# On-Farm Methane and Ammonia Emissions from Housing and Manure Storage in Ireland

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## Abstract
Agriculture is the principle contributor to both ammonia ($NH_3$) and methane ($CH_4$) emissions in Ireland, with losses from cattle housing and slurry storage facilities representing substantial sources of both gases. To date, there have been very few studies quantifying these gaseous losses from facilities in Ireland. Ammonia and methane fluxes were measured from cattle housing and/or outdoor tanks on two beef and two dairy farms. The impact of abatement strategies, such as slat mats and valves, altered diet and aeration were also investigated on individual farms. Mean ammonia and methane emissions were 16.6 ± 8.4 g $NH_3$-N 500 kg $LW^{-1}$ $d^{-1}$ and 112 ± 93 g $CH_4$-C 500 kg $LW^{-1}$ $d^{-1}$ respectively. Slat mats with valves that covered the slat opening were observed to reduce $NH_3$ emissions, while aeration induced a large increase in $NH_3$ with unclear effects on $CH_4$ losses.

### Introduction
Globally, animal production systems contribute significantly to both greenhouse gas (GHG) and transboundary gaseous emissions. Methane ($CH_4$) comprises the majority of greenhouse gas emissions within the livestock sector and is principally associated with either enteric fermentation within ruminants or storage and management of slurries and manures. Recent estimates suggest that animal husbandry accounts for 45% of the total emissions attributed to agriculture, with 70% of these emissions originating from cattle systems, and 25% of this amount being emitted from the manure in barns or during storage [1, 2].

In Ireland, agriculture accounts for 32% of total greenhouse gas (GHG) emissions and 98% of total ammonia ($NH_3$) emissions. Dairy and non-dairy cattle account for the majority (63%) of the agricultural sector GHG emissions and 76% of $NH_3$ losses. Methane and $NH_3$ emissions associated with slurry management constitute 12% and 30% of sectoral GHG and $NH_3$ emissions respectively [3, 4]. Within Food Harvest 2020 targets, dairy and beef production are envisaged to increase in Ireland by 50% and 20% respectively [5]. Concurrently, the EU 2020 Climate and Energy Package has set a 20% reduction targets for GHG's. Allied to this, future ammonia emissions targets are likely to be more stringent.

There are currently few empirical gaseous emissions studies on housing and storage systems in Ireland, and emissions inventories are currently generated using Tier 1 methodologies. The objective of this experiment was to evaluate two beef farms (BFa, b) and two dairy farms (DFa, b) in Ireland with differing manure management systems and report on the $CH_4$ and $NH_3$ emissions associated with housing and storage from each management system.

### Material and Methods
*Field experiment*
Ammonia and $CH_4$ emissions were measured on five farms in Ireland. These comprised two beef farms and two dairy farms with varying diets, slurry management systems and animal types. One beef farm (BFa) had three under-floor slatted slurry tanks in naturally ventilated sheds. The animals and diets fed on each slatted tank are described in Table 1. Emissions on the second beef farm (BFb) were measured from two separate tanks within the same naturally ventilated slatted shed, with each tank having the same animal type and diet, but differing in slatted surface, with one tank having concrete slats, and the other having curved slat mats fitted with valves designed to restrict air passage from the under-slat to the above-slat air space (Table 1).

Housing on the first dairy farm (DFa) consisted of a naturally-ventilated shed with four separate tanks that were aerated four times daily. The second farm (DFb) had cubicle housing with slurry being removed by regular scraping into an outdoor open tank adjacent to the shed.

*Gas measurements*

Concentrations of $CH_4$ emissions for BFa and BFb were measured using a photoacoustic analyser (LumaSense Technologies, Inc., Denmark) at specific heights (10cm, 20cm, 60cm and 150cm) above the slat surface on all five farms, during the winter housing period October 2011 to March 2012. Each tank was measured for a period of 40 minutes, alternating between the four different heights at 1 minute intervals. External (ambient) concentrations were also measured during each 40 minute cycle. Ventilation rates through the housing were measured using tracer techniques and fluxes generated from the difference between inside and outside concentrations scaled for the airflow through the housing system. Integrated daily ammonia concentrations were measured using acid traps (Ferm tubes coated with 3% oxalic acid) were deployed for 24 hours in the housing systems.

For all housing and lagoon systems, emissions were also measured at various heights (as above) both up-wind and down-wind of the housing and lagoon systems using photo-acoustic analysis and acid-trapping. Concentration measurements were combined with windspeed and direction data (Campbell CSAT anemometer, UK). Daily emissions were subsequently generated using Windtrax 2.0, which generated point source emissions using backward Lagrangian stochastic dispersion modelling (BLs).

Slurries were analysed for their main chemical characteristics. Dry matter was determined by drying duplicated subsamples of each manure type in an oven at 105°C for 24 hours. Total ammoniacal nitrogen ($NH_4$-N) was extracted from fresh mixed slurries by shaking 25g of manure in 500 ml 0.1 M hydrochloric acid on a peripheral shaker and filtered through Whatman No. 2 filter paper. The $NH_4$-N concentration was determined by analysing the filtrate on an Aquakem 600 discreet analyser (Thermo Electron OY, Vantaa, Finland). Total nitrogen was determined on fresh slurry samples using the Kjeldahl digestion method. The emissions of $NH_3$-N and $CH_4$-C were normalised across tanks and farms on an emissions per 500 kg liveweight (LW) basis.

## Results

*Ammonia emissions*

Ammonia emissions were observed to be highly variable across all farms, with daily mean fluxes ranging between 4.5 g $NH_3$-N 500 kg $LW^{-1}$ $d^{-1}$ and 33.1 g $NH_3$-N 500 kg $LW^{-1}$ $d^{-1}$ (Table 1). The mean ammonia emission across all farms was 16.6 ± 8.4 g $NH_3$-N 500 kg $LW^{-1}$ $d^{-1}$. The lowest emissions were associated with beef cattle housing that had employed slat mats with valves and this abatement technique was observed to reduce ammonia emissions by 60% (Table 1). However, there were no differences in emissions from either grooved or curved mats on farm BFa. Emissions from the outdoor lagoon on dairy farm DFb were 70% lower than the mean $NH_3$ emission rate at the other dairy farm and this may be related to lower temperature associated with outdoor storage. In contrast, some of the highest ammonia emissions were associated with housing that had employed automatic aeration systems to agitate the slurry (DFa) as aeration promoted volatilisation. There was no clear effect of animal type and/or diet on ammonia emissions.

**Table 1. Description of animal type, housing/storage, and diet, and associated slurry chemical characteristics and emissions measured on each of the farms used in this study.**

| Farm | Description | Animal type | Storage type | Manure management system | No. animals | Mean LW (kg hd$^{-1}$) | Tank area (m$^2$) | Diets | Slurry DM content (%) | Slurry $NH_4$-N content (g kg$^{-1}$) | $NH_3$–N emissions (g 500 kg LW$^{-1}$ d$^{-1}$) | SD | $CH_4$–C emissions (g 500 kg LW$^{-1}$ d$^{-1}$) | SD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BFa | Slatted floor grooved mats | Suckler Cows | Indoor | Agitation prior to landspreading | 14 | 710 | 56 | Grass silage ad lib & 1.5 kg rolled barley to rape cake (4:1) mix | 11.8 | 3.2 | 16.8 | 4.44 | 47 | 6.0 |
| | Slatted floor grooved mats | Steers | | | 7 | 350 | 27 | Straw ad lib & 3 kg rolled barley & balancer (3:1) mix | 10.2 | 2.1 | 15.0 | 0.30 | 48 | 11.3 |
| | Slatted floor curved mats | Heifers | | | 34 | 265 | 56 | Grass silage ad lib & 1.5 kg barley to rape cake (4:1) mix | 9.1 | 1.8 | 19.1 | 4.81 | 45 | 9.4 |
| BFb | Slatted floor no mats or valves | Steers | Indoor | Agitation prior to landspreading | 24 | 280 | 61 | Grass silage & concentrates | 9.4 | 2.4 | 10.9 | 8.01 | 300 | 226.9 |
| | Slatted floor, curved mats & valves | | | | 25 | 295 | 61 | | 9.8 | 2.1 | 4.5 | 2.89 | 193 | 44.1 |
| DFa | Grass silage | Dairy Cows | Indoor | Slatted flooring with aeration | 24 | 590 | 72 | Grass silage | 8.3 | 3.2 | 21.6 | 9.05 | 75 | 34.7 |
| | Maize silage | | | | 24 | 595 | 72 | Maize silage | 8.9 | 3.6 | 19.6 | 7.39 | 44 | 18.7 |
| DFb | Open tank | Dairy Cows | Outdoor | Agitation prior to landspreading | 27 | 650 | 137 | Grass silage | 8.2 | 1.5 | 8.6 | 5.44 | 144 | 66.5 |

*Methane emissions:*
The mean methane emission rate across all farms and cattle type was 112 ± 93 g $CH_4$-C 500 kg $LW^{-1}$ $d^{-1}$ with mean daily fluxes ranging from 44 g $CH_4$-C 500 kg $LW^{-1}$ $d^{-1}$ for steers and heifers on BFa to 300 g $CH_4$-C 500 kg $LW^{-1}$ for steers on BFb. The highest emissions on farm BFb may be due to the fact that the measurement period encompassed several agitation events resulting in ebullition of methane from the slurry tank (Table 1). Despite these high levels, slat mats and valves appeared to reduce methane emissions by 35%. Methane emissions from dairy cows fed a predominantly maize diet were 41% lower compared to cows on a grass silage-based diet on Farm DFa (Table 1). Emissions associated with a predominantly maize silage diet are likely to have resulted in reduced emissions due to changes in slurry C:N ratio. Comparably low methane values (45 - 47 g $CH_4$-C 500 kg $LW^{-1}$ $d^{-1}$) were recorded on beef farm BFa and these emissions were independent of animal type. The effect of aeration on methane emissions was inconclusive. Whilst emissions from the dairy housing with aeration (DFa) were 59%-76% lower than those from dairy cows on Farm DFb or steers on BFb, the emissions were similar to those from beef cattle on farm BFa.

## Conclusion and perspectives

Farm emissions of ammonia and methane were highly variable. In general, both $NH_3$ and $CH_4$ emissions were higher for dairy cows, whilst slat mats and valves appear effective at reducing ammonia emissions. In contrast, aeration increased ammonia loss three-fold while the effects on methane emissions were inconclusive. Further farm monitoring and the inclusion of additional farms would provide a more extensive dataset for use in the development of National ammonia and methane inventories.

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