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Title	Profile of ammonia and water vapor in an Irish broiler production house
Authors(s)	Kelleghan, David B.; Hayes, E. T.; Curran, Thomas P.
Publication date	2016-06-20
Conference details	American Society of Agricultural and Biological Engineers (ASABE) Annual International Meeting, Orlando, Florida, USA, 17-20 July 2016
Publisher	ASABE
Link to online version	http://www.asabemeetings.org/
Item record/more information	http://hdl.handle.net/10197/7802
Publisher's version (DOI)	10.13031/aim.20162461252

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An ASABE Meeting Presentation
DOI: 10.13031/aim.20162461252
Paper Number: 162461252

Profile of ammonia and water vapor in an Irish broiler production house

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Written for presentation at the
2016 ASABE Annual International Meeting
Sponsored by ASABE
Orlando, Florida
July 17-20, 2016

ABSTRACT. *Ireland produces approximately 8 million broilers annually from 550 farms. In Irish systems, broiler litter is allowed to build up during the 37 day growing cycle, after which it is removed and used for either land spreading or mushroom compost production. It is important to monitor key indoor environmental parameters in order to optimize bird performance but also to comply with legislation such as the EU National Emissions Ceilings Directive. This study used Off Axis - Integrated Cavity Output Spectroscopy to evaluate the ammonia and water vapor content of air within an Irish broiler house. Three broiler cycles were measured at different times of the year to account for seasonal variation, covering spring, summer and autumn. This paper examines the difference in ammonia and water concentrations at 1 m, 2.5 m, and 4 m above floor level following the flow of air from the ground through to the exhaust fan. Autumn had the highest concentration of ammonia indoors throughout the cycle with an average of 1.23 ppm, while summer had the lowest concentration for the majority of the cycle, though increased by a spike towards the end with an average of 0.69 ppm.*

Keywords. Agricultural wastes, air, ammonia, animal health, animal housing, broiler, chicken, gas, manure.

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Introduction

Ireland produces approximately 8 million broilers annually from 550 farms. Irish broiler production houses generally operate in growing cycles of 37 days, where manure accumulates throughout the cycle and is extracted following the removal of broilers. As manure accumulates and the broilers grow, so too do associated emissions, such as ammonia, carbon dioxide and nitrous oxide (Miles et al., 2014, Wheeler et al., 2006, Hayes et al., 2006). Ammonia in particular can potentially influence the health of the broilers and staff that use the house. Ammonia concentration in the air is listed as one of the three highest impacts on broiler welfare, in addition to stocking density and litter quality (Bessei, 2006). High levels of ammonia have been linked to breast blisters, skin lesions, reduced body mass and increased mortality (Bessei, 2006, Miles et al., 2004). Ventilation is vital in the design of such buildings, which allows for ammonia and other contaminants to leave the building. This process reduces the concentrations indoors, thereby reducing the risk to the broilers but increasing any potential environmental impacts nearby the houses.

Higher manure moisture content can encourage the production of ammonia through enhancing microbial interactions in the broiler manure, which has been linked to increased cases of contact dermatitis (Bessei, 2006). Internationally, concentrations of ammonia as high as 50 ppm have been recorded inside broiler houses (Miles et al., 2004); in this case manure is allowed to build up continuously between cycles. Irish systems remove all manure and sterilize the houses after each cycle. In the US, maximum concentrations of 25-50 ppm atmospheric ammonia are recommended, the lower of which is based on the 8 hour human exposure limit. The only ammonia measurements taken on an Irish broiler farm to date show average concentrations from 8.8 – 9.8 ppm (Hayes et al., 2006). It is difficult to quantify potential impacts on broilers from concentrations less than 10 ppm as previously observed in Ireland, as the lowest concentration tested in laboratory conditions is 25 ppm (Miles et al., 2004, Quarles et al., 1974, Caveny et al., 1981), though as these results usually show no or little impact at 25 ppm, it can be assumed that any impact in the region of 10 ppm on broiler welfare is minimal.

As wet manure encourages the breakdown of uric acid into ammonia, non-leaking nipple drinkers are currently in use in broiler houses in order to reduce wet patches in the manure. However, if the moisture content of the manure is too dry the production of particulate matter may increase. Mechanical ventilation systems are often programmed to use temperature or levels of carbon dioxide (CO_2) as a guide for how much ventilation is required, as high levels of both can potentially impact on the wellbeing of poultry. These systems also need to allow for adequate control of ammonia and water vapor in order to ensure minimal stress on the broilers. As temperature plays such a large role in ammonia production and the ventilation rate of the building, the season also has an influence on ammonia concentrations and emission rates.

Studies in the US show that on new litter, broiler ammonia production is non-existent for the first six days of the cycle, but begins to increase once manure builds up on the litter, compared to reusing litter which showed very high concentrations at the start of the cycle, reducing once ventilation increased as the birds grow (Wheeler et al., 2006). Staged feeding is a method used to reduce the emission of ammonia from broilers. Crude protein content has been linked to ammonia emission from broiler manure, where in the US a study divided the diet into two stages, starter and grower. Here each stage was tested against three ranks of crude protein content in their diet, low (21.9 & 16.5 %), medium (24.1 & 19.5 %) and high (26.4 & 21.8 %). This work showed ammonia concentrations of 53 – 58 ppm for low and medium content, whereas the high content resulted in a concentration of 83 ppm (Ferguson et al., 1998). The high concentration is 0.6 % lower than the starter diet studied by Hayes et al. (2006) in Ireland, though the crude protein in Hayes et al. (2006) for the grower stage was lower than the lowest content of the study by Ferguson et al. (1998) by 2.5 %. Reducing the crude protein content in feed requires the addition of amino acids in order to compensate for the reduced weight gain of the birds (Hussein et al., 2001).

Materials & Methods

Six locations were sampled for ammonia and water vapor within an Irish broiler production building, in addition to one location outdoors for the final 22 days of three 37 day broiler cycles. The broiler house contained on average 34,000 broilers. The building was fully mechanically ventilated, controlled by temperature and CO_2 concentrations. Each cycle was selected in order to compare the influence of season on ammonia and water vapor concentrations; each cycle started on March 6th (spring), August 6th (summer), and October 10th (autumn), respectively. Each location was sampled using a Los Gatos Research ultraportable ammonia analyzer (LGR), an Off Axis - Integrated Cavity Output Spectroscopy (OA-ICOS) unit using a multiple inlet unit to allow for switching between sample locations. The LGR was stored in a thermostatically controlled enclosure outside the broiler house, this was necessary in order to ensure condensation did not form in tubing as samples were extracted from the warm broiler house. It was decided that sampling would follow the path of ammonia from the ground through to the vents, with two sample locations located at 1 m above the floor, two just below the vent at 3 m and the final two sampled air as it passed through the vent. The sampling locations are illustrated in Figure 1. The two most frequently used fans were selected for monitoring, as the whole broiler house had 6 exhaust ventilation fans.

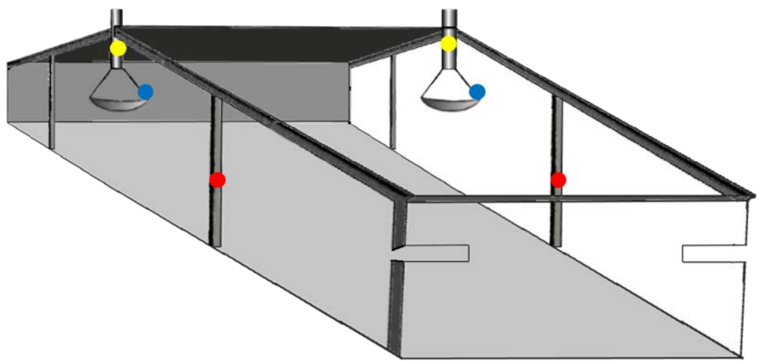

Figure 1: Sample locations in broiler house, figure is not to scale. Red = 1 m above floor, Blue = 3 m, yellow = 4 m.

During the monitoring periods, data were recorded for every second, and was subsequently analyzed in Microsoft Excel. As the sample locations were sampled through tubing (not exceeding 20 m), it was necessary to exclude the first ten minutes of each fifteen minute sample, in order to allow for analysis of measurements at the sample locations rather than measurements from air left in the tube from the previous sample. 20 m was selected as a maximum length of tubing following discussion with staff at ADAS in the UK, who were using the LGR monitoring equipment for a similar study. Following the exclusion of unnecessary data, daily averages for both ammonia and water vapor content were obtained and subsequently compared in order to determine the influence of season and sampling location.

Results

Ammonia

Ammonia concentrations varied between seasons, with autumn showing the highest indoor concentrations for all three inlets. The summer concentrations indoors were the lowest of all three seasons, due to the increased ventilation during this season as the temperature was higher than either the spring or autumn seasons. The spike observed towards the end of the summer season is likely due to the removal of female birds, which occurs 3 – 5 days before removal of males. This has increased the average value for ammonia concentration indoors for that season. Spring measurements fall between the summer and autumn measurements for 1 m and 4 m height, though summer appears higher for 3 m. Sample locations 1, 3 and 4 m all show a drop at day 29 - 30, likely due to increasing ventilation rates towards the end of March.

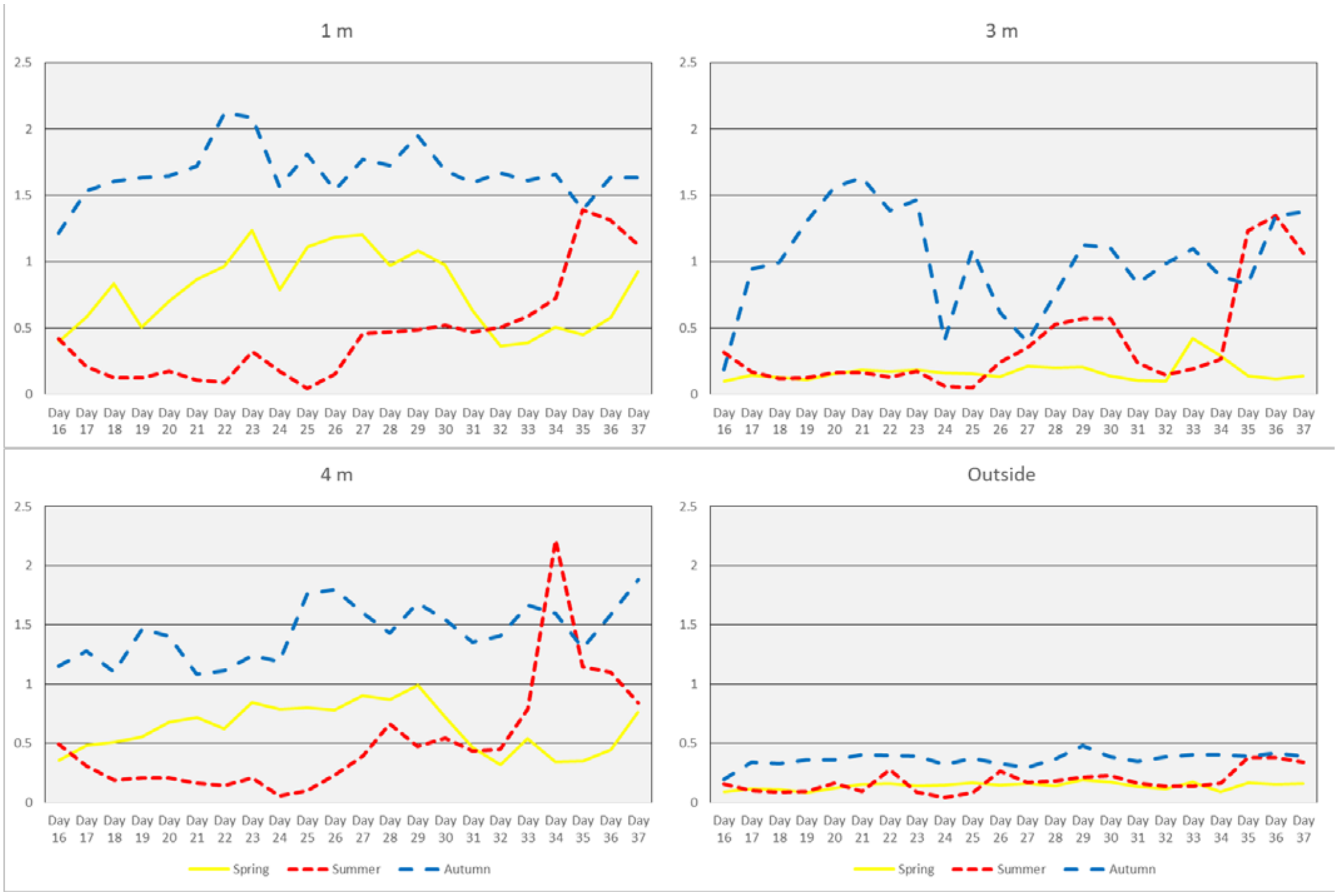

Figure 2: Ammonia concentrations (ppm) at three different heights indoor of a broiler house and one outdoor location across three different seasons.

Water Vapor

Water vapor was highest in the summer for all sample locations, excluding 4 m high (inside the vent). For 1 m and 3 m (just below the vent) water vapor follows the same patterns, highest in summer, followed by autumn, with the lowest values in spring. At the 4 m sample point, inside the vent, the spring and summer values are very similar, whereas autumn continues to follow a similar pattern to other sample locations. This is shown in figure 3. As similar patterns and concentrations were observed outdoors it was deemed to reflect ambient conditions.

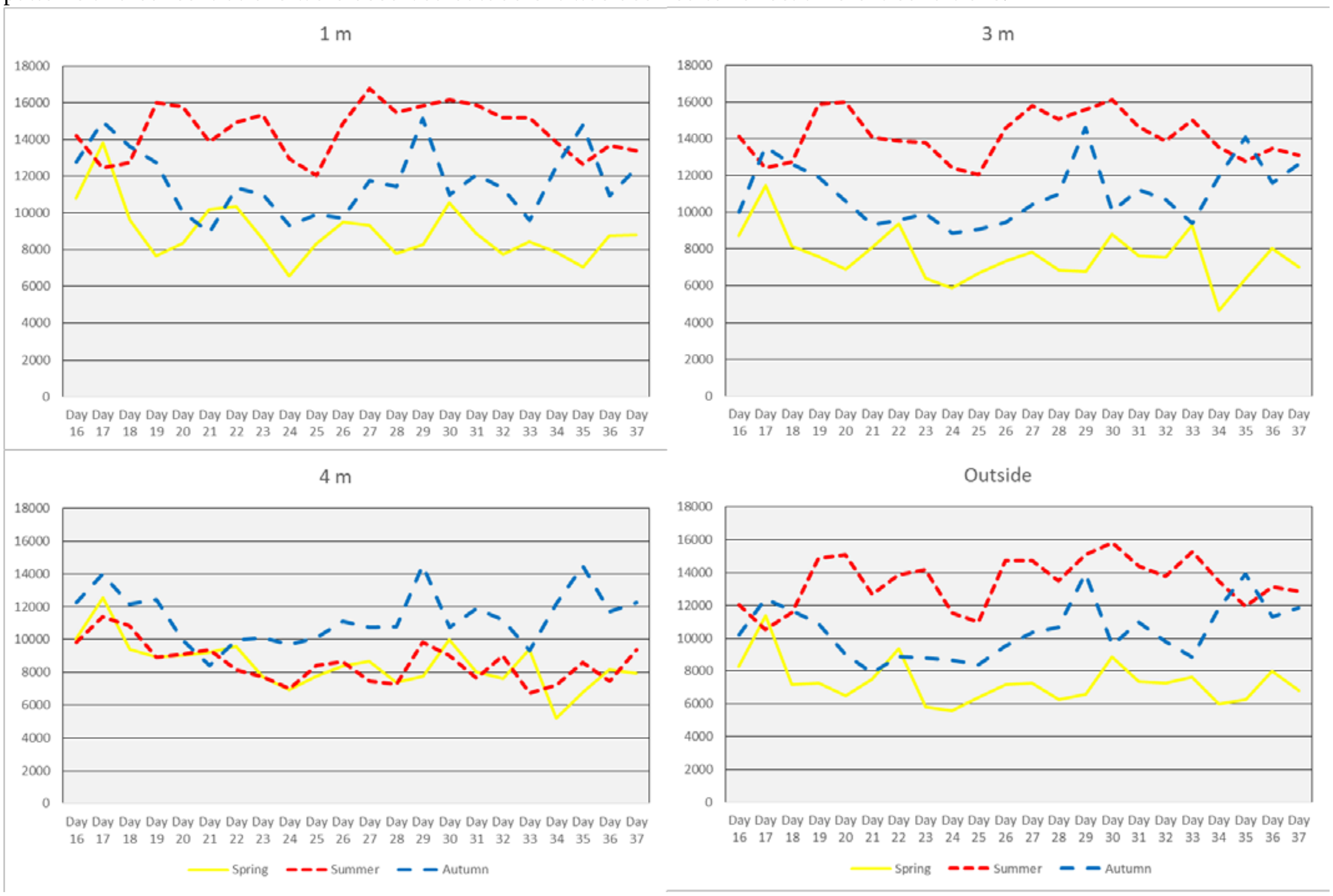

Figure 3: Water vapor concentrations (ppm) at three different heights indoor of a broiler house and one outdoor location across three different seasons.

Discussion

Comparing the results of ammonia monitoring to US studies, which have highlighted expected concentrations to be between 25 – 50 ppm (Miles et al., 2004, Hussein et al., 2001, Miles et al., 2014), indicates that this particular farm had exceptionally low ammonia concentrations. The highest daily average concentration observed was 2.21 ppm on day 34 of the summer cycle. This spike is likely due to the removal of female broilers 3 -5 days before the end of the cycle, as disturbing the manure releases more ammonia. Female broilers are removed before males as growth rate falls off at approximately day 31 of the cycle and it is no longer economically viable to feed them as their feed conversion ratio is significantly reduced.

In the US, the indoor ammonia concentration is generally higher at the start of the cycle due to existing manure on the litter, which only reduces once the ventilation increases as the broilers grow (Miles et al., 2004); broiler production in Ireland follows a similar pattern with minimal ventilation for the first two weeks of the cycle. Concentrations of 50 and 75 ppm have shown body weight reductions of 17 and 21% , respectively, whereas those exposed to 25 ppm weighed the same as the control group (Miles et al., 2004). However, as Irish broiler houses have new clean litter for the start of each cycle, the initial concentrations are minimal and were excluded from this study. Hence, Irish systems are much less likely to expose broilers to high levels of ammonia indoors as when the broilers are young they produce relatively little manure and are subsequently exposed to very low levels of ammonia. As they grow, similar to US farms the ventilation increases, further reducing their exposure to high ammonia concentrations as its production in the litter increases. Studies have investigated the impact of 25 ppm as the lowest exposure limit for broilers; as the highest indoor reading in this project was 2.2 ppm, exposure to ammonia on Irish farms could be considered to be of relatively little concern. Further analysis of this data will investigate the emission of ammonia from this broiler house, this will show the influence of ventilation rate on the indoor concentration.

Previous research on ammonia concentrations in Irish broiler houses using an iTX electrochemical sensor showed average concentrations of 8.8, 9.7 and 9.8 ppm indoors in Winter, Spring and Summer, respectively (Hayes et al., 2006). These concentrations were taken within an automatically controlled naturally ventilated broiler house, and would be expected to be higher than those taken in a fully mechanically ventilated house. As these measurements were taken in 2004, there may have been further enhancement in poultry management to reduce the concentrations indoors such as reducing protein content in the feed. Current Best Available Techniques (BAT) guidelines for broiler production in Ireland recommends three feeding stages of 20 – 22% crude protein (CP), 19 – 21% CP, and 18 – 20% CP for starter, growers and finishers, respectively (JRC, 2015). In 2004, the broilers studied in Hayes et al. (2006) were fed a diet of 27% CP as a starter and 14% CP as a finisher. Though the finisher protein currently recommended is 4 % higher than was used in 2004, the starter diet is 6 % lower on average. This is likely to play a role in the current concentrations and subsequent emissions, though the influence is not directly comparable between the two studies due to the difference in ventilation systems and other factors.

Conclusion

In conclusion, broilers in this case study in Ireland were exposed to significantly lower ammonia concentrations than typically experienced by their US counterparts, thereby reducing stress on birds. Considering the only additional monitoring on Irish farms indicated concentrations of 10 ppm, it can be assumed that Irish broiler management practices and climatic conditions lend themselves to lower ammonia emissions. Ammonia concentrations in Ireland varies more by season than by sampling location in the house; no trend was observed when comparing sample locations during each season, though the difference between season was obvious. This is likely due to different ventilation rates during the year - summer generally has the lowest indoor concentration due to high ambient temperatures and subsequent high ventilation rates. Summer also had the highest concentrations of water vapor suggesting that these levels do not enhance ammonia production to an extent to stress the broilers.

Acknowledgements

The authors acknowledge funding for this project by STRIVE as administered by the Environmental Protection Agency. The authors would also like to thank both the EPA and the National Parks and Wildlife Service for information and support provided. Further details of the project are available at http://ssu.ie/research/ammonian2k/ and on our twitter page https://twitter.com/AmmoniaN2K/.

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