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Utilisation of poultry litter as an energy feedstock

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ARTICLE INFO

Article history:
Received 23 August 2011
Received in revised form
6 November 2012
Accepted 10 December 2012
Available online 18 January 2013

Keywords:
Energy
Poultry litter
Phosphorous
Fluidised bed combustion
Ash

ABSTRACT

This paper examines poultry litter (PL) as a resource in fuel quality terms and illustrates how the small scale application of fluidised bed technology solves both energy and waste problems, while producing a nutrient rich ash. PL was found to have a higher heating value (HHV) of 18 GJ t^{-1} on a dry basis (db). On an as received basis (ar), it had an ash mass fraction of 9% and the elemental phosphorous content of the ash was 110 g kg^{-1}. The resultant mineral matter can be utilised as a nutrient substitute for mineral fertiliser.

1. Introduction

1.1. Background

Approximately 56 billion land animals are raised and slaughtered worldwide each year for human consumption [1] and livestock inventories are expected to double by 2050, mostly in developing countries [2].

The growing demand for animal protein products has led to the intensification of the agricultural industry, leading to the birth of the so called “factory farm” or “CAFO” (concentrated animal feeding operation). These farms allow meat and eggs to be produced at a much lower cost than traditional methods. The animals on these farms are usually confined for most of their life span, under increased stocking densities, leading to large volumes of excreta being accumulated in concentrated areas.

Manure generated from CAFOs consists of both solid and liquid fractions. The solid fraction mainly consists of faeces and bedding material recovered from the floor of the houses while the liquid contains a mixture of water, urine and soluble faecal components, and is drained through gutters [3,4]. This manure is considered an industrial waste and must be managed in an environmentally responsible way [5]. Animal excreta are high in nutrients such as nitrogen, phosphorous, potassium, calcium and sulphur, and as such, are generally spread on land as an organic fertiliser.

However, manure production from CAFOs is often greater than local crop and proximal pastureland nutrient requirements. Over-application of manure can lead to eutrophication, nitrate leaching, high biological oxygen demand (BOD), ammonia toxicity, high chlorine concentrations, pathogen contamination, nuisances (e.g. flies and odours), crop toxicity (due to high concentrations of ammonia, nitrite, nitrate

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0961-9534/$ – see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.biombioe.2012.12.009

and soluble salts), fish kills and human and animal health impacts [6].

1.2. Phosphorous recovery

Phosphorous (P) is perhaps the most important nutrient in animal manure, not only due to its agronomic benefit, but also its status as a non-renewable resource. Current global reserves may be depleted within 50–100 years [7]. The merging of food and fuel economies has seen an increased demand for mineral P fertiliser, and its price increased by over 200% in 2007 [8]. The expected global peak in phosphorus production is predicted to occur around 2030. The quality of remaining phosphate rock is decreasing due to some trace element impurities; while production costs are also increasing as removing these impurities generates hazardous waste and may require high energy input [7–9].

1.3. Poultry litter

Poultry litter is one of the drier and bulkier manures produced in intensive agriculture. It consists of a mix of bedding material, excreta, waste feed and feathers. Bird mortalities may also be present, however under EU Regulation 1774/2002 [10] these must be removed and disposed of separately. According to Szogi & Vanotti [8], recoverable P from poultry litter is about 39% of the total recoverable P from all animal manures in the U.S. because of its high P concentration with respect to other manures. Phosphorous in poultry litter is present as both solid phase organic P and inorganic P (2:1), it can vary with diet and husbandry practices, and has a reported mass fraction range of 0.3%–2.4% on a dry basis [11,12]. However, this P is largely present in the acid soluble fraction, limiting its bioavailability [13].

A total of 18 billion meat chickens were slaughtered in Europe and the USA in 2009 [1]. Using the calculation of 1.4 t of litter per 1000 birds, this amounts to a reserve of litter of 25,000,000 t as received (moisture unspecified) in the USA and Europe combined in a single year.

Agriculture is the single largest source of waste in Ireland. According to the EPA National Waste Database, of a total of 85,256,685 t of waste generated in 2004, 60,170,025 t (70.6%) were generated in a managed environment from agriculture. Poultry litter represented 0.3% (172,435 t) of the total managed agricultural waste produced in 2004 [14]. The majority of the litter generated was derived from chicken (broiler) production [15].

1.4. Poultry production

In northern and temperate climates, temperature control in the initial stages of broiler production is paramount and involves the use of an external heat supply for the first four weeks of the production cycle. The requirement for heat is normally reduced in the later stages of the cycle. Typically, fossil fuels (such as propane or diesel) are used to heat the poultry houses directly. Rising energy costs have led to some farmers reducing ventilation of the sheds as a cost saving measure. This can be detrimental to bird health as it can increase the moisture content of the litter, leading to hock burn and dermatitis and can also lead to the build up of harmful emissions such as ammonia and carbon monoxide, increasing bird mortality [16,17].

1.5. Poultry litter as a fuel

Poultry litter is recognised as a biomass fuel, and is generally a free-flowing, granular material, with a consistency and physical appearance similar to a mixture of wood chips and sawdust. It can vary from wet compacted manure to a dry dusty powder. It is generally recognised as a low value fuel due to its relatively high moisture and ash contents. The moisture content of poultry litter is highly variable and this impacts on the homogeneity and the lower heating value (LHV) of the fuel, which can range from 9 GJ t^{-1}–13 GJ t^{-1} [18,19]. The use of poultry litter as an alternative fuel source on a large scale basis has been carried out since Fibropower opened their poultry litter-fired power plant, at Eye in Suffolk UK in November 1993 [6].

Use of poultry litter as a combustion fuel concentrates the nutrients of the litter in an inorganic, sterile form. Nitrogen is lost during combustion, however; phosphorous and potassium are both retained, as well as several other macro and micro nutrients.

1.6. Fluidised bed combustion of poultry litter

For the purpose of this research a 200 kW atmospheric bubbling fluidised bed combustion (FBC) unit was employed. FBC technology was selected as it is well documented as being suitable for low value fuels such as poultry litter [6,20,21]. The unit used in this work was a commercial unit, operated by Biomass Heating Solutions Ltd., Ireland. The FBC was located adjacent to a broiler operation and as such the litter did not leave the site of production. The design of the FBC made it suited to on-site location for small scale operations (30,000 birds) which are common across Ireland. A schematic of the FBC is shown in Fig. 1. The resultant ash was collected via a series of heat exchangers, a cyclone and a bag house filter.

Fluidised bed combustors have been shown to be a versatile technology capable of burning practically any fuel or biofuel combination while producing low emissions [22].

1.7. Overview

This paper examines the suitability of poultry litter for use in FBC technology in terms of its basic fuel characteristics. It is clear that managed agriculture faces many problems, primarily energy generation and waste disposal. This paper shows how the small scale application of FBC technology can solve both energy and waste problems, and create an additional revenue stream in the form of a mineral rich ash suited for fertiliser substitution.

2. Materials and methods

Poultry litter samples were collected from broiler production facilities, following the guidelines of BS EN 14778:2011, 'Solid biofuels – Sampling ' [23], and prepared according to BS EN 14780:2011, 'Solid biofuels – Sample preparation' [24].