Establishing ammonia emission factors for shallow pit, fully-slatted finisher buildings

Summary

Ammonia (NH_3) emissions levels determined for a fully slatted, shallow pit (<900mm) pig finisher building were determined to be significantly lower than current figures being used by the Environment Agency (EA) for permitting and permissions.

The reduction in determined emission levels are anticipated, due to a variety of factors, eg improved measuring capability and control in building environment, in addition to developments in diet formulation, genetics and modern production systems. It has been reported that 'Much of the work on which UK emissions estimates from buildings and stores are based has not reported data with enough explanatory variables to fully account for variation among reported NH_3 emissions' (Ricardo-AEA, 2014). 'Existing studies used in the preparation of the UK NH_3 inventory provide little supporting data, particularly with respect to factors such as the diet fed to the pigs, nitrogen (N) and total available N (TAN) excretion and the floor area allowed per animal' as reported by (Ricardo-AEA, 2014). Key factors not reported include growth rate and feed conversion ratio (FCR) of the pigs.

The study was conducted on a commercial farm operating to their standard practice. The study followed the Verification of Environmental Technologies for Agricultural production (VERA) Test Protocol for Livestock Housing and Management to ensure the results could be compared with other studies and were not open to the same uncertainty of past studies.

Ammonia was quantified over a year for three batches of pigs from approximately 40–120kg. This allowed us to capture emissions values during all four seasons to remove any seasonal variation. The average ammonia emission was found to be 1.72kg per animal place per year. The range recorded was 0.57 to 2.76kg. In comparison, the EA ammonia emissions factor (kg NH_3/animal place/year) is currently at 3.1 for this type of system.

Background

Ammonia is an important air pollutant that can have significant effects on both human health and ecosystems. Agriculture plays a significant role in contributing to NH_3 emissions and accounts for approximately 81 per cent of total ammonia emissions on an annual basis (Defra, 2018). As a consequence, reduction targets of 23 per cent by 2020 have now been put into place.

Emissions for inventory purposes (Environmental Permitting Regulation/Integrated Pollution Prevention and Control) and environmental impact modelling are calculated from a series of emissions factors that are linked to pig age and housing type. In October 2014, a report for AHDB Pork (formerly BPEX) by AEA Technology highlighted a shortcoming with the emission factors currently in use. In summary, it was concluded that 'from what the emission estimates from buildings and stores are based on, it has not reported data from enough explanatory variables to fully account for variation among reported NH_3 emissions'. These variables include protein levels of the feed fed (growth rate and FCR) and the floor area allowed per animal, both of which have changed dramatically over the last few years. The need for up-to-date, accurately and scientifically measured emissions factors has become all the more relevant as the European Commission published the Intensive Farming Best Available Techniques reference document (BREF), Version 2 in February 2017. This now includes emission limits associated with Best Available Techniques ammonia emission limits (BAT AELs) which must be complied with by IPPC/EPR permit holders. The aim of the study is to establish an ammonia emission factor in kilograms per animal place per year (kg/AP/yr) from a fully slatted, fully ventilated finisher building with a shallow pit (<900mm).

Materials and Methods

Buildings

Two modern, commercial, fully slatted, fully ventilated pig finisher buildings were used for the study. The slurry pits are emptied every 6–7 weeks.

The internal layout of the buildings is identical. Each building consists of two rows of pens (six on each side) running the length of building with a central walkway. The building is designed to house 420 pigs per room, with two rooms per building. Each pen houses approximately 35 pigs. The layout of the buildings is demonstrated in Figure 1.

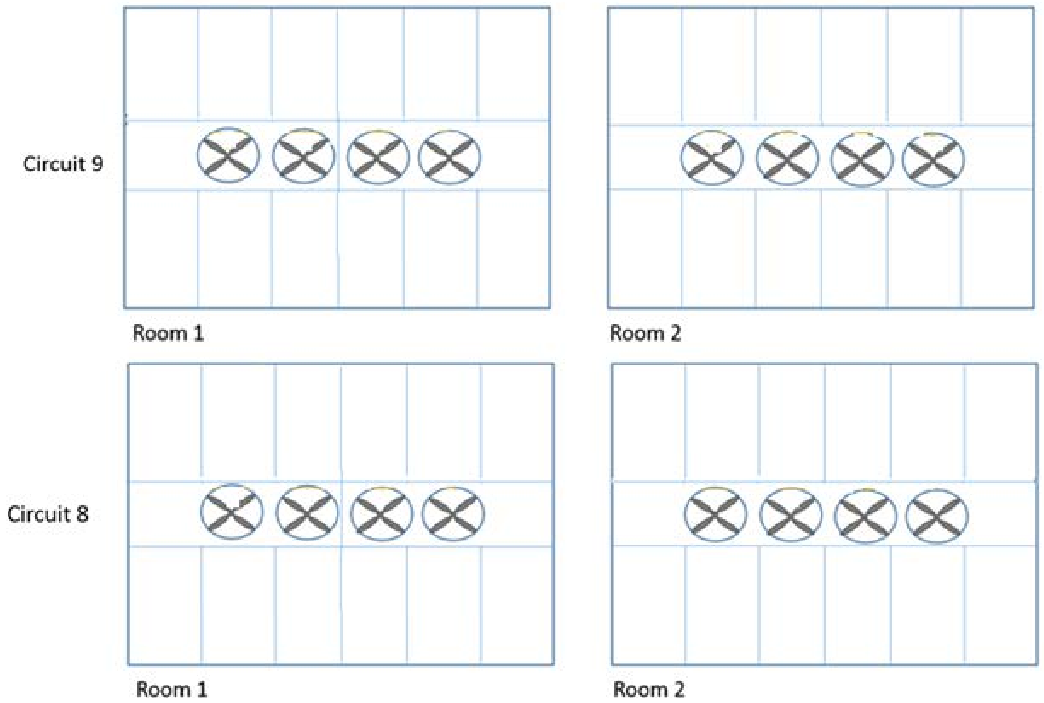

Figure 1: Building and pen layout (not to scale)

The dimensions and measurements of the building are outlined in Table 1.

Table 1: Dimensions and measurements of the building

Building feature	Detail/measurement
Length of building	19.2 metres
Width of building	13.98 metres
Height of eaves	2.13 metres
Flooring type	Plastic slats
Depth of slurry pit	0.914 metres
Drinkers	2 (nipples)
Pen size	6.4 metres x 3.17 metres
Feeder space	1.6 metres per pen
Feed form	Wet feed (co-products)
Building set temperature	15-18°C

Pigs enter the building at approximately 40kg and leave at approximately 120kg (roughly 92 days). The building is filled in two stages, approximately six days apart (eg one room is filled first and then the second is filled six days later). While sampling is continuous, data has only been analysed when the building was fully stocked.

Circuit 8 building consists of 8 x 710mm fans (four in each room), with a capacity of 60,000m^3/hour (per room) and 1 per cent vent of 600m^3/hour. Circuit 9 Building consists of 8 x 630mm fans (four in each room), with a capacity of 40,000m^3/hour (per room) and 1 per cent vent of 400m^3/hour. All fans were run in two pairs in each room at variable speeds with duty fans rotating to ensure wear is evenly distributed between pairs of fans.

There are two temperature sensors in each room which are coupled to a "Dicam" controller (Farmex), which is a proportional or "P" type ventilation controller. These temperature sensors and Dicam control the ventilated rate on a room-by-room basis to maintain a stable environment.

Both buildings and ventilation systems have been built to comply with BS 5502.

The building conforms to the requirements of the Verification of Environmental Technologies for Agricultural production (VERA) Test Protocol for Livestock Housing and Management Systems. The building has been used for more than one batch of pigs. In excess of 50 pigs are housed in the weight range of 25–110kg liveweight. Growth rate in previous batches is in excess of 760g per day.

VERA states that buildings must not exceed 3000ppm of CO_2 (as per section 5.3). We have ensured this is the case during the monitoring periods by first using buildings built to BS 5502 (which must provide ventilation to maintain CO_2 concentrations below 3000ppm) and by monitoring for any abnormal ventilation events.

Stocking rates in the building meet Red Tractor standards, which are shown in Table 2.

Table 2: The minimum permitted space allowances defined by the average weight of pig

Average Liveweight (kg)	Minimum Total Floor Area (m2/pig)
<10	0.15
10.1 – 20	0.20
20.1 – 30	0.30
30.1 – 50	0.40
50.1 – 85	0.55
85.1 – 110	0.65
>110	1.00

Monitoring

Ammonia concentration – Measurements of ammonia concentration were taken at the inlet and exhaust points in accordance with the Test Protocol for Livestock Housing and Management Systems (developed by VERA). The equipment used to monitor ammonia levels was a 'Solus' multipoint portable ammonia analyser (Protea). The Solus is based on the LGD F200 tuneable diode laser (TDL) sensor. The machine was calibrated at the beginning and end of the study and was rechecked at the end of the study and found to be accurately recording ammonia within specification. For details of the calibration, see report (Appendix 1). Ventilation systems were checked prior to the study commencing to ensure they were functioning correctly.

Air samples for analyser were taken from 10 points, with the eleventh sample acting as a purge of the optic as shown in Figure 3. Those labelled as a fan are the exhaust points and the two ambient sample points are external to the building.

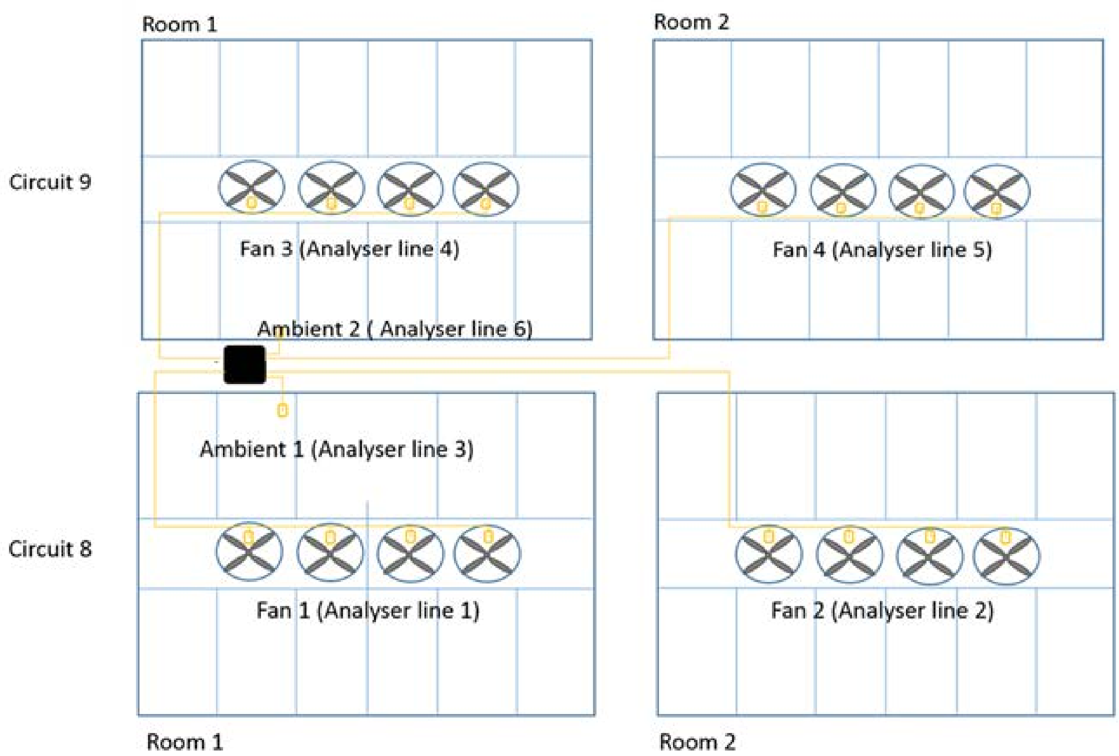

Figure 3: Pen layout and numbering for ammonia analyser sampling points (not to scale)

Samples were collected throughout the study period on a continuous basis during the time the building was fully stocked.

Three production cycles (batches) were monitored in total across a 12-month period.

The analyser was located in a secure insulated box on the floor between the two buildings as shown in photo 1.

Photo 1: Area between two buildings to place ammonia analyser

Ventilation rate

Ventilation rate and internal temperature for each room, plus external temperature, were continuously monitored and logged by an online environmental recording system (Farmex).

Pig numbers

The number of pigs entering the building at 40kg was recorded. Pigs that were drawn early for another contract were also recorded, alongside the draw date and the average weight.

Analysis of data

1. Average inlet and outlet ammonia gas concentration were calculated for each sampling cycle period (approximately 17 minutes).
2. The average inlet ammonia concentration was subtracted from the average outlet value to create a 'net' concentration figure.
3. The net concentration figure provides the ammonia concentration in the air leaving the building via the fan shaft (exhaust point) in ppm (attributed to the housed pigs).
4. The net concentration figure was then converted to grams of ammonia per m3 of air (g/m3) using the fixed conversion figure of 0.0007*.
5. This figure was then multiplied by the ventilation rate closest in time to the concentration readings (to provide a kg of ammonia leaving the building per hour, as ventilation rate is expressed as m3/hr), multiplied by 8760 (to provide kg ammonia per year) and then divided by the number of pigs that entered the building at the beginning of each batch recorded.
6. This figure was then multiplied by a percentage occupancy figure of 92 per cent (based on the number of days that the building is completely empty in a year) to provide a kg/ap/yr ammonia figure.

The calculation methodology was verified by Rothamsted Research.

*The fixed figure of 0.0007 is derived from the ideal gas law that states that any gas at 1 atm pressure and 25°C occupies 24 litres. 17 (the molar mass of ammonia) is then divided by 24 to provide a conversion from PPM to grams per m3 of 0.7. This was divided by 1000 to provide a conversion factor of 0.0007 from ppm to kg/m^3 of ammonia (assuming the building is at 1 atm at 25°C).

Results

Table 3 shows the results of the study. In production period 3, C8 RM1 and C8 RM 2 were excluded from analysis due to veterinary intervention as a result of a health breakdown during the batch.

As per section 5.7 of the VERA protocol that states 'Measurement results during which the test location did not comply with the required management conditions (5.3)' the data from Circuit 8, rooms 1 and 2 for period 3 has been discounted as the pigs did not meet the required management conditions.

Table 3: Results from the study

Production period	**Circuit and room**	**Date batch started**	**Date batch finished**	**DWLG**	**NH_3 Emission Factor (kg/ap/yr)**	**Number of pigs**
1	C8 RM1	12/04/16	13/07/16	870	2.71	420
	C8 RM2	18/04/16	18/07/16	879	1.46	421
	C9 RM1	14/03/16	08/06/16	930	1.00	420
	C9 RM2	08/03/16	06/06/16	889	0.57	420
2	C8 RM1	19/07/16	26/10/16	808	2.35	422
	C8 RM2	25/07/16	27/10/16	851	1.84	420
	C9 RM1	13/06/16	19/09/16	816	0.97	402
	C9 RM2	13/06/16	19/09/16	816	1.14	420
3	C9 RM1	26/09/16	14/12/16	1001	2.39	420
	C9 RM2	26/09/16	13/12/16	1002	2.76	419
Average		/	/	/	1.72	/

Table 4: Pig movements during the study

Production period	**Pigs in total**	**Number of light pigs drawn ***	**Average weight of light pigs drawn**	**Production day at draw**	**Pigs remaining to bacon weight**
1	C8 RM1	0	/	/	420
	C8 RM2	45	83.1	13/06/16	376
	C9 RM1	43	83.5	09/05/16	377
	C9 RM2	47	84.5	02/05/16	373
2	C8 RM1	26	81.4	09/09/16	396
	C8 RM2	26	82.0	09/09/16	394
	C9 RM1	50	83.2	01/08/16	352
	C9 RM2	26	82.8	08/08/16	394
3	C9 RM1	33	83.0	14/11/16	393
	C9 RM2	42	82.7	07/11/16	385

*A number of pigs from each production period were sold part way through the production period (on average 83kg). The number sold varies from 0–50 across the periods. The emission factor was calculated in two sections, the first takes into account the total number of pigs housed before a selection were pulled light. The second was calculated based on the number of pigs remaining in the building till slaughter weight. This was then weighted as a percentage of time spent in each period and then corrected for annual occupancy rates per room.

The pigs were fed a combination of two diets during the finisher period. The percentage of these diets and the specification are detailed in Table 4.

Table 5: Diet specification and details

Week number	Pig weight (kg)	Mix 1 (% fed)	Mix 2 (% fed)	TOT LYS (%)	CP (%)
Week 1	40	100	0	1.28	21.37
Week 2		100	0	1.28	21.37
Week 3		80	20	1.24	20.85
Week 4		70	30	1.23	20.59
Week 5		60	40	1.21	20.33
Week 6		50	50	1.19	20.07
Week 7	76	40	60	1.17	19.80
Week 8		25	75	1.15	19.41
Week 9		15	85	1.13	19.15
Week 10		0	100	1.1	18.76
Week 11		0	100	1.1	18.76
Week 12		0	100	1.1	18.76
Week 13	120	0	100	1.1	18.76

Discussion

Table 2 shows that all three batches have an emission factor lower than current figures used by the EA. This creates an average of 1.72kg of ammonia per pig place per year (range of 0.57 to 2.76kg).

A review carried out by the Danish Ministry of the Environment in 2014 highlighted some of the factors influencing ammonia emissions include the floor type, emitting surface in the pit and the slurry depth (Danish Ministry of the Environment, 2014). Aarnink and Wagemand (1997) report that between 25 per cent and 75 per cent of the NH_3 emissions in a pig system originate from the slurry pit below the floor, while the rest comes from the fouled portion of the floor, thereby management can be a large influencing factor.

The study was carried out as per the VERA protocol using a calibrated a TDL gas analyser. In comparison with some of the previously published work, which was used to produce the existing emission figures, this study was based on current (2016/17) genotypes, finishing rations and production regimens. In 1995, when the emissions were originally documented, the average growth rate of pigs was significantly lower than today's production figures. However, today it is common to see an average of 841g/day (AHDB, 2018). In addition, slaughter weights have also increased from 67.2kg in 1995 to an average of approximately 82kg in 2016. As a result, the industry is producing heavier pigs over a shorter period of time. Considering this, these figures are robust and more representative of current emissions from commercial, fully slatted finisher buildings in England.

In addition to regular removal of slurry, or part slatted systems, you would expect this figure to be even lower.

Significance and relevance to the pig industry

IPPC/EPR is a challenge for some pig businesses when they look to expand their holding. Ammonia modelling and the prediction of ammonia emissions is a key part of the IPPC/EPR process. The models are based on emissions factors that were highlighted in a 2014 report that was commissioned by BPEX (now AHDB Pork) as not reporting 'data from enough explanatory variables to fully account for variation among reported NH_3 emissions'.

These studies have allowed for more up-to-date and accurate figures to be scientifically determined for a variety of pig housing in the UK, using current diets, ventilation and management practices. Currently, this figure is lower than those used in the existing model by government agencies or consultants. This suggests that existing and future planned sites may be emitting less ammonia than was previously thought. This may ease the permitting process for many producers, or even alter the stocking limits on non-permitted sites.

The potential impact of this on UK pig production is considerable. These findings possibly limit the need for farmers to invest large amounts of capital in abatement technologies, which are then expensive to run on a per pig basis. As more emissions factors from other housing types are added to the study, we can more accurately compare UK-based emissions factors for these various housing types. This means that producers could potentially choose their housing type taking emissions levels into consideration. This would reduce the environmental impact of their production system and future-proof their businesses against future emissions regulations to some degree. It also allows the pig industry in the UK to actively engage with and contribute toward the industry target of a 23 per cent reduction in emissions by 2020.

In conclusion, the results from this study have been highly encouraging. A rolling programme of work is being carried out to allow for emissions factors to be accurately quantified from as many differing types of finisher and sow housing as possible, to create a database of routinely updated, scientifically established emissions factors for UK production.

References

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Appendices

Appendix 1. Ammonia analyser calibration information

Protea
technology leadership
in measurement solutions

SERVICE SUMMARY

Customer:	AHDB Pork	Protea Service Contract Number:	S11046-2
Date of service:	19/04/2017	Customer Purchase Order Number:	812599
Contact name:	Sue Rabbich	Telephone:	07772 598 412
Service Carried out:	☑ Protea ☐ Site	E-mail:	Susan.Rabbich@ahdb.org.uk
Service Engineer:	Jake Holden		
Analyser Model#	SOL-T	Analyser S/N:	SOL-T-1601
Description of application/usage of analyser:	Ammonia gas analyser		
Reason for Service:	☑ 6 monthly service ☐ 12 monthly service ☐ 1 off service ☐ Unscheduled maintenance ☐ Warranty Repair		

Description of problems before work and remedial work before serice

N/A

Work carried out :

☑	Confirm system details, current operation, recent issues and visual check
☑	Fault find and fix issues
☑	Carry out performance validations
☑	Gas cell service, inc. replacement of windows, o-rings, seals as appropriate
☑	Flow, temperature and pressure calibration of FTIR analyser all passed
☐	Replacement of O2 sensor (if appropriate)
☑	Re-assemble, validate and adjust analyser optics
☑	Record performance validations post-service. All passed. Instruct for future service needs on FTIR parts
☑	Sampling system equipment checks. Temperature, flow and pump checks. Alarm validations. Probe checks.
☑	Span gas validations carried out and passed
☑	Save updated calibration files

Notes:

Cleaned all the pipework inside the instrument, replaced servicable parts of the sample pump, re-calibrated the cell pressure sensor and gas cell cell. There has been quite a bit of liquid found inside of the pipework and pump, it is recommended that a knock-off pot be installed after the valves to stop the ammnia being absorbed by the liquid. The PAS-Pro software was outdated, updated to the newer 1.14.13 version.

Parts Used:

Part Number	Description	Qty	Unit Price	Discount	Price
					£ -
					£ -
					£ -
					£ -
					£ -
					£ -
					£ -
				PARTS SUB TOTAL	£ -

Labour Charge (normal hours)	hours @ £	75 /hour	£ -
Mileage Charges	miles @ £	0.45 /mile	£ -
	Other Travel Costs		
	Subsistence		
	TOTAL		£ -

Full service tasks check sheet and diagnostic results sheet available on request

Signed for Protea Limited:		Signed (Customer):	

PROTEA LIMITED
10 Propserity Court
Middlewich, Cheshire UK
CW10 0GD

Form PL 47/4

Span Check

Analyser:	SOL-T-1601	Date:	19/04/2017

Gas cylinder number:

Certificate number: 40006443275

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Component	Certified Concentration	Stable readings	Average	Difference / Conc.	Difference / %
NH_3	9.7	9.24	9.24	0.5	4.7

AHDB