

Survey on Ammonia Concentrations in Dairy Cattle Tie-Stall Barns

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Abstract

The aim of the study was to quantify the ammonia concentrations from the air of dairy cattle tie-stall barns and to compare it with threshold limits recommended in our country and in other countries. The significance of interactions between ammonia concentration and air temperature, relative humidity and air flow velocity was also determined. Two measurements were done in each barn, in the morning and in the evening of the same day. The Mann-Whitney U test indicated significant differences between the two measurements only for the ammonia concentrations in the air ($p=0.003$). In 20% of the investigated cattle barns the ammonia concentration was below 10 ppm, in 20% of these it varied from 11 and 26 ppm while in 60% of these, it exceeded 26 ppm. There was a significantly positive correlation between relative humidity and ammonia concentration in all barns, both for the morning ($r=0.57$, $p=0.008$) and for the evening ($r=0.64$, $p=0.002$) measurements. Assuming an ammonia threshold limit of 26 ppm, 60% of the dairy cattle barns in this study exceeded this recommended limit, indicating a need for improved housing conditions in the future.

Keywords: air temperature, closed buildings, noxious gases, relative humidity.

1. Introduction

Ammonia has been considered the most significant air pollutant in cattle barns as its irritating effect on the respiratory epithelium appears to directly reduce the number of ciliated cells and thus decrease the efficiency of mucociliary transport [1]. When gases produced in concentrated dairy facilities escape from the buildings, they contribute to environmental problems such as global warming, acid rain and upset the nutrient balance in the environment [2]. The sources of ammonia in dairy barns include manure, urine, bedding materials and animal feed.

Ammonia concentrations in the air of cattle barns shows large variations depending on the type of housing, number and size of the animals, environmental conditions (air temperature, relative humidity, air velocity),

pH of the manure, sizes of surfaces exposed to faeces and urine, bedding type, ventilation, frequency of cleaning and the feed ration [3,4].

Based on these considerations, the ammonia concentrations in the air of the animal houses are set at certain threshold limits. The most frequently recommended maximal value of ammonia in the air of cattle barns is 20 ppm [5], although other recommendations indicate only 10 ppm, considering the cumulative effects of harmful components [6]. The maximal value admitted for ammonia in the air of cattle barns from Romania is 26 ppm [7].

This study aimed to quantify the ammonia concentrations from the air of tie-stall dairy cattle barns in Transylvania, Romania, and to compare it to maximal recommended values in our and in other countries. The objective was to verify how many of the investigated dairy cattle barns exceeded an assumed ammonia threshold, which would indicate ammonia-related health hazards due to the gaseous indoor circumstances in dairy cattle barns. We hypothesized that the ammonia

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concentration will be related to air temperature, relative humidity and air velocity, therefore the significance of interactions between these parameters was also determined.

2. Materials and methods

The investigations were carried out in Transylvania, Romania, from December 2009 to January 2010, in 20 tie-stall dairy cattle barns, housing from 32 to 113 dairy cows/barn. All of the barns were closed, with solid flooring. The removal of manure was either manual (in 75% of the barns) or mechanical (in 25% of the barns). With only one exception, the cattle barns had natural, either unorganized (in 8 of the barns) or organized (in 12 barns), ventilation. The cow stalls were short in most (60%) of the barns. Medium length beds were found in 35% of the barns, while the long type of stalls was present in only one barn. Bedding (straw, sawdust) was used in 90% of the barns. The cows were tethered in the barns during the cold season (pasturing in the rest of the year during daytime) or permanently, without access to the pasture. For the purposes of the study, each barn was visited once. The ammonia concentration in the air, the temperature, the relative humidity and the air flow velocity were measured in the morning, at 5-6 am and in the evening, at 7-8 pm, in three different points of the barn, at the inspiration level of the animals. The mean values were calculated for each barn, both for the morning and for the evening samplings.

Ammonia concentration was determined by air sampling with a Dräger – Multiwarn II (Dräger Safety, Germany) device. Air temperature, relative humidity and air flow velocity in the barns were determined simultaneously (Testo 400, GmbH & Co). The obtained data were statistically processed with the SPSS version 17 software. Descriptive statistical indicators (mean, standard deviation, median, minimum and maximum) of the measurements as well as the correlation coefficient (Spearman r) between ammonia concentration and relative humidity, air temperature and air flow velocity were calculated. The Mann-Witney U test was used to estimate the statistical significance of the obtained values. The relative frequency distribution of ammonia concentration as a function of the maximal admitted values in the air of the investigated dairy cattle barns was also calculated.

3. Results and discussion

The results obtained for the measurements made in the morning and in the evening in the tie-stall dairy cattle barns are shown in Tables 1 and 2. Table 2 presents the correlation between ammonia concentration and relative humidity, temperature and air flow velocity, for both moments of the day. The relative frequency distribution of ammonia concentration in the tie-stall dairy cattle barns is shown in figure 1. It was noticeable that in 20% of the investigated barns the ammonia concentration was below 10 ppm, in 20% it was between 11 and 26 ppm and in 60% of the barns ammonia exceeded 26 ppm.

The indoor ammonia concentration depends on the flooring type and bedding material, on the age of the animals, the microclimate factors and the system in use to evacuate manure, on the frequency of cleaning and on the diet of animals [3, 4, 8]. The manuring interval and storage time in a dairy barns influence the amount of exposed manure and the release of ammonia. Ammonia concentration and emissions can be reduced by removing manure before most of the ammonia has volatilized. The lowest ammonia concentrations were recorded in the barns with mechanical manure removal. NH_3 levels in animal barns can exceed 25 ppm when lower winter ventilation rates are used and can reach 40 ppm in poorly ventilated shelters [3]. The results of some researches showed that the lowest ammonia concentration is normally found in tie-stall facilities [9]. Because animal movement is limited, most manure is deposited in a relatively small area and normally in a deep gutter. With less exposed surface, volatile loss is reduced. In addition, manure is normally removed on a daily basis, allowing less time for loss to occur. In an evaluation of 34 dairy farms in Sweden, ammonia concentrations in tie-stall barns with solid manure handling were about half those in free stall barns with liquid manure removal [8].

Ammonia is considered the most significant pollutant in the air of the cattle barns, due to its irritating effect on respiratory epithelium [1]. At concentrations lesser than 100 ppm and in a poorly ventilated facility, ammonia appears to affect pulmonary function in cattle. There are mechanisms that protect the lungs from invasion of foreign materials:

nasopharyngeal filtration, mucociliary transport, macrophage function, coughing reflex, and humoral and cellular immunity. Of these defensive mechanisms, mucociliary transport and alveolar

macrophage functions are most severely affected by ammonia and possibly hydrogen sulphide [10].

Table 1. Descriptive statistic analysis for ammonia concentration, relative humidity, air temperature and air flow velocity in the investigated dairy cattle barns, in the morning

Parameter	n	Mean	SD	Median	Minimum	Maximum	95% CI	
							From	To
Ammonia (ppm)	20	22.85	9.93	27.50	4.00	37.00	18.19	27.50
Temperature (C°)	20	11.85	4.52	10.95	6.40	19.70	9.73	13.96
Relative humidity (%)	20	83.48	10.69	85.90	59.20	98.65	78.48	88.48
Air flow velocity (m/s)	20	0.34	0.03	0.34	0.29	0.40	0.32	0.36

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

Table 2. Descriptive statistic analysis for ammonia concentration, relative humidity, air temperature and air flow velocity in the investigated dairy cattle barns, in the evening

Parameter	n	Mean	SD	Median	Minimum	Maximum	95% CI	
							From	To
Ammonia (ppm)	20	14.10	7.86	13.50	4.00	27.00	10.42	17.77
Temperature (C°)	20	11.34	4.01	10.85	6.00	19.40	9.46	13.22
Relative humidity (%)	20	79.57	8.27	81.20	61.50	94.00	75.70	88.44
Air flow velocity (m/s)	20	0.34	0.03	0.33	0.28	0.40	0.32	0.36

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

Table 3. The correlation between ammonia concentration and relative humidity, temperature and air flow velocity, measured in the morning and in the evening

Correlation	n	Correlation coefficient (Spearman's r)	P value	95% CI	
				From	To
NH ₃ (ppm) and RH (%)	20	0.57	0.008*	0.1628	0.8155
NH ₃ (ppm) and t (C°)	20	0.36	0.11 NS	-0.1067	0.7024
NH ₃ (ppm) and v (m/s)	20	0.24	0.24	-0.2376	0.6272

NH₃ = ammonia concentration, RH = relative humidity of the air, t = temperature of the air,

v = air flow velocity, n = number of barns, CI = confidence interval

*P < 0.05, considered significant

NS p > 0.05, considered not significant.

The ammonia was found in each of the investigated barns, in the morning as well as in the evening. Its concentration was higher than those described in literature which is 6 to 10 ppm [2, 3, 11, 12, 13, 14]. Clark and McQuitty [15] studied the air quality in six Alberta commercial dairy barns and found that NH₃ was present in all six barns and the overall mean values ranged from 7 to 20 ppm. Groot Koerkamp et al. [3] investigated

concentrations and emissions of ammonia in different livestock buildings in England, the Netherlands, Denmark and Germany. The highest ammonia concentration of 22.7 ppm was found in cattle barns from Germany, with mean values ranging in different countries from 0.9 ppm to 7.1 ppm. Another survey on ammonia concentrations in Germany [13] found in cow barns a mean value of 6.4 ppm. In a more recent study conducted in

dairy cow barns in Finland and Estonia, the ammonia concentrations varied between 0 and 64 ppm [6]. The maximal reported value was higher than our study's highest value (37 ppm). High ammonia concentrations are usually found in closed buildings. Usually, the ammonia in closed barns for dairy cattle is produced in large amounts by hydrolysis of urine, resulting urea [16].

In the majority of the studied barns, the ammonia concentration (Tables 1 and 2) was significantly higher in the morning ($p=0.003$) than in the evening. These results highlight the importance of ammonia measurements in the air of the barns early in the morning, before aerating, to correctly monitor the real concentration not only of ammonia, but of other harmful gases as well, which affect the cows at night. The ammonia concentration in the barns is usually lower during the day, due to opened doors and windows. In our study, limited to closed tie stall-barns, the barns with high ammonia concentrations were poorly ventilated and dirty.

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 thermal environment around a dairy cow varies according to the complex interactions between environmental conditions and animal-related factors. Furthermore, factors such as the dairy breed and age, structural design, floor type, stocking rate, and nutrition also influence how the thermal conditions in the building affect individual animals. Under certain optimal environmental conditions, dairy cows are not only comfortable, but produce higher outputs [6].

Temperature had similar mean values at the two measurements (in the morning and in the evening), in agreement with those recommended for dairy cattle barns (Tables 1-2). Nevertheless, the maximal recorded value was higher than the suggested optimal temperature. Various recommendations for temperature conditions for keeping dairy cows are available in the literature [5, 13, 6]. The recommended optimal temperature for dairy cows ranges in Romania between 10 and 14 °C [7].

In a study performed by Teye et al. [6] in dairy cow barns in Finland and Estonia, the relative humidity varied from 38% to 92%. For the relative

humidity in animal shelters, CIGR recommends [5] maximal and minimal values as a function of indoor temperature. Relative humidity in the dairy barns 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 recommended optimal relative humidity for dairy cows varies in Romania from 60% to 75% [7]. The measured relative humidity had in the morning and also in the evening a mean value exceeding the optimal value for dairy cattle barns (Tables 1-2). No significant differences between the values of temperature and humidity of the air measured in the morning and in the evening were shown by the Mann-Whitney U test ($p>0.05$).

The velocity of the air flow had the same mean values in the morning and in the evening, corresponding to those recommended for dairy cattle barns (Tables 1-2). The maximal recorded values were slightly higher (0.4 m/s). The results are in conformity with those obtained by other researchers [6].

Considering the maximal admitted values for the ammonia in the inner air of cattle barns in our country and in other countries, a distribution of the relative frequency of morning values was generated (Figure 1). The fact that in more than half of the investigated barns (60%) the ammonia concentration exceeded 26 ppm is alarming, especially considering that the maximal admitted value from literature for ammonia in cattle barns is that of Romania. If we would consider as maximal admitted value for ammonia a 10 ppm concentration, the situation worsens, since the ammonia concentration we found exceeded this value in 80% of the investigated barns. The results of a German study indicated that in 72% of dairy cattle barns ammonia was below 7 ppm, and none exceeded the concentration of 15 ppm [13]. High concentrations of NH_3 inside the dairy cattle shelters serves as an indicator for improper housing conditions, with the risk of disease for animals and humans.

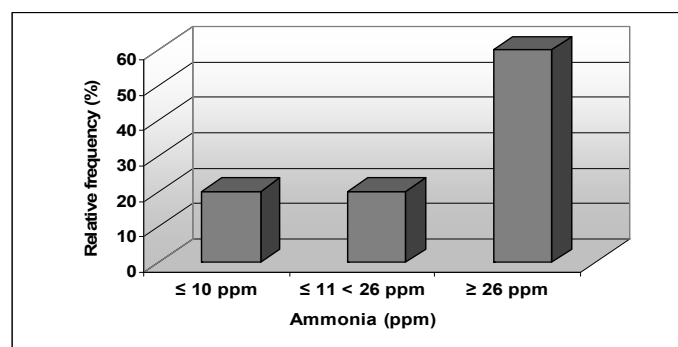


Figure 1. Relative frequency distribution of ammonia concentration in Transylvanian tie-stall dairy cattle barns in the morning

The production and emission of ammonia are usually influenced by microclimate parameters such as temperature, relative humidity of the air and the air flow velocity. In the barns we investigated, the only significant correlation established was between relative humidity of the air and ammonia, in the morning ($r=0.57$, $p=0.008$), and in the evening ($r=0.64$, $p=0.002$) (Table 3). In a study conducted by Seedorf and Hartung [13], none of the observed interactions were statistically significant for cattle barns. Nevertheless, in pig shelters a positive correlation between ammonia concentration and relative humidity of the air was found.

4. Conclusions

Assuming an ammonia threshold limit of 26 ppm, 60 % of all dairy cattle house in this study exceeded this recommended limit, indicating a need for improvement of the housing conditions in the future. The results showed that humidity is one of the factors influencing the ammonia concentration in the air of the studied dairy cattle tie-stall barns.

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