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POULTRY WASTE MANAGEMENT OPTIONS AND OPPORTUNITIES: A SHORT REVIEW

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Abstract

Poultry waste is a significant issue of today. Poultry industry has an important role in global food production, as it is a major source of eggs and meat consumed by human population. With the rapid increase in population, the demand of poultry products has also increased substantially and subsequently humans' dependence on poultry food has raised manifold as it is the easiest source of proteins available to low- and middle-class population. The world poultry production peaked at 123 million tons in the year 2018 while the world's egg production also was up by 18% and to date remains the most produced and consumed products. This trend continues to rise as world's demand for poultry derived products increases each day. In the beginning of 2020, the poultry production grew 7.7%. This high consumer demand caused an increase in poultry farms which consequently increases the poultry wastes. Poultry waste production is associated with large amounts of wastes produced which need to be handled effectively. This review article discusses available options for effective management of poultry wastes. Use of poultry wastes efficiently can be achieved by using it on agricultural fields, use as renewable energy resource, use in fish farming, as animal feed etc. The importance of waste management and the techniques used to manage it have also been discussed.

Keywords
Poultry, Waste Management, Animal Feed, Bioconversion, Poultry Litter, Feathers, Thermal Insulator, Energy Source

1. Introduction

Poultry industry plays a distinct role in global food market. Global production of poultry products in 2015 was around 74 million tons which rose to 123 million tons in the year 2018 and still remains the most consumed meat in the world. It further grew in an upward trend during 2018-2028 (Wattagnet, 2018). Poultry meat production and consumption is an evolving pattern and has shown a growing trend worldwide with an increase from 119,205.21 metric ton in 2018 to 120,884.63 metric ton in

2019 . The top 3 producers of poultry meat are USA, China and EU. Overall, in the world there are over 23 billion poultry animals (Mottet & Tempio., 2017). Poultry market is expected to show a compound annual growth rate of 4.1% during the years 2020-2025 (Market-Growth, 2020). It was predicted that demand for animal meat will grow up to 70% from year 2005 to 2050 (Alexandratos & Bruinsma., 2012).

Global poultry meat production is escalating with two-thirds of the rise originating in the Asia-Pacific. Likewise, the poultry industry of Pakistan has an important, pivotal role in the food industry. It contributes about 1.3% to the national GDP (Wattagnet, 2018). Later, following the onset of Asian Avian influenza in 2006, this positive growth paused quite abruptly in Pakistan as in the rest of the South East Asia. Notwithstanding this setback, the industry still managed to gain a 127% growth in bird production, 126% in meat production and 71% in eggs produced during 2000 to 2010 (Arshad *et al*., 2018).

A large number of poultry farms are operating worldwide to meet the populations demand for poultry. A total of 25,000 poultry farms operate in Pakistan to fulfill the protein demand not just locally but also internationally through its export (Arshad *et al*., 2018).

Due to an increase in poultry farming there is a significant increase in the production of poultry wastes. Poultry waste is majorly organic in nature and can be utilized in many ways. The waste produced is mostly non-hazardous but has the potential to cause nuisance and various diseases if not managed effectively and without any proper treatments.

Poultry waste comprises blood, feathers, and organic matter (manure). Approximately 2 kilograms of manure is produced per chicken and if we only consider Pakistan's poultry industry about 1 million tons of manure is produced each year. Manure (droppings) of chickens is the biggest source of organic matter in poultry wastes and can be converted to biogas (Arshad *et al*., 2018). Figure 1 illustrates a clear perspective of waste produced from one bird during slaughtering.

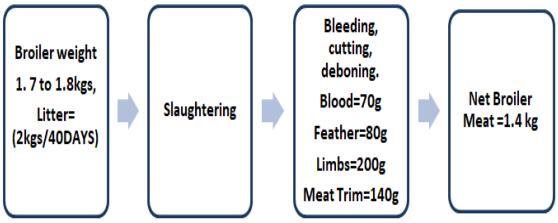

Figure 1: Total Wastes and Meat Produced After Slaughtering of Birds (Arshad *et al*., 2018).

Recent studies and researches have promoted the idea of using poultry wastes for production of worthwhile resources. Some of these options are discussed in this brief review.

2. Poultry Waste Management Techniques

Poultry feather, poultry offal and poultry litter/manure are the major poultry waste products which need to be managed because they are responsible for environmental pollution, for instance, poultry litter can cause diseases in the animals because it may contain pathogenic

bacteria (e.g. Salmonella), molds and yeast. Poultry wastes may also result in algal bloom in water bodies, decrease the clarity of water and decrease submerged aquatic vegetation etc. (Gerber *et al*., 2007). These waste products have high nutrient values and so can be reused or recycled for different nutritional purposes. The reuse and recycle of poultry waste not only aids in preventing environmental pollution but also helps in dealing with odor problems. It helps in keeping poultry farms clean, organized and aesthetically pleasant. Poultry wastes can be utilized as fertilizer and animal feed. It is an excellent source of fuel. Besides it can be used in textile industries and for making biodegradable plastic. Responsible disposal is another method of poultry waste's effective management and there are multiple techniques to actualize this goal e.g. burial, rendering, incineration and vermiculture etc. (Muduli *et al*., 2019) and (Šafarič *et al*., 2020).

2.1.Poultry Waste as Animal Feed

Poultry feathers can be treated chemically and biologically to produce animal feed whereas poultry litter can also be processed to produce animal feed. Both ways in which poultry waste can be converted to animal feedstuff are explained below:

2.1.1. Bioconversion of Poultry Feathers

Slaughterhouse wastes such as feathers, blood and innards have high protein content so they can be recycled to produce animal feed (Šafarič *et al*., 2020). Chicken feathers contain approximately 91% protein, 8% water and 1% lipids (Alahyaribeik *et al*., 2020). According to the Researchers from biotechnology department of Lund University, Sweden, chicken feather can be converted into animal feed by using bacteria that can convert the protein present in feathers of chicken into edible amino acids. For this purpose, in the hydrolysis process, bacteria (Genus, Bacillus) were added into the feathers which converted the feathers into proteins which can be utilized as animal feed and have prospects of being further processed for human consumption in the future (Syed *et al*., 2009).

In a similar study conducted in Iran, the bioconversion of chicken feather wastes was done using *Kerathinolytic* bacteria. Chicken feathers after washing and drying were ground and sealed. The results of this study showed that feather degrading bacteria *(B. licheniformis)* and their proteolytic enzymes are useful in production of animal feed (Alahyaribeik *et al*., 2020). Likewise, the bioconversion of chicken feathers has been performed by using *Bacillus aerius* and *Aspergillus niger* (De Oliveira *et al*., 2019). This method provides a collective means of providing animal feed from poultry waste.

2.1.2. Poultry Litter as Animal Feed

The litter, after proper treatment, is fed to poultry, lambs, swine, cows, cattle and ewes etc. Poultry litter is used as food for livestock in many countries such as India, Israel and within some states of the USA. Drying of poultry litter/manure is one of the oldest methods of treating the poultry waste for refeeding. Drying poultry litter in the sunlight

is the most economical and feasible method to convert it into animal feed but due to high water content and pathogens in the poultry waste, more advanced treatments are essential. Dried poultry manure contains adequate levels of digestible energy, fat, protein, crude fiber, iodine and cobalt. However, it does not have enough amounts of sodium, calcium, chloride, magnesium, iron, copper, potassium, zinc, sulphur and phosphorous required for a proper diet (Ghaly & MacDonald., 2012).

Use of chicken litter as an animal feed became a debatable topic in the USA. It was marketed as cheap feed there. The use of chicken litter as feedstuff is still unrestricted in USA but, in the European Union its use has been banned since 2001 .

2.2. Poultry Feathers as Thermal Insulator

The sustainable approach towards tackling poultry feathers is to convert them into environment friendly and biodegradable insulating material. Poultry feathers are lightweight, insulating, water resistant and biodegradable. Thus, the aero powder obtained from the treatment of poultry feathers can be used as an insulator and its foam board can be prepared within months (Šafarič *et al*., 2020). A study conducted in Morocco tested different treatments for converting feather waste into insulating material.

The feather waste after cleaning and shredding is treated with different cleaning agents such as Hydrogen peroxide, ethanol, acetone and IMOPON DPL-V detergent. The purpose of treating the waste with cleaning agents is to remove impurities. IMOPON DPL-V showed the best results in eliminating impurities. After treating feather waste with the cleaning agents, needle punching technique is used for getting final product (Dieckmann *et al*., 2020). Finally, the end product is used as textile insulator material. Furthermore, the tensile strength of insulator fabric produced by chicken feathers is six times higher than that of regular textile insulators. Fabric made from chicken wastes has good heat resistance as compared to regular insulation fabric (Soekoco *et al*., 2018).

The following figure explains a simple treatment of feather waste into insulating material. The feathers are collected, washed, shredded and then processed into fiber and this fiber is then used to form air laid nonwoven material. This process increased the prices of waste feathers in the United Kingdom (Dieckmann *et al*., 2020).

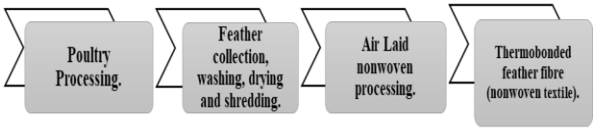

Figure 2: Feather Waste Conversion into Thermal Insulator (Dieckmann *et al*., 2020).

2.3. Poultry Waste to Biodegradable Plastic

Poultry waste can also be converted into biodegradable plastic. This can be done by the process of polymerization. In this process, feathers are cleaned and ground into fine dust and chemicals are added into them. Chemicals

make the keratin molecules come together to form long chains. Thermoplastic made from this process is water resistant. It can be further molded into various shapes on heating at 170℃. It does not contain any fossil fuels and it can be used for making all kinds of products from plastic plates to plastic furniture (Muduli *et al*., 2019). Few American researchers performed graft polymerization of chicken feathers with methyl acrylate as a substituent for petroleum product and it proved to be successfully grafted onto the functional groups on the surfaces of the chicken feather. They productively converted the feather waste into thermoplastic (Jin *et al*., 2011).

2.4.Poultry Waste as Fertilizer in Agriculture

Livestock and poultry wastes contain nutrients that are beneficial for crop health and productivity, the application of manure on soils enhances soil quality and makes it nutrient rich. The amount of useful nutrients for soil that are available in poultry wastes vary with factors such as feed of the birds, way of collection and storage of wastes, water availability, climate and the specie of crop on which manure is applied (Sim & Wolf., 1994). Level of elements and inorganic salts in the feed of birds eventually determines the nutrients in manure. The type of waste handling and processing of manure affects the nitrogen content. Manure dried under sun in the presence of air loses considerable amounts of nitrogen. Long term treatment also makes manure nitrogen deficient (Risse, 2009).

In comparison, 5 to 15% phosphorus and potassium are lost in processing and if carried at open feedlots and lagoons, then the P and K losses from manure can amount to 40 or 50% due to leaching or runoff (Risse, 2009). Although if manure is applied quickly and efficiently then lesser N, P, K losses are experienced and maximus benefits of manure application on soils are achieved. To achieve maximum productivity, it is advisable to apply manure to soils before the cropping of plants. In sandy and coarse soils manures must be applied often, regularly and in low concentrations throughout the growth period to enhance plant growth and to also ensure environmental safety. It is further advised that manure should not be applied to soils with more than 10% slope, or if they are applied then injecting of manure should be practiced to prevent runoff. For nutrients to be available to plants manure must be organic in nature and be in the liquid state (Risse, 2009).

2.5.Composting of poultry waste

Composting is the aerobic biological process used for the degradation of organic material. Poultry slaughterhouse wastes, manure, litter and sometimes feathers are treated by the process of composting (Muduli *et al*., 2019). Composting can decompose carcasses effectively within just a months' time and produce manure that can be safely applied as compost (Sims *et al*., 1993). The poultry manure can be accumulated for years in the pits by the process of composting. Usually, the manure present in the pits can be divided into three

layers. The bottom layer contains the manure with anaerobic biological activity due to lack of aeration. The middle layer contains the manure which is under the composting process and the top layer contains the fresh manure. Proper aeration should be done of the fresh, wet manure to avoid any odor formation in the pits. If proper care and measures are taken and the pits are watertight so there will be no odor related problems and the manure removal can be delayed for years. The process of composting reduces the pathogens and the compost formed can be used for soil amendments or as soil fertilizer. Table 1 provides a summary of the nutrients present in the manure and compost:

Table 1: Nutrients in Manure and Compost **(**Source: Jin *et al*., 2011)

Analysis	Buildup Litter	Dead bird compost
Moisture, percentage	21.00	46.10 ± 2.19
Nitrogen, percentage	4.15	2.20 ± 0.19
Phosphorus (P_2O_5), percentage	3.80	3.27 ± 0.23
Potash (K_2O)	2.85	2.39 ± 0.13
Calcium, percentage	1.70	1.33 ± 0.15
Magnesium, percentage	0.91	0.82 ± 0.10
Sulfur, percentage	0.51	0.40 ± 0.02
Manganese, parts per million	208.00	122.00 ± 18.00
Zinc, parts per million	331.00	245.00 ± 32.00
Copper, parts per million	205.00	205.00 ± 28.00

2.6.Poultry Waste as Fertilizer in Fish Farming

Dry manure and chicken droppings have adequate nutrients such as phosphorus that make it useful as a fertilizer in not just regular agricultural farming but also in fish farming. It has been calculated that a 500 g dose of poultry manure is suitable for promoting fish growth in ponds (Vohra *et al*., 2012). This amount successfully induces apt physio-chemical parameters into ponds to make them productive for cultivation of fish. The productivity of any water body is determined by the amount of planktons in it which can sustain the life of fishes. One of the ways by which biological productivity of water bodies can be increased is by application of animal manure into them. This resultantly increases fish availability as well. But as of now the use of poultry wastes to increase the production of phytoplankton and zooplanktons in ponds is very rare (Vohra *et al*., 2012).

2.7.Poultry Waste as Renewable Energy Source

To achieve energy security, it is vital to adopt renewable practices. For this purpose, poultry waste can be converted to biogas. According to estimates a 2.5 MWh of electricity can be generated from 1 cubic meter of poultry waste (Arshad *et al*., 2018).

Being organic and biodegradable, poultry waste (carbohydrates, proteins and lipids) is converted into sugars, amino acids and long fatty acid chains followed by production of biogas by

processes of hydrolysis, acidogenesis, acetogenesis and methanogenesis. Combination of manure and rice husk has been suggested as a good way for producing energy at low costs. Further anaerobic digestion is not only viable for converting manure into biogas, it also leaves behind nutrients which can be collected and used as fertilizers on agriculture land (Arshad *et al*., 2018).

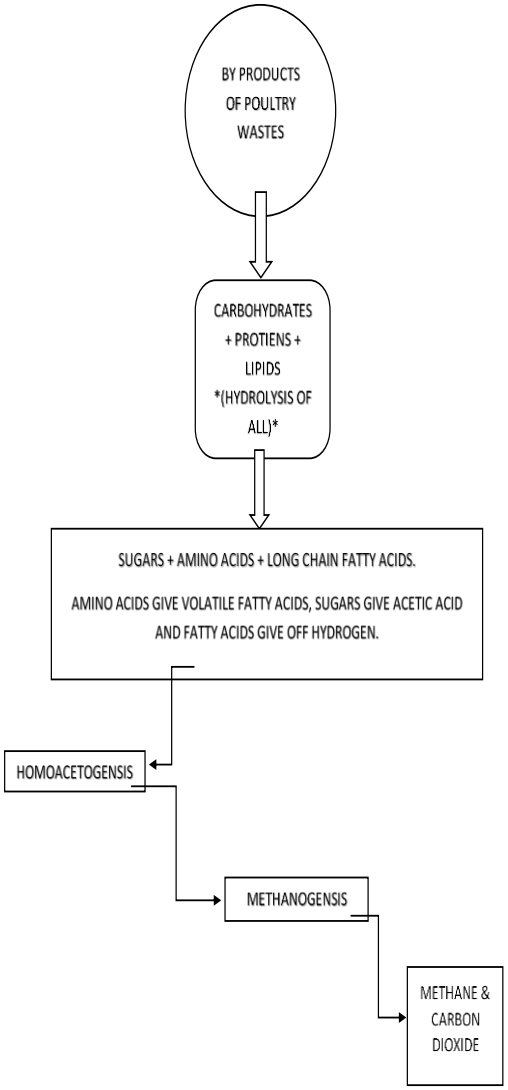

Figure 3: Degradation of Poultry Waste to Biogas, (Arshad *et al*., 2018

Use of poultry waste is one of the environmentally sound options of promoting renewable energy sources in Pakistan (Ali *et al*., 2016) but owing to limited research, financial hurdles and overall ignorance of the authorities in managing wastes in a sound and safe manner, this potential has not been realized. This technique effectively empowers the circular economy of countries and keeps them safe in regards to waste disposal and management. In USA a facility has been set up by North Carolina Utilities Commission to use waste from poultry farms to produce electricity. One coal power plant was converted into a biomass based facility, the Georgia Renewable Power plant, which is now utilizing manure to produce energy (Campbell, 2019).

In conclusion, to counter the energy deficit use of poultry waste and other sources in producing renewable energy has many benefits. Biogas plants based on poultry waste have gained a lot of attention all over the world, USA, China and countries in the EU are setting up such facilities to move towards a cleaner energy production route (Torrijos, 2016). This will help in reducing harmful environmental impacts of poultry wastes (Arshad *et al*., 2018).

3. Disposal Methods for Poultry Waste

Poultry waste is a hazard to the environment and health because it releases toxins which necessitate its proper disposal by effective poultry waste disposal methods. It was observed that 65% of poultry farms do not manage their wastes effectively and safely (KA & Benson.,

2014). This can have serious health implications. There are various methods which can be employed to dispose different types of poultry wastes a few of them have been discussed below.

3.1.Burial

Burial is the most convenient and ancient method used for the disposal of poultry wastes. This method includes several variations like burial pits, sanitary landfills and inverted feed bins. For the disposal of poultry wastes, burial pits are made and due to water contamination concerns these pits are made minimum 5ft high from the water table and then the poultry wastes are placed there, in pits with 10 ft depth with the layers of clay of minimum 2ft. This is done to avoid the leachate problem arising due to the poultry carcasses. Moreover, the ventilation strips of lose fill dirt of minimum 3ft width is placed across the center of the pit to reduce pressure from decaying poultry carcasses (Swayne *et al*., 2009). Disposal pits actually provide for aerobic and anaerobic microorganism to completely decompose the organic matter. Burial is the simplest, cost-effective method. However, if it is not managed properly then it may lead to environmental degradation, surface and ground water contamination. Hence this method is only safe when it is executed properly (Kim & Kim., 2017).

3.1.1. Burning

Burning is the most common method for disposal of poultry wastes and it is in fact common among small scale farmers. In this method poultry waste such as carcasses are allowed to fully burn at high temperatures. The biggest disadvantage of this disposal method is that it is not very environmentally friendly and it leads to atmospheric pollution.

This disposal method is actually not regarded as the preferred method for poultry disposal because of its environmental concerns. This type of disposal method should be performed at a distance from public places, shallow underground pipes, buildings and busy roads (Moreki & Chiripasi., 2011).

3.1.2. Rendering

Rendering is another alternative method for the disposal of poultry waste. Rendering involves the process in which poultry carcasses are mechanically crushed into 2 in^3 of tissue and then those tissues are cooked under steam which works for removal of moisture from the dry proteinaceous particles so that it can be used as animal feed protein source. The process of steaming and heating usually kills the pathogens of carcasses but there are still chances of spreading of pathogenic diseases. The rendered products are usually used in feed production. But there is a chance that the process of rendering of carcasses can invoke the threat of spreading various pathogenic diseases during the transportation of carcasses to the rendering facilities. So, there are several measures that should be taken before transporting the carcasses to the rendering facilities to avoid bio security problems. These treatments include

refrigeration, acid preservation and fermentation. Refrigeration involves the freezing or storage of the carcasses for a short period of time before sending it to the rendering facilities and this is an effective process for decreasing the threat of spreading pathogenic microorganism. Although it may prove as an expensive measure because it requires high capacity units and excess amounts of electricity.

Another measure that should be taken prior to transporting the carcasses to the rendering facilities is acid preservation in which carcasses are preserved by minerals and organic acids. Preservation inactivates the pathogens and it can be easily transported to the rendering facilities. Another process which can be used for the inactivation of pathogen is fermentation. Lactic acid fermentation can actually minimize the pathogen threat because it can successfully inactivate the pathogenic microorganism and the fermented material can be stored for a long time.

The last technique that should be applied prior to the transport of carcasses to rendering facilities is extrusion. It is simply a high temperature short term treatment. This involves the principle of friction as a means of generating, heat and pressure. First of all, the material which is meant to be extruded is fed into a barrel and it is forced by screwing against different restrictions which produces a force of friction and pressure within the barrel which aids in the product getting cooked to a selected temperature of about 115 to 155 degree Celsius in even less than 30 seconds (Blake & Donald., 1992), (Bayr *et al*., 2012).

3.1.3. Vermicomposting

Vermicomposting is the process in which earthworms are employed to convert the organic matter into humus or nutrient material. This process comprises of both physical and biochemical actions of earthworms. Physical processes comprise of substrate aeration and grinding whereas, biochemical processes include microbial decomposition of substrate in the intestine of earthworm. The most important benefit that vermicomposting of organic waste gives is the increase in stabilization of organic matter. In vermicomposting usually exotic species of earthworms are used for the decomposition of organic waste into vermicompost such as E. foetida and E.eugineae but the selection of the earthworm solely depends upon the type of poultry waste used for vermiprocessing (Subramanian *et al*., 2010).

A comparative study of poultry waste management through vermicomposting employing exotic and indigenous species of earthworms was conducted by the Hitkarini College of Engineering & Technology in India. In this study experiments were done with varieties of earthworm such as Eisenia foetida (exotic species) and Lampitto mauritti (indigenous species). The results of the experiments show that the Eisenia foetida and Lampitto mauritti species of earthworm in different combinations started making the vermicompost on the third day.

The whole study was designed in such a way that firstly the poultry waste gets collected from

the poultry farms and for the best result of composting and survival of the selected earthworms, suitable pH, moisture and organic content must be given to earthworms and especially pH must be alkaline. Pits are prepared for the semi decomposition of organic waste and pits method is usually used for the semi decomposition of organic waste because in this method moisture level can be easily maintained. After then earthworms allowed to inoculate on the semi decomposed material present in the pits and these earthworms change the pure poultry waste into useful vermicompost. Around 45 days' time period is required for the semi decomposition of the organic waste (Beohar & Srivastava., 2011).

3.1.4. Incineration

Incineration is regarded as one of the safest waste disposal methods. It completely eradicates the threat of disease. Poultry waste and carcasses are burned at high temperature in purpose-built incinerators. In this technique wastes can be disposed as quickly as they are accumulated. But its high operational costs and ability to emit air toxics in the air have made it less desirable (Moreki & Chiripasi., 2011). Incineration of poultry waste is being carried out all over the world in an effort to manage and dispose of wastes effectively. In North Carolina laws are in effect to allow incineration of poultry wastes to achieve renewable energy. Some of the emissions that emanate from incineration of poultry wastes include particulate matter, arsenic and a few other toxins. Therefore, it is a necessity to ensure that if poultry wastes are incinerated, they are incinerated safely and the incinerator facilities follow all protocols to manage their emissions (Stingone & Wing., 2011).

4. Conclusion

Poultry waste is an environmental pollutant and requires effective management. Poultry waste can serve as a potential resource for various applications. Poultry feather can be treated biologically and chemically to produce animal feed, thermal insulator and biodegradable plastic. Poultry manure/litter can be composted which can be used as soil amendments or soil fertilizer. Poultry litter can also be used as an energy source when converted to biogas. Poultry waste disposal can be done by burial, rendering, incineration and vermiculture. However, incineration is considered as the safest method of poultry waste disposal or for the elimination disease threat.

5. References

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

Alexandratos, N., & Bruinsma, J. (2012). World Agriculture Towards 2030/2050: The 2012 Revision.

Ali, G., Bashir, M. K., Ali, H., & Bashir, M. H. (2016). Utilization of rice husk and

poultry wastes for renewable energy potential in Pakistan: An economic perspective. *Renewable and Sustainable Energy Reviews*, 61, 25-29.

Arshad, M., Bano, I., Khan, N., Shahzad, M. I., Younus, M., Abbas, M., & Iqbal, M. (2018). Electricity generation from biogas of poultry waste: An assessment of potential and feasibility in Pakistan. *Renewable and Sustainable Energy Reviews*, 81, 1241-1246.

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.

Beohar, P. A., & Srivastava, R. K. (2011). Poultry waste management through vermicomposting employing exotic and indigenous species of earthworms. *Journal of Soil Science*, 1(1), 04-11.

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

Campbell, N. (2019). *In the land of KFC, chicken droppings produce electricity*. Living Circular.

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(2), 209-216.

Dieckmann, E., Onsiong, R., Nagy, B., Sheldrick, L., & Cheeseman, C. (2020). Valorization of Waste Feathers in the Production of New Thermal Insulation Materials. *Waste and Biomass Valorization*, 1-13.

Gerber, P., Opio, C., & Steinfeld, H. (2007). Poultry production and the environment—a review. *Animal production and health division, Food and Agriculture Organization of the United Nations, Viale delle Terme di Caracalla*, 153.

Ghaly, A. E., & MacDonald, K. N. (2012). Drying of poultry manure for use as animal feed. *American Journal of Agricultural and Biological Sciences*, 7(3), 239-254.

Jin, E., Reddy, N., Zhu, Z., & Yang, Y. (2011). Graft polymerization of native chicken feathers for thermoplastic applications. *Journal of Agricultural and Food Chemistry*, 59(5), 1729-1738.

KA, A., & Benson, O. B. (2014). Poultry wastes management strategies and environmental implications on human health in Ogun state of Nigeria.

Kim, M. H., & Kim, G. (2017). Analysis of environmental impacts of burial

sites. *Journal of Material Cycles and Waste Management*, 19(1), 432-442.

Market-Growth, G. (2019). Trends, and Forecast (2020-2025). *Mordor Intelligence*.

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

Mottet, A., & Tempio, G. (2017). Global poultry production: current state and future outlook and challenges. *World's Poultry Science Journal*, 73(2), 245-256.

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.

Risse, L.M. (2009). Land application of livestock and poultry manure. *University of Georgia, Tennesse valley authority. Circular*, 826.

Šafarič, R., Fras Zemljič, L., Novak, M., Dugonik, B., Bratina, B., Gubeljak, N., & Strnad, S. (2020). Preparation and Characterisation of Waste Poultry Feathers Composite Fibreboards. *Materials*, 13(21), 4964.

Sims, J. T., & Wolf, D. C. (1994). Poultry waste management: Agricultural and environmental issues. In *Advances in agronomy*, Academic Press. 52, 1-83.

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.

Soekoco, A. S., Ichwan, M., Hananto, A., & Mustafa, D. (2018). Application of chicken feather waste as a material of nonwoven insulator. In *AIP Conference Proceedings*, AIP Publishing LLC. 2014(1), 020104.

Stingone, J. A., & Wing, S. (2011). Poultry litter incineration as a source of energy: reviewing the potential for impacts on environmental health and justice. *New Solutions: A Journal of Environmental and Occupational Health Policy*, 21(1), 27-42.

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.

Swayne, D. E. (Ed.). (2009). *Avian influenza*. John Wiley & Sons.

Syed, D. G., Lee, J. C., Li, W. J., Kim, C. J., & Agasar, D. (2009). Production, characterization and application of keratinase from Streptomyces gulbargensis. *Bioresource technology*, 100(5), 1868-1871.

Torrijos, M. (2016). State of development of biogas production in Europe. *Procedia Environmental Sciences*, 35, 881-889.

Vohra, A. R., Narejo, N. T., Naeem, M., Wadhar, G. M., & Dayo, A. (2012). Effect of dry poultry waste on the physico-chemical and fish growth parameters of exotic carp, Cyprinus carpio at carp fish hatchery (District Badin), Sindh, Pakistan. *Sindh University Research Journal-SURJ (Science Series)*, 44(2).

Wattagnet (2018). *Latest poultry, egg market forecasts available in 2018, WATT Poultry Trends*. [Online]. Retrieved from https://www.wattagnet.com on November 13, 2020.