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Simple Processing Method for Recycling Poultry Waste into Animal Feed Ingredient

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Abstract

Poultry wastes (PW) namely broiler litter (BL), caged-layer droppings (CLD) and layer litter (LL) were evaluated for nutrient composition and microbial loads in order to select the most suitable for use as a feedstuff. Broiler litter had the highest amount of crude protein (16.8%) and a phosphorus content of 0.49%. There were more bacteria (cfu/g) in all the test materials than fungi. The total heterotrophic bacteria (THB) load was lowest in BL at 2.8 ×10^6 cfu/g. The total heterotrophic fungi (THF) load of 1.1 × 10^2 cfu/g was lowest for CLD. Total microbial load (TML) was lower in BL with a value of 1.4 x10^6 cfu/g. Klebsiella edwardsii was prevalent in all the test materials, while the fungi identified were moulds. Broiler litter also had the least number of identified microorganisms. The crude protein (CP), phosphorus (P) content, and the TML showed BL as the most suitable PW that can be processed as a feedstuff. The processing method developed in this study for recycling poultry litter into feedstuffs potentially useful for integration into animal-feeding systems for non-ruminants is simple, feasible and cheap.

Keywords: poultry waste; phosphorus; nitrogen; microbes; brewers' dried grains

Introduction

Intensive livestock production systems cause serious problem of waste management. The problem arises due to feeding of animals huge amounts of high-density nutrient concentrates, plant biomass, and agro-industrial by-products. The concentration of large inputs on small areas results in unfriendly environmental issues regarding animal waste management. Sharpley *et al*. (1994) noted that since most of the livestock wastes were produced in confinement units, the nearby land base becomes readily available to accommodate the waste in an environment-unfriendly manner. With intensification of livestock production, manure has been viewed as a waste product in need of disposal as opposed to a source of fertilizer for integrated cropping and livestock production systems (McAllister *et al*., 2011). Poultry waste (PW) is predominantly solid; which includes the faecal and urinary wastes, bedding material, wasted feed, feathers and non-degradable materials. Poultry industry wastes are non-consumables to humans but could be recycled and become consumables to livestock, thus entering the human food chain. Poultry waste is not a product of uniform quality (USEPA, 2000).

Pickard (2006) observed that recycling available nutrients for re-use in animal

production rather than for disposal would go a long way in reducing the final volume of animal wastes released into the environment. In addition, an effective use of animal waste resources might provide a partial, but still important, contribution in reducing net carbon (iv) oxide (CO_2) emissions (Ceotto, 2005). Earlier reports on PW processing as animal feed were based on individual waste being dehydrated by air-drying, oven drying, autoclaving (Fianu *et al*., 1984); sun-drying (Fombad and Mafeni, 1989; Saleh *et al.,* 2002); composting (Fontenot, 1996; Eden *et al.,* 2007) ensiling (Caswell *et al.,* 1978) chemical treatment (Caswell *et al.,* 1975) and pelleting (Fontenot, 1996). These methods require the skill or the technical-know-how or high capital outlay making them not feasible for small-medium scale farmers. In addition, Caswell *et al.* (1975) reported that heating and drying processes are more efficient than deep stacking or fermentation in killing pathogenic bacteria. Fianu *et al*. (1984) observed that processing litter by either air-drying, oven drying or autoclaving was not satisfactory for the control of odour, pathogens and nitrogen loss. On the other hand, sun drying may be have low cost investment, but its resultant product of low quality due to repeated wetting and re-drying, contamination from dust, birds and animals is a major disadvantage.

The future success of the livestock sector in providing meat and other animal products may depend on the utilization and the acceptability of animal waste by the major stakeholders as useful input recycled into the industry. This will bring economic benefits and support the efforts to reduce environmental degradation. This study was, therefore, designed to evaluate the prospect of possible combinations of the PW, characterize the products based on nutrient, mineral (Ca and P), microbial constituents and develop a simple processing technique that will be easily adoptable by small-medium scale poultry farmers in order to convert PW into animal feed.

Materials and Methods

The PW used as test materials were broiler litter (BL), caged layer droppings (CLD) and layer litter (LL). The procedure for determining the test material to be processed as a feedstuff was in two phases:

(a) analysing for the nutrient, mineral, and microbial constituents

(b) processing of selected test material as a feedstuff

Test materials (TM) were sieved using metal sieves with mesh size of 5 mm^2 to remove caked material and unwanted items such as feathers, carcasses, metal objects, stones, etc. They were thereafter sun-dried to moisture content of less than 20% by spreading them out thinly on black polythene sheets (0.7 mm thickness), on a surface area of 0.67 m^2 on the concrete roof (20.5 m high) of the Faculty of Agriculture, Obafemi Awolowo University, Ile-Ife, Nigeria. The surface temperature was not less than 44 ºC. Drying started at about 9.00 h until sunset. Test materials were turned twice within the first 3 h of drying. This involved rubbing handfuls together to break up clogs and spreading again. Bulk of the dried and cooled TM were bagged in high-density transparent polythene bags, labelled and then stored in a dry place under ambient room conditions for subsequent use, while samples of about 500 g were thoroughly hand-mixed before being milled through a 1 mm screen in order to ensure homogeneity. The decision criterion was to select the product with the highest CP and P contents with the least total

microbial load (TML). Proximate and mineral analyses were done in triplicates while the microbiological analysis was done in duplicates.

Chemical analysis

Proximate composition of samples was determined according to the methods of AOAC (2005). The NDF, ADF and ADL content were determined also according to the methods of AOAC (2005) by digestion with neutral detergent and acid detergent solutions. Hemicelluose and cellulose contents were analysed according to the methods of AOAC (2005) while soluble carbohydrates were calculated as described by NRC (1998). Mineral content determination was according to the methods of AOAC (2005), with the exception of P. Total P content was determined by using atomic absorption spectrophotometer (JENWAY 6405 UV/VISIBLE Spectrophotometer, UK) at 882 nm wavelength, after sample solutions were prepared and blue colour developed using Molybdophosphate method. Gross energy (GE) concentration was determined using the e2k Combustion Calorimeter, S.A., version 2.0 (2008).

Microbiological analysis

Microbiological analysis was carried out according to the procedure outlined by Seeley and van Demark (1972). Total viable count (TVC) for bacteria and fungi was carried out by the pour plate method, using Plate Count Agar for total heterotrophic bacteria (THB) and Malt Extract Agar for total heterotrophic fungi (THF), with the Petri dishes incubated at 30 and 25 ºC for 3 and 5 days, respectively. Isolated organisms were characterized and identified. The numbers of colonies were expressed as colonies formed per unit (cfu/g). Biochemical examinations carried out included the Sulphide-Indole-Motility, catalase, citrate utilization, Methyl Red and Vages-Proskaur, nitrate reduction, Oxidation-Fermentation and sugar fermentation, respectively.

Statistical analysis

Differences in nutrient and mineral contents and microbial load between the test materials were analysed with the 2-way analysis of variance using the General Linear Model procedure of SAS (2000) for a completely randomized block design while the differences between processed BL and brewers' dry grain (BDG) were analysed with the One-way analysis of variance. The replicates per test material were analyzed as blocks. Mean differences in nutrient and mineral contents and microbial load between test materials were resolved by Duncan's NMRT of SAS® statistical package (SAS, 2000). Statistical significance was established when probability was less than 0.05 level of significance.

Processing of poultry litter into animal feedstuff

Poultry litter (PL) was collected fresh from broiler houses from 4 weeks of production to the end of a production cycle at 8 weeks. The litter was stacked on the concrete floor of a half open-sided roofed structure for 4 days to sustain the heat produced by the litter. The litter was spread out in the same shed for another 3 days to allow for proper drying before it was sieved twice, using metal sieves with mesh size of 5 mm^2 to remove caked material and unwanted items. Sieving involved breaking up clogs of litter by rubbing a handful between the palms of the hand. Sieved litter was bagged

in jute sacs, stacked, and stored in a cool, dry and secured place (a storehouse) under ambient conditions until ready for use. The processing steps are as shown in Fig. 1.

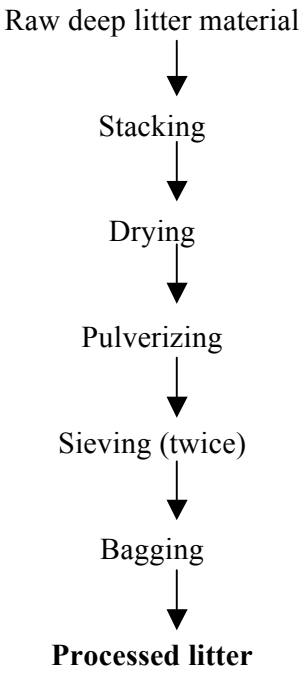
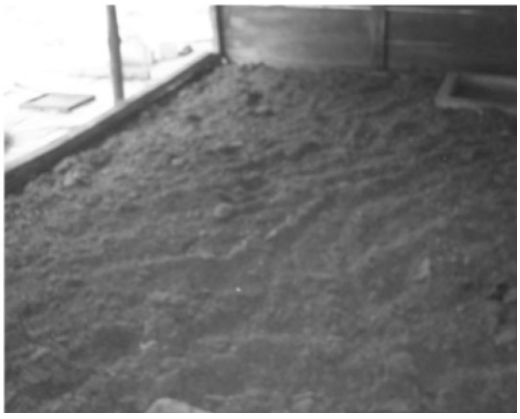
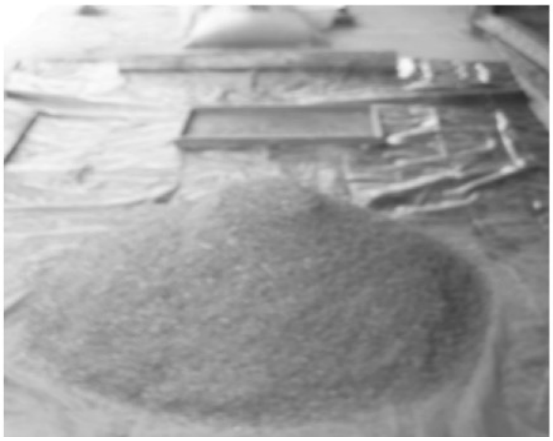


Fig. 1: Flow chart for the production of poultry litter

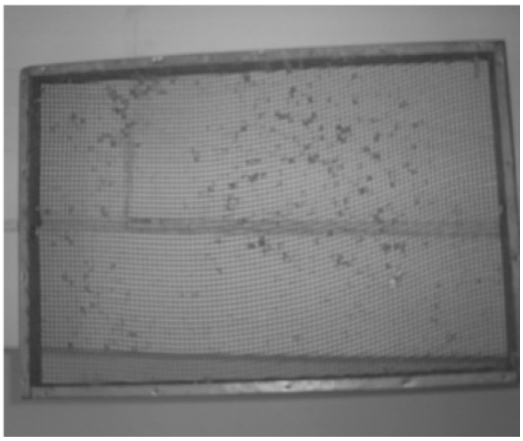
Unprocessed broiler litter

Poultry litter spread out to dry





Sieved broiler litter



Metal sieve

Plate 1: Production of broiler litter

Results

The input-to-output turnover ratio was 2:1 (i.e. two bags of raw litter gave one bag of processed litter). The proximate and mineral analyses of the test materials as shown in Table 1 showed that BL had the highest (*P<0.05*) amount of CP (16.8%), Ca (2.1%), and P (0.5%). The lignin content (*P>0.7)* was similar for both BL and BDG. The acid detergent fibre (ADF), neutral detergent fibre (NDF), hemicelluloses and cellulose contents of BDG were lower (*P<0.05)* Bacteria and fungi loads in the test materials showed that there were more bacteria in the proposed feedstuffs than fungi (Table 2). The THB load was higher (*P<0.02*) at 8.0 $\times 10^9$ cfu/g in CLD, while BL had the least THB of 2.8 $\times 10^5$ cfu/g. However, the difference between the THF loads of the test material was marginally close ranging from 10^2 to 10^3 cfu/g. CLD had the least (*P<0.004*) fungi load of 1.1 $\times$ 10^2 cfu/g. In terms of TML, BL had lower load (*P<0.02*) value of 2.8 x10^6 cfu/g compared with 8.0 x 10^{10} cfu/g for CLD. Isolation and identification of the microorganisms in the processed test materials showed that four different pathogenic bacteria were identified (Table 3). *Klebsiella edwardsii* was prevalent in all the feedstuffs, while *Pseudomonas aeruginosa* and *Klebsiella pneumoniae*, were present in CLD. BL had two fungi; LL had four while CLD had three identified microorganisms. *Fusarium sp*. was identified in LL and CLD while *Trichophyton rubrum* was identified in BL and CLD. Processed BL was compared with BDG (a known industrial by-product) for the purpose of evaluation (Table 4). Processed BL had a higher (*P<0.004*) crude fibre (15.0%) and ash (18.8%) content, a lower CP (20.2%) and gross energy (2850 kcal/kg) content. The levels of minerals in BL was higher (*P<0.05*) compared with BDG. The THF compared favourably *(P>0.31)* for both BL and BDG while the THB level was slightly lower (*P<0.05)* in BL at 2.8 $\times$ 10^5 cfu/g compared with 6.5 $\times$ 10^5 cfu/g in BDG.

Table 1: Proximate and mineral composition of broiler litter, layer litter and caged-layer droppings

PARAMETERS	BL	LL	CLD	SEM	P-value
MCW, %	41.2[b]	42.0[b]	80.6[a]	8.2	0.002
Ash, %	34.9[b]	37.9[a]	39.5[a]	1.2	0.02
Crude fibre, %	14.9[a]	14.4[a]	9.1[b]	1.0	0.03
Ether extract, %	1.9[b]	0.5[c]	3.4[a]	0.5	0.01
Crude protein, %	16.8[a]	15.5[a]	10.8[b]	1.2	0.03
Nitrogen-free extract, %	26.5	26.4	27.3	0.4	0.10
Calcium, %	1.6[ab]	1.8[a]	1.4[b]	0.2	0.04
[a]Phosphorus, %	0.5	0.4	0.4	0.01	0.3

a,b,c Means in a row within an item with different subscripts are significantly different (P<0.05)
SEM = standard error of means
MCW = moisture content (on wet-basis)
[a]total phosphorus
BL = broiler litter; LL = layer litter; CLD = caged-layer droppings

Table 2: Bacteria and fungi concentrations in broiler litter, layer litter, caged-layer droppings

Parameters	BL	LL	CLD	SEM	P-value
THB, cfu/g	2.8×10^{5b}	3.4×10^{5b}	8.0×10^{9a}	1.7×10^{9}	0.02
THF, cfu/g	1.6×10^{3a}	1.5×10^{3a}	1.1×10^{2b}	271	0.04
TML, cfu/g	2.8×10^{6b}	3.4×10^{6b}	8.0×10^{10a}	1.7×10^{9}	0.02

[a,b,c,] Means with different subscripts are significantly different (P < 0.05)
SEM = standard error of means
BL= broiler litter; LL = layer litter; CLD = caged-layer droppings
THB = total heterotrophic bacteria; THF = total heterotrophic fungi; TML = total microbial load

Table 3: Microorganisms identified in broiler litter, layer litter, and caged-layer droppings

Identified microorganisms	BL	LL	CLD
Bacteria			
Klebsiella edwardsii	+	+	+
Klebsiella pneumoniae			+
Pseudomonas aeruginosa			+
Pseudomonas stutzeri		+	
Fungi			
Absidia sp.		+	
Aspergillus flavus	+		
Aspergillus glaucus		+	
Cladosporium werneckii			+
Fusarium sp.		+	+
Mucor mucedo		+	
Trichophyton rubrum	+		+

Bacteria – identified bacteria are known to be pathogenic
Fungi – all identified fungi are moulds; no yeast
BL = broiler litter; LL = layer litter; CLD = caged-layer droppings

Discussion

The crude protein (16.8%) and phosphorus (0.5%) content coupled with the low microbial load made BL the preferred test material. However, Mullan *et al*. (2008) noted that the criteria for inclusion of an ingredient in the diet include the unit price, content and availability of various nutrient components and in some cases, the presence and levels of anti-nutritional factors may affect either feed intake or nutrient metabolism. Jordaan (2004) reported that mycotoxins pose no greater problems in litter than in conventional feedstuffs. Coleman and Moore (2003) noted that feedstuffs are not only a source of energy and nutrients, but can become a carrier of undesirable substances they may contain (Zoiopoulos and Natskoulis, 2008). Bagley and Evans (1998) concluded that BL is as safe as any other livestock feed if processed and handled properly. Processing will

destroy pathogens, improve storage and handling characteristics, and maintain or enhance palatability (CAST, 1978). Broiler litter is readily available at little cost, which is the cost of transportation. This cost is variable depending on proximity to the poultry farm. *Klebsiella edwardsii* was the only bacteria identified in BL, the other microorganisms, *Aspergillus flavus* and *Trichophyton rubrum* were fungi. The fungi identified were moulds, known to be highly prevalent in the soil. Wright *et al*. (1976) reported that *Klebsiella edwardsii* is not pathogenic in man. *Klebsiella edwardsii* has been recovered from vegetable and from ready to eat meals in airline catering (Yassien and El-Essawy, 1990). *Aspergillus flavus* is a common mould in the environment, particularly in corn and peanuts (Kenneth, 2008). *Clostridium perfringens*, which is specific to faecal waste and is believed to be a reliable indicator of the presence of many pathogens (Sorensen *et al*., 1989), was not detected in all the PW. Bhattacharya and Taylor (1975) concluded that poultry waste could be safe for re-feeding when pathogens are neutralized and the waste substrate was combined in optimal concentrations with conventional feedstuffs. Caswell *et al.* (1978) observed that litter tends to buffer the acids that might otherwise destroy bacteria. The THB load in BL (2.8×10^5 cfu/g) was higher than 1.7×10^4 cfu/g reported by Saleh *et al.* (2002). The observed difference may be due to many factors such as handling and processing method. Individual load of bacteria (total heterotrophic bacteria) and fungi (total heterotrophic fungi) and the total aerobic viable count for broiler litter were found to be within the accepted safe limit of 10^7 cfu/g for total viable count or coliform count recommended for both human and animal consumption (Gilbert *et al.,* 2000).

The 9.9% moisture content of BL was lower than 12 to 25 per cent recommended for any material to be used in animal feed by Odhuba (1989). The processing of the BL resulted in a product that had its colour and odour resembling caramelized chocolate. The 22.6% CP in the BL compared favourably with 23.8% reported by Adesehinwa *et al.* (2010) and was within the 20-30% CP recommended for any material that can be used as a feedstuff (Odhuba, 1989); Bhattacharya and Taylor (1975). Flegal *et al.* (1972) and Odhuba (1989) asserted that litter could be low in CP because of excess volatilization of N in the poultry house due to either high temperature or excess moisture. The amount of spilled feed also influences the CP content in the litter (Odhuba, 1989). Odhuba (1989) and Ruffin and McCaskey (1990) reported that a litter is suitable for use as a feed ingredient only if its CP is not below 18%; moisture is below 25% and ash below 28%. The ash content (18.8%) in the BL was higher than 13.2% reported by Adesehinwa *et al.* (2010). Ash content usually provides the most information about the quality of the BL. Ash analysis measures the mineral content of the litter. Ash content between 15 and 25 per cent are acceptable (Odhuba 1989; Ruffin and McCaskey, 1990). The variation in ash content for BL and BDG might not be unconnected with the degree of soil contamination during processing, nature and the type of wood used as litter (i.e. sawdust or wood shavings; soft wood or hard wood). The BL used in this study had proximate composition (on dry matter basis) similar to those reported by Fontenot (1978, 1996); Crickenberger and Goode, (1996) and Saleh *et al*. (2002), except for EE. The 4.4% EE

content observed for BL was higher than the range from 2.1 to 3.3% reported by these researchers as well as the 3.5% reported by Adesehinwa *et al.* (2010). The difference between the EE level in the BL and the BDG may be due to the composition of the broiler diet, which usually contains a substantial volume of solvent-extracted milling by-products. The low EE observed in the BL in this study might also be due to the high ash content. Processed BL had NFE value of 29.1%, which compared with 29.5% reported by Bhattacharya and Taylor (1975) and within the range of 27.1-33.6% reported by Fontenot (1978). Bhattacharya and Taylor (1975); Fontenot (1978) and Rankins (2000) gave the CF content of BL in the range of 16-24% which was higher than 15.0% observed in this study. The CF observed in this study was however higher than the 11.2% reported by Adesehinwa *et al.* (2010). Vest and Merka (2004) asserted that CF in litter varies considerably with the quantity of bedding material used and overall management; the average being around 20.6%. Handling and processing method will also play a very important role in the amount of CF in a feedstuff as well as its utilization. The high CF content of litter is indicative of lower total digestable nutrient content (Vest and Merka, 2004). Brewers' dried grains had higher GE content of 3701 kcal/kg compared with 2850 kcal/kg in BL.

The lignin content of 2.5% in the BL compared favourably with 2.7% reported by Emmambux and Driver (2001) but lower than 8.8% reported by Adesehinwa *et al.* (2010). The amounts of NDF (45.6%) and ADF (20.1%) observed for BL compared favourably with 42.7% and 22.8% reported by Adesehinwa *et al.* (2010). The differences observed in the fibre components of both BL and BDG may be due to the effect of source of the fibre and processing technique. Mineral composition analysis showed that BL had a higher mineral content than BDG. Broiler litter contained 2.1% Ca and 1.5% P, which were greater than 0.3% and 0.4% in the BDG. The observed value for Ca in BL compared well with the Ca level of 1.5 to 2.5% reported by Bhattacharya and Taylor (1975), Fontenot (1978) and Rankins (2000). Likewise, the P level in BL was within the range 0.6 to 3.9% reported by Bhattacharya and Taylor (1975); Fontenot (1978) and Rankins (2000). In addition, BL had a lower THB load compared with BDG. Again, this could be due to the nature and condition of production. Alternative feedstuffs are known to be more variable in composition and quality than the traditional feedstuffs (Myer and Hall, 2004).

Conclusions

The study provided information on nutrient, mineral and microbial composition of other poultry waste which resulted in the selection of BL as the TM to be processed into useful product as livestock feedstuff.

The simple processing method developed in this study is capable of recycling BL into a feedstuff that is potentially useful for integration into animal-feeding systems for non-ruminants. The procedure could contribute to reduction in problems of environmental pollution caused by land-fills, dumping and burning, and provide an additional income source for poultry farmers. However, utilization of more efficient machines to pulverize and sieve may improve quality of product and increase efficiency of production.

Broiler litter is abundant and available at the cost of collection, transportation, processing and storage. Broiler litter, if properly handled, is free from potential

health hazards; do not require special handling, processing and storage requirements.

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