EFFECT OF SOLID AND SLATTED FLOORS AND TEMPERATURE ON AMMONIA AND GHG EMISSIONS IN A SCALE MODEL OF DAIRY CATTLE HOUSES

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1 INTRODUCTION

Dairy cattle are usually housed in naturally ventilated dairy houses, in witch the presence of urine and faeces, during a few hours or some days, lead to gaseous emissions. The aim of this study was to evaluate, at a scale model, the effect of a solid and a slatted floor at different air temperatures on NH_3 and greenhouse gas (GHG) emissions (N_2O, CO_2 and CH_4).

2 MATERIALS AND METHODS

Scale models of two types of concrete floors (slatted and solid) that are commonly used in naturally ventilated dairy cattle houses, were built with a steel-framed box with two levels and an experimental area of 1.0 × 1.0 m^2. In the top level of one box was laid a solid concrete floor (no sloped) and in the other a slatted floor made with concrete pieces with 40 mm slat openings. A drainage channel was placed in the lower level and the two models were enclosed in hermetic plastic containers. Eight holes were made on each of the two opposite sides of each hermetic box from which air was pumped with a constant flow rate of 12.5 exchanges h^{-1} above the floors. Before the beginning of the experiments the floors were put during one year in a cattle building and used by the cows to promote urease activity in the floors surfaces. The two scale models were housed in a large chamber equipped with a temperature control system. Ammonia and GHG emissions were measured in triplicate at temperatures of 5, 15 and 25 ºC over 72-h following applications of a mixture of urine (0.8 L) and faeces (1.2 kg) deposited in each floor. This mixture (urine:faeces), after being homogenised, was spread uniformly over each floor surface which have originated an emitting layer with about 2 mm of thickness. The urine and faeces were obtained from lactating cows in a commercial dairy farm located in NW Portugal. Subsamples of urine and faeces were analysed by standard analytical methods to assess the following physico-chemical properties: pH, dry matter, total C and N, total ammoniacal N content (TAN), NO_3^--N and urea-N contents.

For the measurement of the NH_3 emissions in each replication, were used acid traps (containing 150 mL of H_3PO_4 0.02 M) with exposure periods of 1-h. One acid trap was connected to the inlet air tubes of the scale model and an air subsample (4 L min^{-1}) was driven through the acid trap to quantify the NH_3 in the air entering the chamber. Immediately after each scale model, a subsample of the outlet air was driven (4 L min^{-1}) through a second acid trap to collect the NH_3 emitted inside the container. The derivation of air subsamples was made by means of a vacuum pump and the flow rate controlled by a flow meter with a needle-valve located before the vacuum pump. The period of time that the airflow passed through the acid traps was recorded, and the NH_3 collected in the solutions was analysed for the TAN content. Ammonia emissions were measured 24-h day^{-1} for the first 24-h and then 20-h day^{-1} for the next 48-h to estimate the daily fluxes. The fluxes of N_2O, CO_2 and CH_4 were measured directly through a sampling point located immediately before and after the scale model, with a photoacoustic field gas-monitor (INNOVA 1412). The concentrations of these gases were made in each replication at 0, 0.5, 1-h, every 2-h during the first 24-h and every 6-h in the following 48-h. The emission rates of N_2O, CO_2 and CH_4 were determinate discounting, in each measurement period, the initial concentration of each gas in the inlet air.

The cumulative emissions of NH_3, N_2O, CO_2 and CH_4 were determinate by averaging the flux between two sampling dates and multiplying by the time interval between sampling dates. The cumulative emission was expressed as the percentage of total N and urea-N applied in each camera lost as NH_3-N and N_2O-N, and as the percentage of total C lost as CO_2-C and CH_4-C. Mean cumulative emissions were compared to evaluate the effect of

floor type and temperature using the two-way ANOVA procedure in STATISTIX 7.0. To assess the emission kinetics a Michaelis-Menten type curve (by nonlinear regression) was fitted to the cumulative gaseous emissions, as used by Sommer and Ersboll (1994).

3 RESULTS AND DISCUSSION

Cumulative NH_3, N_2O, CO_2 and CH_4 emissions at the three temperature levels during the first 72-h after excreta deposition on the solid and slatted concrete floors are shown in Fig. 1. The increase of the temperature between 5 and 15 ºC and between 15 and 25 ºC stressed the increase of cumulative NH_3 emissions with the raise of 10 ºC in those temperature intervals being responsible for, respectively, significant increases ($P < 0.05$) of 25 and 45% in the emissions. The effect of the temperature was not the same for the two types of floor. The increase of the temperature between 5 and 25 ºC increased significantly ($P < 0.05$) in 70 and 104% the cumulative NH_3 emissions, respectively, in the slatted and solid floor. At 5 ºC of temperature the mean cumulative NH_3 emissions, expressed in percentage of the amount of total N deposited on the floors, represented ca. 30% of total N in both types of floor. However, at 15 and 25 ºC cumulative values of NH_3 emission from the solid floor was about 36% higher than in slatted floor. Ammonia emissions from floor surfaces were influenced by the characteristics of the surface layer of the floor that affected the urea decomposition rate by the extent of the contact area between the urine and the enzyme urease present in floors, and by the characteristics of the emitting layer, namely the eventual presence of urine puddles that might have influenced the amount of urine in the floor surface (Aarnink et al., 1996; Braam and Swierstra, 1999). Cumulative N_2O emissions represented less than 0.1% of the total N deposited on the floors or by the urea in the urine. How was expected, N_2O emissions were very low in this study, which must have occurred in aerobic conditions throughout the nitrification process (Ellis et al., 2001). Denitrification was not likely to have occurred due the absence of NO_3^- in urine and faeces deposited on the floors. It was observed a significant increase ($P < 0.05$) of the cumulative N emissions in the two floors with the increase of the temperature and the time after deposition of the mixture on the floors (Figs. 3a and 3b). Following 36-h after deposition of excreta at 15 ºC, and also following 12-h at 25 ºC, cumulative N ($NH_3 + N_2O$) emissions were significantly higher ($P < 0.05$) in the solid than in the slatted floor. However, at 5 ºC emissions did not differ significantly ($P > 0.05$) between the two floors. At 5 ºC of temperature, cumulative N emissions in the two floors reached less than 50% of the amount of N as urea in the urine deposited on the floors. At 15 ºC cumulative N emissions represented between 51 and 73% of the urea-N in the urine applied and at 25 ºC this value was between 67 and 100% (Fig. 3b). Our results showed that at indoor air temperatures between 5 and 25 ºC, N emissions in dairy houses should be originated mainly from urea of the urine because N emissions were lower than 100% of N amount in the urea.

Cumulative CO_2 and CH_4 emissions, expressed in percentage of total C deposited by excreta, were lower than 20 and 0.4% of total C deposited on floors, respectively. In our study, cumulative CO_2 emissions corresponded to ca. 94% of the CO_2 originated by the hydrolysis of the urea. The cumulative C ($CO_2 + CH_4$) emissions were significantly higher ($P < 0.05$) in the solid floor comparatively to the slatted floor. These higher C emissions from solid floor were observed following the first 3, 6 and 24-h after deposition of mixture at 25, 15 and 5 ºC, respectively. The temperature increase and the time after deposition of mixture on the floors led to a significant increase ($P < 0.05$) of the cumulative C emissions (Fig. 3c). The cumulative GHG emissions, expressed as CO_2-equivalents, were determined to assess the warming potential of GHG (cumulative N_2O, CO_2 and CH_4) of the two floors under different temperatures. Results showed that GHG emissions were significantly higher ($P < 0.05$) in the solid floor (ca. +45%) than in the slatted floor and, for both floors, increased significantly ($P < 0.05$) with the increase of temperature (ca. twice higher for each 5 ºC of temperature raise). In both floors and at all temperatures, GHG emissions were originated mainly by CO_2 emissions (> 79%). Nevertheless, the contribution of CO_2 to the total GHG emissions decreased with the increase of the temperature. CH_4 emissions contributed with less than 17% to the total GHG in the two floors and at all temperatures, but were higher in the slatted floor relatively to the solid floor. The N_2O emissions represented less than 8% of the GHG in the two floors and at all temperatures (Table 1). Our results were in agreement with the results reported by Ni et al. (1999); these authors found important amounts of CO_2 release from manure in pig houses. Hence, it can be concluded that in dairy cattle houses with liquid systems, a major contributor to GHG from floors is the CO_2 emission due to the CO_2 release by urea hydrolysis. This suggests that the introduction of mitigation techniques for NH_3 emissions abatement will have effect on the reduction of the GHG emissions from buildings.

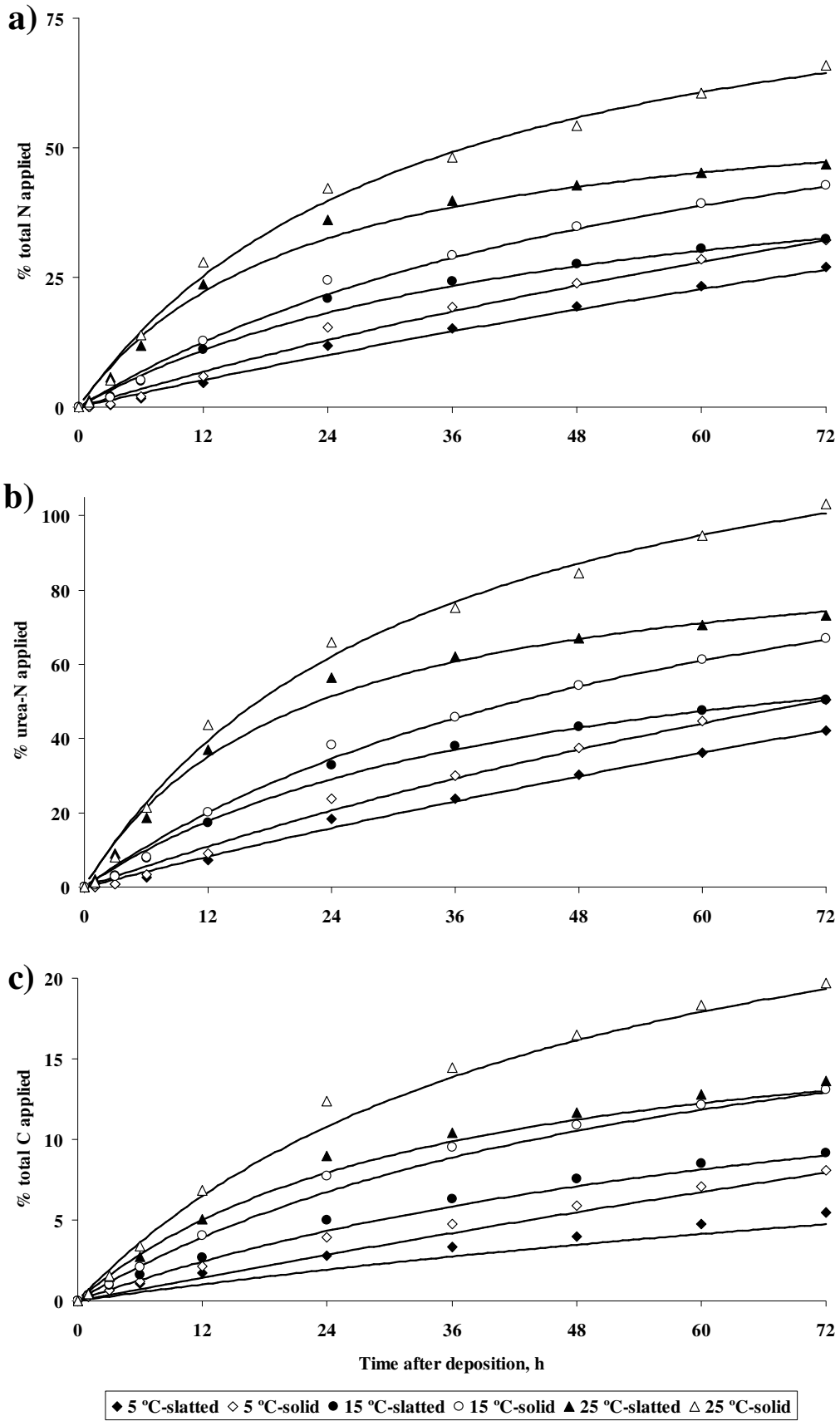

FIGURE 1 **Cumulative N ($NH_3 + N_2O$) and C ($CO_2 + CH_4$) emissions from excreta deposited on concrete floors in scale models: a) - as percentage of total N applied; b) - as percentage of the urea N applied; c) - as percentage of total C applied (N = 3).**

TABLE 1 **Total cumulative greenhouse gas emissions from excreta deposited on concrete floors in scale models and relative contribution of the different gases (N = 3).**

Floors	Temperature (ºC)	GHG emissions			
		[A] g CO_2-eq m^{-2}	[B] N_2O (%)	[B] CO_2 (%)	[B] CH_4 (%)
Slatted	5	19[d]	1	99	0
Solid	5	29[c]	3	96	1
Slatted	15	38[c]	5	84	11
Solid	15	53[b]	8	85	7
Slatted	25	60[b]	6	77	17
Solid	25	85[a]	8	79	13

[A] Cumulative (72-h) GHG emissions expressed in CO_2-equivalents m^{-2}.
[B] Percentage of N_2O, CO_2 e CH_4 emitted relatively to the total emission of GHG, respectively.

4 CONCLUSIONS

Important NH_3 and GHG emissions occurred from slatted and solid floors of cattle houses when indoor air temperatures ranged between 5 and 25 ºC. Results obtained show that ammonia emissions from both floors did not differ significantly at 5 ºC. In both floors ammonia emissions were significantly increased by temperature. Comparatively to 5 ºC, the cumulative emissions at 15 ºC were 25% higher in both floors, and at 25 ºC were 70 and 104% higher respectively in the slatted and in the solid floor. Average cumulative ammonia emissions were significantly higher, ca. 36%, in the solid floor. Cumulative GHG emissions (as CO_2-equivalents) were significantly higher in the solid floor (+45%) comparatively to the slatted floor and increased significantly with temperature. CO_2 emissions were the most important GHG emitted from the two floors at all temperatures, accounting to more than 79% of total GHG emission.

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