Relationship between cattle stocking density and NH3 emissions from cattle housing

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Introduction

Cattle housing is a major source of ammonia (NH_3) emissions to the atmosphere, accounting for *c*. 16% of total emissions from agriculture in the UK (Misselbrook *et al*., 2007). Such a significant emission source warrants both a robust estimate and also full consideration of potential mitigation strategies. The estimate of national NH_3 emission from cattle housing is derived using standard emission factors based on a number of observations on both experimental and commercial farms, differentiating between slurry-based and straw-bedded (deep-litter) systems. It is known that livestock density on outdoor concrete yards influences NH_3 emissions (Misselbrook *et al*., 2006), with less emission per animal for a greater livestock density. This knowledge might reasonably be transferred to slurry-based cattle housing, where we could assume that a reduction in the fouled floor surface area per animal would lead to reductions in NH_3 emission of the same order as observed in the outdoor concrete yards. However, a significant number of cattle in the UK are housed on straw-bedded systems (34% of dairy cattle and 82% of beef cattle), for which such assumptions regarding the relationship between stocking density and NH_3 emission may not apply. The aim of this study, therefore, was to assess the influence of livestock density on NH_3 emissions from cattle housed on a straw-bedded system.

Methodology

The study was conducted at IGER, North Wyke using a system of polytunnels designed specifically for measuring gaseous emissions from housed cattle (Gilhespy *et al*., 2006). To achieve different livestock densities, the floor area within each of the four polytunnels was kept constant and the number of animals housed was varied. Beef heifers (Red Devon, weight range 350 – 500 kg) were used in the trial with either 3, 4 5 or 6 housed per polytunnel, achieving area allowance per animal of 11.7, 8.8, 7.0 and 5.8 m^2 (hereafter referred to as treatments SD1, SD2, SD3 and SD4), respectively, all of which comply with the current minimum welfare standard. Cattle were housed for 6 weeks, with the first week being an acclimatisation period followed by 5 weeks of NH_3 emission measurement. The trial was conducted as a Latin square design, with a total of four 6-week housing periods with each livestock density treatment being allocated to each polytunnel once over the four measurement periods. Cattle were initially allocated to groups to achieve similar mean livestock weight between groups and were retained in those groups for the entire trial.

Straw bedding was added three times per week, with a target straw addition of 4 kg per animal per day. The cattle were fed hay on an *ad libatum* basis, with the total quantity consumed by each group being recorded. Samples of straw and hay were taken on a regular basis for dry matter and total N analyses. Following each of the 6-week housing periods, cattle were removed from the polytunnels and weighed to establish liveweight gain. The total quantity of farm yard manure (FYM) generated in each polytunnel was weighed and samples taken for total N, total ammonical N, dry matter and pH determinations.

Ammonia emission measurements were made on two occasions per week for 5 of the 6 weeks of each housing period. The polytunnels housing the cattle were essentially used as large dynamic chambers, being mechanically ventilated for each 4-hour measurement period with air inlet via a reduced opening at the rear of the tunnel and air exhaust via a fan at the front. Between measurement periods, the polytunnels were naturally ventilated via large openings at front and rear. The NH_3 emission over each 4-hour period was determined as the product of the difference in concentration between inlet and outlet air (subsampled through acid absorption traps) and the total air volume flow through the tunnel. Cumulative NH_3 emission from each group of cattle over each housed period was derived by interpolation between measurement occasions. Ammonia emissions from the different livestock density treatments were compared using analysis of variance (GENSTAT) based on the Latin square design.

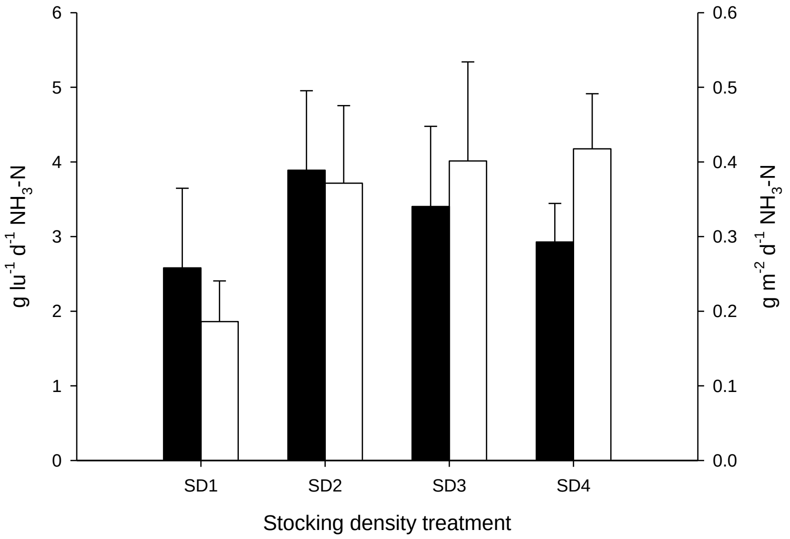
Results and Discussion

Mean emission rates per treatment for each of the four housing periods were in the range 1.2 – 6.6 g lu^{-1} d^{-1} NH_3-N (where lu is livestock unit = 500 kg liveweight). These are much lower than the mean emission factor of 17.2 g lu^{-1} d^{-1} NH_3-N reported by Misselbrook *et al.* (2000). This is most probably because of the very low protein diet of the cattle in this study - hay with a mean N content of only 11 g kg^{-1} DM, with no concentrate supplements. The cattle were on a maintenance only diet and this was reflected in the minimal liveweight gains over the housing period of 0.1 – 0.2 kg $animal^{-1}$ d^{-1}.

Mean emission rates over the entire housing period were not significantly different between stocking density treatments (P>0.1), whether expressed on a per liveweight basis or on a per m^2 floor area basis (Fig. 1). There was no significant relationship (P>0.1) between either mean emission rate per livestock unit or mean emission rate per m^2 floor area and the area allowance per animal. Excluding the lowest stocking density (11.7 m^2 per animal), a significant relationship did exist between emission per livestock unit (F, g lu^{-1} d^{-1} NH_3-N) and area allowance per animal (A, m^2 $animal^{-1}$):

$$F = 0.040 + 0.105A \qquad (r^2\ 0.855)$$

Figure 1. Ammonia emission rates from straw-bedded beef cattle housing on a per livestock unit (black bars) and per m2 floor area (white bars) basis for each stocking density. Error bars show ± one standard error of the mean.



There was some evidence, therefore, of a similar effect as observed with emissions from outdoor concrete yards used by cattle, *i.e.* a decrease in emission per animal as stocking density increases while emission per m^2 floor area remains the same. The lowest stocking density did not fit with this relationship. Visually, this treatment remained the cleanest, with least trampling and wetting of the straw bedding. The straw bedding would have therefore been a more effective physical barrier to emission in this treatment than at the higher stocking densities. In this study, straw addition was kept constant per housed animal and was therefore increasing per m^2 floor area with increasing livestock density. A previous study has shown that increasing straw use per animal can reduce NH_3 emissions from straw-bedded beef cattle housing (Gilhespy *et al*., manuscript in preparation). The results from the present study would indicate that for a given straw use, increasing livestock density can reduce NH_3 emissions. However, there may be interactions between the effects of straw use per animal and straw use per floor area and further study combining these treatments would be beneficial in producing recommendations for optimal livestock density and straw use. Additionally, baseline data are required on current commercial practices regarding stocking densities and straw use for beef cattle housing.

A nitrogen balance was conducted for the entire housing period for each stocking density treatment (Table 1), with measured outputs and losses accounting 82 – 90 % of measured N inputs. There may have been some small unmeasured N losses via denitrification and leaching, and errors in measurements of both inputs and outputs, but the high proportion of input N which has been accounted for lends confidence to the results. Mean N excretion per animal, calculated as the difference between feed N input and liveweight gain, was equivalent to 39 kg $year^{-1}$. This is substantially less than the mean value of 56 kg $year^{-1}$ N assumed for cattle for this size and age in the UK NH_3 emissions inventory (Misselbrook *et al*., 2007), again a reflection of the diet of the animals in the present study. Ammonia emissions accounted for an average of 2.5 % of N excretion across all treatments, an emission factor much lower than that given by Webb and Misselbrook (2004) for straw-bedded cattle housing of 12.5 % of N excretion. The NH_3 emission derives predominantly from the readily available N excreted, which is largely the urea component of urine. This is often referred to as total ammoniacal N (TAN) and Webb and Misselbrook (2004) assume as standard that 60% of N excretion is as TAN, deriving an emission factor for straw-bedded cattle housing of 21 % of TAN excreted. In the present study, no measurements were made of urine or faecal N, but it might be assumed that the TAN content would represent a much lower proportion of total N excretion because of the low protein diet used.

Table 1. Nitrogen balance for housed beef cattle

Treatment	N inputs (kg per 500 kg liveweight)		N outputs (kg per 500 kg liveweight)			% N input unaccounted
	Feed	Straw	LWG	FYM	Ammonia	
SD1	15.1	7.9	0.5	19.8	0.4	10
SD2	14.4	7.5	1.1	17.5	0.6	12
SD3	14.5	7.4	0.4	17.2	0.6	17
SD4	15.2	7.1	0.8	17.0	0.5	18

Conclusion

Ammonia emissions from beef cattle on a low protein hay diet, in straw-bedded housing, were low, averaging 3.2 g lu^{-1} d^{-1} NH_3-N or 2.5 % of N excretion. Although there were no significant differences between treatments, there was some evidence of decreasing NH_3

emission per animal with increasing stocking density. This relationship did not hold at the lowest stocking density, presumably due to the maintenance of a clean straw bed.

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