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Scope of Poultry Waste Utilization

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Abstract: *Poultry farming wastes containing excreta, bedding material, waste feed, dead birds, broken eggs, feathers and offal could emerge into major environmental pollutants. Proven technology and disposal methods are necessary to mitigate their threat on the environment. The major wastes like poultry feathers, offal and litter have different field applications. Poultry feathers being rich sources of keratin proteins and amino acids, can be converted into valuable products such as feather meal, bio diesel, biodegradable plastic and fertilizer. Poultry offal contains certain nutrients and can be used as a dried poultry manure and fertilizer or as an organic raw material for methane production. The remaining waste could be disposed off possibly by incineration or by burial and controlled landfills. Poultry manure is also useful as fertilizer, methane and to produce electricity. This review discusses in detail about the scope for utilization of various poultry wastes. Poultry waste generation is enormous. However, cost effective technologies are yet to be identified to recycle the waste to useful products.*
Key words: *poultry waste, feather meal, offal, litter*

I. Introduction

Poultry waste includes a mixture of faecal and urinary excreta (manure), bedding material or litter (e.g. wood shavings or straw), waste feed, dead birds, broken eggs packing material and feathers removed from poultry houses. It also includes waste from cage, conveyer belt and water flushing systems (Kelleher *et al.* 2002).The method of disposal of poultry waste play a major role in controlling and eradication of infectious diseases. Inadequate approach and carelessness of this essential aspect of production process in poultry, will lead to constant threat of disease ailments on poultry farms. This results in direct losses in the form of mortality and reduced productivity. Therefore, early disposal of wastes with efficient method is an important poultry waste management tool for raising healthy and profitable poultry farming activity.

It is mandatory to concentrate on the following poultry farm waste products which are mainly responsible for the environmental pollution:

1. Poultry feather
2. Poultry offal
3. Poultry litter/manure

Poultry Feather

1.1 Composition

Chicken feathers contain nutrients approximately 91% protein (keratin), 1% lipids, and 8% water. The amino acid sequence of a chicken feather is exactly same as that of other feathers and also has a great deal in common with reptilian keratins from claws. The amino acid sequence is mainly composed of cystine, glutamine, proline and serine. However almost histidine, lysine, tryptophan, glutamic acid and glycine are absent. Serine (16%) is the most abundant amino acid in chicken feathers (Kannappan and Bharathi, 2012)

Keratins are insoluble proteins present in feathers, wool, hooves, scales, hair, nails (hard keratins) and also in stratum corneum (soft keratins). These specific proteins which belong to the scleroprotein groups are compounds that are highly resistant to physical, chemical and biological actions. Mechanical stability and high resistance to proteolytic degradation of keratin is due to the presence of disulfide bonds, hydrogen bonds, salt linkages and cross linkages.

Amino acid content in keratin fiber from chicken feather

Functional groups	Amino acid	% Contents
Positively charged	Arginine	4.30
Negatively charged	Aspartic acid	6.00
	Glutamine	7.62
Hygroscopic	Threonine	4.00
	Serine	16.0

Hydrophobic	Tyrosine	1.00
	Leucine	2.62
	Isoleucine	3.32
	Valine	1.61
	Cystine	8.85
	Alanine	3.44
	Phenylalanine	0.86
	Methionine	1.02
Special	Proline	12.0
	Aspargine	4.00

Chicken feather fiber basically consists of α- helical and some β- sheet conformations. Its outer quill is almost entirely made up of β- sheet conformations and few α- helical conformations. Hard β- sheet keratins have higher cystine content than soft α- helix keratins and thus a much greater presence of disulphide (S-S) bonds that link adjacent keratin proteins. The presence of strong covalent bonds stabilize the three-dimensional protein structure and are very difficult to break (Kannappan and Bharathi, 2012).

1.2 Utilization:

1.2.1 Feather meal:

Feathers are also converted to feather meal with usage as animal feed, organic fertilizers and feed supplements, as it is made up of >90% protein and are rich in hydrophobic amino acids like cystine, arginine and threonine. One of the most common methods of feather meal production is hydrothermal process where feathers are digested under high pressure at high temperature. However, hydrothermal treatment leads to destruction of essential amino acids like methionine, lysine, tyrosine, tryptophan that accounts to poor digestibility and low nutritional value (Ekta and Rani, 2012).

1.2.2 Chemical hydrolysis

Chicken feather keratin when treated with lime (calcium hydroxide) to get a liquid product rich in amino acids and polypeptides, can be used as an animal feed supplement. At high temperatures (150°C), 80% of feather keratin is solubilised within 25 min. However a relatively longer reaction time (300 min) is needed at moderate temperatures (100°C). After 3 h of hydrolysis at 150°C, 95% of feather keratin is digested. Under the recommended conditions (100°C, 300 min, and 0.1 g Ca(OH)2/g dry feather), after lime treatment, about 54% of calcium can be recovered by carbonating. In rumen fluid, ammonia production from soluble keratin similar to that of soybean and cottonseed meals and is greatly less than that of urea, showing that ammonia toxicity will not result from cattle being fed with soluble keratin (Coward-Kelly, 2006).

1.2.3 Feather bioconversion

Feather wastes are utilized on a limited basis only as a dietary protein supplement (as feather meal). Initially, the feather wastes can be cooked either with steam or chemically to make it more digestible, but such treatments are expensive. Meanwhile, microorganisms play an alternative role to increase the biovalue of feather wastes. It has already been reported that the feather-lysate produced by *Bacillus licheniformis* PWD-1 has nutritional features for feed similar to soybean protein. Even though bacterial keratinolytic proteases showed a potential for feather bioconversion, improvement of enzyme activities and higher yields are required to make these suitable for industrial applications (Kim *et al.* 2001)

Feather-degrading bacteria are now isolated from poultry waste. Among those isolates, three strains of *Bacillus subtilis*, *Bacillus pumilis* and *Bacillus cereus have the potential to* degrade feathers with a production of 142, 96 and 109 units of keratinolytic activities, respectively. The production of keratinolytic protease by *B. pumilis* and *B. cereus* are possible with feathers, but not with *B. subtilis* since it produces the enzyme constitutively in the presence of various proteins such as casein, feather and BSA. The optimal conditions required for the specific enzyme production by *B. subtilis* are 40 °C and pH 5–9, for *B. pumilis* 40 °C and pH 5–6 and for *B. cereus* 30 °C and pH 7.0. The maximum keratinolytic activities of *B. subtilis* and *B. pumilis* are 161 and 149 units/ml after 84 and 72 h of cultivation, respectively.

1.2.4 Bio diesel

Slaughter house wastes like feathers, blood, and innards are being processed and utilized as high-protein animal feed sources or as fertilizer due to its high nitrogen content. It is estimated that these wastes contain up to 12 per cent fat. Scientists from the University of Nevada isolated the animal fat and successfully produced biodiesel comparable to biodiesel from other feed stock.

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- esterified into biodiesel using potassium, nitrogen and methane; 7-11% biodiesel (on a dry basis) is produced in this process. ASTM analysis confirmed that biodiesel from feather meal is of good quality when compared to other biodiesel made from other common feed stocks.

1.2.5 Technical textiles

The nonwoven is prepared by using low cost chicken feathers. The advantage of application of chicken feathers in textile field are wide. The nonwoven textile materials prepared by chicken feathers are very versatile and have a wide application in the field of technical textiles (Chinta *et al.* 2013).

1.2.6 Biodegradable plastic

Poultry feathers are also converted into biodegradable plastics by a process called polymerization. In this process, feathers which contain keratin protein are pulverized into fine dust. Chemicals that make keratin molecules to join together are used to form long chains (polymerization). It is further moulded 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.

1.2.7 Fertilizer

A slow release nitrogen fertilizer is developed from poultry feathers. In this attempt, the structure of keratin fibres are modified by steam hydrolysis for 12 weeks to break disulphide bonds, enzymatic hydrolysis by *Bacillus licheniformis* to break polypeptide bonds and steam hydrolysis (autoclaving) to improve mineralisation followed by cross linking of protein by formaldehyde reaction to minimize excess mineralisation (Jong-Myung Choi and Paul V. Nelson, 1996).

II. Poultry Offal

2.1 Organic solid by-products and waste

Organic solid by-products and wastes produced in broiler farming and slaughtering are blood, feet, head, bone, trimmings and organs. Offal consists of 5.3% of total Kjeldahl nitrogen, 32% proteins, 54% lipids and 0.6 to 0.9 % methane production potential (Salminen and Rintala, 2002).

2.2 Microflora

Poultry by-products and wastes contain several 100 different species of micro-organisms in contaminated feather, feet, intestinal contents, and processing equipments, including harmful pathogens such as Salmonella sp., Staphylococcus sp., and Clostridium sp. Finnish meat products contain considerably lower pathogen levels (Ministry of Agriculture and Forestry, 2000). For example, in 1997, positive Salmonella samples in broiler and turkey meat in slaughtered flock and meat from cutting plants rated between 0.6% and 3.1%, respectively (Ministry of Agriculture and Forestry, 2000). In comparison, in the US, about 30% of chicken products were contaminated with live Salmonella, and 60–80% of chickens were contaminated with Campylobacter, many strains of which are resistant to common antibiotics.

2.3 Residues

Birds also accumulate various heavy metals, drugs, and other chemicals added in their feed for nutritional and pharmaceutical purposes. Veterinary drugs and other chemical contaminants are also present in poultry in different concentrations; e.g., zinc and copper concentrations in poultry feeds in England and Wales range from 28–4030 to 5–234 mg/kg TS, respectively. However zinc and copper concentrations in poultry manure are ca. 400 and ca. 80 mg/kg TS, respectively (Nicholson et al., 1999). Poultry litter in Israel showed to contain varying levels of testosterone (up to 700 ng/g) and oestrogen (up to 500 ng/g), which can interfere with reproductive function (Shore et al., 1993).

2.4 Utilization

2.4.1 Incineration

Incineration refers to technologies of thermal destruction, apparently among the most effective methods for destroying potentially infectious agents (Ritter and Chinside, 1995). Air-dried poultry litter 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 having a high moisture content have little or no energy value. In incineration, the air emission, process conditions, and the disposal of solid and liquid residues need to be strictly controlled.

2.4.2 Burial and controlled landfilling

Burial of dead birds on the farm has to be strictly monitored to avoid groundwater contamination. As the operation, monitoring, and control of land filling also became more tightly regulated under Directive 1999/31/EC (Commission of the European Communities, 1999), in Europe landfills must prevent as much as possible, its adverse effects on the local environment, particularly the pollution of surface water, groundwater, soil and air. All these measures may increase the costs of land filling.

2.4.3 Rendering

Rendering refers to different heating applications to remove fat from meat (Swan, 1992). Rendering at 133°C for a minimum of 20 min at 3 bars or an alternative heat treatment is required for high-risk materials used for animal feed or as an intermediate product for the manufacture of organic fertiliser or other derived products. Rendering produces meat-bone-meal, which can be used in animal feed or as fertiliser 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 good source of proteins and vitamins and are used as animal feed (Pulsa, 1996). As one among the biggest fur animal producers in the world, Finland uses an annual 370 million kg of fur animal feed, more than half of which are by-products from the meat and fish industry (Pulsa, 1996). Legislation, however, has become stringent about the use of slaughter by-products for animal feed to reduce the risk of disease transmission via the feed and the food chain.

2.4.4 Composting

Composting is an aerobic biological process to degrade organic material. It is a common method to treat poultry slaughterhouse wastes, grease trap residues, manure, litter, and sometimes also feather. Composting reduces pathogens, and the resulting compost can be used as soil conditioner or fertiliser. However, wastes having high moisture with low fibre content need higher amounts of moisture-sorbing and structural support to compost well (Tritt and Schuchardt, 1992).

2.4.5 Anaerobic digestion

Anaerobic digestion is a biological process in which organic matter is degraded to methane. Methane can be used as a source of bio-energy to replace fossil fuels thereby reducing carbon dioxide emissions. Anaerobic digestion reduces pathogens and odours and requires little land space for treatment, and can treat wet and pasty wastes (Braber, 1995; Shih, 1993). In addition, any releases to air, water, and land from the process can be well controlled. Most of the nutrients also remain in the treated material and can be recovered for agriculture or feed use.

2.4.6 Methane production

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. The methane production of offal need more time probably due to long-chain fatty acid inhibition. The length of time depends on the source and various concentrations of inoculum and incubation temperature. Sewage sludge at 35°C, have the shortest delay of a few days, while granular sludge did not produce methane within 64 days of incubation. Feather showed somewhat lower methane yield of 0.21 m^3 kg^{-1} when volatile solids were added (50 m^3 ton^{-1} wet weight) (Thyagarajan, 2013).

Combined thermal (120ºC, 5 min) and enzymatic (commercial alkaline endopeptidase, 2-10 g 1^{-1}) pre-treatments resulted in increased methane yield by 37 to 51%. Thermal (70-120ºC, 5-60 min), chemical (NaOH 2-10 g 1^{-1}, 2-24 h), and enzymatic pre-treatments are less effective, with methane yield increasing only by 5 to 32%. 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). Pre-treatments improve the methane production of feather. (Thyagarajan, 2013).

III. Poultry manure

3.1 Composition of poultry litter

The three wastes of primary concern in poultry production are the bedding materials used for poultry housing, the manure resulting from poultry production and dead birds common to all operations. Poultry litter and manure predominantly have carbon (C), nitrogen(N), Phosphorous (P) and water and chlorine (Cl), Calcium (Ca), Magnesium (Mg), Sodium (Na), Manganese (Mn), iron (Fe), copper (Cu), zinc (Zn) and arsenic (As). Poultry manure contains solid dry matter of about 150 g/ kg (Kelleher et al. 2002).

3.2 Manual application as a fertilizer

It is the easiest method for utilizing the manure in fields. However, it will lead to following ill effects:

- Surface and ground water pollution
- Aesthetic problems with odors and insects
- Over accumulation of manure and trace elements leading to reduced crop yields.

3.3Compositing the manure

Composting is the fast aerobic degradation of biodegradable organic waste, taking typically 4–6 weeks to reach a destabilised material. The composted material is odourless and fine textured with low moisture content. Composted poultry litter is easy to handle and pathogen free. Moisture and C/N ratio have a major influence on a successful composting process. The moisture content has a major influence on the decomposition rate and the tendency to stabilise, as metabolic heat generation during decomposition drives evaporation. (Kelleher et al. 2002).

3.4 Production of biogas by Anaerobic Digestion

It involves the degradation and stabilisation of an organic material under anaerobic conditions by microbial organisms and leads to the formation of methane and inorganic products including carbon dioxide:

$$\text{Organic matter} + H_2O \xrightarrow{\text{anaerobes}} CH_4 + CO_2 + \text{New biomass} + NH_3 + H_2S + \text{Heat}$$

The organic components of poultry litter are classified into broad biological groups: proteins, carbohydrates and lipids. Carbohydrates make up the bulk of the biodegradable material and include cellulose, starch and sugars. Proteins are large complex organic materials having hundreds of thousands of amino acid groups. The anaerobic treatment of poultry litter involves two distinct stages (Williams, 1999). In the first stage, complex components, including fats, proteins and polysaccharides, are hydrolysed and split in to their component subunits. This is facilitated by facultative and anaerobic bacteria, subsequently by hydrolysis to fermentation and other metabolic processes converting to simple organic compounds. This first stage is commonly referred to as acid fermentation and in this stage organic material is simply converted to organic acids, alcohols and new bacterial cells. The second stage involves the conversion of the hydrolysis products in to gases (mainly methane and CO2) by different strictly anaerobic bacteria which is referred as methane fermentation. The two stages are presented in the figure below.

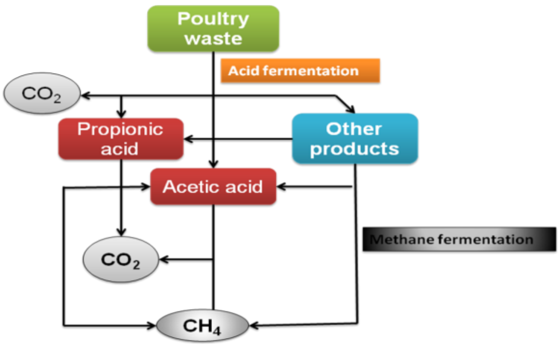

Fig 1: Methane production by anaerobic fermentation of poultry waste

3.5 Combustion

Direct combustion of poultry litter has the potential to provide both space heating of poultry houses. Modern systems have efficient combustion facilities with sophisticated gas cleanup, which produce energy and lower the waste to an inert residue. The calorific value of poultry litter decreases with increasing moisture content, air dried samples having a typical value of 13.5 GJ/ton, which is about half that of coal. Poultry litter has a low ash fusion temperature. This ash fusion can cause problems when using a conventional grate combustion system. Parameters such as combustion temperature, air mixture and moisture content must be held within optimal specifications for the efficient running of a combustion facility and vary for combustion design. The process produces an ash residue, which retains most of the phosphate and potash present in the fresh litter. The original nitrogen concentration is variable and loss to the atmosphere on combustion as NOx is not considered a problem (Dagnall, 1993). The ash is stable, sterile, easier to handle and transport and more marketable as an organic fertiliser than conventional poultry litter.

3.6 Vermicomposting

The vermicomposting potential of P. ceylanensis on the organic substrate, turkey litter in combination with cow dung (1:1, w/w), results in the production of nutrient-rich vermicompost. The soil nutrients and microbial population are higher in vermicompost which can be used as a fertilizer (Jayakumar et al, 2011).

3.7 Electricity generation

The poultry litter energetic potential is high. Several types of technologies are being implemented for conversion of this type of biomass to electrical energy. Anaerobic digestion and Biomethanation of poultry litter results in methane (biogas) production which are used to run turbine to generate power. The biogas generated from poultry litter can also be used as a source of thermal energy to heat the chicken at the beginning of the batch (Oliveira et al. 2012).

IV. Solid Waste Treatment systems

Solid waste treatment systems include

- Generating power from steam turbine
- Rendering to produce pathogen free hatchery waste protein meal
- Autoclaved hatchery waste to be used as livestock and poultry feed
- Boiling and dehydrating dead embryos to be used as poultry feed and livestock feed
- Ensiling
- Enzyme or Sodium hydroxide treatments
- Composting
- Anaerobic digestion systems

Hatcheries disposing wastewater into lagoons could adopt the integrated aquaculture approach to produce water suitable for irrigation and other potential products such as ornamental fish; a multi-billion industry worldwide.

V. Conclusion

Poultry waste is one of the major pollutants if not properly disposed. Poultry feathers can be treated chemically or biologically with microbes to improve the nutritive value of feather wastes which can be used as animal feed. They can also be biologically converted into feed supplements, biodiesel, and biodegradable plastic and organic fertilizer.

The offals are utilized by various methods like rendering, incineration, burial, controlled land filling, composting and anaerobic digestion. Rendering produces meat-bone meal which may be used as animal feed or fertilizer. Composting reduces pathogens. The compost is used as soil conditioner or fertilizer.

Poultry litter contains carbon, nitrogen, phosphorous, chlorine, calcium, magnesium, and sodium, manganese, ferrous, copper and arsenic. It is used as a very good source of fertilizer. Methane gas produced from poultry litter is converted into electricity using a patented technology.

Altogether, poultry wastes can be effectively utilized if properly treated to reduce the ill effects and a range of value added products like fertilizer, biodiesel, animal feed, electricity, bone meal and biodegradable plastic can be produced.

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