Energetic Valorization of Poultry Waste: The Sideview

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Summary

The poultry farming waste, as a mixture of dropping and bedding material, is usually used as a fertilizer in agriculture because of their richness of mineral materials. However, expanded production of broilers, with decreased availability of agricultural land and potential negative effects of long-lasting application of such a material on land, encourage searching for alternative ways for use of this materials.

Generally speaking, there are two ways, beside of abovementioned: (1) exploitation of poultry waste in compost production and (2) its use for energy production.

This paper exposes the overview of state-of-the-art (techniques and equipment) within the field of energetic valorization of poultry waste by direct thermal methods, and discusses various aspects of mentioned practices.

Key words

poultry, waste, energy, arsenic, chlorine

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Introduction

Waste (litter) from poultry farms is traditionally used in land applications as a fertilizer because it is rich in nutrients. However, the rise in poultry production combined with the decreasing availability of land and potential deleterious environmental impacts creates concern about traditional litter disposal methods. Beside that, poultry farming is a 12-month-a-year business, but taking the litter away and spreading it on fields can only happen in spring and fall during fertilizer spreading season. So, there is a need for an alternative use of their litter that is not seasonal.

The poultry industry and community are, obviously, concerned about the management of chicken litter, primarily, from the perspectives of utilization of the waste product. The community wants "clean" food and is concerned about such issues as odour emissions from sheds and the potential contamination of water tables and streams with nutrients and pathogenic organisms from litter being spread on land.

This paper exposes a review of poultry litter issues associated with the poultry shed litter management practices and the utilization of litter. It also highlights available opportunities for litter utilization, with the stress on issues connected with energy production.

The key question here is: "Is it possible, at least – partially, to promote energy ready for market from the undesired surplus of waste made trough poultry farming, but on economically and environmentally viable manner on long-term basis?". For sure, the one and only fair answer has to be: "Yes, but not without problems, not anywhere and not always". The restrictions mentioned in this answer are the result of survey of available practices and techniques, given below, through a few options for litter utilization.

Non-energetic uses of poultry waste

<u>Raw litter applied to land as a fertilizer or soil conditioner</u>. Poultry manure contains a broad range of plant nutrients (Table 1) that make it suited to use as a general fertilizer for vegetable crops and pastures, which is the main reason for the fact that this material has traditionally been used as an organic fertilizer in the intensive horticultural and cropping industries and in broad acre pastoral agriculture.

Chicken litter also has a soil conditioning value that is considered important as it adds humus. The addition of organic matter to soil promotes both crop and soil health, enhances the soil structure and improves the availability of nutrients to plants. It is difficult to define how much these effects are worth financially to the end user, as the value depends on the crop to be grown and the soil type, nutrient and organic matter status. The monetary value of poultry litter as a chemical fertilizer based on its nitrogen, phosphorous and potassium (NPK) analysis is relatively easily defined.

Most of the chicken litter produced is utilized off the poultry farms. Direct application of untreated poultry litter to agricultural production (small crops, tree crops, grain crops and pastures) and home gardens is the traditional and most popular method for utilizing chicken litter. According to Runge et al., (2007), in Australia, the horticultural industries have used large quantities of poultry litter in their production systems. The survey showed that 11 % of the litter was applied to pasture, 29 % to horticultural crops, 6 % to broad acre crops, 5 % was composted and 49% went to litter contractors with no knowledge of end use.

Table 1. Poultry litter composition

Characteristic	Average	Range
pH	8.1	6.0-8.8
Electrical conductivity* (dS/m)	6.8	2.0-9.8
Dry matter (%)	75	40-90
Nitrogen N (% of dry matter)	2.6	1.4-8.4
Phosphorus P (% of dry matter)	1.8	1.2-2.8
Potassium K (% of dry matter)	1.0	0.9-2.0
Sulphur S (% of dry matter)	0.6	0.45-0.75
Calcium Ca (% of dry matter)	2-5	1-7-3.7
Magnesium Mg (% of dry matter)	0.5	0.35-0.8
Sodium Na (% of dry matter)	0.3	0.25-0.45
Carbon C (% of dry matter)	36	28-40
Weight per m^3 (kg)	550	500-650

* Electrical conductivity is a measure of salinity, measured as a 1:5 suspension in water. Source: Griffiths, 2007

The average N : P_2O_5 : K_2O ratio found in litter is about 3.0 : 3.0 : 2.5. Since plants need more N than P, this ratio does not supply nutrients according to the plant's nutrient requirements. At present, it is recommended (Espinoza et al., 2007) that poultry litter be applied based on the phosphorus needs of the crop to be grown and/or the corresponding phosphorus recommendation obtained from a soil test. Applying litter based on the crop's nitrogen requirement would result in phosphorus rates well above the P-fertilizer rate required for optimum crop growth and yield.

University of Arkansas even plans the field studies, looking at solutions for removal phosphorus from soils where poultry litter has been applied for many years.

Extensive direct application of poultry litter at high rates on pastures in areas surrounding poultry production areas in the United States (Division of Agriculture, 2008) has contributed to degradation of the environment in these areas. Application of nutrients in excess of plant uptake and requirements in areas of light soils and shallow water tables has resulted, in these areas, in nutrient movement through the soil profile into the ground water and in overland flow into surface water. These nutrients have contributed to eutrophication of water bodies and degradation of environmental values.

Additionally, it is very likely that regulations on greenhouse gas emissions may affect the way chicken litter is managed to minimize greenhouse gases and ammonia release into the atmosphere.

It was one side of the story of raw litter utilization as a soil amendment, but not the only one. The other is maybe more serious: a range of pathogens may potentially be present in poultry litter. Some of these organisms are pathogens of humans, others of poultry and yet others of poultry and humans. Beside that, there are and other areas of concern viz. antibiotics and antibiotic resistance genes, heavy metals and endocrine disruptors, are also covered. For the purpose of this paper, the stress will be on those pathogens that are relevant to public health or animals exposed to chicken litter. According to Runge et al. (2007), a short list of the main issues of concern and their relevance to human health is set out below.

High priority pathogens/health risks potentially associated with poultry litter are:

— *Campylobacter coli/jejuni* (major cause of human gastro-enteritis);
— *Clostridium botulinum* (Botulism is also important disease of both humans and animals. The types associated with human cases (types A, B, E and F) are not the types associated with chickens (types C and D). However, other animals, e.g. dairy cattle, are at risk from *Cl. botulinum* types C and D.
— *Salmonella* spp. (Salmonellosis of humans is typically an acute gastro-enteritis following the consumption of contaminated food. It is usually a self-limiting illness and fatalities are uncommon).
— Antibiotic resistance genes, in both normal flora and pathogens (Antibiotic resistant forms of *Salmonella*, *Campylobacter*, *E. coli* and *Listeria* are either known to exist or are suspected to exist. The movement of antibiotic resistance genes across bacterial species raises the possibility of normal flora bacteria passing on resistance to pathogens. There is emerging evidence of a link between animal production facilities and infections in humans associated with antibiotic resistant bacteria. This includes a recent US case of child infected with a Salmonella resistant to 13 antibiotics for which the source of infection was suggested as cattle on the family property).

Medium priority pathogens/health risks potentially associated with poultry litter could come from *Cryptosporidium* spp., *Listeria* spp. and heavy metals — arsenic, copper, zinc etc.

Low priority pathogens/health risks potentially associated with poultry litter are: *Brachyspira (Serpitlina) pilosicoli*, *Clostridium perfringens*, *Erysipelothrix rhusiopathiae*, *Mycobacterium* spp., *Pasteurella multocida*, *Staphylococcus aureus*, *Yersinia pseudotuberculosis* and group of hormones and endocrine disruptors (The hormones mentioned here occur naturally and are not growth hormones added to feed.

Community and government pressures on the poultry industry for clean air and water and safe food are forcing the poultry industry and litter users to look at more acceptable options to utilize litter, because concerns and uncertainty regarding potential pathogens contained in poultry litter easily could result in a sudden and substantial reduction in the amount of poultry litter being utilized directly.

<u>Composting</u> is natural process capable of stabilizing organic wastes. The stabilization process considerably reduces odour emissions, and dries up the waste making it easier to handle and transport. Also, proper composting effectively destroys pathogens and weed seeds due to high temperature (55-65°C) achieved through the metabolic heat generated by microorganisms. Composting is an effective and safe way for reduction of the manure's mass and volume, destruction of pathogens and stabilization of nutrients and organic matter in it (Michel et al., 1996; Tiquia et al., 2000).

Composting turns poultry litter to a more marketable, value added and environmentally more acceptable product. Composting, also, reduces the mass of the initial litter, in turn decreasing the cost of storage and transport.

In addition, with either partial composting or full composting, there is a range of potential mechanisms that could kill any pathogens present. These mechanisms include heat, microbial competition, nutrient destruction depletion and antagonism from indigenous microorganisms and time. Of these potential mechanisms, it is generally accepted that temperature and time have the major effects in pathogen killing. Antagonism from indigenous organisms and nutrient destruction depletion are regarded as the major mechanisms for ensuring that pathogens do not re-grow.

A widely accepted rule is that a minimum temperature of 55°C for at least three days would result in a highly efficient kill of pathogens; and an alternative guideline of 60°C for 30 minutes has been suggested as a better basis for ensuring pathogen killing.

However, composting facilities can pose the potential for soil and water pollution through run off and infiltration of nutrients and air pollution from dust and odour. Appropriate facility design and diligent management can address and minimize these potential concerns, regarding concentrated contaminants (pathogens, toxins, heavy metals and inclusions) in the finished composts.

Energy production

The apparent alternatives to utilization of used litter as a fertilizer and soil amendment, without using of energy surplus, are various techniques developed for production of energy based on biomass wastes.

Though the technologies based on aerobic digestion of poultry litter produce gas rich in methane (weak biogas), the compost is the main product of these technologies, so that produced biogas usually being burned on torch within the composting plant, or (more often) released to atmosphere. Anaerobic digestion of poultry litter is for sure (from both energetic and environmental point of view) more perspective technique, but not yet developed enough.

However, there are more available and mature technologies for energy production, primarily developed for utilization of biomass wastes. These are technologies based on thermal treatment of biomass.

The oldest such technique is combined heat and electricity production (CHP) by direct burning of biomass. The world's first three poultry-litter fueled power plants with industrial capacity (Fibrowatt, 2008) were built in the United Kingdom

Table 2. In addition to Chlortetracycline, chlorinated drugs used in poultry feed in the U.S.

Chlorinated Poultry Feed Additive	Other Names	Chemical Formula	Chemical Name
Amprolium	Amprol		(1-[(4-ami no-2-propylpiridin-5-yl)methyl]-2-methyl-pyridimium chloride hydrochloride)
Clopidol	Coyden	$C_7H_7CI_2NO$	3,5-Dichloro-2,6-dimethyl-4-pyridinol
Diclazuril	Diclazo	$C_{17}H_9CI_3N_4O_2$	Benzeneacetonitrile,2,6-dichloro-alpha-(4-chlorophenyl)-4-(4,5-di hydro-3,5-dioxo-1,2,4-triazin-2(3H)-yl)-
Halofuginone Hydrobromide	Deccox	$C_{16}H_{17}BrClN_3O_3$	HBr,DL-trans-7-bromo-6-chloro-3-(3-(3-hydroxy-2-piperidy)acetonyl)quinazolin-4(3H)-one hydrobromide
Robenidine Hydrochloride		$C_{15}H_{13}Cl_2N_5$	HCl,1,3-bis[(p-chlorobenzylidene)amino] guanidine hydrochloride
Meticlorpindol			3,5-dichloro-2,6-dimethylpyridine-4-ol
Enrofloxacin (1 of 2 poultry fluoroquinolones)		$C_{19}H_{22}FN_3O_3$-HCl	1-Cyclopropyl-6-fluoro-1,4-dihydro-4-oxo-7-[(4-ethyl)-1 - piperazinyl]-3-quinolinecarboxylic acid, hydrochloride

Source: Ewall, 2007

in the 1990s. These plants, which were built in response to the poultry industry's need for a litter disposal alternative, generate homegrown renewable energy.

Nowadays, this well-proven technology is being introduced to select poultry-producing communities in the United States. Fibrominn, the nation's first poultry-litter fueled power plant, opened in Benson, Minnesota, in the mid-2007. This plant uses more than 500,000 tons of poultry litter annually, as well as other biomass, producing 55 megawatt of electricity, heat for district heating and an ash that can be used as fertilizer. This ash contains concentrated forms of phosphorous and potassium, which makes it possible to economically transport it at greater distances. The concentrated fertilizer also enables farmers to make fewer trips across their fields, and is in a form well-suited for crop uptake.

Unfortunately, this technology, based on direct burning and "classical" steam cycle is for sure most matured and well-proven, but, in the same time, most controversial, amongst other technologies for energy production from biomass (Ewall, 2007). These controversies arise from one of the most basic principles of incineration: "What goes in must come out". So, if there are toxic heavy metals like lead, mercury or arsenic going in one end, they must come out in the form of toxic ash and toxic air emissions. Different situation is when another class of contaminants, known as halogens, enters an incinerator. These halogens (chlorine being the most prominent) are often released in the form of acid gases (contributing to acid rain and respiratory problems) and also are released in small volumes of extremely toxic chemicals called dioxins and furans (among the most toxic chemicals ever studied).

The main sources of these contaminants are additives to poultry feed. In example, Roxarsone, or 3-nitro-4-hydroxyphenylarsonic acid, is currently the most commonly used arsenical compound in poultry feed in the United States, with a usage of 23 to 45 grams of chemical per ton of feed for broiler chickens for increased weight gain, feed efficiency, improved pigmentation, and prevention of parasites. By design, most of the chemical is excreted in the manure, with arsenic concentrations in poultry litter of between 15 and 35 ppm (ibid.). At these concentrations, one can expect that the Fibrowatt's plant for 500,000 tons per year of turkey waste in Benson, Minnesota would burn waste containing 7.5 to 17.5 tons of arsenic each year. Even if pollution control equipment was able to remove 99 % of this arsenic that would leave 75-175 kg of arsenic air pollutants, making this incinerator a major source of arsenic air pollution in Minnesota.

Ewall (ibid.) also claims that "any arsenic captured in pollution controls would not simply disappear, but would become part of the fly ash, which Fibrowatt plans to sell as fertilizer", but it is quite possible that claim is wrong, because only "low ash" being usually used as a fertilizer, but the flying ash has to be managed as a special waste.

In 1997 the International Agency for Research on Cancer (IARC) classified 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD; the most potent dioxin congener) as a group one carcinogen based on limited evidence in humans. The new evidence generally supports the 1997 IARC classification (Steenland et al., 2004).

Dioxin is formed accidentally in the course of most incineration processes where chlorine and hydrocarbons are present. Poultry litter is rich on hydrocarbons, but there should be enough chlorine, either.

One of the sources of chlorine are various drugs and pesticides used in the poultry industry. Chlortetracycline is a chlorinated growth-promoting antibiotic widely-used in the broiler industry. Also, at least seven other drugs, most of them anticoccidials are chlorinated (Table 2).

Furthermore, poultry are often treated with copper sulfate to avoid a common disease called "aspergillosis". Evidence from chicken litter in Arkansas shows nearly twice as much copper as arsenic in poultry manure (Hollemann, 1992). Iron and zinc are also used as feed additives. They are found in even higher levels in poultry manure than arsenic and copper. Arkansas chicken manure contains 11 times as much iron as arsenic and 12 times as much zinc (ibid.).

According to primary researches (Hinton and Lane, 1991; Gullet et al., 1992), strong correlations may indicate catalytic activity in the synthesis of PCDDs (polychlorinated dibenzo-p-dioxins) and polychlorinated dibenzofurans (PCDFs). Copper is strongly correlated with PCDD concentration. Other correlations include positive effects by iron, sulfur, chlorine, sodium, potassium and zinc.

All abovementioned controversies address to the need for further R/D either in the field of direct combustion and in the field of advanced techniques for energetic valorization of poultry wastes.

Actually, the alternatives appear. Amongst them, most prominent are techniques based on gasification. The process of gasification is the thermal conversion of a solid biomass feed into a gas. The intent of a gasifier is to produce a gas for use exterior to the gasifier. The advantages of gasification technology are that the lower operating temperatures vaporize less of the inorganic nutrients, i.e. phosphorus, potassium, etc., and the evolved gas exiting the gasifier can be dry scrubbed to remove any minor amounts of vaporized contaminants. At the moment, there is just one IGCC (Integrated Gas Combined Cycle) demonstration plant based in Tulsa (Primenergy, 2008).

The other alternative is process proposed by GTI (Gas Technology Institute, 2005). GTI has successfully demonstrated that chicken litter can be gasified to produce hydrogen and generate electricity using a solid oxide fuel cell (SOFC). Under a project funded by the U.S. Department of Agriculture, Earth Resources, Inc. (prime contractor), GTI and the University of Georgia are working to convert chicken litter into energy and fertilizer. As part of this USDA-funded project, GTI conducted a test to demonstrate the suitability of chicken litter as a low-Btu fuel for the SOFC. This process is still under development.

Discussion

The survey given above is not complete list of possible uses of poultry wastes. There is even more alternatives, such are recycling of litter as livestock feed, pelleting of litter, production of enhanced pellets and compost mixes, etc., but these alternatives are very rarely used, because of inability of setting-up the Eco-Eco concept of such production.

Hence, obviously, the simple, unique answer on “the question” set up above does not exists. There is many available uses of poultry waste; some of these uses are mature, well proven, but associated with many concerns and controversies; the others are perspective, but still in the research or demonstrating phase.

Conclusion

Speaking about sustainability, any project within the field considered here must pass many exams, must prevails public concern and satisfy requirement of community, must be environmentally acceptable, and finally, must have the strong founded economical concept, in order to be completely sustainable on the long-term basis.

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