RESEARCH ARTICLE

# Effect of biochar on nitrogen and phosphorus losses in broiler litters

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***ABSTRACT***

*Potential of biochar to reduce nitrogen (N) and phosphorus (P) leaching from three types of broiler litters was assessed. One thousand eighty (1080) day-old Hubbard F-15 male broilers (average body weight±SD, 35.8±1.32 g) fed with a commercial diet were raised on a litter containing either wood shavings (WS), paddy husk (PH) or paddy straw (PS) in triplicates (120 birds per replicate) until day 35. Representative litter samples collected from the respective pens on day-35 (n=9) were used to prepare litter samples either unamended (U) or amended (A) with rice (Oryza sativa) hull biochar produced through pyrolysis at 500 to 520 °C. A sample of red yellow podzolic soil was used as the control (C). The leachates obtained from the control (C), biochar unamended (UWS UPH; and UPS) and amended litter samples (AWS, APH and APS) were tested for N and P leach outs on day 0, 5, 10 and 15. A significant treatment x time interaction was observed for both N ($P<0.05$) and P ($P<0.05$) concentrations in leachates. The highest leaching of P and N was observed ($P<0.05$) in UPS over the period. Biochar amended WS, PH and PS significantly reduced ($P<0.05$) leaching of P and N compared to unamended counterpart but seemed to be highly time dependent. Amendment of WS with biochar reduced N ($P<0.05$) and P ($P<0.05$) leaching than the other two litter types tested over the period. The present study concluded that the WS has the best potential to reduce N and P leaching when amended with biochar.*

***Keywords:*** *Biochar, nitrogen, paddy husk, phosphorus, wood shavings*

## INTRODUCTION

Broiler litter is typically composed of manure, bedding materials, wasted feed, feathers and soil (Jacob *et al.,* 1997). However, selection of litter materials for intensive poultry farming largely depends on their locality. The most commonly use litter materials include wood chips, sawdust, chopped straw, corn cobs, peanut hulls, paddy husk and recycled paper products. Due to low moisture contents, broiler litters are generally considered as the most valuable animal manures for crops (Wilkinson, 1979). Poultry litters contain large amounts of nitrogen (N), phosphorus (P), potassium (K) and some trace elements (Wright *et al.,* 1998; Kelleher *et al.,* 2002).

Excretion of excess P from intensively managed poultry is one of the critical global environment concerns today (Mutucumarana *et al.,* 2014). Inability of poultry to utilize phytate-bound P and inclusion of P in poultry diets as a safety margin are the major reasons for excretion of P in poultry excreta (DeLaune *et al.,* 2004; Mutucumarana, 2014). It is well known that improper poultry litter management has led to leaching of N and P run-off into the surface water bodies (Wright *et al.,* 1998). Over-use of broiler litter can enrich water bodies resulting eutrophication, spread of pathogens, production of phytotoxins, air pollution and emission of greenhouse gases (Jungbluth *et al.,* 2001; Phetteplace *et al.,* 2001; Kelleher *et al.,* 2002). Currently, eutrophication has been proposed as the main reason for impairment of global surface water resources. Moreover, excessive application of poultry litter in crop cultivation can result contamination of groundwater with $NO_3^-$ (Bitzer and Sims, 1988). However, high $NO_3^-$ levels in drinking water is well known to cause methemoglobinemia, cancers, and respiratory illnesses in human and fetal abortions in livestock species (Stevenson, 1986). Several recent researches have demonstrated that land application of litter generates a potential risk of contaminating surface water with P (Vories *et al.,* 2001; Chan *et al.,* 2007a).

Biochar is defined as a carbon-rich material produced from slow pyrolysis of biomass (Chan *et al*., 2008; Brantley *et al.,* 2015). The potential of biochar to improve soil quality by increasing (i) anion and cation exchange capacities, (ii) surface area, (iii) water holding capacity and (iv) bioavailability of nutrients such as N and P is well known (Chintala *et al*., 2014). Over the decades, biochar has been used widely in soil amendments to improve and maintain soil fertility (Glaser *et al*., 2002a, 2002b) and to increase soil carbon sequestration (Lehmann *et al*., 2003; Herath *et al*., 2015).

Beneficial effects of biochar as a soil amendment in terms of increased crop yield and improved soil quality have been reported, but the responses vary widely (Iswaran *et al*., 1980; Glaser *et al*., 2002*a*; Chan *et al*., 2007*b*) depending upon the type of biochar and the soil type used (Chintala *et al*., 2014). According to Steiner *et al.* (2007), it has been reported that this trapped N may be plant available because increased plant growth was seen in biochar-amended and N-fertilized soil compared to un-amended soil with heavy leaching conditions.

Number of published reports is available on application of biochar on specified poultry litter materials (Doydora *et al*., 2011). However, the studies comparing the effects of biochar on different litter materials are highly limited. Therefore, the present study was carried out to (i) investigate the potential of biochar on reduction of N and P leaching from three different broiler litter types, (ii) measure and compare N and P run-off between three different types of biochar-amended litter materials, and (iii) to compare biochar amended and un-amended broiler litter in relation to release of N and P.

## MATERIALS AND METHODS

### Birds and housing

One thousand eighty (n=1080) day-old male broilers (Hubbard-F15) obtained from a commercial hatchery were individually weighed (average body weight±SD, 35.8±1.32 g) and assigned to nine floor pens in triplicates (120 birds per replicate) in an environmentally controlled poultry house. The birds were fed with commercial broiler rations from day-1 until day-35 (Table 1). Management of room temperatures, lighting and light intensity during the experimental period were based on the Hubbard broiler management guide (2014).

**Table 1:** Calculated composition of the broiler diets fed to broilers.

| Item | Broiler Chick Booster<br>Day 1-7 | Broiler Starter<br>Day 7-18 | Broiler Grower<br>Day 18-26 | Broiler Finisher<br>Day 26-32 | Broiler Withdrawal<br>Day 32-35 |
|---|---|---|---|---|---|
| Crude protein (%) | 23.5 | 22.0 | 21.0 | 20.0 | 20.0 |
| Crude fat (%) | 7.0 | 6.0 | 6.5 | 7.0 | 7.0 |
| Ash (%) | 7.0 | 7.0 | 6.5 | 7.5 | 7.5 |
| Crude fibre (%) | 4.5 | 4.5 | 4.5 | 4.5 | 4.5 |
| Calcium (%) | 1.0-1.2 | 0.95-1.2 | 1.0 | 0.9-1.2 | 0.9-1.2 |
| Total phosphorus (%) | 0.7-1.0 | 0.7-1.0 | 0.7 | 0.65-1.0 | 0.65-1.0 |
| Metabolizable energy (kcal/kg) | 3000 | 3000 | 3000 | 3100 | 3100 |

### Preparation of litter

Paddy Straw (PS), Paddy Husks (PH) and Wood Shavings (WS) were used as the test litter materials and each was tested in triplicates. Litter materials were sun dried for 48 h and PS were chopped into 2 cm pieces. The litter height of each litter material in replicate pen was maintained at 5 cm. All litter materials were turned over from day 4 to 35. On day 35, random samples of litter materials from each replicate pen were collected, mixed together and composite samples were prepared (n=9).

## Preparation of leachate

Commercially available rice (*Oryza sativa*) hull biochar ('Biochar', Balangoda, Rathnapura-Sri Lanka) produced through pyrolysis at 500 to 520 °C was used as the biochar source. Red yellow podzolic soil samples (soil classified in intermediate low country agroecological zone) were homogenized, air-dried for 48 h and passed through a 2 mm sieve. Representative samples of composite poultry litter samples collected from the poultry pens (n=9) were used to analyze for pH (Doydora *et al*., 2011), total carbon and total N (Nelson and Sommers, 1996), and total P (USEPA, 1979). Same procedures were used to analyze pH, total C total N and total P in biochar and soil.

Five-centimeter diameter PVC tubes plugged with cotton at the bottom were used to place the prepared samples. Twenty-one tubes were prepared to accommodate three replications of seven treatments in a completely randomized design. The seven treatments include: Control (C), UWS (soil+ WS), UPH (soil + PH), UPS (soil+ PS), AWS (soil + WS + biochar), APH (soil + PH + biochar) and APS (soil + PS + biochar). The tubes for the control were filled with 500 g of soil. The tubes of UWS, UPH and UPS were filled with a mixture of soil (500 g) and the respective litter material (250 g).

The tubes for treatments AWS, APH and APS contained 250 g of biochar placed at the bottom of the tube plus a mixture of 250 g of litter and 500 g of soil placed above. The contents in each tube were drained with 1500 mL of deionized water and the respective leachates were analysed in triplicates for P and N contents (Eaton *et al*., 1995). The leachates were collected at 0, 5, 10 and 15-days intervals.

## Statistical analysis

Broiler litter properties were compared between broiler litter sources by analysis of variance (ANOVA) using the statistical software (SAS, 2001). When appropriate, means were separated by Least Significant Difference (LSD) at $P<0.05$. Based on the completely randomized design, a two-factor ANOVA was conducted using SAS to determine the effects of biochar on different litter materials and their interaction with the time intervals. Means were separated by LSD at $P<0.05$. One-way ANOVA was also conducted to investigate the effect of biochar on different litter materials at individual collection period. Means were separated by LSD at $P<0.05$.

# RESULTS AND DISCUSSION

## Composition of soil, biochar and litter materials

The analysed total C, total N, total P (g/kg) and pH of soil, biochar, PH, WS and PS derived litter types are presented in Table 2. The pH of the soil was acidic. The broiler litter composed of PS contained the highest N and P contents. Carbon level was maximal in WS. The total C, total N and total P contents were significantly different ($P<0.05$) between litter types. The differences in chemical compositions of original samples may have partially contributed to the differences among total C, total N and total P in each litter types when analyzed. The values provided in Table 2 strongly indicated that the broiler litter enriches in terms of N and P.

**Table 2:** Properties of soil, biochar and broiler litters used in the experiment.

| | pH | Total C (g/kg) | Total N (g/kg) | Total P (g/kg) |
|---|---|---|---|---|
| Soil | 5.2 | 28.06±0.48 | 2.17±0.15 | 0.72±0.01 |
| Biochar | 8.9 | 830.33±1.0 | 3.50±0.02 | 0.356±0.005 |
| ***Litter types*** | | | | |
| PH[1] | 8.62 | 360.8$^{c}$±0.59 | 41.95$^{c}$±0.49 | 16.65$^{c}$±0.26 |
| WS[2] | 8.4 | 551.33$^{a}$±1.39 | 47.29$^{b}$±0.72 | 19.07$^{b}$±0.13 |
| PS[3] | 8.53 | 407.93$^{b}$±0.34 | 48.74$^{a}$±0.16 | 20.85$^{a}$±0.40 |

[1] Paddy Husk.
[2] Wood Shavings.
[3] Paddy Straw.
$^{a\text{-}c}$ Means in a column not sharing a common superscript are significantly different ($P<0.05$).

**Nitrogen and phosphorus leaching; Effects of different treatments**

The influence of different treatments on the leach out of P and N at different collection periods is presented in Table 3. Phosphorus and N contents of the leachates were affected significantly ($P<0.001$) by both the treatment and the time of collection. Significant ($P<0.001$) treatment and time interactions were observed for both P and N concentrations of the leachates. This observed interaction for N may be primarily due to the lower N leach out from the treatment C during the collection period (days 0 to 15) and a greater increase in N content of leachate from UPS from day 10 to day 15.

When P is concerned the observed treatment and time interaction effect can be explained by the fact that the gradual reduction of P in leachates of APH and APS on day 15. When main effects are concerned, PS with no biochar (UPS) had the poorest ability to retain N and P, and of three litter types amended with biochar, WS had the best ability to retain P ($P<0.05$) and N ($P<0.05$) than the other two litter types. Nitrogen content present in leachates increased gradually ($P<0.05$) with the time of collection from day 0 to 15.

**Table 3:** Nitrogen (N) and phosphorus (P) leach out (mg/L) as affected by different treatments and time of collection.

| Treatment[1] | Time (d) | Leachate composition (mg/L) | |
|---|---|---|---|
| | | P | N |
| C[1] | 0 | 0.012[a] | 0.314[a] |
| | 5 | 0.032[b] | 0.330[b] |
| | 10 | 0.040[c] | 0.372[c] |
| | 15 | 0.061[d] | 0.382[c] |
| UWS[2] | 0 | 0.325[f] | 0.638[d] |
| | 5 | 0.347[h] | 0.711[g] |
| | 10 | 0.360[i] | 0.868[k] |
| | 15 | 0.403[l] | 0.925[l] |
| UPH[3] | 0 | 0.413[n] | 0.671[e] |
| | 5 | 0.435[s] | 0.763[h] |
| | 10 | 0.442[t] | 0.948[m] |
| | 15 | 0.471[v] | 0.986[o] |
| UPS[4] | 0 | 0.433[r] | 0.697[fg] |
| | 5 | 0.443[t] | 0.837[j] |
| | 10 | 0.487[w] | 0.995[o] |
| | 15 | 0.517[x] | 1.265[p] |
| AWS[5] | 0 | 0.321[e] | 0.633[d] |
| | 5 | 0.344[g] | 0.711[g] |
| | 10 | 0.362[i] | 0.832[j] |
| | 15 | 0.380[j] | 0.914[l] |
| APH[6] | 0 | 0.418[o] | 0.666[e] |
| | 5 | 0.424[p] | 0.757[h] |
| | 10 | 0.406[m] | 0.913[l] |
| | 15 | 0.390[k] | 0.968[n] |
| APS[7] | 0 | 0.432[qr] | 0.694[f] |

| | | | |
|---|---|---|---|
| | 5 | 0.430[q] | 0.785[i] |
| | 10 | 0.461[u] | 0.977[no] |
| | 15 | 0.442[t] | 0.985[o] |
| SEM[8] | | 0.023 | 0.024 |
| **Main Effects** | | | |
| **Treatment** | | | |
| C | | 0.036 | 0.350 |
| UWS | | 0.359 | 0.786 |
| UPH | | 0.440 | 0.842 |
| UPS | | 0.470 | 0.949 |
| AWS | | 0.352 | 0.772 |
| APH | | 0.410 | 0.826 |
| APS | | 0.441 | 0.860 |
| SEM[8] | | 0.0199 | 0.0176 |
| **Time** | | | |
| 0 | | 0.336 | 0.616 |
| 5 | | 0.351 | 0.699 |
| 10 | | 0.366 | 0.843 |
| 15 | | 0.380 | 0.918 |
| SEM[8] | | 0.0189 | 0.0152 |
| **Probability (*P* ≤)** | | | |
| Treatment | | <0.001 | <0.001 |
| Time | | <0.001 | <0.001 |
| Treatment x Time | | <0.001 | <0.001 |

[1]C=control (soil); [2]UWS= soil + wood shavings; [3]UPH= soil + paddy husk; [4]UPS=soil+ paddy straw; [5]AWS=soil + wood shavings + biochar; [6]APH= soil + paddy husk + biochar; [7]APS= soil+ paddy straw+ biochar.
[8]Pooled Standard Error of Mean.
[a-v]Means in a column not sharing a common superscript are significantly different (*P*<0.05).

***Phosphorus (P) leach out***

Phosphorus leach out (mg/L) of different treatments collected at different time periods are presented in Table 4. In all treatments except APH and APS, the P content of leachates increased with the time. Reduction of P content from the leachates obtained from APH and APS was observed after day 10 and day 15, respectively. The highest P content in leachates reported for day 0, 5, 10 and 15 were observed from the treatment UPS which contained PS as the sole litter material.

**Table 4:** Phosphorus leach out ± SD1 (mg/L) of different treatments.

| Days | Treatment[2] | | | | | | |
|---|---|---|---|---|---|---|---|
| | C | UWS | UPH | UPS | AWS | APH | APS |
| 0 | 0.012$^{f}$±0.023 | 0.325$^{d}$±0.026 | 0.413$^{c}$±0.021 | 0.433$^{a}$±0.020 | 0.321$^{e}$±0.019 | 0.418$^{b}$±0.015 | 0.432$^{a}$±0.01 |
| 5 | 0.032$^{g}$±0.018 | 0.347$^{e}$±0.021 | 0.435$^{b}$±0.020 | 0.442$^{a}$± 0.19 | 0.344$^{f}$±0.017 | 0.424$^{d}$±0.020 | 0.430$^{c}$±0.016 |
| 10 | 0.040$^{f}$±0.015 | 0.360$^{e}$±0.021 | 0.442$^{c}$±0.019 | 0.487$^{a}$±0.016 | 0.362$^{e}$±0.021 | 0.406$^{d}$±0.016 | 0.461$^{b}$±0.019 |
| 15 | 0.061$^{g}$±0.017 | 0.403$^{d}$±0.018 | 0.471$^{b}$±0.014 | 0.517$^{a}$±0.017 | 0.380$^{f}$±0.019 | 0.390$^{e}$±0.018 | 0.442$^{c}$±0.021 |

[1]Standard deviation.
[2]C=control (soil); UWS= soil+ wood shavings; UPH= soil+ paddy husk; UPS=soil+ paddy straw; AWS=soil+ wood shavings+ biochar; APH= soil+ paddy husk+ biochar; APS= soil+ paddy straw+ biochar.
[a-g]Means in a row not sharing a common superscript are significantly different ($P$<0.05).

As compared to UWS, amendment with biochar significantly reduced ($P$<0.05) the P content of leachate obtained from the WS (AWS) on days 0, 5, 10, and 15 (Table 4). However, P content in the leachates obtained from UPH and APH on respective dates was significantly different ($P$<0.05) and amendments with biochar was found to be effective only after day 5 (Table 4). However, PS when incorporated with biochar (APS *vs.* UPS) significantly reduced leach out of P on days 5 ($P$<0.05), 10 ($P$<0.05) and 15 ($P$<0.05) (Table 4), when compared to its unamended counterpart (UPS).

It was evident that in most of the treatments, both N and P leach out had increased with the time interval. However, the addition of biochar to both PH (APH) and PS (APS) was shown to be effective on reducing P leach out as the time advances. Of three litter types tested, application of biochar was most effective on reducing P leach out from WS. This was followed by PH and PS, respectively.

***Nitrogen leach out***

Nitrogen leach out (mg/L) of different treatments collected at different time periods are presented in Table 5. In all treatments N content of leachates increased with the time. The highest N leachates reported for day 0, 5, 10 and 15 were reported from the treatment UPS which contained PS with no biochar.

As compared to UWS, amendment with biochar reduced ($P$<0.05) the N content of leachate from AWS only on day 10 (Table 5). A similar trend ($P$<0.05) was observed for the N contents in the leachates obtained from UPH and APH on Day 10. However, amendment of biochar to PS (APS *vs.* UPS) significantly reduced leach out of N on days 5 ($P$<0.05), 10 ($P$<0.05) and 15 ($P$<0.05) (Table 5).

**Table 5:** Nitrogen leach out ± SD1 (mg/L) of different treatments.

| Days | Treatments[2] | | | | | | |
|---|---|---|---|---|---|---|---|
| | C | UWS | UPH | UPS | AWS | APH | APS |
| 0 | $0.314^{d}\pm0.012$ | $0.638^{c}\pm0.016$ | $0.671^{b}\pm0.014$ | $0.697^{a}\pm0.013$ | $0.633^{c}\pm0.015$ | $0.666^{b}\pm0.019$ | $0.694^{a}\pm0.02$ |
| 5 | $0.330^{e}\pm0.012$ | $0.711^{d}\pm0.014$ | $0.763^{c}\pm0.012$ | $0.837^{a}\pm0.011$ | $0.711^{d}\pm0.012$ | $0.757^{c}\pm0.016$ | $0.785^{b}\pm0.014$ |
| 10 | $0.372^{g}\pm0.016$ | $0.868^{e}\pm0.013$ | $0.9484^{c}\pm0.012$ | $0.995^{a}\pm0.015$ | $0.832^{f}\pm0.012$ | $0.913^{d}\pm0.015$ | $0.977^{b}\pm0.018$ |
| 15 | $0.382^{d}\pm0.012$ | $0.925^{c}\pm0.013$ | $0.986^{b}\pm0.015$ | $1.265^{a}\pm0.021$ | $0.914^{c}\pm0.019$ | $0.968^{b}\pm0.017$ | $0.985^{b}\pm0.011$ |

[1]Standard deviation.
[2]C=control (soil); UWS= soil + wood shavings; UPH= soil + paddy husk; UPS=soil+ paddy straw; AWS=soil+ wood shavings+ biochar; APH= soil+ paddy husk+ biochar; APS= soil+ paddy straw+ biochar.
[a-g]Means in a row not sharing a common superscript are significantly different ($P$<0.05).

When compared to APH and APS, the treatment AWS showed a significant reduction ($P$<0.05) in N leach out than APH and APS on each respective day. Of these three treatments, the treatment which contained PS (APS) was the least affected by biochar amendment and contained the highest N concentrations in leachates. However, the N contents of the leachates from APH and APS were similar ($P$>0.05) on day 15.

***Biochar and nutrient leach out***

The main characteristic of biochar is its stability in soil due to the chemical recalcitrance of its structure, mainly formed by aromatic and heterocyclic C (Lehmann *et al.*, 2009). The addition of charred material to soil modifies the chemical composition of the soil Organic Matter (OM) by adsorption of dissolved organic carbon (Pietikäinen *et al.*, 2000). These changes reinforce the resistance of soil OM to microbial degradation and mineralization, consequently promoting the build-up of soil OM with a mean residence time of several hundred to several thousand years (Lehmann *et al.*, 2009). Other beneficial effects of biochar application to agricultural soils are related to the improvement of water-holding and Cation Exchange Capacity (CEC) and interactions with nutrient cycling through increases in soil pH and reductions in nutrient leaching (Chintala *et al.,* 2014).

As described by Novak *et al*. (2009b), the greater biochar production temperatures could result more alkaline pH, high ash contents, and greater surface areas in biochar which could elevate soil pH. The alkaline pH (8.9) of the biochar used in the present study may be a result of high temperatures applied during the manufacturing process.

Biochar-soil combinations raised soil pH from 5.15 to 6.15 (Tryon, 1948). As the soil nears neutral pH, nutrients in the soil become available. In contrast, concentrations of acid-forming cations, such as aluminum (Al), iron (Fe) and manganese (Mn) in the soil solution are lowered (Troeh and Thompson, 2005).

The analysed total N content of the litter types used in the present study ranged between 41.95 and 48.74 g/kg. Four forms of N are identified in poultry litter that includes complex organic N, labile organic N, ammonium and $NO_3^-$ (Sims and Wolf, 1994; Sharpley and Smith, 1995; Diaz *et al.*, 2008). Complex forms of organic N in poultry litter include constituents of feathers, spilt and undigested feed, and bedding materials. Labile organic N is largely uric acid and urea. Uric acid in the fresh manure is rapidly hydrolyzed to urea by the uricase enzyme, and the urea is subsequently hydrolyzed to ammonium by urease enzyme. Nitrate is formed when the ammonium ions are oxidized during aerobic composting. Compared with biochar produced at high temperatures, biochar produced at low pyrolysis temperatures showed comparatively low Ca, Mg, and $NO_3$-N leaching (Gajić and Koch, 2012). This is mainly due to lower C-to-N ratios, and the presence of microbially degradable C (Gajić and Koch, 2012).

In the present study, amendment of poultry litter with biochar reduced both N and P leaching. This effect was dominant when the wood shavings were used. Kameyama *et al.* (2012) studied $NO_3$–N retention by calcareous Japanese soils amended with biochar produced from bagasse at 400 to 800 °C. These authors showed that the sorption of $NO_3$-N by biochar was increased along with increasing temperatures due to the formation of base functional groups (Kameyama *et al.*, 2012). This increased retention of nutrients and water in biochar micropores have resulted reduced $NO_3$ leaching and provided a greater opportunity for crops to utilize available $NO_3$-N.

In contrast, a study by Sarkhot *et al.* (2012) showed that the addition of the equivalent of 20 mg/ha biochar as is or enriched in nutrients from dairy manure effluent showed no differences in N leaching as compared that of unamended soil. It was suggested that the biochar either acts as a slow release source of N or that it caused N immobilization.

P in poultry litter is about two thirds present as solid-phase organic P and one third as inorganic P (Edwards and Daniel 1992; Sharpley and Smith 1995;

Sharpley *et al*., 2004). The amount of total P in poultry litter varies with the diet and bedding material, and ranges from 0.3 to 2.4% of dry matter. Fractionation studies have shown that a large proportion of P in poultry litter is in acid soluble fraction, indicating low bioavailability (Bolan *et al*., 2010). According to Turner and Leytem (2004), acid extractable P in raw broiler litter is dominated by inorganic (35 to 41%) and organic P forms (58 to 65%). Inorganic phosphate fractions in poultry manure include dibasic calcium phosphate, amorphous calcium phosphate and weakly bound water-soluble phosphates (Sato *et al*., 2005), while organic P in poultry litter is largely in the form of phytic acid salts (Turner and Leytem, 2004). Reduction in the amounts of lost P may be achieved by the biochar's capacity to adsorb phosphate (Lehmann *et al*., 2006). According to McBride (1994), Villapando *et al.* (2001) and Dume *et al*. (2017) sorption is one of the commonly used mechanisms to describe retention of P in soil. High AEC of biochar was shown to (i) enhance the availability and plant uptake of P; (ii) reduce availability of Al and Fe in soil, and (iii) reduce P fixation (Deluca *et al*., 2009; Novak *et al*., 2009a). Cui *et al*. (2011) showed that P sorption on pure ferrihydrite was decreased with the application of rice straw-derived biochar.

DeLuca *et al.* (2009) found that the use of biochar altered soil P availability through the biochar's AEC or by influencing the activity/availability of cations that interact with P. Laird *et al*. (2010) observed that addition of biochar reduced leaching of P from a manure applied soil due to sorption of both orthophosphate and organic P by the biochar. These facts partially explain the reasons for reduction of P concentrations in the leachates obtained from biochar amended litter types observed in the present study. The amount of P in the leachates of PH (APH) and PS (APS) amended with biochar in the present study were declined with the time. It has been found that the most of the N and P in poultry manure which are in organic forms (Edwards and Daniel, 1992), may not immediately available to plants.

The retention of P and N was significant for PS. However, the use of amendments, such as straw, peat, woodchip, paper waste, elemental sulphur and zeolite was shown to reduce the N losses during composting of poultry waste. Aerobic composting with cereal straw, which contains readily decomposable carbon, was found to be the most effective in reducing the N losses (Preusch *et al.,* 2002).

## CONCLUSIONS

In conclusion, the present study confirmed that the amendment of broiler litter with biochar reduced the N and P leach-out. The rates of N and P loss are varied with the type of litter material and the time of exposure. Amendment of WS with biochar reduced N and P leaching than the other two litter types over the period. The degree of leaching from litter materials increased with the time. Amendment with biochar reduced P leaching of PH and PS with increasing time. There is a potential of biochar to reduce the N and P leaching from WS, PH and PS derived broiler litter. The present study also concluded that the WS bear the best potential to reduce N and P leaching when amended with biochar.

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