Journal of Sustainable Veterinary & Allied Sciences
P-ISSN-2695-2661 e-ISSN: 2811-1346
JoSVAS 2023, Vol 4, Issue 2: 137-145

Review

Poultry waste management in Nigeria: a neglected sector

[1]*Akporube, K.A., [1]Kalu E. [2]Ikpendu C. & [1]Edward I.G.

[1*]*Department of Veterinary Public Health and Preventive Medicine,* [2]*Department of Veterinary Microbiology, Michael Okpara University of Agriculture, Umudike, Nigeria*

*Corresponding author: akporube.kelechi@mouau.edu.ng; +2348064963441

ABSTRACT

The recent surge in poultry production has led to an increase in poultry waste production. Waste from poultry production often includes hatchery waste, dead birds, condemned carcasses, and manure. Manure is normally applied to agricultural soils as a source of fertilizer. Excessive production of waste from poultry farms and its improper disposal has led to air pollution and contamination of agricultural farmlands and eventually surface and water groundwater pollution and this has become a major public health concern to the society. Improper disposal of poultry waste affects poultry farmers, individuals residing close to the farms, and the environment. Published articles on poultry production and poultry waste management were retrieved from the search engine Google Scholar and were used to summarize the impact of poultry waste as a source of contamination and/or pollution to the environment with associated public health implications on animals and humans. Options for proper disposal and utilization of waste from poultry production are further discussed.

KeyWords: Environmental pollution, poultry, waste disposal waste management.

INTRODUCTION

At the global level, poultry farming is one of the fastest-growing agricultural businesses largely due to its economic benefits as meat and eggs are always in high demand (Adeoye *et al.*, 2014). Poultry farming in Nigeria plays a major economic role in creating wealth, and providing employment opportunities for millions of youth in the industries and associated value chain. Currently, poultry production in Nigeria amounts to 454 billion tonnes of meat and 3.8 million eggs per year with a standing population of 180 million birds (ASL 2050, 2018) The waste generated from poultry production is in solid and liquid forms from hatcheries, poultry farms and abattoirs (Prabakaran & Ezhil Valavan, 2021). The solid waste could be excreta (manure), wood shavings, feathers, empty shells, infertile eggs, dead embryos, shells from cracked and broken eggs, sludge, offal, blood, and dead birds (Chen & Jiang, 2014; Nowak *et al*., 2017). The liquid waste is mainly from the wash water from poultry farms and abattoirs. These wastes give rise to environmental hazards such as pollution from the production of greenhouse gases, ammonia, ammonia, aerosols, etc., and human health risks due to the spread of bacteria and diseases (Zhang *et al*., 2023).

Due to the recent increase in poultry farming, there has been a significant increase in the production of poultry wastes (Ali *et al.*, 2020). This challenge is aggravated by the large-scale accumulation of waste which poses disposal and pollution problems (Kalu, 2015). The waste from poultry production includes hatchery wastes, manure (bird excrement), litter (bedding materials such as sawdust, wood shavings, straw, and peanut or rice hulls), and on-farm mortalities while the processing of poultry results in additional waste materials, including offal (feathers, entrails and organs of slaughtered birds), processing wastewater and biosolids (Kalu, 2015).

There are several methods of disposing of poultry waste. These include burial, rendering, incineration, compositing, and conversion of poultry waste to livestock feed , the use of manure as fertilizer for crops, and the production of energy(biogas) (Moreki & Kealkitse, 2013). Unfortunately, some of these innovative modern methods for waste disposal such as processing into feed for animals, green disposal, gasification, and biogas production involve a certain level of biotechnology and hence, have not been optimized for wider use across most parts of Nigeria. Other factors limiting adoption of these technologies are high cost, level of awareness, lack of enforced regulation of poultry waste disposal by the government, and lackadaisical attitude of poultry farmers (Adeoye, *et al*., 2014). The major challenges in managing poultry waste are inadequate information, weather condition, lack of convenient dumping space, and unavailability of litter material (Gbigbi, 2020). Continuous dumping of poultry waste on land could lead to microbial buildup in the soil which could also lead to soil nutrient imbalance, eutrophication of surface water by phosphate, and buildup of nitrate in the soil to 3m depth or even up to the bedrock (Vizzier *et al.,* 2009).

The aim of this review, therefore, is to examine the current poultry waste management practices in Nigeria and help in providing options on how to properly dispose of and utilize waste from poultry production.

METHODOLOGY

Relevant publications on poultry and poultry waste management in Nigeria were obtained by the four authors from online databases using the Google Scholar search engine between the months of July 2022 – May 2023. Publications used included research articles and local, national, and international reports on poultry and poultry waste management. The inclusion criteria for publications included relevance to the topic with complete, recent, and verifiable referencing. Exclusion criteria included publications that were without references, inadequate referencing, obsolete references, irrelevant topics, unverifiable information, and duplicate information. Out of forty- two (49) articles obtained from the search, twenty-five (30) were eligible and majorly used for drafting the content in this review.

CLASSIFICATION OF POULTRY WASTE

The waste generated from poultry production can be classified under the following headings:

POULTRY LITTER/MANURE

This is known to be the main waste generated in poultry production and it is usually a mixture of the poultry manure, bedding materials in poultry houses such as wood shavings, and spilled feed (Zhang *et al*., 2023). A single poultry bird is estimated to produce about 1kg of poultry litter and manure waste within a growth period of about 47 days (Ma *et al*., 2019).

FEATHER WASTE

An estimated 5-10 % of the total body weight of a bird is held in its feathers and so a significant waste is generated (Guray *et al*., 2016). Keratin is the main component of bird feathers which is an insoluble, fibrous protein and has a wide range of applications (Bhari *et al.,* 2018). This waste is of serious human health and environmental safety concern as many pathogens such as Salmonella and Vibrio can be found in them and pollutants such as ammonia, nitrous oxide, and hydrogen sulfide can be emitted from them (Mazotto *et al.,* 2011).

MORTALITY WASTE

Mortality waste includes dead birds and dead embryos from poultry production. It is estimated that in Nigeria, 83.34% of poultry farms have on average a monthly mortality rate of 7.4% (Akanni & Benson, 2014). Mortality waste contains a great amount of protein, phosphorous, and calcium but the improper methods of disposal such as landfilling (burying) and burning pose a threat to the environment and human health (Gündüz *et al*., 2019; Modak *et al*., 2019).

ABATTOIR WASTES

This is the waste generated during the slaughter of poultry and includes offals, visceral organs, blood, and bones. Several species of microorganisms and residues are contained in this waste and it is usually disposed of by dumping, burning, or burial resulting in the risk of transmission of diseases (Muduli *et al*., 2019; Nicholson *et al*., 2005).

HATCHERY WASTE

Poultry hatcheries produce both solid and liquid wastes. Some of the solid waste produced are egg shells, infertile eggs, dead-in-shells, and decaying tissue (Glatz *et al.*, 2011). Composting, landfill, incineration, and rendering are the common methods for disposal of solid wastes while irrigation or channeling directly into sewers are the disposal methods for the wastewater (Prabakaran & Ezhil Valavan, 2021).

Proper disposal and management of poultry waste are very essential because poultry waste provides a favorable environment for microbes to thrive and also leads to environmental pollution through its offensive odors and by producing phytotoxic substances that pollute the air, promoting the breeding of flies and rodents, resulting in transmission of infectious diseases.

POULTRY WASTE DISPOSAL AND UTILIZATION

POULTRY MANURE/ LITTER

Poultry manure contains lots of minerals such as carbon (C), nitrogen(N), Phosphorous (P) and water and chlorine (Cl), Calcium (Ca), Magnesium (Mg), Sodium (Na), Manganese (Mn), iron (Fe), copper (Cu) and zinc (Zn) (Kelleher *et al.*, 2002). Poultry manure/ litter can be disposed of or utilized in the following different ways:

ORGANIC FERTILIZER

Poultry litter has useful properties as a fertilizer and soil amendment and has been used for many years in the production of a range of crops and products for human consumption (Runge *et al.,* 2007). Poultry litter has high plant nutrient levels which makes it a valuable organic fertilizer that provides plants with nutrients such as nitrogen (N), phosphorus (P) and potassium (K) (Kelleher *et al.*, 2002). Applying poultry litter residues to crop soil reportedly increases the organic matter, increase the number and diversity of soil microorganism and improve the uptake of nutrients by plants (Muduli *et al.*, 2019).

LIVESTOCK FEEDS

Scientific research has documented that nutrients and energy from poultry waste by-products, including manure and litter, can be safely recycled as a component of livestock and poultry diets when pathogens therein have been neutralized (McCaskey, 1995). Poultry litter has been estimated to be three times more valuable as a feedstuff than as a fertilizer for crop nutrients. Waste from caged layers can be fed to ruminants as a source of protein supplementation. The microbes in the rumen degrade the uric acid in poultry to ammonia.

According to Muduli *et al*, 2019, adding broiler litter to beef cattle rations at a level of 20% or higher will generally meet the animal's needs for crude protein, calcium, and phosphorus. The beneficial effects of feeding corn silage to which poultry litter has been added have also been reported. Owen *et al*. (2008) investigated the nutrient quality of heat-treated poultry litter in Nigeria to ascertain its use in animal feeds and it was observed that the dry matter (DM), crude protein, energy, crude fiber, ether extract, and ash had values of 87%, 20%, 621.41 kcal/kg, 10.40%, 2.2%, and 18.50%, respectively while the values of phosphorus, calcium, sodium, potassium and magnesium in the litter were 4.50%, 2.00%, 0.10%, 2.05 and 0.48%, respectively. It was therefore concluded that poultry litter could be safely incorporated into animal feeds.

BIO-ENERGY GENERATION

Poultry manure and litter are rich in organic matter which can be transformed into bio-energy. In the technology for anaerobic digestion/conversion of poultry litter to methane (biogas), manure is digested anaerobically under controlled conditions to produce a mixture of gas with varying concentrations of combustible methane (Muduli *et al.,* 2019). The biological methane production rate and yield of different poultry slaughtering residues differ from each other. Poultry offal, blood, and bone meal which were rich in proteins and lipids, showed high methane yields at different concentrations of volatile solids. Blood and bone meal produced methane rapidly (Muduli *et al.,* 2019).

Biogas is a source of energy; it can be used as a fuel for engines, generation of electricity, and other energy-consuming purposes and digester effluents could be used as fertilizer and feed supplement for animals, although the nutritive value of the effluent is dependent on the digestion system and operation method as well as the method of collection (Muduli *et al.,* 2019). They can also be used as a source of thermal energy to heat chicks at brooding (Oliveira *et al.* 2012). Anaerobic digestion of the poultry slaughter residues appears a promising possibility because of the high methane yield and nitrogen content of these residues (8 to 14% N of total solids).

COMPOSTING

This is a natural biological process where microbes especially thermophilic microbes are broken down and decomposed under increasing temperatures into carbon dioxide, water, minerals and stabilized organic matter (Muduli *et al.,* 2019). Composting waste is a biological process in which organic wastes are stabilized and converted into a product to be used as a soil conditioner and organic fertilizer.

Composting provides an inexpensive alternative for the disposal of animal-based wastes and other biological residuals. Properly composted material is environmentally safe for producing crops meant for consumption by humans and animals (Thyagarajan *et al.,* 2013). Partial composting or deep stacking has the potential to pasteurize poultry litter ensuring that it is free from pathogens and providing a product at a cost likely to be acceptable for application to vegetables, fruit, crops and soils used for growing pastures for stock (Runge *et al*., 2007).

COMBUSTION

This is the most effective and successful conversion of poultry litter to energy and it involves the use of mass burn combustion and, in particular, step-grate combustion systems (Kelleher *et al*., 2002). The wastes can be burnt in purpose-built incinerators and the heat is used to produce electricity or to provide heating for the buildings. Also, combustion provides fertilizer-grade ash. Direct combustion and incineration are recognized as efficient options for generating renewable energy and fertilizer-grade ash from litter (Muduli *et al.,* 2019).

POULTRY CARCASS/OFFALS

Poultry offal consists of 5.3% of total Kjeldahl nitrogen, 32% proteins, 54% lipids, and 0.6 to 0.9 % methane production potential (Salminen & Rintala, 2002). In the poultry industry, lots of drugs and chemicals are often added to the feed for nutritional and pharmaceutical purposes and these accumulate and form residues in birds. Poultry offals (feathers, feet, intestinal contents) are contaminated with several different species of micro-organisms including harmful pathogens such as *Salmonella sp.,* and *Staphylococcus sp* (Salminen & Rintala, 2002). Methods of utilization and disposal of poultry offals are as follows.

BURIAL

Burial is the most cost-effective, convenient and ancient method used for the disposal of poultry wastes and this method includes several variations like burial pits, sanitary landfills and inverted feed bins. Burial of dead birds on the farm may have the disadvantage of environmental pollution and contamination of groundwater. Therefore, the burial of dead birds or offals on the farm must be strictly controlled. This is done to avoid the leachate problem arising due to the poultry carcasses (Kim & Kim, 2017). However, if it is not managed properly then it may lead to environmental degradation, surface and groundwater contamination. Hence this method is only safe when it is executed properly (Kim & Kim, 2017).

RENDERING

Rendering is an alternative method for the disposal of poultry waste and it involves mechanically crushing poultry carcasses into a tissue then those tissues are cooked under steam which works for the removal of moisture from the dry proteinaceous particles so that they can be used as an animal feed protein source (Blake & Donald, 1992; Bayr *et al*., 2012). Rendering also removes fat from meat through different heating applications (Swan, 1992). Rendering at about 133°C for a minimum of 20 min or alternative heat treatment is required for high-risk materials used for animal feed or as an intermediate product for the manufacture of organic fertilizer or other derived products. Rendering produces meat-bone-meal, which can be used in animal feed or as fertilizer, or further processed via anaerobic digestion or composting. In addition, rendering produces fat, which may be used for animal feed, in chemical industry products, or burned as fuel. Slaughterhouse by-products are preserved with formic acid as it has a good source of proteins and vitamins and is used as animal feed (Bayr *et al*., 2012). However, the use of slaughter by-products for animal feed increases the risk of disease transmission via the feed and the food chain.

COMPOSTING

Composting is an aerobic biological process that degrades organic material and it is a common method used to treat poultry slaughterhouse wastes. Composting can decompose carcasses effectively within just a month and produce manure that can be safely applied as compost (Sims *et al*., 1993). The process of composting reduces the pathogens and the compost formed can be used for soil amendments or as soil conditioner or fertilizer (Tritt & Schuchardt, 1992).

INCINERATION

This is one of the most effective methods for destroying potentially infectious agents in poultry offals (Ritter & Chinside, 1995). It completely eradicates the threat of disease but its high operational costs and ability to emit air toxics in the air have made it less desirable (Moreki & Chiripasi., 2011). Air-dried poultry by-product is an established combustible solid fuel with a gross calorific value of about 13.5 GJ per tonne, about half that of coal. But materials with high moisture content possess little or no energy value (Muduli *et al*., 2019).

ANAEROBIC DIGESTION

This is a biological process in which organic matter is degraded to methane which can be used as a source of bio-energy to replace fossil fuels thereby reducing carbon dioxide emissions. Anaerobic digestion has a great advantage because it reduces pathogens and odor and requires little land space for treatment, and can treat wet and pasty wastes (Braber, 1995; Shih, 1993). Other features of anaerobic digestion include the ability to effectively control any releases to air, water, and land from the process. Most of the nutrients also remain in the treated material and can be recovered for agriculture or feed use. The biological methane production rate and yield from different poultry slaughtering residues vary. Poultry offals, blood, and bone meal are rich in proteins and lipids and show high methane yields at different concentrations of volatile solids. The methane production of offal needs more time probably due to long-chain fatty acid inhibition. The length of time depends on the source and various concentrations of inoculums and incubation temperature (Thyagarajan *et al.*, 2013).

VERMICOMPOSTING

Vermicomposting is the process in which earthworms are employed to convert organic matter into humus or nutrient material. This process comprises both the physical and biochemical actions of earthworms. Physical processes comprise substrate aeration and grinding whereas, biochemical processes include microbial decomposition of the substrate in the intestine of earthworms. The most important benefit that vermicomposting of organic waste gives is the increase in the stabilization of organic matter (Subramanian *et al*., 2010).

POULTRY FEATHERS

Chicken feathers contain nutrients of approximately 91% protein (keratin), 1% lipids, and 8% water. The amino acid sequence of chicken feathers is mainly composed of cystine, glutamine, proline, and serine. Serine (16%) is the most abundant amino acid in chicken feathers while, histidine, lysine, tryptophan, glutamic acid, and glycine are present in trace amounts. (Kannapan & Bahraini, 2012). Poultry feathers can be used for the following purposes:

FEATHER MEAL

Feathers are converted to feather meals for use as animal feed, organic fertilizers and feed supplements, due to their rich protein composition (>90% protein). According to the researchers, chicken feathers can be converted into animal feed by using bacteria that can convert the protein present in the feathers of chicken into edible amino acids (DeOliveira *et al*., 2019; Alahyaribeik *et al*., 2020). Hydrothermal treatment is one of the most common methods of feather meal production. It is the digestion of feathers under high pressure at high temperatures but it can lead to the destruction of essential amino acids like methionine, lysine, and tyrosine (Ekta & Rani, 2012). Chicken feather keratin when treated with lime results in a product rich in amino acids and polypeptides that can be used as an animal feed supplement (Coward-Kelly, 2006).

FERTILIZER

Waste from the slaughtering of poultry birds like feathers, blood, and innards is being processed and utilized as high-protein animal feed sources or as fertilizer due to its high nitrogen content. Nitrogen fertilizer is developed from poultry feathers by steam hydrolysis for 12 weeks to break disulfide bonds, modifying the structure of keratin fibers, enzymatic hydrolysis by *Bacillus licheniformis* to break polypeptide bonds, and steam hydrolysis (autoclaving) to improve mineralization followed by cross-linking of protein by formaldehyde reaction to minimize excess mineralization (Jong-Myung & Paul, 1996).

CONVERSION INTO BIODEGRADABLE PLASTICS

Poultry waste can also be converted into biodegradable plastics by the process of polymerization. Feathers that contain keratin protein are pulverized into fine dust. Chemicals that make keratin molecules join together are used to form long chains (polymerization) and are further molded into various shapes when heated at 170°C. These thermoplastics can be popularised to manufacture all kinds of products, from plastic cups and plates to furniture (Thyagarajan *et al*., 2013). Thermoplastic made from this process is often water resistant (Muduli *et al*., 2019).

PRODUCTION OF BIODIESEL

Environmental friendly processes are developed for the production of biodiesel from feather meal. In biodiesel production, primarily fat is extracted from feather meal in boiling water (70°C) and subsequently trans-esterifies into biodiesel using potassium, nitrogen and methane; 7-11% biodiesel (on a dry basis) is produced in this process. Biodiesel from feather meal has been confirmed to be of better quality when compared to biodiesel made from other common feedstocks (Thyagarajan *et al*., 2013).

HEALTH AND ENVIRONMENTAL IMPACTS OF IMPROPER WASTE MANAGEMENT

In Nigeria, the current poultry waste disposal methods are neither economical nor environmentally friendly (Adeoye *et al*, 2014; Kalu *et al* 2016). Waste materials from poultry houses, regardless of flock size, have the potential of causing serious health problems as a result of improper management or recycling (Akanni & Benson, 2014). Inappropriate waste disposal may have varying health effects depending on the type of waste, the population exposed, the concentration of pollutants, and the length of exposure (Mozhiarasi & Natarajan, 2022).

Poultry farm waste, which includes both organic and inorganic by-products, can be a source of elements, chemicals, veterinary drugs, pathogenic microorganisms, pest- and vermin-carrying insects, as well as other toxins that are harmful to both human health and the environment (Akanni & Benson, 2014). In a study carried out by Onu *et al*. 2015 in Abia State, the majority of the farmers (50%) adopted the method of application of manure for crop production while others adopted selling, burning, flushing into pits, toilets, streams, or a combination of several methods. The health effects of nuisance odorants and greenhouse gas emissions are serious public health issues because of global climate change and growing human populations near poultry farms (Akanni & Benson, 2014). Some of these effects include;

AIR POLLUTION

Wastes produced from poultry houses and products contaminate the air thus affecting air quality as ammonia, hydrogen sulfide, dust particles and other volatile organic compounds (VOCs) emitted are associated with health disturbances and nuisance odorants in individuals living near these poultry farms (Akanni & Benson, 2014; Onu *et al*. 2015).

Decomposing poultry droppings produce unpleasant chemicals, such as hydrogen sulfide, methane, and ammonia, which can be irritating to the eyes, nauseating to the poultry worker and harmful to the birds (Akanni & Benson, 2014). As a result of the high organic nitrogen content of poultry waste, exposure to nitrous oxide, ammonia, and methane has a detrimental effect on health, resulting in respiratory and gastrointestinal symptoms in farm workers and other people such as a runny nose, sore throat, excessive coughing, and diarrhea in communities near livestock farms (Kelleher *et al*., 2002; Ritz *et al*., 2004; Delgado *et al*., 2010; Kulcu *et al*. 2010; Gbotosho & Burt, 2013).

Prolonged exposure to ammonia and particulate waste matter such as bedding and faecal droppings of birds, increases the risk of workers contracting animal-to-human diseases, acute and chronic lung disease, airway irritation, coughing or difficulty breathing, and worsening asthma (Gbotosho & Burt, 2013). These symptoms have the potential to cause harm in affected people who act as economic agents and the overall state of the economy (Akanni & Benson, 2014). Furthermore, the burning of poultry wastes could cause atmospheric pollution which might pose some danger to human and animals health (Onu *et al*., 2015). Improper disposal of solid wastes from poultry houses through burning releases several noxious air pollutants like sulfur dioxide, oxides of nitrogen, carbon monoxide, and particulate matter (Kumar & Prakash, 2020). These airborne pollutants may have a substantial negative influence on human health, increasing the risk of developing several conditions including cancer, common cold, allergies, and cardiovascular and respiratory illnesses (Sankoh *et al*. 2013).

LAND DEGRADATION AND GROUND WATER CONTAMINATION

Mismanagement of poultry wastes due to excessive application of poultry waste on land contaminates groundwater and surface water supplies constituting a source of risk to humans (Akanni & Benson, 2014; Onu *et al*. 2015; Iheke, 2016). Contamination of public water supplies from nearby poultry waste dumpsites could increase the potential health risk of livelihood through infection due to the presence of pathogens and water pollutants, acting as a source of contaminants for food and water, potentially leading to gastro-intestinal infections such as typhoid fever, cholera, and hepatitis E (Raman & Narayanan, 2008; Cabral, 2010; Gautam *et al*. 2012).

Pollution of water bodies caused by waste contamination produces skin disease in humans as a result of itchy skin after using polluted water, as well as an unpleasant odor (Grant & Marshalleck, 2008). Poultry manure also contains pathogens such as *Salmonella* species and *Escherichia coli*, which can contaminate food and water supplies, predisposing humans to food-borne illnesses (Mozhiarasi & Natarajan, 2022). Stacking of poultry manure on farms can cause leaching of nutrients such as calcium and nitrate which contaminate water sources (Kelleher *et al*., 2002). Drinking contaminated water from such water sources on the farm or surrounding areas can result in stomach aches and diarrhea (Gbotosho & Burt, 2013). This serves as a warning signal to the owners of residential houses in areas where poultry farms are sited to properly sanitize and treat their wells and boreholes or put into consideration such factors before digging their water source (Onu *et al*., 2015).

Furthermore, illegal dumping of poultry waste in nearby streams can also have harmful effects on both human and aquatic life downstream resulting in oxygen deprivation, nutrient enrichment, hazardous chemical production and water-borne illnesses for those who drink from these streams (Onu *et al*., 2015; Mozhiarasi & Natarajan, 2022). The practice of open dumping of poultry waste (landfilling) causes the breeding of mosquitoes, cockroaches, rats, flies, and other pests, which directly influence the surrounding residential areas that affect their well-being by acting as vectors of transmitting disease to humans (Mozhiarasi & Natarajan, 2022). Residents who live close to open poultry dump yards are subjected to nuisance from scavenging birds and animals, which can hurt their psychological well-being (Mozhiarasi & Natarajan, 2022). Heavy metals, antibiotics, including the genes that give resistance to them, endocrine disruptors, and other compounds may also be present in poultry litter which poses a threat to public health when used as manure for crop production(Modak *et al*., 2019). Similarly, heavy metal poisoning can cause mental disorders in humans (Brinkel *et al*., 2009; Ziraba *et al*., 2016).

ENVIRONMENTAL CONTAMINATION

Indiscriminate disposal of poultry waste and its long-term impacts have been a subject of concern to environmentalists, the general public, and poultry farmers over the years (Gbotosho & Burt, 2013). Environmental contamination occurs when the land application of poultry manure exceeds crop utilization potential or is done under inadequate management conditions, resulting in nutrient loss through environmental factors such as soil erosion or surface run-off during rainfall (Akanni & Benson, 2014). Poor waste management practices culminate in environmental pollution, washing off unprotected poultry waste on farms into nearby water bodies (Iheke, 2016). Increased loading of nutrients such as nitrogenous compounds, volatile organic compounds, methane, sulfur dioxide and phosphorus including potassium in some locations where poultry houses are situated have negative environmental impacts resulting in soil acidification, degradation of nearby surface and/or groundwater (Akanni & Benson, 2014; Gržinić *et al*. 2023).

Severe environmental consequences of improper disposal of poultry feces and other waste include the discharge of untreated harmful germs (fecal coliform) into the environment and destruction of aquatic life, bioaerosol contamination, attraction of rodents and pests, deterioration of the earth's biological structure and offensive smell in poultry facilities vicinity (Akanni & Benson, 2014; Iheke, 2016). Deposition of excess amounts of naturally occurring elements (e.g. nitrogen, phosphorus), pollutants (e.g. pharmaceuticals, steroid hormones, heavy metals), and pathogens (bacteria, fungi, and viruses) found in poultry waste into water bodies can disrupt the balance of water ecosystems, affecting plant life including invertebrates and vertebrates (Gržinić *et al*. 2023).

CHALLENGES OF POULTRY WASTE MANAGEMENT IN NIGERIA

Some of the challenges of poultry waste management in Nigeria include i) Unavailability of agricultural lands for the burying of poultry waste, ii) the economic implications as a result of the cost of implementing adequate and appropriate poultry waste disposal which currently lies solely on the farmer which makes it unaffordable and therefore not sustainable, iii) lack of government policies as regards appropriate poultry waste management and iv) lack of awareness/information about appropriate waste management practices by the poultry farmers which can be addressed by the setting up of extension services by the Federal Government geared towards establishing programs to educate these farmers on the appropriate waste management practices and their public health significance. Lastly, the challenge of modern innovation of converting poultry waste products into energy, biogas, and other utilizable resources are biotechnological driven and hence is yet to be fully adopted in Nigeria as means of treating poultry waste.

CONCLUSION/RECOMMENDATION

The continuous rise in the number of poultry farms in Nigeria due to the high demand for poultry meat has led to increased waste production. Most farmers do not know how to properly utilize or of dispose waste from their daily poultry activities leading to improper accumulation of waste in the surrounding nearby farms and water bodies. Poultry farmers should be enlightened about the effect of contaminating the environment with waste and proper ways of handling poultry waste. The present methods of poultry waste disposal in Nigeria are neither economical nor environmentally friendly; hence, there is a need for adaptation and adoption of modern biotechnology in treating poultry waste.

REFERENCES

Adeoye, P. A., Hasfalina1, C. M., Amin, M. S. M., Thamer, A. M. & Akinbile, C. O. (2014). Environmental Implication of Poultry Waste Generation and Management Techniques in Minna, Semi-arid Region of Nigeria. *Annual Research & Review in Biology*, 4(10), 1669-1681.

Akanni, K. A. & Benson, O. B. (2014). Poultry wastes management Strategies and environmental implications on human health in Ogun State of Nigeria. *Advances in Economics and Business* 2(4), 164–171.

Akanni, K.A. & Benson, O.B. (2014). Poultry wastes management strategies and environmental implications on human health in Ogun States of Nigeria. *Advanced Economic Business*, 2, 164–171.

Alahyaribeik, S., Sharifi, S.D., Honarbakhsh, S. & Ghazanfari, S. (2020). Bioconversion of chicken feather wastes by keratinolytic bacteria. *Process Safety and Environmental Protection*, 135,171-178.

Ali, A., Khadija, G. & Mahe M. (2020). Poultry waste management options and opportunities: a short review. *Journal of Natural and Applied Sciences Pakistan,* 2 (2), 472-484.

ASL 2050. (2018). Livestock production systems spotlight Nigeria. FAO, Rome, Italy

Bayr, S., Rantanen, M., Kaparaju, P., & Rintala, J. (2012). Mesophilic and thermophilic anaerobic co-digestion of rendering plant and slaughterhouse wastes. *Bioresource Technology*, 104, 28-36.

Bhari, R., Kaur, M., Singh, R.S., Pandey, A. & Larroche, C.(2018). Bioconversion of chicken feathers by Bacillus aerius NSMk2: A potential approach in poultry waste management. *Bioresource Technology*, 3, 224–230.

Blake, J. P. & Donald, J. O. (1992). Alternatives for the disposal of poultry carcasses. *Poultry Science*, 71(7), 1130-1135.

Braber K. (1995). Anaerobic digestion of municipal solid waste: a modern waste disposal option on the verge of a breakthrough. *Biomass Bioenergy*, 9, 365-376.

Brinkel, J., Khan, M. H. & Kraemer, A. (2009). A systematic review of arsenic exposure and its social and mental health effects with special reference to Bangladesh. *International Journal of Environmental Research and Public Health*, 6(5), 1609-1619.

Cabral, J. P. S. (2010). Water microbiology. Bacterial pathogens and water. *International Journal of Environmental Research and Public Health*, 7(10), 3657–3703.

Chen, Z. & Jiang, X. (2014). Microbiological Safety of Chicken Litter or Chicken Litter-based Organic Fertilizers: A Review. *Agriculture*, 4 (1), 1–29.

Coward-Kelly, G., Chang, V.S. & Frank K. (2006). Lime treatment of keratinous materials for the generation of highly digestible animal feed: Chicken feathers. *Bioresource Technology* 97(11), 1337-43.

De Oliveira, C. C., De Souza, A. K. S., & De Castro, R. J. S. (2019). Bioconversion of chicken feather meal by Aspergillus Niger: Simultaneous enzymes Production using a cost-effective feedstock under solid state fermentation. *Indian Journal of Microbiology*, 59, 209-216.

Delgado, M. M., Martin, J. V., Imperial, R. M., León-Cófreces, C. & García-González, M. C. (2010). Phytotoxicity of uncomposted and composted poultry manure. *African Journal of Plant Science*, 4(5), 154-162.

Ekta, T. & Rani, G. (2012). Rapid conversion of chicken feather to feather meal using Dimeric Keratinase from *Bacillus licheniformis* ER-15. *Journal of Bioprocessing and Biotechniques*, 2, 4.

Gautam, S. P., Bundela, P. S., Pandey, A. K., Jamaluddin, Awasthi, M. K. & Sarsaiya, S. (2012). Diversity of cellulolytic microbes and the biodegradation of municipal solid waste by a potential strain. *International Journal of Microbiology,* 1(2), 325907.

Gbigbi, T. M. (2020). Contributing Factors of the Choice of Poultry Waste Management Practices: Evidence from Nigeria. *International Journal of Environment, Agriculture and Biotechnology,* 5(3), 788-795.

Gbotosho, O. & Burt, P. J. A. (2013). Environmental and health impacts of poultry manure disposal methods: A case study of Lagelu and Egbeda local government areas in Oyo State, Nigeria. *International Journal of Agricultural Sustainability* 11(1), 38–51.

Grant, S. & Marshalleck. A. (2008). Energy production and pollution mitigation from broiler houses on poultry farm in Jamaica and Pennsylvania. *International Journal for Service Learning in Engineering,* 3(1), 41-42.

Gržinić, G., Piotrowicz-Cieślak, A., Klimkowicz-Pawlas, A., Górny, R. L., Ławniczek-Wałczyk, A., Piechowicz, L., Olkowska, E., Potrykus, M., Tankiewicz, M., Krupka, M., Siebielec, G. & Wolska, L. (2023). Intensive poultry farming: A review of the impact on the environment and human health. *Science of the Total Environment*, Vol. 858).

Gündüz, S., Aslanova, F. & Abdullah, K.S.H. (2019). Poultry waste management techniques in urban agriculture and its implications: A case study of Tripoli, Libya. *Ekoloji*, 28, 4077–4084.

Gurav, R.G., Mirajkar, D.B., Savardekar, A.V. & Pisal, S.M. (2016). Microbial degradation of poultry feather biomass by Klebsiella sp. BTSUK isolated from poultry waste disposal site. *Resource Journal of Life Sciences, Bioinformatics, Pharmaceutical and Chemical Sciences*, 1, 279.

Iheke, O. R. (2016). Analysis of livestock waste management practices among rural farmers in Abia State. *International Journal of Agricultural Science, Research and Technology in Extension and Education Systems (IJASRT in EESs)*, *6*.1, 21–27.

Jong-Myung, C. & Paul Nelson V. (1996). Developing a Slow Release Nitrogen Fertilizer from Organic Sources: II. Using Poultry Feathers. Journal of *American Society for Horticultural Sci*ence, 121(4), 634-638.

Kalu, E. (2015). Poultry litter/manure management practices in intensively managed poultry farms in Port Harcourt. *IOSR Journal for Agriculture and Veterinary Science*, 8(3), 53-58.

Kalu, E., Ajaruonye, A. N. & Okwara, N. (2016). Waste Management Practices in Selected Poultry Farms in Umuahia, Abia State. *Journal of Veterinary Advances*, 6(9), 1310-1316.

Kannapan. S. & Bharathi, D.(2012). Exploration of amino acid content and morphological structure in chicken feather fiber, *JTATM* 7, 3

Kelleher, B.P., Leahy, J.J., Henihan, A.M., O'Dwyer, T.F., Sutton, D. & Leahy, M.J. (2002). Advances in poultry litter disposal technology. *Bioresource Technology*, 83, 27-36

Kim, M. H. & Kim, G. (2017). Analysis of environmental impacts of burial sites. *Journal of Material Cycles and Waste Management*, 19(1), 432-442.

Kulcu, R., Ekinci, K., Evrendilek, F. & Ertekin, C. (2010). Long-term spatiotemporal patterns of CH4 and N2O emissions from livestock and poultry production in Turkey. *Environmental Monitoring and Assessment* 167.1-4, 545-558.

Kumar, M. & Prakash, V. (2020). A review on solid waste: its impact on air and water quality. *Journal of Pollution Effects & Control* 4(8), 252.

Ma, Q., Paudel, K. P., Bhandari, D., Theegala, C. & Cisneros, M. (2019). Implications of poultry litter usage for electricity production. *Waste Management*, 95, 493–503.

Mazotto, A.M., Coelho, R.R.R., Cedrola, S.M.L., de Lima, M.F., Couri, S., de Souza, E.P. & Vermelho, A.B. (2011). Keratinase production by three Bacillus sp. using feather meal and whole feather as substrate in a submerged fermentation. *Enzyme Research*, 11, 723–780.

McCaskey, T. **(**1995). Feeding poultry litter as an alternative waste management strategy. In K. Steele, ed. *Animal waste and the land water interface*, pp. 475–484. New York, Lewis-CRD.

Modak, M., Chowdhury, E. H., Rahman, M. S. & Sattar, M. N. (2019). Waste management practices and profitability analysis of poultry farming in Mymensingh district: A socioeconomic study. *Journal of the Bangladesh Agricultural University* 17(1), 50–57.

Moreki, J. C., & Chiripasi, S. C. (2011). Poultry waste management in Botswana: A review. *Journal homepage: http://www. ojafr. ir*, 285, 292.

Moreki, J.C & Keaikitse, T. (2013). Poultry waste management practices in selected poultry operations around Gaborone, Botswana. *International Journal of current microbiological Applied Science*, 2(7), 240-248.

Mozhiarasi, V. & Natarajan, T. S. (2022). Slaughterhouse and poultry wastes: management practices, feedstocks for renewable energy production, and recovery of value added products. *Biomass Conversion and Biorefinery*, 1-24.

Muduli, S., Champati, A., Popalghat, H. K., Patel, P., & Sneha, K. R. (2019). Poultry waste management: An approach for sustainable development. *International Journal of Advanced Scientific Research*, 4(1), 08-14.

Nicholson, F.A., Groves, S.J. & Chambers, B.J. (2005). Pathogen survival during livestock manure storage and following land application. *Bioresource Technology*, 96, 135–143.

Nowak, A., Bakuła, T., Matusiak, K., Gałęcki, R., Borowski, S., & Gutarowska. B. (2017). Odorous Compounds from Poultry Manure Induce DNA Damage, Nuclear Changes, and Decrease Cell Membrane Integrity in Chicken Liver Hepatocellular Carcinoma Cells. *International Journal of Environmental Research and Public Health* 14 (8), 933–940.

Onu, D.O, Offor, E.I. & Okpara, B.O. (2015). Poultry wastes management strategies and environmental implications in Abia State. *International Research Journal of Agricultural Science and Soil Science*, 5(6), 159-164.

Owen, O.J., Ngodigha, E.M. & Amakiri, A.O. (2008). Proximate Composition of Heat Treated Poultry Litter (Layers). *International Journal of Poultry Science*, 7(11), 1033-1035.

Prabakaran, R. & Ezhil Valavan, S. (2021). Wealth from poultry waste: an overview. *World's Poultry Science Journal.*

Raman, N. & Narayanan, D. S. (2008). Impact of solid waste effect on ground water and soil quality nearer to Pallavaram solid waste landfill site in Chennai .*Rasayan. Journal of Chemistry* 1(4), 828–836.

Ritter, W.F. & Chinside, A.E.M. (1995). Impact of dead bird disposal pits on groundwater quality on the Delmarva Peninsula. *Bioresource Technol*ogy, 53,105-111

Ritz, C. W., Fairchild, B.D. & Lacy, M.P. (2004). Implications of ammonia production and emissions from commercial poultry facilities a review. *Journal of Applied Poultry Research* 13.4, 684-692.

Runge, G.A., Blackall, P.J. & Casey, K.D. (2007). Chicken Litter issues associated with sourcing and use. *Rural*

Industries Research and Development Corporation, 07(35), 10–15.

Salminen, E. & Rintala, J. (2002). Anaerobic digestion of organic solid poultry slaughterhouse waste – a review. *Bioresource Technology*, 83, 13-26.

Sankoh, F. P., Yan, X. & Tran, Q. (2013). Environmental and health impact of solid waste disposal in developing cities: a case study of Granville brook dumpsite, Freetown, Sierra Leone. *Journal of Environmental Protection*, 4(7), 665-670.

Shih, J.C.H. (1993). Recent development in poultry waste digestion and feather utilization – a review. *Poultry Science* 72, 1617–1620

Sims, J. T., Murphy, D. W., & Handwerker, T. S. (1993). Composting of poultry wastes: implications for dead poultry disposal and manure management. *Journal of Sustainable Agriculture*, 2(4), 67-82.

Subramanian, S., Sivarajan, M., & Saravanapriya, S. (2010). Chemical changes during vermicomposting of sago industry solid wastes. *Journal of Hazardous Materials*, 179(1-3), 318-322.

Swan, J.E. (1992). Animal by-product processing. In: Hui, Y.H. (Ed.), *Encyclopedia Food Science Technology*, 4, 42–49.

Thyagarajan, D., Barathi, M., & Sakthivadivu, R. (2013). Scope of Poultry Waste Utilization. *International Journal of Advanced Scientific Research*, 6, 29-135.

Tritt, W.P. & Schuchardt, F. (1992). Materials flow and possibilities of treating liquid and solid wastes from slaughterhouses in Germany. A review. *Bioresource Technology*, 41, 235-245

Vizzier, T.Y., Bazli, C.L., & Tankson, J.D. (2009). Relationship of broiler flock numbers to litter micro flora. *Journal of Applied Poultry Research*, 12, 81-84

Zhang, L., Ren, J. & Bai,W. (2023). A Review of Poultry Waste-to-Wealth: Technological Progress, Modeling and Simulation Studies, and Economic-Environmental and Social Sustainability. *Sustainability*, 15, 5620.

Ziraba, A. K., Haregu, T. N. & Mberu, B. (2016). A review and framework for understanding the potential impact of poor solid waste management on health in developing countries. *Archives of Public Health* 74(55), 1-11.