania.

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