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Monitoring Environmental Parameters in Poultry Production Facilities

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Abstract

Increases in fuel and feed prices are placing a significant burden on the poultry industry in Ireland and worldwide. For producers to meet their financial targets, increased performance and output is a key issue, now more than ever. To optimise performance in broiler production houses, the effect of environmental and air quality parameters on bird performance and energy consumption must be known to allow farmers make informed management decisions. This paper concentrates on the application precision livestock farming sensors to develop recommendations for improved bird performance and energy consumption in broiler production farms in Ireland.

Air temperature, relative humidity, light, air speed and air quality (in particular CO₂ and NH₃ concentrations) are identified as important parameters for improving bird performance and energy consumption in broiler production houses. Several of these parameters (temperature, relative humidity, CO₂ and NH₃) were monitored on two farms during the study over the initial 2 weeks of the production cycle. Air quality was often overlooked during the production process, as farmers struggled to limit high heating and feed costs. However, elevated levels of CO₂ (>3000 ppm) did not appear to affect broiler growth rates. Additionally, a strong correlation was observed between relative humidity and NH₃ ($R^2 = 0.86 - 0.92$). Producers tend to use relative humidity as an indication for NH₃ levels and the research shown in this study confirms the close relationship between the two parameters. It is recommended that further data should be gathered from producing units and novel performance technologies should also be investigated.

Keywords

Poultry, monitoring, performance, energy, food production, agriculture, environment, data analysis

Background

In 2011 in Ireland, fuel prices increased by 56% from 2009 figures, as Brent crude oil prices rose to \$114 per barrel [1]. During October 2012, electricity and gas prices rose by 8-10% to offset the weakening of the Euro, as well as rising transmission and distribution network costs [2, 3]. For livestock producers to meet their financial targets, increased performance and output is a key issue, now more than ever. Farmers have moved from a position of 'price setters' to 'price takers'. The introduction of the EU directive 'Integrated Pollution Prevention and Control' further increases the burden on a farmer's livelihood, as well as regular inspections of livestock regarding animal welfare. There is indirect pressure on the farmer from the consumer to ensure acceptable food standards, a readily traceable product and most of all that the product is safe to eat [4, 5].

Poultry accounted for 22% of meat consumption per capita in the 27 EU member states in 2010 [6]. Brazil produced almost 11 million tonnes of chicken meat in 2009, out of which 70% was exported,

accounting for approximately 50% of the world market [7, 8]. The size of the global poultry meat sector has increased by more than 4% per year since 2000, and this has resulted in its share in global meat production rising from 15% in the 1970's to 33.5% in 2010 [9]. Approximately 84.5 million poultry birds were slaughtered in Ireland in 2011. Poultry exports from Ireland in 2011 were €210 million, a 3% increase from 2010 [10]. Poultry production and exportation is a huge industry worldwide, and lack of confidence at consumer level could have detrimental effects on the industry.

In temperate climates such as Ireland, heating is required the majority of the year. Adequate air quality standards are often overlooked in order to reduce heating bills for famers, particularly during winter periods [11]. Space heating accounts for over 80% of the total energy consumption (Table 1) in poultry houses [12]. The breakdown of electrical use in poultry houses is also investigated by Teagasc [12]. Lighting, ventilation and fans are shown to account for over 80% of total electrical consumption. The report states that careful management of the link between heating and ventilation is required, particularly during winter when excess ventilation can significantly increase total costs.

Farmers are required by law [13, 14] to monitor environmental conditions (temperature, relative humidity (RH), light, carbon dioxide (CO₂), ammonia (NH₃), and ventilation rates) in the poultry houses. Temperature, RH and light are easily measured, but other factors (ventilation rates and air pollutants) are often overlooked which may be important for improving bird performance and decreasing energy costs throughout each production cycle.

Table 1. Percentage breakdown of total energy consumption and total electrical consumption in poultry farms

Total energy consumption		Total electricity consumption	
Heating	84%	Ventilation	45%
Ventilation	7%	Lighting	37%
Lighting	6%	Feed, motor & water pumps	13%
Feed, motors & water pumps	2%	Miscellaneous	5%
Miscellaneous	1%		

Environmental conditions in poultry farms

One of the key issues for growers in temperate climates such as Ireland is the difficulty associated with providing a sufficiently regulated and controlled environment to avoid limiting bird performance. According to Mutai *et al.* [15], the most basic form of controlling the poultry environment is by maintaining suitable temperatures in these buildings by adjusting ventilation and heating rates.

RH of over 70% is undesirable and should be contained through use of ventilation in buildings [13]. RH levels below 50% result in higher production of dust and air borne micro-organisms, but this is not very common. During summer months birds can experience discomfort due to high RH combined with high temperatures [16].

When exposed to colder temperatures, birds eat more feed to sustain normal body temperature. When feed is used for warmth, it is not converted to meat [17]. On the other hand, when temperatures become too warm energy is also wasted as birds attempt to keep cool [18]. In these cases, broilers will exhibit higher incidence of ascites (metabolic disorder resulting in performance reduction) and increased mortality. A recent study has suggested that when different groups of broilers were exposed to two differing temperature ranges (26 and 32 °C) during growth, the group grown under the higher temperature showed better growth performance, and also consumed less feed [19].

Monitoring air pollutants (CO₂ and NH₃)

Modern poultry housing is designed and constructed to reduce heat loss and improve energy efficiency, but when combined with a reduction in ventilation to prevent losses of heat energy, this can result in an increase in CO₂, NH₃, moisture, dust and odours [11, 19]. Several authors have pointed out that air quality problems in poultry buildings are direct products of low ventilation rates [20, 21]. The two main sources of CO₂ in poultry buildings are from gas heaters and from the birds themselves. Initially, the majority of CO₂ is produced by the heating system, but as birds reach the end of their growth cycle they generate a higher proportions of CO₂ [22].

Another harmful airborne pollutant in poultry houses is NH₃. High levels of RH improve conditions for microbial growth in poultry litter. As this microbial population increases, more NH₃ is generated from nitrogen sources found in the bird fecal matter [19]. Increased levels of NH₃ in poultry buildings can reduce total weight gains for birds. Wang *et al* [23] suggests that the significant variation in body weight over different concentrations of NH₃ in the study by Miles *et al* [24] could be related to breed of birds and age of parents.

Increases in NH₃ concentration levels in poultry buildings can be caused by high moisture levels, along with high temperatures which promote bacterial growth and causes organic material to decompose [25]. NH₃ concentration levels are directly affected by various environmental factors; temperature, pH, moisture, and nitrogen content of the litter or manure [26]. Severe problems can occur when NH₃ levels exceed 50 ppm. Poultry regulations in Ireland state that NH₃ levels should not exceed 20 ppm over any 8 hour period or 35 ppm over any 10 minute period during the poultry production cycle [14, 27]. These levels are similar to those recommended by other European countries; Germany also has a 20 ppm limit, while the UK and Sweden have set 25 ppm limits, for any 8 hour period. Sweden also has a second limit of 50 ppm for a maximum of five minute exposure [25].

The objective of this study is to monitor the main environmental factors in two broiler production houses which use alternative heating systems. Consideration is given to how these parameters could affect production performance and, therefore energy consumption.

Methods

Farm locations

The two farms used in this study (Farm A and B) were based in the Cavan/Monaghan region of Ireland. The two producers were associated with the processor Carton Group Ltd. Both farms used liquefied petroleum gas (LPG) cylinders for supplemental heaters. The heating system for Farm A consisted of 2 gas blowers coupled with a new heat exchanger system¹ while Farm B consisted of 2 gas blowers and 12 individual radiant brooders². Natural ventilation was used in both farms.

Bird husbandry

Ross 308 broilers were used during the monitoring process. The total amount of broilers in Farm A and Farm B was 24,700 and 22,917 respectively, housed within a floor area of approximately 1,150m².

Birds were fed *ad libitum* to a final market weight of approximately 2 kg. Each flock was kept for a period of 42 days, with approximately 50% of flock removed after day 33-34. The first 14 days of the growth cycle were monitored during this study, as this is widely acknowledged as being the most critical stage in the broiler production cycle [28]. After 14 days, the birds have learnt to self-regulate their body temperatures [19] and are therefore less susceptible to fluctuations in in-house environmental conditions.

¹ High energy efficiency heating systems (<http://www.bigdutchman.de/en/poultry/products/poultry-climate-control.html>).

² The radiant brooders were not incorporated into the automated system, but were operated manually by the farmer as required.

Best practise environmental guidelines

The environmental conditions in the poultry houses were assessed against standards in the poultry industry [13, 14, 28, 29]. Guideline environmental conditions for first 14 days of the growth cycle are outlined in Table 2. After day 14 the birds are expected to reach a weight of approximately 450 g [30, 31].

Table 2. Recommended environmental conditions for Ross birds (day 0-14)

Day	Temperature (°C)	RH (%)	CO ₂ (ppm)	NH ₃ (ppm)
0-6	32-35	60-70	<3000 ^a <5000 ^b	<20 ^a <50 ^b
7-13	28-31	50-70		
14	25-27			

a = long term period (approximately 8 h), *b* = short term period (approximately 5-10 min)

Data acquisition

The monitoring period took place from September to December 2012. The sensors were enclosed and placed at bird level (approximately 0.5-0.6 m above ground level). Temperature and RH was measured using an EL-USB-2 Humidity, Temperature and Dew Point USB Data Logger [32]. NH₃ was measured using a TGS 826 Ammonia Gas Sensor [33] and CO₂ was measured using a TGE-0011 Tinytag CO₂ data logger [34].

Sensors were placed at the nearest available power source, in the centre of each building. Data was measured at 5 minute intervals for all sensors, apart from CO₂, which was monitored at 1 minute intervals. The data acquisition process took place over the first 14 days of the growth cycle. Data was subsequently downloaded via USB connection to Excel spreadsheets.

Results and discussion

The following paragraphs presents the data acquired from each of the farms in this study.

Temperature & relative humidity

Temperature and RH data appeared to be within acceptable guidelines as set out in [28, 29], which differ slightly from those quoted in the British Standards [13] standards document. Acceptable RH levels in the aforementioned standards are 50-70% over a poultry growth cycle. Low initial RH values (below 40%), in the case of both farms is due to initial heating of the building, which is required in order to attain the recommended temperature levels for day old broilers (see Figures 1 and 2). Poultry growers are required to ensure that RH should not remain at these low levels during the growth cycle, as this would promote dust build-up and the growth of parasitic microorganisms can affect poultry health.

As expected, a strong correlation between temperature and RH was observed in the case of both Farm A (R^2 value = 0.70) and Farm B (R^2 value = 0.84). RH levels rose steadily during the first 7 days of the growth cycle, with supplementary heating required to keep levels below 70%. Ambient RH levels in the study region are often in excess of 85-90% during winter periods [35]. This can be a significant energy burden on farmers as they are required to maintain RH levels at best practice levels by artificially heating the production houses.

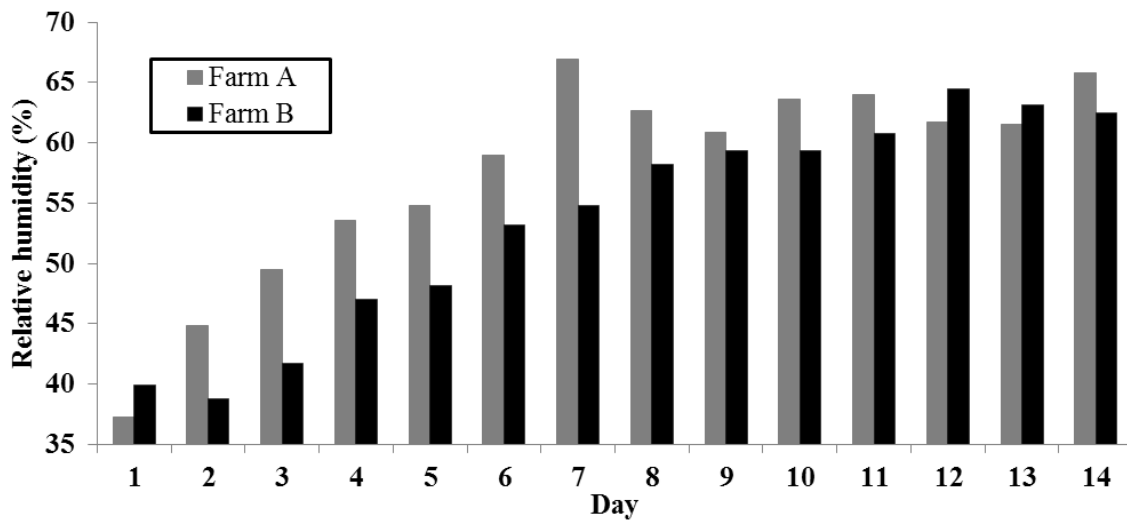


Figure 1. Relative Humidity Measurements

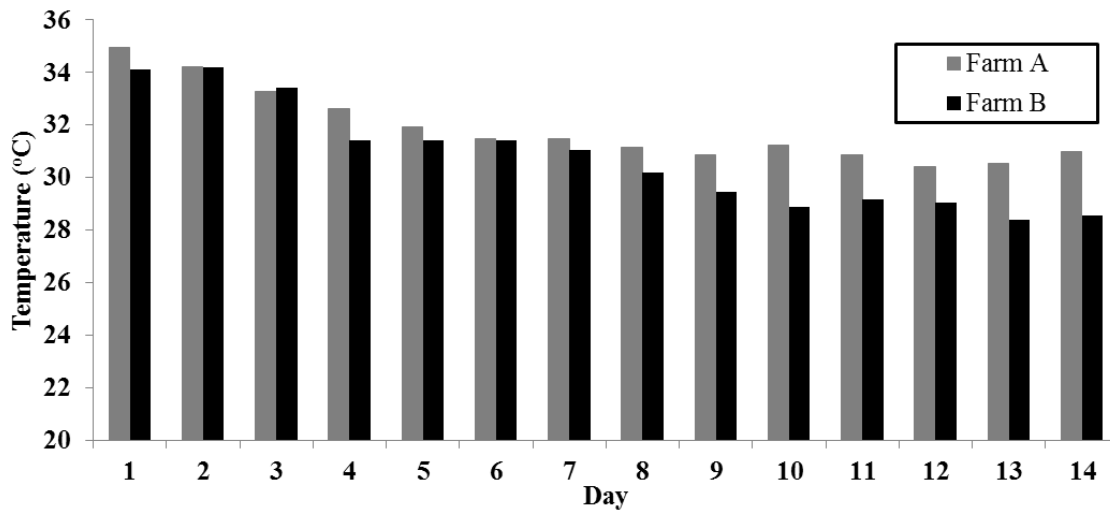


Figure 2. Temperature Measurements

Carbon dioxide (CO₂)

It is recommended that CO₂ levels do not exceed 3,000 ppm (Table 2). Measurement results from both farms show that this upper limit was exceeded at some points during the monitoring period (Figure 3). Anecdotal evidence from farmers suggests achievement of an upper limit of 3,000 ppm would be extremely difficult. A number of researchers suggest that keeping CO₂ levels below 5,000 ppm would be acceptable [36]. However, studies have shown that elevated levels of CO₂ can suppress body weight gain and increase mortality levels in poultry [37]. Olanrewaju *et al.* (11) studied the effect that short-term elevated CO₂ concentrations had on poultry growth performance. Results from the study found that elevated CO₂ concentrations primarily effected growth rates during the first 14 days.

Figure 3 shows CO₂ concentrations for each day of the monitoring period. Cross referencing of recorded flock body weights for both Farms against the CO₂ levels shown in Figure 3 indicates that the variation in CO₂ levels observed did not have any adverse effect on daily growth rates. Further studies in this area are required to determine if the recommended maximum CO₂ level of 3,000 ppm set out by the European Council Directive [14] is unrealistic for broiler producers, particularly in the current economic climate with volatile increases in fuel and feed prices. Czarick & Fairchild [36] recommend that keeping RH below 60% should ensure adequate air quality, while exceeding 70% RH will result in CO₂ and NH₃ levels reaching harmful levels. The collected data show that elevated periods of CO₂

levels are observed in tandem with high RH levels. This appears to confirm the comments made by Czarick & Fairchild [36].

Lower CO₂ levels were observed in Farm A when compared to Farm B. It is thought that this is due to the fact that Farm A is heated using an integrated heat exchanger / gas blower system rather than a stand-alone gas blower system. In addition, the ventilation in Farm A is controlled by CO₂ levels, meaning that ventilation is instigated when CO₂ levels exceed a specified set-point (3,000ppm in this case). As seen in Figure 3, Farm A - CO₂ levels rise steadily to approximately 3,000 ppm, at which point the ventilation system is activated in order to maintain that level for the rest of the cycle. In the case of Farm B, CO₂ levels are relatively uncontrolled, resulting in high levels of CO₂ for the majority of the cycle.

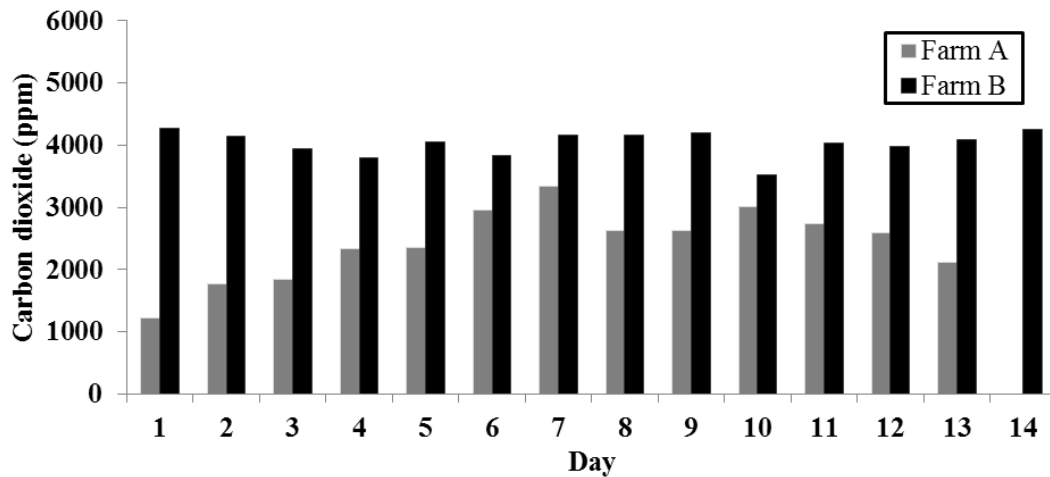


Figure 3. Carbon Dioxide (CO₂) Measurements

Ammonia (NH₃)

As anticipated, a strong correlation between NH₃ and RH was observed in the case of both Farm A (R² value = 0.92) and Farm B (R² value = 0.86). This is in agreement with the findings of Czarick & Fairchild [36] who suggest that RH levels are directly proportional to NH₃ levels. NH₃ levels are shown to gradually increase during the first week of the poultry cycle (Figure 4).

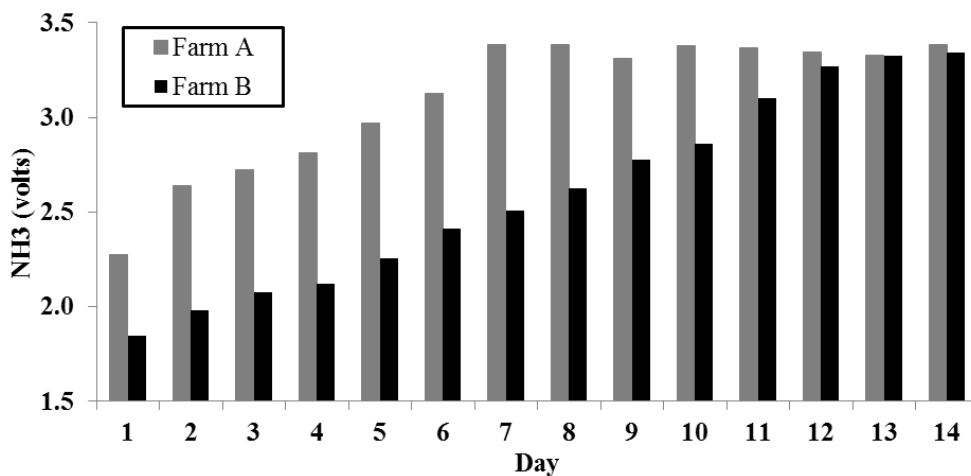


Figure 4. Ammonia (NH₃) Concentration Measurements

Farm A reaches its NH_3 and RH concentration peaks earlier than Farm B as shown in Figures 4 and 5. Farm B has a lower initial NH_3 level than Farm A, which could be accounted for by different farm husbandry techniques. There is a strong correlation between NH_3 and RH levels as illustrated in Figure 5. In theory, this correlation, following suitable additional data collection, could be used in order to reduce the amount of variables that need to be monitored i.e. only one of these variables may need to be monitored on site.

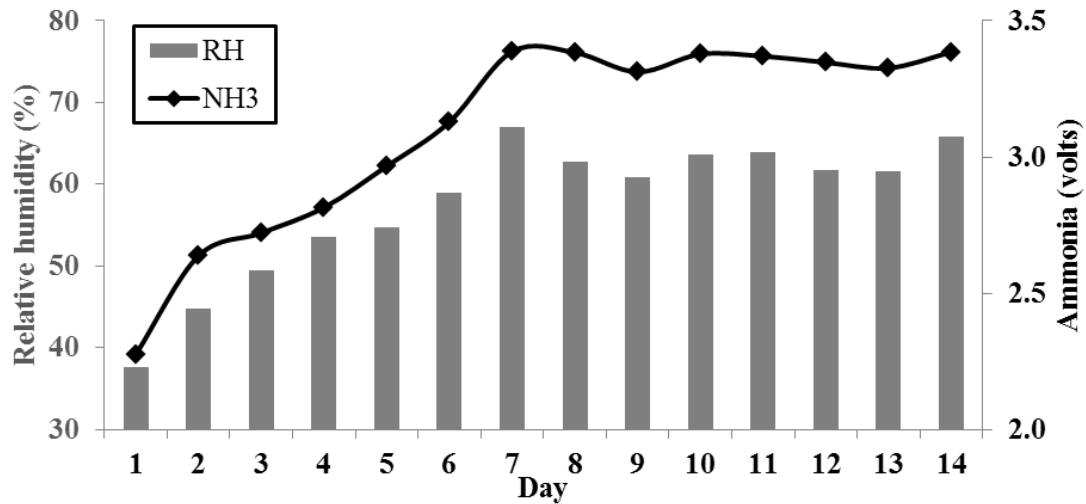


Figure 5. Comparison Between RH and NH_3 Measurements for Farm A

Conclusions

Air quality parameters are not regularly monitored on poultry farms, and particularly in colder weather, standards are often overlooked as farmers look to reduce ventilation rates in order to reduce energy costs. An integrated poultry production house monitoring and analysis system is required to facilitate an improvement in production performance and to help reduce energy costs. The results of this preliminary study suggest that measured RH levels may be used for the prediction of NH_3 levels in poultry production houses. A larger data set is required in order to establish the sensitivities associated with the observed correlation so that it can be applied to poultry production houses under varying climatic conditions.

The results of this study indicate that lower CO_2 and NH_3 levels are maintained at Farm B (heat exchanger system) when compared to Farm A (traditional gas system). This suggests that heating systems which are not traditionally used in the poultry production industry should be investigated further to determine their effectiveness and the levels of savings for the producer. These systems could be optimised to improve air quality conditions in buildings (e.g. carbon dioxide and ammonia), as well as reducing overall energy costs for farmers

In conjunction with EU directives outlining the need for control of CO_2 in poultry production buildings, as well as the global pressure on the agricultural community to reduce their carbon footprint, farmers are required to move towards systems that provide ventilation as a function of CO_2 levels in farms, as opposed to traditional methods of ventilating based on bird weight.

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