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Full Length Research Paper

A study of the management of poultry litter and its effects on soil application and growth of okra

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Poultry litter constitutes one of the animal wastes that are produced in large quantity. Information on the quantity generated may enhance planning for its utilisation. Quantification of poultry litter (PL) generated and its utilisation is rare in Nigeria. This study was designed to investigate PL management in Lagos, Nigeria and possible utilisation potential. Questionnaires were distributed to poultry farmers in Lagos to evaluate poultry waste generation and management practices. Additionally, PL was also quantified from selected farms. Greenhouse experiments were conducted to evaluate the agronomic effects of raw and composted PL (each applied at 0, 5, 10 t/ha and replicated four times) on the growth and heavy metals uptake of *Abelmoschus esculentus* (okra). Poultry farms were situated in the residential, non-residential and industrial areas with non-residential areas housing a larger percentage. About 53% of the farms were located near rivers or streams. A few of the poultry farmers treated and utilised PL using chemical and physical methods before disposal. Also, no record of waste utilization was found in 72.3% of the farms. About 87.4% of the farmers quantified the PL generated. About 89.3% of the farmers disposed PL in open dumpsites. Mean poultry litter generated from four farms per bird/day was 0.11 ± 0.001 kg. The HMs contents in plants grown on the poultry treated soils were below the permissible levels in soil. The heavy metals concentrations in the leaves and fruits (which are usually the edible parts of okra plants) for all the treatments fall within WHO/FAO permissible levels. Overall, soil amended with 5 t/ha composted poultry litter performed best in terms of fruit production and reduction in HMs uptake. The use of composted poultry litter as fertiliser at calculated quantity will increase PL management.

Key words: Poultry litter management, heavy metals, Lagos, *Abelmoschus esculentus.*

INTRODUCTION

Poultry farming is one of the largest and fast growing agricultural businesses worldwide. This is due to its economic and health benefits. There is high demand for poultry products in form of meat and eggs which makes poultry business to be lucrative and high source of income (Aklilu et al., 2008). This demand stems from the fact that poultry products serve as sources of animal protein as well as micronutrients like iron, selenium and zinc (Pereira and Vicente, 2013; Demirbas, 1999).

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Protein originating from poultry meat has been categorized as complete protein which consists of all the essential amino acids required by man for healthy functions of the body. Additionally, in terms of value to human health, eggs have a high digestibility score. According to Protein Digestibility-Corrected Amino Acid Scores (PDCAAS), a higher PDCAAS of 1.00 has been attributed to egg white when compared with PDCAAS of 0.92 for meat (Pereira and Vicente, 2013). However, among major environmental issues facing the poultry industry is the huge accumulation of waste, particularly poultry litter and its management. For instance, based on 18 billion meat chickens slaughtered in the USA and Europe in 2009, 25 million tons of litter was estimated per annum (Lynch et al., 2013), about 2 M tons of poultry waste/year were reported in Jordan (Abu-Ashour et al., 2010).

Poorly managed PL may have grave consequences for the environment. The possible environmental consequences include air, surface water and soil contamination. Air may be contaminated with emission of greenhouse gases (CH_4 and CO_2) and ammonia due to microbial action on the litter (Martinez et al., 2009). Most of the environmental problems associated with improper handling of PL are contamination of surface water with nitrogen and phosphorus (Sims et al., 2005). The contamination may be caused by leaching and run-off from open-dumping of PL on land or through direct disposal in water bodies. The leaching of phosphorus and nitrogen from the litter could result in eutrophication, while decomposition of the litter may possibly cause bad odour. Potentially toxic trace elements, such as As, Cd, Cu, Mn, Pb and Zn have been reported in poultry litter (Subramanian and Gupta, 2006).

Economical and environment friendly recycling methods are required to reduce the potential environmental impacts posed by poultry farms. Physical and chemical characteristics of PL have been modified for its utilisation as animal feeds, bioenergy source and activator among others (Martinez et al., 2009; Stephenson et al., 1990). These types of treatment and recycling options could be unaffordable by poultry farmers in the developing countries. Recycling of regulated amount of composted poultry litter as fertiliser may be a viable option. Poultry litter generally contains nutrients and trace elements such as N, P, K, S, Ca, Mg, B, Cu, Fe, Mn, Mo and Zn which can be beneficial for plant growth (Subramanian and Gupta, 2006). It also contains HMs which are toxic. Application of PL in its raw state to agricultural soils may lead to accumulation of these elements in soil with potential effects on plant uptake and washing off into water bodies. In order to salvage these associated environmental problems, the elements can be stabilised in the litter through treatment by composting. Composted PL has been reported to yield a stabilized product which improved physical, chemical and biological properties of soils (Martinez et al., 2009; Sistani et al., 2003; Guerra-Rodriguez et al., 2001).

Comprehensive studies on poultry litter management practices, quantification and utilisation in Nigeria are scanty in literature. The available studies focused mainly on complementary use of NPK fertiliser and poultry litter to improve soil properties and enhance plant growth (Agbede, 2010; Agbede and Ojeniyi, 2009). In this study, practices relating to farm siting and management, PL generation, storage, collection, treatment, utilisation and disposal methods were examined. Information regarding these areas is necessary for improvement on Nigeria environment, awareness raising on both wrong and right PL management practices among poultry farmers and on the part of the appropriate government regulatory authorities to enact and enforce environmental measures regarding PL management. Therefore, this research has the following objectives: (1) Information and generation of data on the PL management practises and PL generation in Lagos state, (2) determination of heavy metal concentrations of raw poultry litter, (3) utilisation as fertilizer to grow okra (*Abelmoschus esculentus*) plant, and (4) comparison evaluation of plant uptake of heavy metals into root, leaves and fruit from the soils treated with raw and composted poultry litter.

MATERIALS AND METHODS

Questionnaire administration

In order to evaluate poultry waste generation and management practices in Lagos, Nigeria, 150 questionnaires were distributed to poultry farmers, out of which only 104 were filled and returned. This means 69.3% of the farmers responded. The questionnaire was designed to obtain information on the farm location, poultry system and poultry waste management. The data were statistically analysed using descriptive statistics.

Study area, sample collection and quantification

The locations of the farms were determined with the use of Geographical Position Sensing (GPS) as shown in Figure 1. On-site quantification of PL generated per day from four selected poultry farms was carried out. The selection was based on the areas (residential, industrial, non-industrial) where the farms were located and the willingness of the famers to participate in the quantification. The quantification was done by collecting PL from a known number of chickens (not less than 30) in a pre-weighed sack spread under the poultry cage. The litter was weighed on daily basis for a week, collected inside polythene bags and transported to the laboratory.

Sample pre-treatment

The collected samples were pooled together to make a composite sample. This was dried, ground, homogenised and sieved to size <

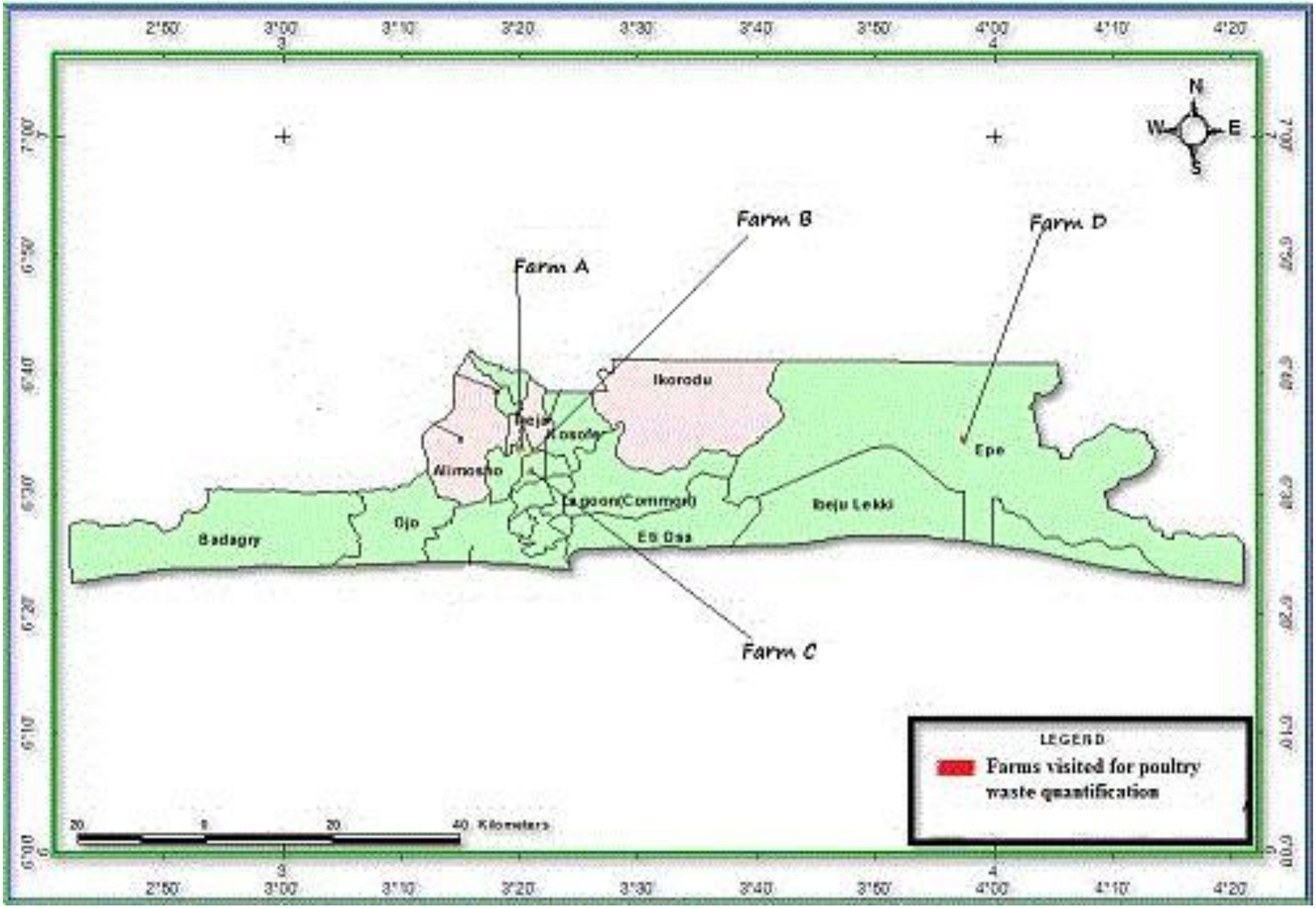

Figure 1. Map of Lagos State showing the four farms where poultry litter quantification was carried out.

Figure 2. Dried raw and composted poultry litter.

2 mm.

Composting of litter

A portion of the composite PL was composted with sunflower at the ratio of 1:3 (poultry litter : sunflower). A polyethene sheet was spread under a shed, then 50 kg of the poultry litter was weighed and 150 kg of sunflower was added to it and covered with perforated polyethylene to allow for the exchange of gases, using partially aerated composting technology. This was left for a period of three months with continuous mixing of the litter and sunflower at a regular interval (Figure 2).

Greenhouse study

A greenhouse experiment was carried out at the Department of Crop Protection and Environmental Biology, University of Ibadan. Top soil used for the experiment was collected at 0 -15 cm depth from the departmental garden. The soil was air-dried, sieved and weighed into each plastic

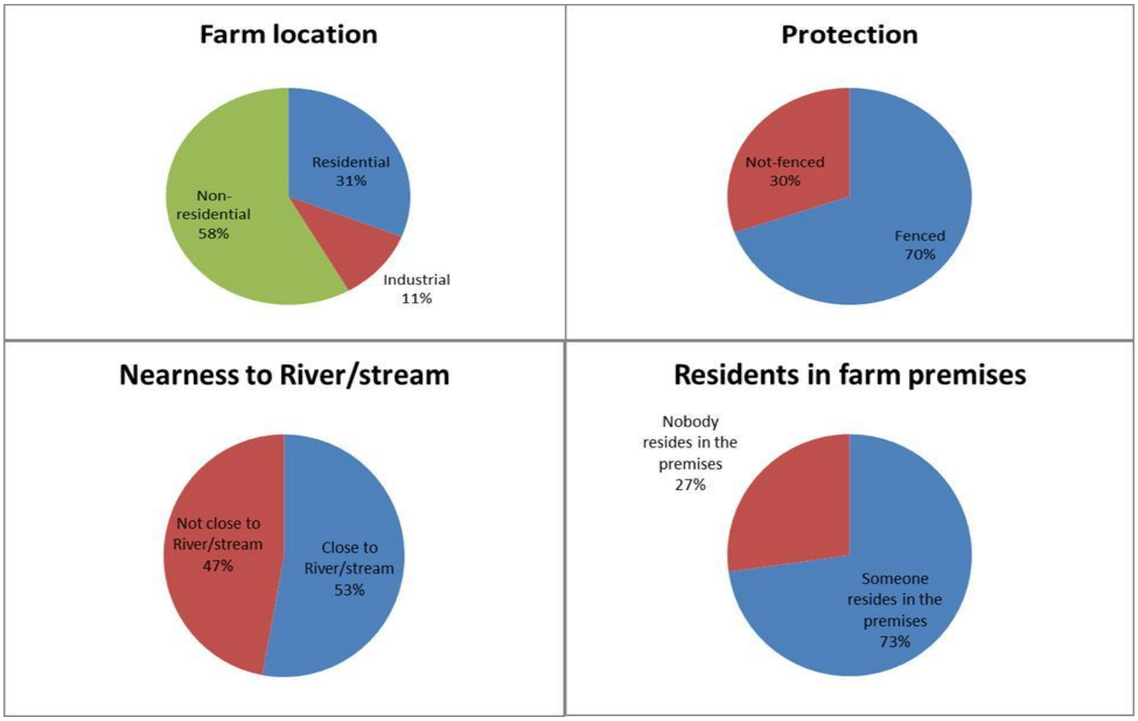

Figure 3. Characteristics of farm sites.

pot. Five treatments were used with each replicated four (4) times. The treatments used were: Treatment 1 (control-0 t/ha); Treatment 2 (soil amended with 5 t/ha composted manure); Treatment 3 (soil amended with 10t/ha composted manure); Treatment 4 (soil amended with 5 t/ha raw manure); Treatment 5 (soil amended with 10 t/ha raw manure). A week before planting, the manure was thoroughly mixed with the soil in each pot and watered to allow for proper equilibration with the soil. After which okra seeds (*A. esculentus*) were planted into each of the treatment pots, and they were watered every two days. Okra was chosen since it requires short time to grow into fruit production and also eaten by many in the South-Western Nigeria. The plants in each pot were thinned out, two weeks after emergence. Growth parameters such as plant height and number of leaves were taken fortnightly while fruit yield was taken at maturity.

Analytical procedures

Physicochemical properties of the poultry litter and soil were determined. These included pH values, total nitrogen, extractable potassium, available phosphorus and heavy metals (Cr, Cu, Mn, Pb and Zn). The pH of soil and litter was determined in the supernatant liquid of the mixture of soil and water (1: 1) using pH meter. Organic carbon content was determined by Walkley-Black method. Total nitrogen was determined by the Kjeldahl method. Phosphorus was determined using the Vanado-Molybdenum method. Potassium was determined with a flame photometer (Jenway, PFP7). The concentrations of Cr, Cu, Mn, Pb and Zn in the litters and soil samples were determined with the use of atomic absorption spectrophotometer (Buck scientific model 205A) with air-acetylene flame after 2 M nitric acid digestion for 2 h at 90-100°C (Ogundiran and Osibanjo, 2009).

Heavy metal determination in plant roots, leaves and fruits

Okra roots, leaves and fruits for each treatment were analysed for Cr, Cu, Mn, Pb and Zn. The samples were washed under a running tap to remove the attached soil. The samples were then dried in the oven at 105°C, ground, sieved and digested (Ogundiran and Osibanjo, 2008). A spiked recovery was used to validate the method of acid digestion. Data were analysed statistically using ANOVA and Duncan's multiple range test was used to separate the means at a $P < 0.05$ level of significance.

RESULTS AND DISCUSSION

Current poultry litter management practices

Information obtained from the poultry farmers on farm system and PL management practices were grouped into five categories: Farm location, system and management, animal care, poultry litter collection and disposal methods, poultry litter treatment and utilisation.

Farm siting

The results on the information about the farm sites are shown in Figure 3. Poultry farms are situated in the residential, non-residential and industrial areas with non-residential areas housing a larger percentage, followed by residential areas. Majority of the farms are protected

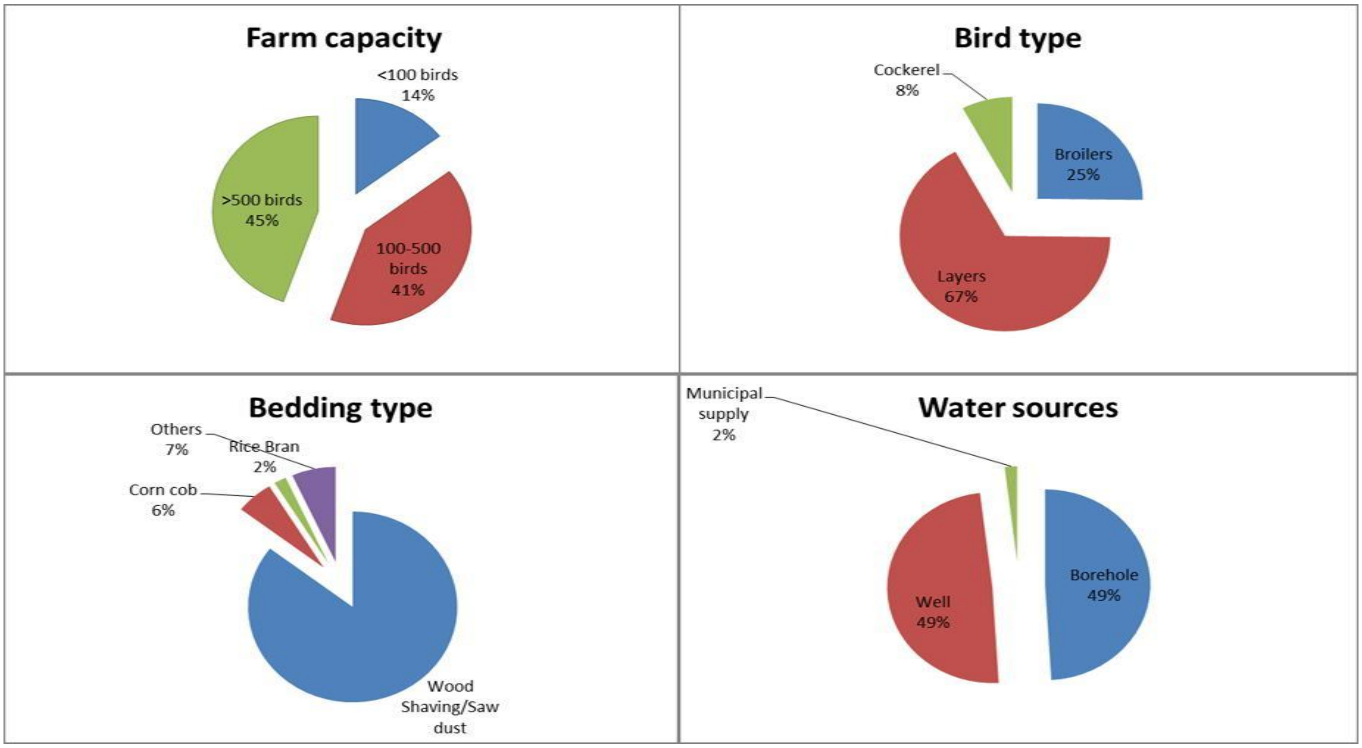

Figure 4. Farm system and management.

while only about 30% are not shielded from access. The current practice of siting and fencing the farms mainly in non-residential areas used by most of the farmers is a right attempt to reduce contact between human beings and the farms. Nevertheless, about 53% of the farms were located near rivers or streams. This raises a concern about the possibility of leaching of PL into the water bodies, which may pose risks of eutrophication and health of those who depend on the river for domestic purposes. Seventy three percent (73%) of the farms have people, including gardeners, security men and farm owners residing in the vicinity. These observations imply that site selection should be considered as a component of effective PL management strategy.

Farm system and management

The results of survey on farm system and management are illustrated in Figure 4. Greater percentage of the farms (44.7%) have farm capacity of more than 500 birds while 40.8 and 14.6% rear 100-500 birds and less than 100 birds, respectively. Based on the type of birds, layers (67.0%) were found to be most commonly reared by the farmers, followed by broilers (25.2%) and cockerels (7.8%). Battery cage system (64.4%) was found to be the most dominant poultry system used followed by deep litter system (35.6%). Among those that practised the deep litter system, majority used wood shaving/sawdust as bedding materials followed by corncob and rice bran. Borehole and well are the main sources of water supply to the farms.

Poultry care pattern

Many farmers feed the poultry with commercial feeds (top and vital feeds) while a few others used self-formulated feeds (Figure 5). Birds were fed twice daily in 91.1% of the farms, others three times daily. The use of vaccine and antibiotics were found to be common in the farms. The use of vaccines and antibiotics in a large number of the farms is an indication of good poultry care and management practices. However, there is need for another study to investigate the residues of these chemicals in poultry litter.

Poultry litter collection and disposal methods

The results of type of waste generated, PL collection methods, collection frequency, disposal methods and distance of the poultry farms to the disposal sites are presented in Figure 6. The results revealed that a larger proportion (88.1%) of the farms generate solid waste, mainly PL. This is supported by Moore et al. (1996) who reported that most broiler operations result in the production of solid poultry manure.

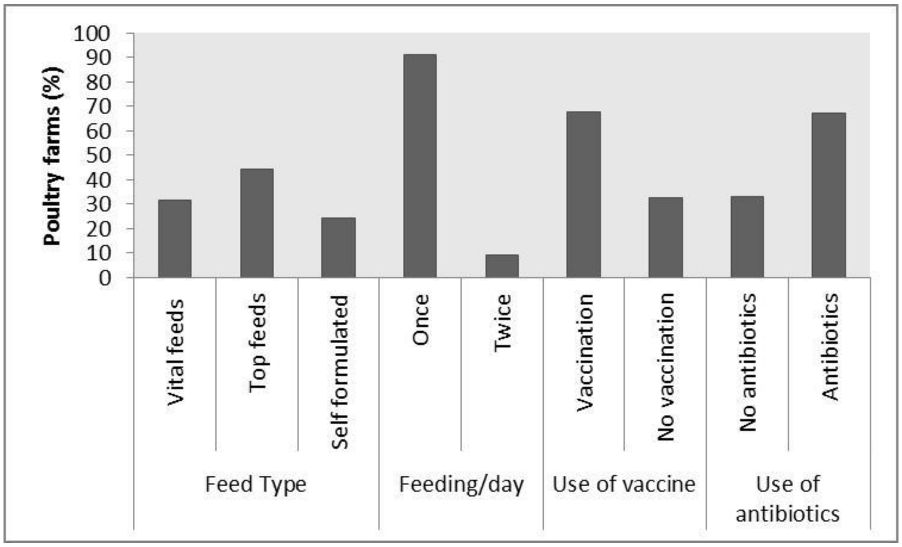

Figure 5. Poultry care pattern.

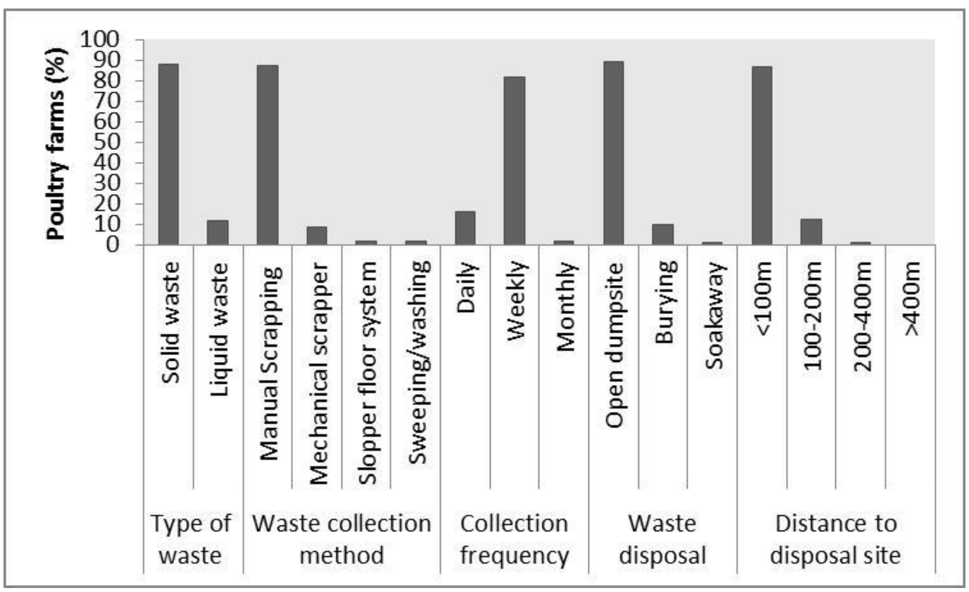

Figure 6. Waste collection and Disposal methods practiced in the poultry farms.

Manual scraping with shovel, which accounts for 87.1% of the responses is the commonest collection method while others include mechanical scraping, slopper floor system, sweeping and washing. Majority of the farmers collected the litter weekly. About 89.3% of the farms practised open-air dumping since it is at little or no cost. These unofficial disposal sites were some metres away from the poultry farms (Figure 6). About 86% of the farmers have their disposal sites located at an estimate of 100 m away from the farms. This disposal method is inappropriate since it can lead to varieties of environmental and human health problems. Consequently, open-air dumping should be discouraged. Poultry litter has been shown to contain high levels of phosphorus and nitrogen, which can be washed off into nearby streams leading to eutrophication (Edwards and Daniel, 1992). Microbial decomposition of PL can lead to emission of methane, which contributes to greenhouse effects (Bhattcharya et al., 1997). Besides potential to releasing hazardous chemical substances, breeding of pathogens and harmful bacteria in the open dumpsites are also possible effects of improper disposal of PL. Flies can be attracted to the open dumpsites, and thereby possibly transferring deadly diseases to humans. For these reasons, there is need for proper guidelines and legislative intervention to regulate management of wastes from

Table 1. Current poultry litter treatment and utilisation methods.

PL treatment and utilisation		Poultry farms (%)
Waste Treatment	No treatment	82.5
	Chemical treatment	4.90
	Physical treatment e.g. drying	3.90
	Burning	8.70
Waste utilisation	No utilisation	72.3
	Fish feeding	5.90
	Manure/composting/fertiliser	21.8
	Biogas generation	Nil
	Electricity generation	Nil
Constraint to waste utilisation and disposal	Lack of utilisation skill	75.0
	Irritation and labour scarcity	4.20
	Difficulty of burning during raining season	3.10
	High cost of Disposal	8.30
	Lack of vehicle or transportation cost	8.30
Estimation of Poultry waste generation	Estimate known	12.6
	No known estimate	87.4

Table 2. Amount (kg) of poultry litter generation per day by four poultry farms.

Farm	No of birds	Day							Total/week	Average daily litter per farm	Average daily litter /bird/farm
		1	2	3	4	5	6	7			
A	50	5.3	5.2	5.4	5.6	5.1	5.3	5.3	37.2	5.31±0.06	0.11
B	58	6.2	6.3	6.1	6.3	6.2	6.2	6.1	43.4	6.20±0.03	0.11
C	65	6.9	6.1	6.8	6.6	6.8	6.7	6.9	46.8	6.69±0.11	0.10
D	45	4.8	4.8	4.7	4.6	4.7	4.8	4.7	33.1	4.72±0.03	0.11

Mean daily litter per bird/day (kg/bird/day) 0.11 ± 0.001

poultry farms in Nigeria.

Poultry litter treatment and utilisation methods

The results of the current poultry litter treatment and utilisation methods practised by the farmers are presented in Table 1. Few of the poultry farms treat PL using chemical and physical treatments, while a greater percentage (82.5%) of the farms do not treat the litter before disposal. Also, no record of waste utilisation was found in 72.3% of the farms. Fish feeding (5.9%) and manure/fertiliser (21.8%) are the current PL recycling methods. It is worth noting that none of the farms generated biogas or electricity from the litter. A majority of the poultry farmers (75.0%) attributed non-utilisation of PL to lack of utilisation skill, irritation, labour scarcity, difficulty of burning during raining season, high cost of disposal and lack of vehicle or transportation cost. About 12.6% of the farmers quantified PL generated while 87.4% did not estimate the quantity of waste generated in the farms. There is need for awareness and training on quantification and utilisation of PL. The developed countries can provide information on the annual generation of PL, which makes it easier to plan for the utilisation of the waste (Lynch et al., 2013; Abu-Ashour et al., 2010). Considering the rate at which the population of Nigeria increases, there is high probability that the production of poultry litter will continue to rise; therefore, there is urgent need for research into various ways that PL can be used.

Quantification of poultry litter generation

The quantity of poultry litter generated daily for a week by a known number of birds is shown in Table 2. The quantity of average daily litter generation was found to correspond approximately proportional to the number of birds. For instance, in Farm C, 6.69 ± 0.11 kg of poultry litter was generated by 65 birds, 58 birds produced 6.02 ± 0.03 kg in Farm B, 50 birds in Farm A have average daily litter weight of 5.31 ± 0.059 kg while 45 birds in Farm D

Table 3. pH, organic carbon, nutrients and heavy metal contents of soil, raw and composted poultry litters.

Parameter	Soil	Raw poultry manure	Composted poultry manure
pH	5.70	6.90	8.00
Organic carbon (%)	4.89	74.9	76.7
N (g/kg)	36.4	12640	8710
P (g/kg)	26.4	11640	5970
K (g/kg)	19.8	1450	1630
Pb (mg/kg)	12.9	42.5	51.4
Cr (mg/kg)	2.45	6.95	10.4
Cu (mg/kg)	22.5	21.6	24.5
Zn (mg/kg)	98.9	83.8	80.0
Mn (mg/kg)	200	170	250

generated 4.72 ± 0.03 kg of litter. However, this may also be a direct indication of the feeding rate. Factors such as body size, type of feed, and level of nutrition have been associated with amount of manure produced by animals per day (Bhattcharya et al., 1997). The mean daily poultry litter per bird estimated from the result of daily measurement from the four farms was 0.11 ± 0.001 kg/bird. This result can be used as supporting information for estimating the amount of poultry litter generated annually in Lagos State and in Nigeria, if the number of birds raised is known. Estimates of poultry litter generated per annum using the data obtained for a certain number of bird have been reported (Lynch et al., 2013; Abu-Ashour et al., 2010).

Chemical analysis

Physicochemical parameters of the soil, raw and composted poultry litter

The results of the physicochemical parameters, and heavy metal contents of the soil, raw and composted poultry litter, are shown in Table 3. The pH of the soil sample was acidic while that of raw litter was about neutral and composted was alkaline. Both raw and composted litter were rich in carbon content. The N, P and K contents of the poultry litter were comparable with a previous report (Sistani et al., 2003). No substantial difference in heavy metals concentrations of the raw and composted poultry litter was observed.

Heavy metal content of the soil, raw and composted poultry litters

The results show that soil, raw and composted poultry litter contained Cr, Cu, Mn, Pb and Zn but not at elevated concentrations (Table 3). Concentrations of heavy metals in poultry litter have been reported to vary, depending on poultry production and management practices (Subramanian and Gupta, 2006; Kunkle et al., 1981).

Plant growth performance parameters

The parameters of plants that were grown on the soil samples, amended with varying quantity of the raw poultry litter and composted litter are shown in Figure 7.

There was no significant difference ($p \geq 0.05$) in the plant height among the treatments, however the number of fruits of the plants grown on control soil were significantly lower ($p \leq 0.05$) as compared to the number of fruits obtained from other treatments. Soil amended with 5 t/ha of composted poultry litter produced okra plants with the highest mean number of fruit (6), while others produced the same number of fruit (4). This implies that 5t/ha composted litter increased the yield of okra by 83.3% while others increased by 75% as compared to the control. Kogram et al. (2002) also reported increase in yield of cassava with composted manure when compared with the control.

Accumulation of heavy metal in the plant parts

The results of Pb, Cr, Cu, Mn and Zn accumulation in the okra plants for various treatments and WHO/FAO guidelines are presented in Table 3. The highest concentrations of the HMs were found in the root followed by the leaves and fruit of the okra plant (Table 4). Distribution of heavy metals in the plant parts for all the treatments followed the same trend for all the HMs. The result of HMs accumulation in the okra plants showed that the content of HMs in plants grown using treatment 1 was significantly lower than those grown using treatments 2, 3, 4, and 5. The highest HMs accumulation was found in plants grown with treatment 5, that is, treatment with higher amount of raw manure and this was significantly different ($P < 0.05$) from those grown using treatments 2, 3 and 4. The composted PL had high reduction capacity on plant HMs uptake when compared with the raw litter. There was no considerable accumulation of Pb and Cr in

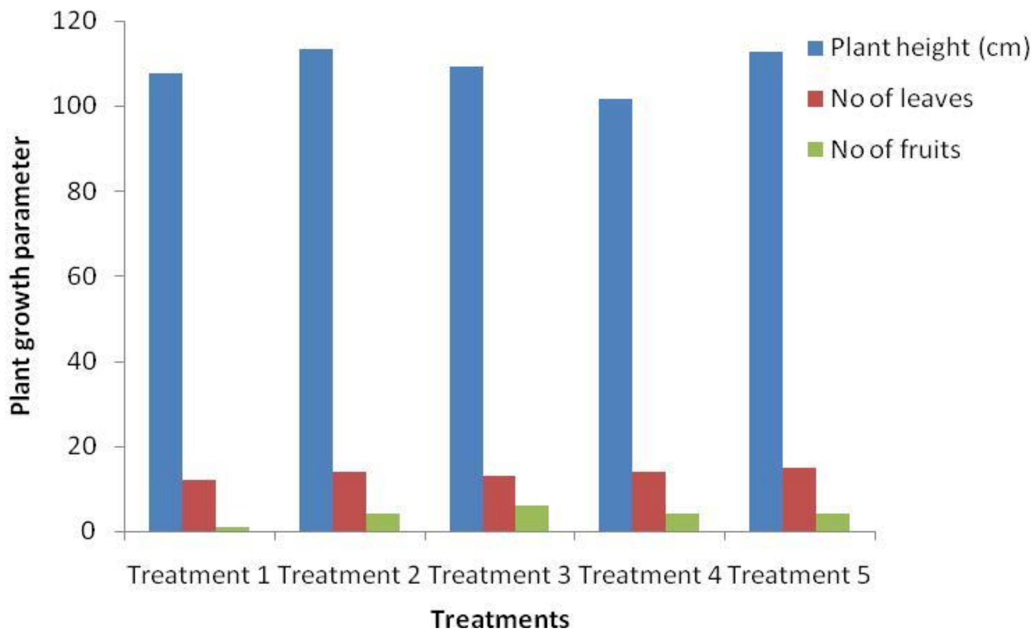

Figure 7. Growth performance parameters of okra plant on the soil sample amended with varying quantities of the raw and composted poultry litter.

Treatment 1: Soil sample only (control-0 t/ha), Treatment 2: Soil sample amended with composted manure (5 t/ha composted manure), Treatment 3: Soil sample amended with 10 t/ha composted manure Treatment 4: Soil sample amended with raw manure (5 t/ha raw manure), Treatment 5: Soil sample amended with raw manure (10 t/ha raw manure)}.

Table 4. Heavy metals concentration (mg/kg) in the roots, leaves and fruits of the okra plants in the pot experiment.

Treatments	Plant parts	Pb	Cr	Cu	Mn	Zn
Treatment 1	Root	5.72±0.005[a]	0.11±0.00[a]	14.27±0.08[a]	109±0.03[a]	67.7±0.05[c]
	Leaves	0.35±0.005[a]	0.003±0.00[a]	7.86±0.05[a]	120±0.00[a]	57.3±0.03[a]
	Fruit	0.00±0.000[a]	0.001±0.00[a]	1.72±0.05[a]	6.06±0.01[a]	16.3±0.03[a]
Treatment 2	Root	5.89±0.005[b]	0.21±0.00[b]	14.50±0.10[b]	109±0.00[a]	69.1±0.01[d]
	Leaves	0.54±0.015[b]	0.001±0.01[b]	8.55±0.05[b]	120±0.13[a]	58.2±0.50[b]
	Fruit	0.00±0.000[a]	0.001±0.00[b]	1.87±0.01[b]	6.30±0.05[a]	41.7±0.08[e]
Treatment 3	Root	6.28±0.025[c]	0.25±0.01[c]	20.23±0.03[c]	143±0.04[b]	69.8±0.00[e]
	Leaves	0.88±0.010[c]	0.001±0.01[c]	8.65±0.05[c]	121±0.00[a]	75.1±0.04[e]
	Fruit	0.05±0.000[c]	0.002±0.00[c]	1.93±0.02[c]	7.91±0.09[b]	24.4±0.00[b]
Treatment 4	Root	8.84±0.030[d]	0.35±0.01[d]	25.96±0.01[d]	144±0.00[c]	58.4±0.00[a]
	Leaves	0.92±0.005[d]	0.002±0.01[d]	8.84±0.01[d]	140±0.63[b]	62.0±0.00[c]
	Fruit	0.02±0.045[b]	0.002±0.00[d]	2.22±0.15[d]	31.2±0.07[c]	25.1±0.65[c]
Treatment 5	Root	13.7±0.065[e]	0.42±0.00[e]	29.42±0.02[e]	149±0.13[d]	61.3±0.01[b]
	Leaves	1.54±0.020[e]	0.002±0.01[e]	9.16±0.055[e]	143±0.13[c]	65.9±0.03[d]
	Fruit	0.01±0.000[a]	0.002±0.00[e]	2.43±0.15[e]	40.3±0.20[d]	26.1±0.19[d]
WHO/FAO limits		5.00	5.00	40.0	-	60

Each value is a replicate determination of Mean ± SEM (n=4). Means with the same letter in the same column are significantly different ($p < 0.05$) using Duncan's multiple range test.

the fruit of the plants grown on all the soils. The heavy metal concentrations in the leaves and fruit, which are usually the edible parts of okra plants for all the treatments, still fall within the permissible consumption level according to WHO/FAO as cited by Yang et al. (2011). Overall, soil amended with 5 t/ha composted litter performed best in terms of fruit production and reduction in HMs uptake. Considering heavy metals reduction in uptake by plants, composted poultry litter performed better than raw poultry litter. This supports the recommendation for the use of poultry litter as a good source of fertiliser, if treated through composting and applied at a regulated quantity to farm soil.

Conclusion

Evaluation of poultry waste generation and management practices among selected poultry farms in Lagos State, Nigeria was carried out. It has been ascertained that currently there is no best poultry litter management practice in Nigeria, due to poor waste disposal and treatment methods, lack of utilization and insufficient education in utilization skills. The locations of poultry farms encourage pollution of surface water. About 53% of the farms were located near rivers or streams. A few of the poultry farms treat and utilize PL using chemical and physical treatments while a greater percentage (82.5%) of the farms do not treat the litter before disposal. Poultry litter is yet to find full utilization by the poultry farmers and the public. A few current applications include fish feeding (5.9%) and manure/fertilizer (21.9%). Quantification of the litter generated was uncommon in a majority of the farms (12.6%). Open-dumping of the litter at some meters away from the farms is the common method of disposal (89.3%). Mean poultry litter generated from four farms per bird/day was 0.11 ± 0.001 kg. The HMs content in plants grown on control soil was significantly different ($P < 0.05$) from the content in plants grown on treated soils. However, they are still within their background levels. The heavy metal concentrations in the leaves and fruit, which are usually the edible parts of okra plants, are generally low for all the treatments and fall within the WHO/FAO permissible level. Considering heavy metal reduction in uptake by *A. esculentus*, composted poultry litter performed better than raw litter.

Overall, soil amended with 5 t/ha composted poultry litter performed best in terms of fruit production and HMs uptake. This supports the use of poultry litter as a good source of fertiliser if a controlled quantity of it is applied to soil. Based on the results of this study, the use of poultry litter in the form of compost at a regulated quantity may be recommended for use as soil amendment in crop production. It is also recommended that there should be regulation and legislation on the disposal and treatment of poultry litter by the relevant authorities. The poultry farmers should be trained on the merits of different utilisation skills for best management of poultry wastes. A national database should be established to document and monitor the quantity of poultry litter generated.

Conflict of Interest

The authors have not declared any conflict of interest.

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