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Biosecurity on Poultry Farms from On-Farm Fluidized Bed Combustion and Energy Recovery from Poultry Litter

Barry Bowen ^{1,*}, Declan Lynch ¹, Deirdre Lynch ², Anne Marie Henihan ², James J. Leahy ² and Kevin McDonnell ¹

¹ Biosystems Engineering, School of Agriculture, Food and Veterinary Medicine, University College Dublin, Belfield, Dublin 4, Ireland; E-Mails: declan.lynch@ucdconnect.ie (D.L.); kevin.mcdonnell@ucd.ie (K.M.)

² Department of Chemical & Environmental Sciences, University of Limerick, County Limerick, Ireland; E-Mails: Deirdre.lynch@staffmail.ul.ie (D.L.); anne.marie.henihan@ul.ie (A.M.H.); j.j.leahy@ul.ie (J.J.L.)

* Author to whom correspondence should be addressed; E-Mail: barry.bowen@ucd.ie; Tel.: +353-1-716-7458; Fax: +353-1-716-7415.

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Abstract: The spreading of poultry litter in recent years has led to a serious increase in levels of eutrophication, nitrate leaching, high Biological Oxygen Demand (BOD), ammonia toxicity, high chlorine concentrations and pathogen contamination. The review presented here details the optimum standards that should be met when storing litter for On-Farm Fluidized Bed Combustion. Storage conditions are paramount to a fuel combusting to its highest possible potential. Safety measures such as the prevention of leaching and spontaneous combustion must be adhered to, so too should the prevention and containment of possible diseases and pathogens to minimize the effects of contamination.

Keywords: biosecurity; storage; welfare; sustainable; energy

1. Introduction

In 2008, University of Limerick (UL), University College Dublin (UCD) and Biomass Heating Solutions Ltd (BHSL) began working on a number of tasks examining the feasibility of the Fluidized Bed Combustion (FBC) of chicken litter. The overall objectives of the project are:

- To establish the optimum combustion and control conditions for the FBC technology to meet EPA IPC licensing requirements including an assessment of propensity for dioxin formation;
- To establish a code of best practice for storage and management of litter prior to combustion to minimize odours, nuisance and to prevent the spread of pathogens or disease;
- To optimize the thermal efficiency of the unit through the use of thermal buffers and sizing/matching of heat exchangers;
- To determine the nutrient value of the ash as a soil additive;
- To assess the market acceptability of and benefits of using this technology.

The poultry industry in Ireland is highly dependent on energy costs (primarily heating) and the continuous waste management of poultry litter. In 2006, Texas University discovered that average litter, cake and total litter (litter plus cake) production rates were 153.3, 74.8, and 228.1 g of dry litter per kg of live broiler weight (g/kg) per batch [1].

From information supplied by Biomass Heating Solutions Ltd. (BHSL), the known optimum weight for broilers at the end of the cycle is 2,474 g [2]. It should be noted that often buyers of poultry may want varying sizes of birds, and so the final bird weight can often depend on sizes as requested by meat suppliers.

Both sources of information combined determine that in Ireland alone there is an annual production of 39,519 tonnes (dry weight) of litter annually. This figure was determined by multiplying the average weight of broilers by the litter known to be produced by the number of chickens reared in Ireland annually. Further calculations tell us that this equates to over 1,000 tonnes of Nitrogen (N) and Phosphorous (P_2O_5) and just over 700 tonnes of Potassium (K_2O) [3].

The waste produced by poultry can cause serious environmental problems. Surface water may be polluted by heavy rainfall sweeping the excess animal waste into nearby ditches, streams and lakes.

According to United Poultry Concerns Inc. (UPC), the annual litter from a typical broiler chicken house of 22,000 birds contains as much phosphorous as in the sewage from a community of 6,000 people [4]. If poultry litter is not utilized properly some harmful side effects can occur. Excess nitrogen converts to ammonia and nitrates, burning fragile cells of land plants and poisoning ground and surface waters. Concentrated poultry waste can spawn excess algae that consume aquatic nutrients and block sunlight needed by underwater grasses. High levels of nitrate in groundwater used as drinking water can cause methemoglobinemia, a blood disorder in infants, commonly known as “blue baby disease” [5]. Leaching may occur, contaminating groundwater with salts, pathogens and nitrates.

Up until recently, poultry litter has been treated as a supplement for crops or as an additive for animal feed. Regulations monitoring the dispersion of nitrates have been in effect since the early 1990s. In 2009, however, big changes were introduced when the New Nitrates Regulations were signed into law by the Minister for the Environment, Heritage and Local Government. The European Communities (Good Agricultural Practice for Protection of Waters) Regulations 2009 revise and replace the previous Regulations made in 2006 and 2007. They provide for strengthened enforcement provisions and for better farmyard management in order to comply with an ECJ judgment in relation to the Dangerous Substances Directive. They also provide the legal basis for the operation of derogation under the Nitrates Directive granted to Ireland by the European Commission. The Regulations came into force on the 31st of March 2009 [6].

The implementation of these regulations has meant that farmers must be extra careful with their waste management practices.

It has been discovered that Combustion is a viable alternative waste disposal strategy. It was also found that that poultry litter from broiler farms could be used as a feasible fuel by exploring heat energy of combustion.

Over the last eight years, BHSL, based in the south west of Ireland, has designed and developed a Fluidized Bed Combustion (FBC) unit that utilizes litter from the preceding batch of chickens to provide heat for the next batch.

Testing carried out by UCD and UL has discovered that not only is this form of energy a cheaper option for farmers, it also eliminates any waste management problems. The residue (ash) from the FBC is relatively low (10.91%) and quite advantageous for other crop growers to use as a fertilizer. In addition to the poultry farmer producing a by-product from the litter used to not only produce heat; they are also saving costs, such as transportation, that would otherwise be incurred by traditional waste disposal methods.

2. Results and Discussions

Ensuring Quality of Litter Remains High

There are a number of reasons that farmers must ensure that the quality of poultry litter produced is monitored to a high standard:

- 1 For the welfare of the broilers during the cycle to avoid difficulties such as hock burn.
- 2 To ensure that the storage of the litter, post batch, will be safe for all concerned.
- 3 To minimize air pollution.

Hock burns are marks found on the upper joints of chickens and other birds raised on broiler farms. These marks are where the ammonia from the waste of other birds has burned through the skin of the leg, leaving a mark. Hock burn occurs where poultry experience blackened skin progressing to erosion and fibrosis on the lower surface of the foot pad, at the back of the hocks and sometimes, in the breast area. If severe, the foot and hock lesions may contribute to lameness or serve as a portal of entry for secondary infections [6].

In order for the storage of litter to be a safe and easy option for the farmer, the quality of the litter produced must be a factor when monitoring the welfare of the birds.

The quality of chicks feed and water are all of great concern to broiler producers. The quality of litter in broiler houses is sometimes not given sufficient emphasis. This is unfortunate, as birds are in continuous contact with litter. Recently, a survey among nutritionists and veterinary professionals showed that 90% of the participants witness the problems associated with wet litter on a daily basis. The effects of wet litter can have a massive impact on the Bio-Security throughout the poultry farm, both before and after the arrival of the broilers.

Litter conditions significantly influence broiler performance and ultimately the profits of growers and integrators. Ideally, litter moisture should be between 20–25%. A good rule of thumb in practically estimating litter moisture content is to squeeze a handful of litter. If it will not adhere at all it may be

too dry, if it adheres slightly it has the correct moisture content and if it adheres tightly and remains in a ball it is too wet.

Poultry litter becomes too wet when the base material has been saturated and the rate of water addition becomes more than the rate of removal (evaporation). This can result from either external (environmentally related) causes or can be as a result of internal flock factors, involving excessive excretion of water. External factors include rain penetration, excessive condensation on the underside of the roof, as well as leaking drinkers and piping. Furthermore, inadequate ventilation and heating may lead to the accumulation of water inside the broiler house, particularly in winter periods [7].

There are two possible internal factors that broilers may experience: diuresis or diarrhoea. Diuresis, which means excessive water coming from urine, has several causes. One cause is a normal reaction to high temperature, that is to say when birds drink more to reduce body temperature by evaporation. Excess levels of salt in the diet, magnesium contamination in limestone or chemical and mineral water impurities are other reasons for excessive water intake. Kidney damage can be a cause of diuresis and might develop due to mycotoxins present in the feed or bedding or by viral infection. In Ireland, the UK and other major countries, poultry producers often use virgin wood shavings as bedding, which has proved act as a deterrent to the spread of mycotoxins. In contrast, diarrhoea is excessive water coming from the intestinal tract. This can be a result of different infections in the intestinal tract, for example protozoal *Elmeria spp*, infection (coccidiosis), bacterial infection (enteritis) or viral infection (including reovirus). It can also be caused by mycotoxins (aflatoxin and fusariotoxins) or even rancid fat. Therefore quality ingredients and high nutritional specifications are very important in feed manufacturing. This indicates a need for high quality ingredients and good dietary specification [8].

Moisture content of litter exceeding 35% is detrimental to health. Research clearly shows that broilers reared on wet litter exhibit a significantly increase incidence of foot pad dermatitis (pododermatitis) or so-called “hock burn”. A second skin related problem is folliculitis, which in serious cases turns into gangrenous dermatitis, causing downgrading of the end product. Both of these are also important welfare aspects that are often raised in the press and considered by the end consumers [8]. They are also subject to specific local regulations, defining a higher price for birds from flocks with a higher welfare status. The wetter the litter the more likely it will be to promote the proliferation of pathogenic bacteria and molds. Toxic fungi proliferation in damp litter creates a mycotoxin threat. Litter moisture above 25% would increase the threat of a coccidiosis outbreak. The incidence of necrotic enteritis could also increase due to the high level of *Clostridium perfringens* and *Escherichia coli* in wet litter. Anything that promotes excessive bacterial growth, such as high moisture levels, and toxin production or slows feed passage rate in the small intestine could promote the occurrence of necrotic enteritis [9].

In general, the bacterial flora that develops in damp litter contributes to a higher level of ammonia release. Prolonged exposure to ammonia causes damage to the respiratory organs, inflammation of the cornea (keratitis) and even blindness. Production is seriously affected with depressed growth and increased feed conversion in broilers by levels of just 25 ppm. The issue of health of poultry workers is also becoming increasingly important and regulations are getting tighter. The EPA has set human exposure standards for ammonia that should not exceed 25 ppm per 8 hours or 35 ppm per 15 minutes of exposure [9].

Essentially, the correct combination of heating and ventilating is an effective means of removing considerable moisture from the house. As air is warmed, its ability to hold moisture increases. A practical way of reducing litter humidity is the control of water losses from leaking drinkers and drinker lines, as well as careful management of foggers and evaporative cooling pads. The bedding used has a crucial influence on overall litter quality. As a number of wet litter cases arise as a result of enteric disorders, general health management is often a key to success. Using proper vaccination programs and Biosecurity controls to prevent infection is crucial to keeping the flock health status high and quality of litter above specifications required for storage [10].

3. Poultry Litter Storage

Disposal of litter through fluidized bed combustion alleviates a number of problems encountered by farmers, such as spreading litter for fertilizer or paying an outside contractor to remove the litter.

With on-farm combustion, farmers only have to ensure that they have adequate and safe storage facilities, and that operational procedures are in place to reduce risk of disease and to control the spread of odors.

As a case study, a farm was examined whose energy supply is controlled by an FBC, manufactured and produced by BHSL. Located in Kinsale, West Cork, the farm currently consists of two broiler houses. Each house is capable of rearing 35,000 chickens per cycle.

While there are a number of options available to farmers for storing litter, many of these options are temporary and would not be ideal for the storage of litter intended for combustion.

The requirements for storage facilities ideal for fluidized bed combustion are as follows:

- Storage sites should be located on high ground that has a good surface drainage and is not subject to flooding. It should be located at least 50 meters from a flowing stream or drainage areas.
- The roof structure must only be supported by outside walls or perimeter posts; interior posts will obstruct loading and unloading of litter; and they might be ignited if spontaneous combustion occurs. A roof height of three meters or higher is recommended to allow for compaction loading of litter, use of front-end loaders, dump truck beds and other equipment; the exact height must be determined after considering the equipment and management that will be used. High roofs will require wall panels and or a long overhang to protect the stored litter from excessive rain and snow.
- Concrete ground liners are recommended for permanent manure storage structures. Where a concrete base is not used, stockpile on an impermeable base such as well compacted clay to minimize leaching to the soil, but ideally in this situation plastic sheeting should be used to protect the soil.
- A minimum of four feet is recommended between the base of the pile and the seasonal high groundwater table.
- Different age litter should be stored separately.
- Prevent storm water intrusion.
- Monitor the internal temperature of the pile. Litter with temperatures that exceed 180 degrees F (82 °C) must be moved to prevent spontaneous combustion.

- To control diseases and to avoid threat of spreading fire should spontaneous combustion occur within the storage pile, do not locate storages closer than 75 meters to dwellings or production houses.
- Practise recommended fly and rodent control around the production houses and in the vicinity of the stockpile. Bird carcasses should not be added to the pile in any circumstances.
- A roofed structure allows for continuous loading or unloading with a minimum of effort when compared to other dry store methods [11].

As seen in Figures 1, 2 and 3, the storage shed in Kinsale is situated at an ideal distance from the poultry sheds. The nearest poultry shed to the FBC unit is more than 25 meters away. The ideal distance that litter should be stored away from poultry houses is 20 meters or more. The shed operates a system that aids quick and easy delivery of litter in a controlled and safe manner. Using a Bobcat, the farmer is able to clear both chicken houses of litter in less than four hours. The litter is deposited through doors at the front of the shed while the Bobcat can access the shed through doors at the back ensuring the litter is stored correctly and compactly. The doors at the rear of the storage shed also give access for the hopper and auger, which feeds a constant supply of litter to the FBC unit.

Rodent bait traps are located in and around the storage areas. This is important, as rodents are known carriers of diseases that affect poultry. Implementing and monitoring a strict and effective rodent and insect control program is essential. Keeping vegetation and debris cleared around poultry houses and storage sheds is also compulsory, as these provide cover for rodents [11].

This farm is an excellent example of how a farm should be managed; incorporating a proper drainage system combined with continuous monitoring of the poultry houses.

Figure 1. Health and Safety measure taken by BHSL.



Figure 2. Litter is deposited through these double doors (front).



Figure 3. Litter is stock piled, ready to be deposited in the auger (structure on the right).



The On-Farm Energy recovery has benefited the farmer greatly. According to the farmer, he has experienced a noticeable increase in bird performance while at the same time the cost of heating the broiler houses has been reduced significantly, through replacing previous fuel, propane, with the combustion of chicken litter.

4. Monitoring Gas Levels

Gas levels within the storage shed can be monitored using a handheld Drager monitor that takes readings of the following gases:

- CH₄—Methane;
- CO₂—Carbon Dioxide;
- O₂—Oxygen;
- H₂S—Hydrogen Sulphide;
- CO—Carbon Monoxide.

These measurements can be compared in detail to readings taken within the sheds during broiler production. With sufficient data it will be possible to predict the levels of gases produced during storage.

5. Managing the Litter Storage Area

It is important that farmers also adhere to the following protocol after the removal of litter from one shed to the other.

- Know the warning signs of major avian diseases.
- Clean and disinfect vehicles and equipment—disinfectants do NOT work properly on dirty surfaces. They can only kill organisms they contact directly. Organic materials (manure, dirt, *etc.*) prevent organisms from direct contact with disinfectants. Therefore, it is extremely important to remove any faecal material and other organic materials from equipment, *etc.*, prior to using a disinfectant.
- Wear sanitized coveralls and boots.

- Keep out unnecessary visitors and equipment.
- Avoid contact with game birds and migratory waterfowl [11].

6. Conclusions

Inadequate storage of litter can provide a risk to the farmer. The storage method must protect litter from contact with rainwater or snow; stockpiling of uncovered litter on the soil for long periods before being fed into the auger can mean a five-fold drop in the amount of nitrogen in the litter. The nitrogen lost may leach or be washed into surface drains or streams or into groundwater. Therefore, improper storage results in greater impact on reduction of water quality in the area. The cover for the manure must be completely waterproof in order to reduce moisture levels. Ideally, the litter should be entering the FBC with a moisture level below 43%. Higher moisture levels will emit more gases such as SO₂ and NO_x as well as the other gases. Results from previous measurements show that Fluidized Bed Combustion of chicken litter under the correct conditions can be a formidable method of reducing litter as a waste product and transform it into a form of fuel. Through careful monitoring of the moisture content levels, it is possible to produce gaseous emissions from the combustion of poultry litter that is not in any way hazardous.

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