Influence of dietary wood charcoal on growth performance, nutrient efficiency and excreta quality of male broiler chickens

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Dietary wood charcoal can be a potential low-cost feed supplement for the improvement of performance in broiler chicken production, while reducing loss of nutrients through birds’ excreta. However, it has no nutritive value and excess feeding may lead to constipation and thereby hamper birds’ production performance. An experiment was conducted with a total of 24 male broiler chickens which were subjected to a commercial broiler finisher diet with 0, 1.5, 3, and 6% wood charcoal (on a dry matter basis), respectively. This was to ascertain the level of dietary wood charcoal that can be included in a commercial broiler feed without negative effects on production performance of broiler chickens, nutrient utilization and losses through birds’ excreta under adverse climatic conditions in Northern Ghana. Birds’ feed consumption, body weight gain, as well as excreta quality were assessed for four days. Results showed that dietary wood charcoal can replace up to 6% of a commercial broiler chicken feed without negative effects on growth performance, nutrient utilization and excreta consistency, while reducing the phosphorous concentration in broiler excreta. Future research should analyze the long-term effect of feeding charcoal on performance and health of laying hens.

Key words: Broiler chickens, dietary wood charcoal, nutrient utilization, production performance, excreta quality.

INTRODUCTION

Poultry production is the fastest growing livestock sector in Ghana (FAO, 2005). However, high feed costs increase the overall cost of production for poultry keepers which could negatively affect its economic sustainability (Sumberg et al., 2017). One of the means of reducing feed cost is to increase the efficiency of feed nutrient usage.
utilization. However, increase in temperature reduces the efficient utilization of feed required for optimum body weight of birds (De Moura et al., 2015).

The reported body weights of broiler chickens in Ghana typically are 2.6 to 2.7 kg after nine weeks with a feed conversion rate of 3.3 to 3.6 at the finisher phase (Oppong-Sekyere et al., 2012). Charcoal has been proposed as feed additive to stimulate feed intake and digestion, thereby enhancing growth performance of broiler chickens in Iran, Cameroon and Poland (Khadem et al., 2012; Kana et al., 2011; Majewska et al., 2011). In pigs, it has been demonstrated that charcoal reduced fecal gas emissions (Chu et al., 2013), and hence might be an option to reduce negative environmental effects of pig production. Finally, charcoal has a good adsorption capability of toxins and therefore has the potential to improve birds’ health (Khadem et al., 2012; Rafiu et al., 2014).

Notwithstanding the potential positive effects, feeding charcoal to poultry might also have negative consequences for animals’ health and feeding behavior, growth performance and nutrient availability in manure. Charcoal has no nutritive value and may cause constipation if fed in excess. In goats, Quaranta et al. (2013) demonstrated that the fecal consistency changed from normal to hard when goats consumed diets with over 5% activated charcoal.

Furthermore, the fecal nitrogen content decreased, while its carbon content increased with higher levels of supplemented activated charcoal (Quaranta et al., 2013). There is lack of research that systematically evaluates the effect of different levels of dietary wood charcoal in a commercial broiler feed on the accretion and utilization of feed nutrients by broiler chickens, and on the quality of birds’ excreta.

Therefore, this study aimed at ascertaining what level of dietary wood charcoal can be included in a commercial broiler diet without negative effects on production performance, as well as nutrient utilization and losses through birds’ excreta under adverse climatic conditions in northern Ghana.

MATERIALS AND METHODS

An experiment was conducted in March 2016 at the Poultry Unit of the University for Development Studies (UDS) in Tamale, Northern Region, Ghana. The study was closely supervised by a Veterinarian and followed the regulations for Animal experiments of UDS. Ethical clearance was obtained on the 14th January 2016 from UDS (code number ANS/FOA/02/14012016).

Experimental birds

Twenty-four 4-week-old healthy male Cobb 500 strain broiler chickens of similar body weight were randomly selected from the experimental flock of UDS and transferred to individual cages with a wire floor (1.6 x 1.4 x 1.6 m³) in a separate house which paved way for natural ventilation. Artificial source of light (10 lx) was provided in the house at night from 18:00 to 7:00 h to encourage feeding. An adaptation period of 14 days allowed the birds to adjust to the new surroundings and diet. The experimental period with data collection lasted four days beginning when birds were 42 days old.

Dietary treatments

Each experimental bird was randomly assigned to one of four experimental diets, each replicated six times. The dietary treatments were based on a commercial finisher feed with vitamin premix and added phytase. The analyzed chemical composition of the commercial broiler feed was 907 g organic matter (OM)/kg, 192 g CP/kg, 397 g carbon (C)/kg and 8 g phosphorus (P)/kg, on a dry matter (DM) basis (Table 1). Wood charcoal was purchased from Tamale market, ground and sieved with 1 mm sieve. The ground charcoal contained 880 g DM, 874 g OM/kg DM, 721 g C/kg DM, 43 g CP/kg DM and 1 g P/kg DM (Table 1). It was thoroughly mixed with the feed, replacing 0% (T-0%), 1.5% (T-1.5%), 3% (T-3%) and 6% (T-6%) of the commercial broiler feed, on a DM basis. All dietary treatments covered 1.2 times the N-corrected metabolizable energy (AMEₙ) requirements of the experimental birds (NRC, 1994) (Table 1). For the wood charcoal, we assumed energy content of 0 kcal. Feed was supplied daily at 07:00 h and clean water was provided ad libitum.

Growth performance, excreta color and consistency

Birds were weighed before feeding on day 42 (initial body weight) and day 46 (final body weight).

Total weight gain (g/bird) = Final body weight (g/bird) – Initial body weight (g/bird)

Daily feed consumption (g/bird) = Daily feed leftover (g/bird) – Daily feed offer (g/bird)

Overall feed conversion rate = Total feed consumption (g/bird) / Total weight gain (g/bird).

Feed leftovers included all the remaining feed in the feeders and on the plastic sheets below the cages after 24 h. Mortality of birds was recorded as it occurred. Birds’ excreta were collected daily from the plastic sheets placed under the wire mesh floor of the cages using the total excreta collection method before feeding. For each cage, five fresh dropping samples were assessed for color and consistency daily. Color assessment was based on a grey scale and value finder (Color Wheel), with graduation 1 for 100% black up to 10 for white. The dropping consistency was determined by feeling fresh dropping samples in between the index finger and the thumb wearing latex gloves. It was given a value from 1 to 4, with 1 being very soft (very watery, dropping flows very easily), 2 as soft (watery yet slightly more viscous than consistency 1), 3 as medium (firm yet does not maintain shape very well after it drops, also shape collapses easily when held with little pressure in between thumb and index finger) and 4 as hard (very firm, maintains perfect conical shape after it drops, sticks together when held between thumb and index finger). A composite score was calculated as mean from color and consistency values of each cage.

Nutrient accretion and utilization

Excreta, feed, and charcoal samples were oven dried (80°C until constant weight), weighed, pooled, and subsampled for each cage. For two cages, subsamples of excreta were missing, resulting in a total of 20 subsamples (replicates), five for each dietary treatment. Subsamples of feed, charcoal, and excreta were ground to pass a 1 mm sieve (Cyclotec, FOSS GmbH, Hamburg, Germany) and
analyzed in duplicate in the laboratory of Universität Kassel in Witzenhausen, Germany. The dry matter (DM) and organic matter (OM) concentrations were determined following the standard procedures of the Association of German Agricultural Analytic and Research Institutes (VDLUFA, 2006). OM was calculated as the difference between DM and crude ash. The vanadate-molybdate-method was used to determine the P content (Hitachi U-2000 photometer, Hitachi Co. Ltd., Tokyo, Japan), and the C and N concentrations were analyzed with a C/N-TCD analyzer using DUMAS combustion (Elementar Analysensysteme GmbH, Hanau, Germany). The N concentration was multiplied by the factor 6.25 to obtain CP concentrations (AOAC, 1990). The values obtained were used to compute accretion and utilization of DM, C, N and P by broiler chickens. Accretion (g/day) was calculated as difference between consumption (g/day) and output in total excreta (g/day), while utilization represented accretion as a percentage of consumption.

Statistical analyses

Data were analyzed with R version 3.3.0 (R Core Team 2016). Data were assessed for conformity to normal distribution using Shapiro-Wilk tests and homogeneity of variances was tested with the Bartlett’s test. Residuals of data that were not normally distributed and/or data with non-homogeneous variances were analyzed using Kruskal Wallis tests. Other data were analyzed using a one way analysis of variance (ANOVA). Differences were considered significant if P<0.05. All graphs were created by the aforementioned software package.

RESULTS AND DISCUSSION

Effects of dietary wood charcoal on growth performance of male broiler chickens

The initial and final body weight of experimental birds and hence the average daily body weight gain were similar, indicating that feeding wood charcoal had no effect on broiler chickens’ growth rate (P > 0.05). Similarly, the total feed consumption did not differ across dietary treatments (P > 0.05), resulting in comparable feed conversion rates across dietary treatments (P > 0.05; Table 2). Also Kana et al. (2011) and Majewska et al. (2011) showed no improvement of feed efficiency in broiler chickens when charcoal was included in the diet, but recorded an increase in body weight gain with the inclusion of charcoal of up to 0.4 and 0.3%, respectively. In contrast, Bakr (2008) demonstrated that wood charcoal

Table 1. Analyzed chemical composition (g/kg DM) of experimental diets and dietary wood charcoal used fed to male broiler chickens.

<table>
<thead>
<tr>
<th>Composition</th>
<th>Wood charcoal</th>
<th>Dietary treatments¹</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T-0%</td>
<td>T-1.5%</td>
</tr>
<tr>
<td>Dry matter (g DM/kg fresh matter)</td>
<td>880</td>
<td>881</td>
</tr>
<tr>
<td>Organic matter</td>
<td>874</td>
<td>907</td>
</tr>
<tr>
<td>Crude protein</td>
<td>43</td>
<td>192</td>
</tr>
<tr>
<td>Carbon</td>
<td>721</td>
<td>397</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>1</td>
<td>8</td>
</tr>
</tbody>
</table>

¹T-0%: Commercial broiler feed with 0% wood charcoal (WC), T-1.5%: Commercial broiler feed and WC replacing 1.5% of the commercial broiler feed, T-3%: Commercial broiler feed and WC replacing 3% of the commercial broiler feed, and T-6%: Commercial broiler feed and WC replacing 6% of the commercial broiler feed (on a dry matter basis). Crude protein was calculated as nitrogen x 6.25. According to the manufacturer’s declaration, the commercial broiler feed contained 2950 kcal metabolizable energy/kg.

Table 2. Growth performance of male broiler chickens fed different substitution levels of charcoal in commercial broiler feed (day 42-45).

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Unit</th>
<th>Dietary treatments¹ (mean)</th>
<th>Overall</th>
<th>Kruskal Wallis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>T-0%</td>
<td>T-1.5%</td>
<td>T-3%</td>
</tr>
<tr>
<td>Replicates⁵</td>
<td>N</td>
<td>5</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Initial body weight</td>
<td>G</td>
<td>1645</td>
<td>1631</td>
<td>1598</td>
</tr>
<tr>
<td>Final body weight</td>
<td>G</td>
<td>1998</td>
<td>1936</td>
<td>1931</td>
</tr>
<tr>
<td>Weight gain</td>
<td>g/bird</td>
<td>353</td>
<td>305</td>
<td>333</td>
</tr>
<tr>
<td>Feed consumption</td>
<td>g FM²/bird</td>
<td>499</td>
<td>537</td>
<td>535</td>
</tr>
<tr>
<td>Feed conversion rate</td>
<td>g/g</td>
<td>1.5</td>
<td>1.8</td>
<td>1.6</td>
</tr>
</tbody>
</table>

¹T-0%: Commercial broiler feed with 0% charcoal, T-1.5%: Commercial broiler feed with 1.5% charcoal, T-3%: Commercial broiler feed with 3% charcoal, T-6%: Commercial broiler feed with 6% charcoal; ²FM: Fresh matter; ³SEM: Standard error of the mean; ⁴Probability values are indicated as *P ≤ 0.05, **P ≤ 0.01, ***P ≤ 0.001. n.s. not significant P > 0.05; ⁵Mortalities were observed during the adaptation period.
increased the feed conversion efficiency and other growth performance parameters in broiler chickens if the inclusion rate does not exceed 2%. However, this effect was age-dependent, limited to birds younger than 29 days, which might explain the missing effect in this study. Finally, Odunsi et al. (2007) observed a negative impact of feeding wood charcoal on growth performance of broilers and did not recommend dietary inclusion of wood charcoal.

**Effects of dietary wood charcoal on nutrient accretion and utilization in male broiler chickens**

The addition of dietary wood charcoal to broiler chicken finisher feed did not show any effect on the accretion of dry matter, carbon, nitrogen, and phosphorus of the birds (P > 0.05; Figure 1). Still, the dry matter, carbon and nitrogen accretion slightly increased with increasing level of dietary wood charcoal in the diet (DM: 69.2 g/day in T-
Figure 2. Utilization of a) dry matter b) carbon, c) nitrogen and d) phosphorus (all in %; P > 0.05, ANOVA) by broiler chickens fed with different substitution level of charcoal using total excreta collection. T-0%: Commercial broiler feed with 0% charcoal, T-1.5%: Commercial broiler feed with 1.5% charcoal, T-3%: Commercial broiler feed with 3% charcoal, T-6%: Commercial broiler feed with 6% charcoal. n = 5 replicates for each dietary treatment.

0%, 86.6 g/day in T-6%; C: 28.3 g/day in T-0%, 39.2 g/day in T-6%; N: 1.2 g/day in T-0%, 1.9 g/day in T-6%), while the phosphorus accretion remained constant at 0.25, 0.13, 0.24 and 0.24 g/day in T-0%, T-1.5%, T-3% and T-6%, respectively (SEM: 0.03 g/day). Accordingly, no effect on the nutrient utilization was observed (P > 0.05; Figure 2). The mean utilization of nutrients by broiler chickens fed T-0%, T-1.5%, T-3% and T-6%, respectively, was 64.7, 62.2, 64.4, and 66.4%, SEM: 1.24% (dry matter); 66.7, 65.9, 67.5, and 67.3%, SEM: 1.10% (carbon); 35.6, 41.9, 42.7, and 48.3%, SEM: 2.72% (nitrogen); and 28.0, 15.0, 27.9, and 27.9%, SEM: 3.31% (phosphorus). This is in accordance with a previous study of Oso et al. (2014) who concluded that the inclusion of dietary wood charcoal did not influence the apparent DM and crude protein digestibility of broilers. In the same study, however, the inclusion of charcoal into unpeeled cassava root meals could counterbalance the negative effect of dietary cyanide on the crude protein utilization. Similarly, the crude protein
The digestibility of broilers fed aflatoxin infested diets was improved using charcoal as a toxin binder (Rafiu et al., 2014) (Figure 1 and 2).

**Effects of dietary wood charcoal on excreta quality of male broiler chickens**

As could be expected, feeding charcoal increased the carbon concentration in total excreta by 5.3% (T-1.5%), 8.0% (T-3%) and 16.3% (T-6%), respectively, compared with excreta of birds fed with the dietary treatment without charcoal (T-0%) (P ≤ 0.05). Charcoal is inert and indigestible and therefore is excreted together with the undigested feed residues, as already argued by Al-Kindi et al. (2016). In contrast to the carbon concentration, the phosphorus concentration of the excreta decreased by 5.9% (T-1.5%), 11.2% (T-3%) and 14.2% (T-6%) in this study (P ≤ 0.05), while the organic matter and nitrogen concentrations of total excreta were not altered by substituting part of the commercial broiler feed by dietary wood charcoal (P > 0.05) as shown in Table 3. This is in agreement with Kutlu et al. (2001), who also detected a linear effect of dietary charcoal on the composition of excreta of broiler chickens, with the exception of the nitrogen concentration. It is also plausible that the reduction in phosphorous concentration in excreta was as a result of the change in gastrointestinal tract microbiota, as evidenced by Prasai et al. (2016) in layers. Although the addition of charcoal had no additional influence on the phosphorus utilization by broiler chickens in the present study, the lower phosphorus concentration in excreta of birds fed high levels of dietary wood charcoal demonstrates the potential of dietary wood charcoal to increase the bioavailability of phosphorus bound in the phytin of poultry diets that is generally limited due to an insufficient production of endogenous phytase in poultry (Maenz and Classen, 1998). Lowering the phosphorus concentration in poultry manure that is usually high (up to 2.4%) (Bolan et al., 2003), might also reduce the risk of surface water contamination (Table 3). As could be expected there was a clear color change of birds’ fresh excreta from light grey for birds fed with no wood charcoal, that is, T-0%, to very dark grey for birds fed with dietary treatment with the highest level of charcoal (T-6%) (P ≤ 0.01); however, the consistency of excreta was not influenced by the addition of charcoal and no signs of constipation or any health problem were observed in broiler chickens fed dietary treatments with wood charcoal (Table 4).

### Table 3. Chemical composition (g/kg DM; mg/kg DM for P) of total excreta of male broiler chickens fed with different substitution level of charcoal.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Dietary treatments¹ (mean)</th>
<th>SEM²</th>
<th>ANOVA p-value³</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T-0%</td>
<td>T-1.5%</td>
<td>T-3%</td>
</tr>
<tr>
<td>Replicates (n)</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Organic matter</td>
<td>797</td>
<td>810</td>
<td>813</td>
</tr>
<tr>
<td>Carbon</td>
<td>374³</td>
<td>394³</td>
<td>404³</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>55.7</td>
<td>49.8</td>
<td>53.2</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>17.0³</td>
<td>16.0³</td>
<td>15.1³</td>
</tr>
</tbody>
</table>

¹T-0%: Commercial broiler feed with 0% charcoal, T-1.5%: Commercial broiler feed with 1.5% charcoal, T-3%: Commercial broiler feed with 3% charcoal, T-6%: Commercial broiler feed with 6% charcoal; ²SEM: Standard error of the mean; ³Probability values are indicated as *P ≤ 0.05, **P ≤ 0.01, ***P ≤ 0.001, n.s. not significant P > 0.05. Letters indicate significant differences within rows (P ≤ 0.05; Tukey HSD test).

### Table 4. Consistency and color of total excreta of male broiler chickens fed with different substitution level of charcoal.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Dietary treatments¹ (median)</th>
<th>Kruskal Wallis p-value²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T-0%</td>
<td>T-1.5%</td>
</tr>
<tr>
<td>Replicates (n)</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Color</td>
<td>7.4</td>
<td>5.7</td>
</tr>
<tr>
<td>Consistency</td>
<td>2.3</td>
<td>2.4</td>
</tr>
</tbody>
</table>

¹T-0%: Commercial broiler feed with 0% charcoal, T-1.5%: Commercial broiler feed with 1.5% charcoal, T-3%: Commercial broiler feed with 3% charcoal, T-6%: Commercial broiler feed with 6% charcoal; ²Probability values are indicated as *P ≤ 0.05, **P ≤ 0.01, ***P ≤ 0.001, n.s. (not significant) P > 0.05. Differences across dietary treatments could not be computed due to ties.
CONCLUSIONS

Dietary wood charcoal could replace up to 6% of commercial broiler finisher feed without negative effect on production performance, nutrient accretion and utilization, as well as excreta consistency of male broiler chickens. The use of wood charcoal as a broiler feed additive, particularly at 6% substitution level, reduced P in total excreta suggesting that wood charcoal could improve the phosphorus utilization in broiler chickens. Increased C excretion through feeding wood charcoal could potentially improve the poor soil quality in northern Ghana. Future research should analyze the long-term effect of feeding wood charcoal on performances and health of laying hens.

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CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES


