Ammonia Production In Poultry Houses And Its Effect On The Growth Of *Gallus Gallus Domestica* (Broiler Chickens): A Case Study Of A Small Scale Poultry House In Riverside, Kitwe, Zambia

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Abstract: Chickens deaminate excess amino acids and excrete the derived nitrogen in the urine mainly as uric acid, which is readily converted to ammonia. This gas has adverse effects on the health of chickens and air quality. Production of ammonia and its effect on the growth of chickens was monitored at a poultry house of House Number 5743, Mukuba Road in Riverside, Kitwe from 21st August, 2013 to 6th June, 2014. Two batches of fifty day old hybrid broiler chicks were bred in house **A** and **B** (5 m x 7 m) under the same management system in three phases. House **A** chicks were fed on Novatek feed only, while those in house **B** were fed on Novatek feed blended with 0.5%, 0.7% and 0.9% (w/w) bamboo charcoal of ≤600μm particle size. Weekly mass recording by the use of a weighing scale provided a measure of growth rate while analysis of the excreta using Kjeldahl method at the Copperbelt University and Nkana Water and Sewerage Company laboratories in Kitwe provided a means of monitoring the amount of ammonia generated. Chickens in house **B** showed a slightly faster growth rate from 28 to 42 days than those in house **A**. The f-test results from the study showed that there was a significant effect of ammonia concentration on chicken growth rate (P<0.05). The results obtained from excreta-litter mixture analysis showed a significant adsorption of ammonia by bamboo charcoal (P<0.05). The study further indicated a direct dependency of ammonia concentration in excreta on chicken age, moisture content and pH.

Index Terms: Adsorption, Ammonia, Bamboo charcoal, Emission, Excreta, Litter, Moisture,

1 Introduction

Ammonia emissions in poultry houses are mainly due to high protein formulated chicken diets. The chickens have no storage mechanisms for amino acids consumed beyond the requirement for protein synthesis, so the excess amino acids are deaminated and the derived nitrogen is excreted in the urine mainly as uric acid (80%), ammonia (10%) and urea (5%), (Goldstein and Skadhauge, 2000). However, the large amount of uric acid excreted is readily converted to ammonia through a chain of reactions catalyzed by enzymes namely uricase (1) and urease (2) which are present in the manure. In the first step, uric acid is converted to alloxan/mesoxalyl urea ($C_4N_2H_2O_4$) and urea (CH_4N_2O) by uricase in the presence of water (H_2O) and oxygen (O_2) as shown in (1), (Bahl and Bahl, 2004)). Urea is finally converted to ammonia (NH_3) and carbon dioxide (CO_2) by urease in the presence of water (2), (Bahl and Bahl, 2004). This conversion takes place under “high temperature, pH 8-13 and in the presence of high humidity” (Becker and Graves, 2004).

$$2C_5H_4N_4O_3 + 2H_2O + O_2 \xrightarrow{uricase} 2C_4N_2H_2O_4 + 2CH_4N_2O \quad (1)$$

$$CH_4N_2O + H_2O \xrightarrow{urease} 2NH_3 + CO_2 \quad (2)$$

Ammonia has adverse effects particularly to the nasal cavity and eyes of affected chickens due to the gas’ alkalinity and corrosiveness. When in contact with nasal moisture, NH_3 reacts with the moisture and forms a corrosive basic solution (3).

$$NH_{3\,(g)} + H_2O_{(l)} \rightarrow NH^+_{4(aq)} + OH^-_{(aq)} \quad (3)$$

The aqueous ammonium solution ($NH^+_{4(aq)}$) formed corrodes the respiratory lining of the affected chicken consequently weakening immunity in the respiratory system making the animal susceptible to bacterial infections especially *E.coli*. The corrosion of the respiratory lining ranges from cilia paralysis to complete loss of cilia of the epithelial cells. Cilia are hair like structures that are found on the trachea lining. Cilia clusters form the mucociliary apparatus that is mainly responsible for cleaning up the upper respiratory system of the chickens. The mucociliary apparatus removes dust particles by trapping and preventing them from reaching the lower respiratory system (air sacs). This happens by the use of propulsive action of the cilia where the dust particles are entrapped by mucus and propelled out of the respiratory system (Aziz and Barnes, 2010). When cilia are corroded or paralyzed by high NH_3 concentrations, “mucus on the mucosal surface of the trachea cannot be cleared and thus entrapped bacteria on dust particles may reach the lungs and air sacs and cause infections” (Aziz and Barnes, 2010). The most common bacterial diseases in chickens are pneumonia, septicemia and airsacculitis. In addition to respiratory diseases, high NH_3 concentrations have an effect on chicken eyes. “Atmospheric NH_3 at high concentrations cause conjunctivitis (inflammation of conjunctivae) and damages the cornea of the eyes” (Aziz and Barnes, 2010). The cornea is affected due to corneal erosion caused by NH_3 corrosion. High levels of ammonia in a poultry house have negative impact on poultry growth particularly at an early age. (Moore *et al*., 2008), found that NH_3 levels as low as 20 ppm compromise the immune system of chickens, making them more susceptible to diseases and damage to respiratory system. Feed conversion and weight gains in poultry are also affected by high levels of ammonia.

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Not only does indoor ammonia pollution affect the chickens but also pose a risk to the health of the agricultural workers in these facilities. Ammonia emissions from poultry houses cause environmental problems such as "acid precipitation, fine particulate matter formation (particulate matter with an aerodynamic diameter less than 10 μm) and nitrogen deposition in aquatic systems" (Moore *et al.*, 2008). When NH_3 deposits on soils with low buffering capacity, soil acidification or cation depletion occurs. This occurs when base cations such as calcium, magnesium, potassium and sodium are leached from the soil (Ndegwa, 2005). Atmospheric particulate matters are tiny pieces of solid or liquid matter usually found in highly polluted atmospheres. When these fine tiny solids are inhaled by animals, they cause serious respiratory complications (Council for Agricultural science and Technology, 2011). High levels of NH_3 emissions cause nitrogen deposition in aquatic systems. This deposition is usually referred to as eutrophication, if it occurs on water bodies with high concentration of phosphates. Eutrophication is "the process by which a body of water acquires a high concentration of nutrients especially phosphates and nitrates. These typically promote excessive growth of algae. As algae die and decompose, high levels of organic matter and the decomposing organisms deplete the water of available oxygen, causing the death of other organisms such as fish" (Art, 1993). The loss of ammonia from chicken excreta does not only cause environmental problems but also leads to poor quality manure for application in agro-systems. This is due to high nitrogen loss during the formation of ammonia gas and subsequent volatilization into the atmosphere. Ammonia being a harmful gas to poultry, care takers and the environment at large, several strategies are employed to minimize NH_3 volatilization into the environment. These include NH_3 gas adsorbers, enzyme inhibitors, feed manipulation and other litter additives such as aluminium sulphate and sodium bisulphate (Moore *et al*., 2008). In this study, bamboo charcoal was used as a cheap adsorbent material in feed manipulation. Bamboo charcoal powder has a higher adsorption capacity than wood charcoal due the special micro-pore structure of their stems (Yamauchi *et al*., 2010). This means that small amounts of bamboo charcoal are sufficient to bind significant quantities of NH_3 (as well as hydrogen sulphide and volatile organic compounds) by adsorption. In addition to being more effective in ammonia adsorption than ordinary wood charcoal, bamboo reaches maturity faster than any ordinary tree. It is a well known world's fastest growing plant; it takes about 3-5 years to reach full maturity (Erie *et al*., 2011). Moreover, bamboo has a rhizome root system. This means that when a mature bamboo tree is harvested, a new shoot grows as a replacement. This makes bamboo to be a more rapidly renewable and sustainable resource than any ordinary tree. Based on these reasons, this study encourages the use of bamboo charcoal in order to reduce demand on hardwood which takes a long period for it to reach maturity. Adsorption is a process by which ions or molecules present in one phase tend to condense and concentrate on the surface of another phase (Sichula *et al*., 2011). There are two types of adsorption depending on the nature of forces existing between adsorbate molecules and adsorbent namely; physical and chemical adsorption. The adsorption of ammonia to charcoal is mainly by chemical adsorption (Chemisorption or Langmuir adsorption).

2 MATERIALS AND METHODS

The study was conducted in three phases; each phase had a treatment and a control.

Phase 1: Started on 21th August, 2013 and ended on 2nd October, 2013. This was the first phase of study and a treatment of Novatek feed blended with 0.5% bamboo charcoal was used.

Phase 2: Started on 4th February, 2014 and ended on 18th March, 2014. Under phase 2, a treatment of Novatek feed blended with 0.7% bamboo charcoal was used.

Phase 3: Started on 25th April, 2014 and ended on 6th June, 2014. Under phase 3, a treatment of Novatek feed blended with 0.9% bamboo charcoal was used.

2.1 Preparation of bamboo charcoal

Stems of Bambusa vulgaris (African bamboo) were cut into pieces measuring approximately 10cm long and air dried in the open for 14 days (from 6th August to 20th August, 2013). The pieces were then packed into a 5 L tin, which was then closed using a lid with 5 perforations. The perforations controlled air/oxygen supply to slow combustion thus ensuring complete carbonization. The closed tin was put on fire and rotated at intervals to ensure uniform combustion until smoke stopped coming out through the holes (Sichula et al., 2011). The contents were allowed to cool, removed from the tin and the charcoal was heated again then suddenly cooled in cold water, it was finally sun dried before crushing. The charcoal was crushed using a pestle and mortar, charcoal particles of ≤ 600µm size were obtained by using a sieve of 600µm mesh size. The obtained charcoal particles were used in feed manipulation (Fig1).

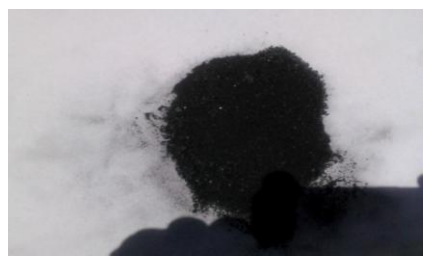

Fig. 1: *Bamboo charcoal of ≤ 600µm particle sizes*

The bamboo charcoal was blended with Novatek feed at;

- **I.** 0.5% level by thoroughly mixing 5g with every 1kg of the feed.
- **II.** 0.7% level by thoroughly mixing 7g with every 1kg of the feed.
- **III.** 0.9% level by thoroughly mixing 9g with every 1kg of the feed.

2.2 Feed and chicks procurement, and brooding conditions

One hundred hybrid day old broiler chicks from Hybrid Farms in Kitwe district were procured from Swiney Agrochemical shop in Kitwe. Bags of Novatek feed each weighing 50kg, vitamin E, New Castle and Gumboro vaccines were procured from Swiney Agrochemical shop in Kitwe. The chicks were randomly split into two (A and B) equal batches in each phase of the study, weighed and placed in a small 1 m^2 pen, which was later enlarged to 2 m^2 after 7 days. Each batch was brooded at a poultry house of House Number 5743, Mukuba Road in Riverside, Kitwe. The poultry house with two rooms each measuring 5m by 7m was cleaned and disinfected with dettol before the introduction of chicks. The chicks were brooded under the same brooding conditions (i.e. feed quantity, ventilation, pen size, temperature, light, vaccine and access to feed and water). The chickens in batch B (Treatments) were fed on Novatek feed blended with 0.5%, 0.7% and 0.9% bamboo charcoal particles while those in batch A (Control) were fed with untreated Novatek feed.

2.3 Measurement of Chicken Weights

Weight of each chicken was taken weekly (every Wednesday). Chicken weight was first taken on the first day the chickens were introduced into the chicken house. Each chicken was weighed and separated from those that are not weighed, this weight was recorded. The total weight of all the chickens in the poultry house was determined by getting the sum of all the chicken weights. The formula below was used to get the total weight.

Total weight= $C_1+C_2+C_3+\ldots\ldots\ldots\ldots\ldots..+C_{50}$
Where; C_1= Weight of the first chicken
C_2= Weight of the second chicken
C_3= Weight of the third chicken
:
:
C_{50}= Weight of the fiftieth chicken

Chicken average weight was taken by getting the mean weight of the chickens in the poultry house. Average Weight= Total Weight of all the Chickens in the Poultry house ÷ Total Number of Chickens the poultry house. The average weight was considered to be chicken's weekly weight, which was used to determine the chicken growth rate. The difference between the successive weekly average weights was considered to be the growth rate of the chickens in the poultry house per week (grams/week). Growth rate for the first Week = (Average $\text{weight}_{\text{week2}}$-Average $\text{weight}_{\text{week1}}$) grams.

2.4 Temperature Monitoring

Weekly temperature for the study was taken from the average daily temperatures. The daily temperatures were totaled for the week and the average temperature was determined and taken as the temperature for that particular week. This was done as follows:

Average Weekly Temperature (°C) = $(DT_1 + DT_2 + DT_3 + DT_4 + DT_5 + DT_6 + DT_7)/7$
Where;
DT_1= Average temperature for the first day of the week.
DT2= Average temperature for the second day of the week.
DT3= Average temperature for the third day of the week.
DT4= Average temperature for the fourth day of the week.
DT5= Average temperature for the fifth day of the week.
DT6= Average temperature for the sixth day of the week.
DT7= Average temperature for the seventh day of the week.

2.5 Measurement of ammonia, pH and moisture in the excreta-litter mixture

Chicken excreta mixed with litter were collected weekly and taken for laboratory analysis at Copperbelt University and Nkana Water and Sewerage Co. in Kitwe. The excreta-litter mixture of approximately 500 g was collected by scooping the top material diagonally from each poultry house and kept in clearly labeled sealable polythene bags under low temperatures to minimize ammonia volatilization. Each mixture from batch A and B was shaken vigorously to ensure proper mixing and divided into a portion for ammonia and pH analysis, and another for moisture analysis. The first portion of 100 g (on wet basis) was dissolved in 1L deionized water contained in a tightly closed sample bottle that was shaken vigorously and left to stand for 2 hours at approximately 10°C. Ammonia (mg/L) in the prepared sample solution was determined on wet basis by the use of kjeldahl method; pH was determined by using a pH meter. Moisture content was determined on dry basis by weighing 50 g of sample followed by oven drying at 105°C for 8 hours. The weight difference between the wet sample and the dried sample was expressed in percentage as moisture content in excreta-litter mixture.

3 RESULTS AND DISCUSSIONS

3.1 Chicken Growth from Day1 to Day 42:

Chicken weights in controls and treatments were almost uniform during the first 21days. However, significant differences in weights between the controls and treatments were observed starting from the age of 28 to 48days (Fig. 2). The findings of the study showed that there was a significant effect of ammonia concentration on chicken growth rate and the final selling/market weight was affected. Chickens fed on 0.5%, 0.7% and 0.9% bamboo charcoal blended feed reached an average market weight of 2kg at 5weeks of age (Fig. 2), while those fed on ordinary feed (controls) were at 1.9kg. At the end of six weeks (the average Zambian poultry market age), chickens in treatments had an average weight of 2.3kg and those in controls reached an average weight of 2.1kg. There was a difference of 0.2kg between treatments and controls. Under the same conditions, there was more production of about 0.2kg per bird in bamboo charcoal treated feed than those in ordinary feed category.

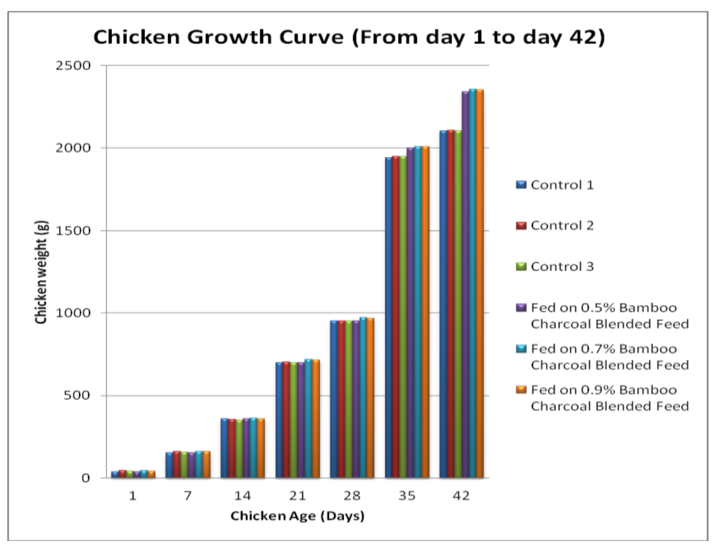

Fig. 2: *Growth of chickens from the first day to the last day of the study.*

3.2 Evolution of ammonia in excreta-Litter mixture from day 7 to day 42:

The concentration of ammonia in chicken excreta-litter mixture were almost the same for the first two weeks above which that from chickens fed with blended feed was higher (Fig. 3). Ammonia concentration in excreta-litter mixture increased with chicken age. Ammonia was higher in excreta-litter mixture for chickens fed on blended feed because of the adsorption properties of bamboo charcoal. Ammonia was bound to charcoal in the excreta by the process of adsorption; this reduced its toxicity inside the chickens' gut.

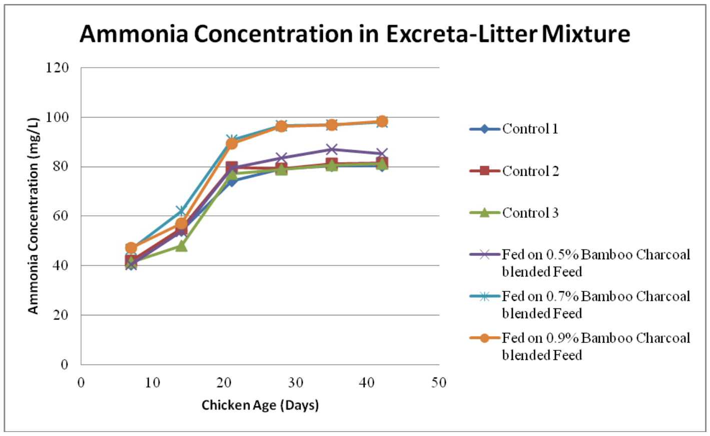

Fig. 3: *Evolution of ammonia in excreta-Litter mixture from day 7 to day 42.*

3.3 Effect of pH on Ammonia concentration in Excreta-litter Mixture:

The concentration of ammonia in excreta increased non-linearly with increasing pH, but reached a maximum at pH of 7.9 (Fig. 4). This showed that pH had a positive effect on ammonia production from excreta-litter mixture.

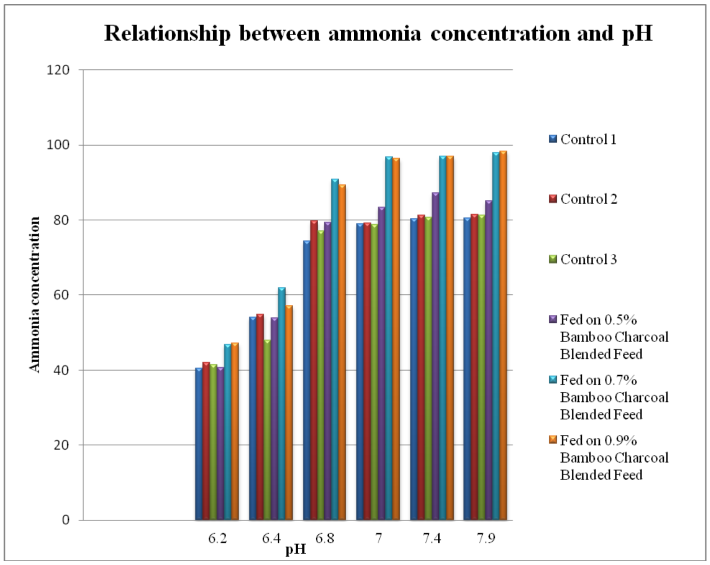

Fig. 4: *Relationship between pH and ammonia concentration in chicken excreta-litter mixture*

3.4 Effect of Moisture content on Ammonia concentration in Excreta-litter Mixture:

There was a direct positive relationship between ammonia and moisture content in excreta-litter mixture. It was observed that high moisture content in excreta-litter mixture led to increased evolution of ammonia (fig. 5).

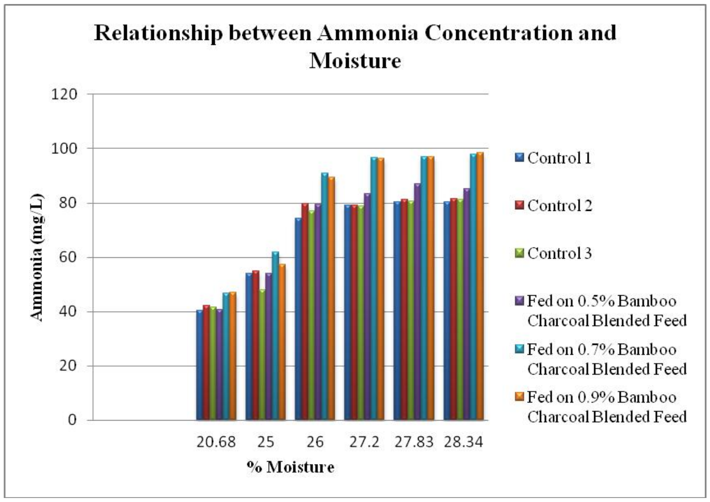

Fig. 5: *Relationship between moisture and ammonia concentration in chicken excreta-litter mixture.*

4 Conclusion/Recommendations

(a) In conclusion, the findings of this study showed that chicken growth is negatively affected by high ammonia concentrations in the poultry house. Poultry houses also produce significant amounts of ammonia as chickens grow older.

(b) In future Zambian poultry famers must consider adopting the use of bamboo charcoal in feed manipulation as a cheaper and sustainable measure to reduce ammonia emissions and also improve on production. Besides bamboo charcoal, other forms of charcoal generated from maize and groundnut husks can be carbonized and used as adsorbents for ammonia.

(c) High moisture levels promote ammonia evolution from litter. This contributes to bad odors in the poultry house and the surrounding neighborhood, hence the need for Zambian poultry farmers to maintain a maximum of 25% moisture content in poultry litter.

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