Chapter 10

Poultry Litter Selection, Management and Utilization in the Tropics

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Additional information is available at the end of the chapter

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Abstract

In many places, poultry farms are sited and intensively managed in the residential areas with little welfare improvement and major concern of poultry waste disposal. The mean poultry litter generated per bird/day was estimated at 0.11 kg so that millions of metric tons of poultry manure are annually generated. Wastes generated from poultry farms constitute hazard to public health as well as potential source of conflict between neighbours. Beside environmental consequences, poultry waste impacts serious welfare and production effects on poultry. Suitable poultry droppings and moist absorbents referred to as litter materials were later discovered. Recently, conventional caging of birds is considered unethical, common litter materials are seasonally available, wood based litter materials are now being diverted for the manufacture of other wood products, the use of poultry litter as fertilizer and livestock feed supplement has increased, therefore, the demand and price for litter materials is now magnified. Adequate litter materials cannot be easily met by farmers and non-environmentally friendly alternative litter materials may be sought by farmers creating negative socio-economic impacts on poultry and the environment. Therefore, careful selection, adequate management and proper storage and utilization of poultry litter are here given due attention.

Keywords: Poultry, Litter, Selection, Management, Utilization, Tropics

1. Introduction

Individuals and organizations worldwide rely directly or indirectly on the poultry industry for substantial portion of their income and low-cholesterol animal protein intake [1, 2]. Breeders and broilers in most countries are raised exclusively on deep litter system, whereas layers in

many places are initially raised on deep litter before transfer to cage [3, 4]. The poultry industry has over the years rapidly expanded with increasing concern of poultry waste disposal [2, 5]. Ammonia and greenhouse gases produced by poultry litter impact negatively on the environment [6]. Therefore, environmentally friendly and economically sustainable technologies for poultry waste management must be focused in today's climatic challenges. Efforts to manage poultry wastes under intensive production systems led to the discovery of suitable poultry droppings and moist absorbents called litter material [7, 8]. Animal welfare organizations have seriously raised concern on how commercial birds are deprived of exhibiting their natural behaviours by caging. To this end, some advanced countries have enacted laws banning the use of conventional poultry cages. Wood shavings and saw dusts are now being utilized to produce paper and other wood products while alternative litter materials, such as rice hulls, pines and groundnut shells, are seasonal [8, 9]. These imply that, deep litter system of poultry management may be more acceptable than caging and consequently the demand and cost of litter materials will significantly increase [9]. Adequate litter materials in deep litter management system may therefore not be guaranteed and/or the litter materials will become scarce and not easily accessible [4]. The implication is that poultry farmers are not likely to obtain adequate and good quality litter material for their birds [1, 8]. This may result in farmers trying many unconventional litter materials that may affect poultry health, welfare, performance and the environment.

Some of the economic losses associated with poor litter in poultry include musculoskeletal problems of the foot and leg, increased respiratory tract infections and poor production performance as a detriment to low feed consumption utilization [9]. Dan et al. observed that the cost of poultry waste disposal is normally omitted in casting production expenses which often contribute significantly to the overall production expenses. In some countries where litter is properly managed, old litter is removed and replaced with new one after many sets of birds are cropped [10, 11]. This seems not to be possible in many developing countries where poultry houses are poorly constructed coupled with poor hygienic and management practices and frequent weather variations which may require frequent litter change and/or adjustment of poultry pen environment. Many poultry farmers in such nations do not make use of facilities required to determine ammonia, humidity, temperature and ventilation levels and efficiencies in poultry pens. Ventilation has been reported to be the primary way to reduce or eliminate moisture in poultry houses, and temperature determines the degree of litter caking during cool weathers [12].

Poultry litter contains high nitrogen and phosphorus making it a very good organic fertilizer and feed supplement [13–17]. The poultry manure enhance physical, chemical and biological fertility of soil by ensuring adequate levels of organic matter, water holding ability and oxygen diffusion rates. However, poultry litter may contain pathogenic microorganisms, drug residues and hard or metallic objects that are injurious to crops, poultry, humans and other domestic animals [8, 11, 17–19]. Arsenic compounds are known for their potentials to cause cancers but unfortunately used to control coccidiosis in many countries [20]. This study discusses aspects of selection, proper management, storage and efficient utilization of poultry litter.

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2. Selection of poultry litter materials

Many research works were conducted to determine the suitability of wood shavings, sand, pine peanut shells, shavings, shredded papers or paper chips, dry straw, rice hulls, maize cobs, corn silage and peat as alternative litter materials [7, 21, 22]. Timber by-products, rice hulls and shredded papers appear to be most accessible worldwide. The basic requirements of a good litter include moisture holding capacity, microbial tolerating ability, low cost, availability and non-toxicity to poultry [23, 24]. Bases for choosing good litter materials should include the ability to protect birds from dirt, damp and cold floor; it should also be able to adequately conserve heat and absorb moisture. For good production performance, litter materials should provide comfort for birds [24, 25].

3. Wood shavings

Soft or hard wood shavings from different trees are available year round in many places. These are normally obtained from the wood work and furniture enterprises. Wood shavings sourced from soft wood the best litter material but is highly demanded for making paper, fibreboard and cardboard making it difficult to obtain [10]. In some instances, the woods may be treated with some chemical preservatives like copper chrome arsenate or even organophosphates which may be harmful. Wood shaving is the most common poultry litter material which today is characterized by periodic shortage due to increasing number of poultry producers [8, 26]. Unfortunately, hard wood shavings are reported to poorly absorb moisture and are frequently contaminated with *Aspergillus* [9], showed highest prevalence of Salmonella organism [22] and posed a significant problem when obtained from chemically treated woods [4]. Wood shaving will be an ideal litter material if free of contaminants and if properly managed. Some countries are reported to specifically produce uniformly sized untreated soft wood shaving as litter material for poultry. Below is a plate (**Plate I**) showing a combination of soft and hard wood shavings used as litter material in many parts on Nigeria.

Plate I. A mixture of soft and hard wood shavings used as poultry litter in Zaria, Nigeria.

Saw dusts are finer wood materials from wood work and furniture enterprises and used as alternative litter material especially where wood shaving is unavailable or unaffordable. Unfortunately, poultry especially chicks consumes as much as 4% of their diet as litter. Turkeys are more prone to consume more litter than chickens, which may lead to nutritional deficiency, crop impaction, starvation and subsequent mortality [9, 24]. Sawdust is very popular as litter material in many places, but it regularly cakes especially around drinkers and feeders [9, 27]. Sawdust has high moisture holding ability but is commonly contaminated with *Aspergillus* [9].

Plate II. Saw dust used as poultry litter material in Zaria, Nigeria.

The above plate (**Plate II**) shows saw dust utilized in many parts of Nigeria as poultry litter. It is common and less expensive than saw dust.

Rice hulls have been reported to work well as litter material because of their uniform sizes, less dusty and most importantly have high thermal conductivity, drying rate and are compressible [4]. They serve as very good litter material for broiler chickens and its organic-based manure has been reported to be well suited for gardeners. Rice hulls can be better litter when combined with other litter materials like pine and wood shavings. In some tropical regions where rice is annually cultivated, rice hulls may be costly and only available seasonally and could also be restricted to certain regions where rice is grown. Unfortunately, rice hulls can easily mould and bacterial growth has been found to be common thus restricting its use [9, 24].

3.1. Corn silage litter

This as litter material that was found to be a suitable alternative for other common litter materials with an added advantage of very low Salmonella prevalence [22]. However, it is not popular and not always available because corn is mainly a seasonal crop grown in certain restricted areas of the tropics.

3.2. Straw litter

This is any grass material that can directly be used or processed to be used as (straw litter) material. It is used worldwide especially in cereal producing countries. Wheat straw is the

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most popular but rye straw was proven to be most superior over other grass straws. Straw generally dries quickly thus discouraging fungal growth, however, it is difficult to manage because of its length and can easily cake and balls up when squeezed requiring routine litter readjustment [20, 24]. However, for straw to be an efficient litter material, it should be chopped to one inch or 37 mm pieces to prevent long straw its usual ability to bridge or mat quickly [24]. Despite the fact that chopped straw was found to be free of Salmonella, it had side effects on environmental health [22]. Straw litter can serve better and more effectively when used as a top dressing over old litter. It is cheaper and most readily available litter material and therefore more economically viable [24]. Straw can best be used in 1:1 combination ratio with shavings, rice hulls or old litters [24].

3.3. Bagasse

Is a sugarcane by-product when sugar or the juice from sugarcane is extracted. It is common but not readily used as litter in many parts of northern Nigeria where sugar cane is cultivated. It is normally burnt and taken to farms as organic fertilizer. If properly harnessed, it can be a good litter material because it is highly moisture absorbent and dries easily; however, care must be taken as it cakes easily [24].

3.4. Recycled papers

Many paper products, such as newspapers, cardboard, shredded papers and chopped newspapers, are increasingly being used as alternative litter materials in poultry farms because they are relative cheap and available. Unfortunately, paper products are reported to retain high level of moisture. This increases its ability to cake easily enabling breast blister formation and other carcass defects [4, 8, 22, 24, 25]. When recycled papers are to be used as litter material, they are best applied as top litter dressing or they can be mixed with other conventional wood-based litter materials [8, 24]. The best size for a shredded paper as litter material is 1–2 cm in diameter, and old newsprint papers are often recommended to be used because some printing inks are toxic to chicks, whereas glossy papers are reported not to absorb moisture [12].

Pine shavings as litter materials were successfully experimented in which variations on broiler performance were not observed [7].

Sand as litter material did not show any variation in broiler performance when compared to other conventional litter materials. Sand was shown to reduce darkling bee infestations, and it had longer period of up to 5 years before clean-out. It was shown not to heat up appropriately during cold periods when compared to wood shavings and is therefore best suited as litter material during the summer [7, 24]. Sand was also shown to be less dusty and improved foot pad quality. However, sand was found not to be compatible with composting, incinerating and pelleting but is currently attracting research interest in many places [7, 24]. Because of its availability, less cost and accessibility it may stand to be the most acceptable to the common man.

Composted litter is another cheap, dust-free litter material that is often associated with low odour and low pathogenic organisms or parasites and therefore appears to be good and

suitable litter, however, it is not recommended as litter material during brooding because NH_3 in composted sand litter may persist for long [4]. Composted sand litter contains higher manure proportion for crop application and also decomposes faster when applied to crops. Furthermore, the pH of the manure from composted sand litter ranges between 5.5 and 6.5, which is most suitable for vegetables and fruits [12].

Groundnut or peanut shells as shown in **Plate III** below have been used alone or in combination with other litter materials where groundnut is cultivated in Nigeria. It only seems to protect birds from being in direct contact with the floor as its warming and moisture absorbing abilities are poor. It may, however, be obtained at no cost but its suitability as a good litter material needs further evaluation.

Plate III. Peanut/groundnut shells used as poultry litter material in some parts of Nigeria.

Finally, each type of poultry bedding material is subject to factors that will enable it to be a successful litter material [9].

4. Litter management

Organic manure decomposition produces odorous gases, such as amides, amines, mercaptans, sulphides and disulphides. These biogases may irritate and disrupt the respiratory tract epithelial lining of animals and men leading to high degree of susceptibility to respiratory tract infections [8].

4.1. Basic factors of consideration in litter management

4.1.1. Ventilation

Is a major factor in moisture control in poultry houses because it provides adequate air movement that will enhance moisture evaporation in poultry houses. Decreased litter moisture will subsequently lead to decrease in free NH_3 and CO_2, which may lead to increased air dust content in poultry houses [8].

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4.1.2. Temperature

It plays a significant role in influencing clumping into layers of litter materials referred to as caking. A normal litter is expected to break easily if hand squeezed but will remain moulded if the moisture content is high and if temperature is high it will result into caking.

4.1.3. Water spillage

It is difficult or almost impossible to avoid water spillage when using manual drinkers in poultry managed on deep litter system. In semi-automated systems of management, water lines that make use of nipple drinking points will have some chances of water spillage and the water lines with nipple and cups will have minimal water spillage.

4.1.4. Quantity of the litter material used

If litter material is liberally applied to a required thickness, the litter will sufficiently absorb moisture making birds more comfortable and enabling them to exhibit some of their natural behaviours thus enhancing birds' growth, performance, environment and welfare [12].

Good litter is made of adequate materials applied to a sufficient depth of at least 2 cm for cool sand, 5–10 cm in case of wood shavings, 10 cm for chopped straw and generally 8 cm for any other litter material on a damp-free floor [2, 7, 8]. However, environmental, management and indoor conditions of poultry houses especially housing temperatures, stocking density and air movements have significant influences on litter quality and degree of NH_3 emissions [6, 8, 28]. Concentrated wastes in the form of uric acid passed out by birds make it possible to house many birds on litter with a major challenge of moisture control [7, 8, 24]. Therefore, deep litter management to miniimze dampness is necessary but seems not to be given due attention in the Nigerian poultry industry [8, 29]. Efforts to maintain good litter should therefore consider factors, such as type of material used as the litter depth, the season of the year, the depth requirement, stocking density, watering devices, nature of the floor, provided pen ventilation, routine litter management practices, litter amendment facilities and procedure at disposal and incidences of litter-related diseases [7]. Generally, the depth and type of the litter used varies with the type of litter material available. This should enhance but not retard performance [2, 7]. High stocking density leads to humid environment due to decreased water and gas exchange between air and litter [6] there is usually high chance of feed and water spillage due to space competition, high levels of waste secretions and excretions into the litter that will lead to temperature and ammonia build up in the poultry house and subsequently high chances of bad litter occurrence. Well-ventilated poultry houses with relatively light stocking densities will maintain good litter [8, 30]. Litters if well managed can be changed at the end of each cycle [8, 30], unless the litter appears bad or if diseases outbreaks occur. Dusty, wet and cakey litters are signs of badly managed litter [8, 30]. A good litter should adhere slightly when squeezed, it should easily break when dropped from the hand, but when litter is too wet it balls up if squeezed in the hand, too dry litter does not normally adhere [30]. Litter materials on earthen floors hold as much as 10% moisture making it almost impossible to effectively manage than litters on damp-proofed concrete floors [28]. A quick test for litter dampness will be if the back

of the hand feels damp when applied onto a litter, then it possibly contains at least 30% moisture which rapidly converts uric acid to toxic ammonia, supports the growth of fly larvae and coccidian organisms and also encourages breast blisters [31].

The rules of litter management are few but most decisions are subject to operator's judgment. Some of these emphasize that litter materials should be checked for bacterial and fungal contaminations, litter materials of fine particle should be covered with paper to avoid litter consumption not eating and new litter materials should be treated with approved anti-fungal agents while litter intended to be reused should also be treated with lime [8, 31]. In managing litter, special attention should be paid to drinker points because such areas are normally damp liable to caking as shown in **Plate IV**, such points should be turned and tilled to activate litter or be removed and fresh litter material added [8, 31, 32]. Unfortunately, tilling of litters is frequently associated with rapid increase in ammonia levels in poultry houses; this should be done with windows open or fans on to rapidly dissipate the ammonia [31]. A good working litter gives desirable warmth and cold to the poultry house while a wet litter cools the house due to heat loss in the process of drying out [25]. It is dangerous to the birds and the operator to allow ammonia build beyond 40 part per million (PPM) is poultry houses [33]. This consequently will lead to decreased feed intake and productivity, respiratory tract infections and blindness [34]. However, ammonia levels of 15–20 PPM is acceptable and can be estimated fairly accurately using the operator's sense of smell or litmus paper or more accurately using commercially available dragger gas detector [35].

Plate IV. Inadequate and poorly managed litter around a drinker in Zaria, Nigeria.

5. Management of ammonia in poultry farms

Some micro-organisms present in the litter convert birds' excreta and spilled feeds to ammonium (NH_4^+), which is soluble in water and is convertible to ammonia in the presence of high

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pH and temperature [32]. However, a high ammonia level in litter is desirable in increasing fertilizer value but with a consequence of environmental pollution and public health hazard [32]. In the rainy season, ammonia contributes to soil acidification and facilitates algae growth in water bodies [32]. Today, there is growing concern in regulating ammonia emissions from livestock environments worldwide [8, 32]. The concept of litter management has thus far shown drastic reduction of ammonia levels in poultry houses thereby improving birds' health and performance in many places [8, 32]. For instance, ammonia emission is reduced with regular litter change, use of appropriate litter material and amendment facilities, decreased manure moisture and improved indoor conditions [6].

6. Litter amendments

The concept of poultry litter amendments to effectively control ammonia levels involves application of acidifiers, alkaline materials, absorbers, inhibitors, microbial and enzymatic treatments and even dietary manipulations [6, 32, 36].

Acidifiers including alum, sodium bisulphate, ferrous sulphate and phosphoric acid are popular, most effective and widely used poultry litter amenders. They work by creating acidic conditions in litter so that NH_4^+ rather than NH_3^+ is retained, which then facilitates bacteria and enzymatic in activities so that ammonia is not produced in the litter [15, 32, 36]. Alum was reported to reduce NH_3 by 71–92% while phosphoric acid did so by 56–92% [15]. They suppressed NH_3^+ levels below 25 PPM for 3–4 weeks post-application and thus improved in-house air quality in poultry pens [32].

Alkaline materials that include agricultural lime ($CaCO_3$), hydrated or slaked lime Ca $(OH)_2$ or burnt lime (CaO) work by increasing litter alkalinity (pH > 7). This helps to convert more of the HN_4^+ within litter to gaseous NH_3^+ that can be readily lost through provided ventilation so that lower NH_3^+ level is maintained. This practice, however, lowers soluble phosphorus level in litter thus affecting fertilizer value and may subsequently have negative impact on the environment as ammonia levels may later increase significantly when fresh manure is added to such a litter [32, 36].

Absorbers are certain natural clay-type-like zeolites and peats, which are good ammonia absorbers thereby lowering ammonia levels if used in poultry houses [32, 36]. Inhibitors are also used in poultry litter to slowly convert uric acid and urea to ammonia by the process of inhibiting enzymes and microbial activities. Phosphorodiamidate was reported to inhibit urease activity and this reduced the conversion of urea into ammonia [32].

6.1. Microbial and enzymatic treatment of litter

This process utilizes beneficial microbes and enzymes which can convert uric acid and urea rapidly into ammonia which can then be lost out thereby reducing the ammonia levels before chicks are placed in the poultry house. Commercial microbial products like USM-98 or *Yucca schidigera* extract as a natural feed additive were reported to significantly lower ammonia levels, improve bird weights and reduce mortality [32, 36].

6.1.1. Dietary manipulation

This technique involves reducing the nitrogen intake per bird by reducing the crude protein in poultry diet. This works on the concept that ammonia is formed by the breakdown of undigested protein and uric acid in the manure [6]. Therefore, a 1% reduction of CP in poultry diet resulted in 10–22% reduced NH_3 emission in poultry houses [6].

6.1.2. Increased age and weight at slaughter

This process is believed to influence NH_3 emissions because nitrogen excretion per day per bird increases with increasing daily feed intake [10].

7. Processing and utilization of poultry waste

Poultry litter generally contains waste materials including the litter material used, feathers, poultry feed and dead birds, which if properly managed will ensure its beneficial use and will help to prevent adverse effects of improperly disposed litter on the environment and poultry health. Litter is not recommended to be reused when a disease outbreak occurs in a flock [31] because zoonotic pathogens, including *Escherichia coli, Salmonella* spp., *Campylobacter jejuni, Listeria* spp., *Clostridium* spp. and many other viruses, survive in poultry litter for a long time posing health risk to birds [8]. Therefore, litter should be treated to destroy these organisms before land application or before use as feed supplements. Mycotoxins especially aflotoxin B_1 responsible for under-performance in especially broilers have been detected in excess levels in poultry litter [37–40]. Mycotoxins have been known to increase susceptibility of broilers to infectious bursal disease and are reported to also act synergistically with stressor to increase severity of poultry diseases [37]. It is therefore necessary to effectively manage poultry litter before utilization. However, effective management of poultry wastes are normally associated with unbudgeted expenses that are not normally recognized in production budgets, such wastes managed may either be valuable by-products or strictly a net cost on investment.

In many advanced countries, poultry farmers were made to register their operations with appropriate agencies and keep records of poultry wastes so as to help develop an approved poultry waste management plan [41]. Unfortunately, managing poultry waste in most developing countries seems to be impossible and therefore contributing greatly to environmental pollution and disease spread. Below are some practical hints that may render poultry waste easily manageable and ensure environmental safety.

7.1. Converting poultry litter into biofuel

Efforts towards safe disposal of poultry wastes resulted into a technology in the recent pass that converted poultry litter to valuable bio-oil, usable gas and crop fertilizers [42]. For instance, broiler and turkey litters were converted into bio-oils and organic fertilizers and the gas generated in this process was used to operate pyrolysis unit in what seems to be a self-

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sufficient machine [42]. The machine is made up of a thermochemical unit that destroys pathogenic microorganisms and reduces chances of disease transmission [42]. Furthermore, several electrical generating plants in the UK and recently in the USA utilize poultry and turkey litters as their primary fuel for small-scale electricity generation [42]. Poultry litter is also reported to be used in Ireland as a biomass energy source, and some companies in addition are developing gasification technologies to utilize poultry litter as a fuel for electrical and heating appliances. They are also producing valuable by-products, including activated carbons and fertilizers [43].

7.2. Composting of poultry litter

Composting of poultry litter with dead carcasses is recommended for poultry disease control and an attempt to increase the market value for organic fertilizer generated from poultry litter, which is in high demand in forestry, crop and vegetable farms, homes, lawns and golf courses [44]. Composting is generally a simple natural biological process of converting poultry litter into odourless, stable, consistent and soil-like organic product that is unable to damage crops and surface waters. The process is a slow controlled decomposing or a natural breakdown of organic materials, which utilizes aerobic microorganisms in the poultry litter in the presence of oxygen and moisture to change the chemical and physical nature of poultry litter so that a humus-like material referred to as compost is formed [31, 44]. Composting is believed to reduce litter quantity and weight by 40–80% [31]. Compost has improved air conditioning effects and quality of soils by adding organic matter, nutrients and beneficial microbes thereby increasing soil porosity, density, water and nutrient holding capacity [44]. Compost is thus referred to as an excellent soil amendment [31]. As an example, composted broiler litter has a pH of 5.5–6.5 and is usually weed-free, thus making it a suitable fertilizer for seedlings, shrubs, roses and fruit tries and is also reported to be rich in vitamin B12 [4, 31].

7.3. Storage of poultry litter

The demand for poultry litter is sporadic but highest during the rainy season in many tropical countries thereby requiring temporary holding until the appropriate demanded time. Unfortunately, fresh poultry litter has the highest nitrogen content available for crops making it of greater fertilizer value as at that moment [4]. Notwithstanding proper storage of poultry litter will still ensure its beneficial use as valuable fertilizer and will prevent contamination of surface waters on farms [17]. The most valuable nitrogen in poultry litter is gradually lost to the atmosphere as ammonium over a prolonged period of exposure to the atmosphere [17]. Covered stockpiles of litter: Is a process that involves stockpiles of litter covered using plastic sheets anchored to the earth or other devices to protect against rain and atmospheric losses for timely use. Stockpiles with ground liners: This is another poultry litter storage means involving the use of good plastic sheets as liner to ground or concrete slabs to primarily prevent nutrient leaching to ground water [17]. Permanent storage structures provided with sufficient roofs and concrete floors is the best approach but this is limited by the high risk of spontaneous combustion and fire outbreaks [17].

7.4. Applying poultry litter to crops

Rich soils for efficient crop cultivation were achieved by increased physical fertility due to increased organic matter, increased water holding capacity, increased oxygen diffusion rate that resisted deterioration and disturbance of soil by mining and other industrial activities. Certain considerations are best put in place before litter can be effectively and safely applied on farms [17]. It is logical that poultry manure should not be applied to very steep lands, lands in close proximity to surface waters, drainage ditches and wells for fear of contamination. Likewise application of poultry waste prior to heavy rains is liable to contamination. When applying litter to crops, it is best done at the time of nutrient needs. It should be ensured that litter is applied to as close to planting time as possible or best applied mechanically by incorporating to plants [44]. In this way, ammonia loss due to volatilization and nutrient loss by wind and water erosion are prevented or minimized. Application of litter well ahead of planting time will lead to de-nitrification and leaching [44]. Studies have shown that adequately applied organic manure from poultry litter increased corn yield many folds, but excessive application of poultry manure on the other hand decreased corn yield by a process called 'salt injury phenomena' [20].

7.5. Poultry litter as ruminant feed supplement

Broiler poultry litter contains 25–50% crude protein and 55–60% total digestible nitrogen (TDN) and is also rich in essential minerals. Its nutritional value may even be higher than that of good quality legume hay [45]. Poultry litter has traditionally being used efficiently as a fertilizer; it is now also used as a cost-saving livestock feed supplement for ruminants especially cattle, goats and sheep [46–48]. It is high in urea, a source of nitrogen, which improves the rumen environment making feed more efficiently utilized and the animal better nourished with whatever feed that is made available [46, 48]. Uric acid is a major component of poultry excretions that can be efficiently utilized by rumen microbes for protein production. It is not easily dissolved in the rumen fluid and so the ammonia that is gradually and slowly released is efficiently utilized even more than other non-protein nitrogenous sources [49]. Composted litter is found to be rich in B vitamins especially B12 and can be a good source of this vitamin [31]. The rumen microbe takes about 3 weeks to fully adapt to the utilization of uric acid and so cattle less than 5 months old and sheep and goats less than 3 months old should not be given poultry litter [46]. When poultry litter is processed by an acceptable method, it serves as a very economical and safe source of protein, minerals and energy for many classes of ruminants [46, 48, 49]. Well-processed poultry litter has a total digestible nutrients value similar to average quality hay and this can provide a major portion of the energy to maintain ruminant when fed to them [49]. Poultry litter has been reported to be economically used in ruminant feeding as a forage substitute during drought periods as it also contains high levels of fibre and ash [47, 50]. At higher levels, however, dry poultry litter had depressed growth rate because of its low contents of essential amino acid and excessive amount of calcium in it [49]. It was further shown that poultry manure can replace groundnut cake in the diet of goats without any depressive effects on growth rate and efficiency of feed utilization when used with a good source of carbohydrates such as cassava peel [48]. Crude fibre digestion was

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reported to be enhanced in rations containing poultry litter and also incorporating poultry litter of up to 25% in the rations of camels did not have any adverse effects [49]. Report of poultry litter as a reliable substitute to cotton seed cake in the diets of suckler cattle was documented [51]. Unfortunately, poultry litter can be contaminated with pathogenic organisms that can cause diseases in other animals but the incidence can be reduced by sun drying [52–55]. For instance, botulism caused by *Clostridium botulinum* has been reported in cattle fed poultry litter [45]. Cupper toxicity was reported in sheep fed on poultry litter when chickens were medicated with cupper as growth promoter in their diets [56]. It may be of scientific concern where poultry feed may contain protein that is prohibited in ruminant feed, such as meat and bone meal particularly where bovine spongiform encephalitis (BSE) had occurred [55] even though this opinion is weak because it seems there has not been any substantial evidence that BSE would survive in chicken intestinal tract. However, wood shavings as the most common litter material in Nigeria are often obtained from wood work industries, and as such may contain sharp or metallic objects which can cause traumatic ventriculitis in poultry and traumatic pericarditis in ruminants [19]. A research concluded that poultry waste intended to be used in compounding rations for cattle should be dried or ensiled and screened for metallic objects to render it safe for use by the animals [19, 57]. Ensiling sorghum forage or molasses with poultry waste had improved crude protein content of the silage almost twofold. Rations formulated with 30% of the concentrate as poultry waste gave about 10 kg of milk/day [55, 58, 59]. However, wet poultry manure should not be fed to livestock and the optimum supplement level for dairy cows is 1–2 kg daily [57].

7.6. Poultry litter as fish feed supplement

Frozen fish is heavily imported into Nigeria [60] and aquaculture is being integrated with livestock and poultry in Nigeria in recent years with a major limitation of formulated fish feeds. Researches have been conducted to determine the effectiveness of feeding cow, pig and poultry manure in variety of fish species [47, 61, 62]. Chickens have short intestines thus excrete about 20% undigested feed and that 10% of feed fed to chickens are wasted to the litter in the process of feeding making available 10–30% total protein content of dry chicken waste. About 1100–1400 Kcal/kg energy and synthesized soluble vitamins are abundant in poultry manure [47, 63]. Some poultry farmers especially in China take this advantage to construct battery cages directly on ponds while others feed poultry manure directly to fish [64], whereas some poultry-fish farmer in Nigeria throw dead poultry into fish ponds so that waste is now recycled into inputs. The nitrogenous waste from poultry litter can efficiently fertilize ponds for growth of plankton as fish food [65]. In fact a report from the United States indicated no difference in terms of growth rate of tilapia raised in poultry litter manure ponds when compared to fish that were fed commercial feed [66].

8. Conclusion

Economic losses as a result of inadequate litter management and utilization are of increasing concern. Selection of litter material is dependent upon cost, availability and quality, which

should not be compromised. Research should be continued in search of proper storage conditions of poultry litter and to find the exact inclusion rate of poultry litter to plants and animals. The basic technology of feed compounding using poultry manure and its conversion to useful biofuel can be developed and transferred to farmers.

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