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Environmental benefits of using turkey litter as a fuel instead of a fertiliser

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ABSTRACT

There is an increased interest in the use of poultry litter as fuel by the relevant industries. Hence the environmental impacts of using turkey litter as fuel to generate electricity instead of using litter as fertilizer were systematically analysed for the first time. For this purpose, a systems modelling-based life cycle assessment approach was used, with data obtained directly from the UK turkey industry. Impacts were calculated per 1000 kg turkey live weight produced at the farm gate (functional unit). The avoided burdens method was used to quantify the effects of the alternative litter use. Differences in the environmental impacts between the two litter use scenarios resulted from the combined effect of the following sub-processes: the loss of nitrogen as a crop fertiliser, the transport for collecting litter and distributing the ash as a phosphorus and potassium fertiliser, displacement of electricity generation by a combined cycle gas turbine, specific trace gas emissions from combustion and the loss of soil carbon from the reduced organic matter supply to arable soils. The results showed that there are substantial environmental benefits from using turkey litter as a fuel to generate electricity rather than using it directly as a fertiliser with reductions in burdens of cumulative primary energy demand (14%), eutrophication potential (55%) and acidification potential (70%). The reduction in acidification and eutrophication potentials were mainly associated with reduced ammonia emissions from the storage and land spreading of the litter. Reductions in greenhouse gas emissions were small (3%) because losses of soil carbon as a result of not applying litter to land partially counteracted the benefits of reduced fossil energy use. Small increases in nitrogen oxides, volatile organic carbon, particulate matter below 10 μm aerodynamic diameter and dioxin emissions were found, although only nitrogen oxides were especially linked to combustion. Despite its potential benefits, stringent management, monitoring and regulation of biomass fuelled power production is still needed, given the potential hazards of local high emissions. Although turkey litter was analysed in this study, similar results can be expected for broiler litter use as a fuel, as long as geographical conditions are similar.

1. Introduction

Poultry litter in the UK (mainly coming from broiler, egg and turkey production) was normally managed only as a fertiliser and soil conditioner until the late 1990s. The high plant nutrient nitrogen (N), phosphorus (P) and potassium (K) concentrations make it more valuable than other (semi-) solid manures (Defra, 2010). The nutrient contents of turkey and broiler litter are very similar and Defra (2010) does not differentiate between their compositions. Turkey and broiler litter includes some bedding, usually wood shavings or chopped straw. Losses of N during litter storage may occur, which can lead to substantial emissions of ammonia (NH_3), and a mixture of di-nitrogen (N_2), nitrogen oxide and dioxide (NO_x) and nitrous oxide (N_2O). These change the actual amount of N available when applied to land and hence the fertiliser value. Here, we use turkey litter as an example of the consequences of using the litter as fuel, instead of applying it to land. Similar arguments apply to the use of broiler litter as fuel, but we had better access to key aspects of turkey litter management activity data and hence report this rather than broiler litter.

UK turkey annual production increased from the 1970s to a maximum of 40 M birds in 1995, steadily fell to about 15 M in 2007,

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Nomenclature

AP	acidification potential (kg SO_2 equiv)
ARU	abiotic resource use in antimony equivalents (Sb equiv, kg)
CED	cumulative energy demand as primary energy (MJ or GJ)
EP	eutrophication potential (kg PO_4^{3-} equiv)
GHG	greenhouse gas
GHGE	greenhouse gas emissions
GWP_{100}	global warming potential over 100 years (kg CO_2 equiv)
NMVOC	non-methane volatile organic carbon (kg)
NO_x	nitrogen oxides, NO and NO_2 (kg)
PAH	poly aromatic hydrocarbons (kg)
PM_{10}	particles below 10 μm aerodynamic diameter (kg)
t-p-d equiv	2,3,7,8-tetrachlorodibenzo-p-dioxin, used as equivalent for all dioxins (kg)
PAN	plant available N
Org-N	organic N

and then remained relatively constant (Defra, 2014). The production of turkey litter from 17.5 M slaughterings in 2013 was 0.9 Mt, which contained 21 kt N, 7.7 kt P (or 17.6 kt phosphorus pentoxide [P_2O_5]) and 13 kt K (or 15.7 kt potassium oxide [K_2O]), using the composition data from Defra (2010). There are poultry (of all species) across most of the country, with higher concentrations in some parts, e.g. East Anglia, which also supports a large fraction of UK turkey production (Fig. 1). This has contributed to pressures in the nitrate vulnerable zones (NVZ) that were introduced as implementation of the 1991 EU nitrates directive, which became more stringent since being introduced.

Two important features affect the application of manure as a fertiliser: an upper limit on N applied per ha and the exclusion of applications in late autumn and early winter (Defra, 2013). With high concentrations of poultry in some areas, finding an alternative to land application consequently became attractive to farmers. This was enhanced by the potential of using litter as a fuel, which added to the UK's use of renewable biomass for generating electricity. The use as fuel started in 1992 and consumed about 13% of UK poultry litter, with the proportion increasing to a current value of about 35% (data used in the UK ammonia inventory, T.H. Misselbrook, *Pers. Comm.*). Poultry litter has been used in The Netherlands for electricity generation since 2008 BMC Moerdijk (2008), Lynch et al. (2013) and Quiroga et al. (2010) investigated the properties of poultry litter as fuel by direct combustion. Jia and Anthony (2011) examined co-combustion of poultry litter and coal. More work seems to have addressed the performance of gasification or pyrolysis of poultry litter (e.g. Di Gregorio et al., 2014; Font-Palma, 2012; Huang et al., 2015; Striūgas et al., 2014). These studies focussed on the technological performance of processes.

Sandars et al. (2003) were the first authors to apply life cycle assessment (LCA) to manure management in the UK, in this case, land application by different technologies. Reijnders and Huijbregts (2005) applied LCA to burning animal wastes in the European Union, including litter and other materials. They found that the greenhouse gas emissions of burning animal waste were very sensitive to the allocation approach chosen. They did not address indirect effects, such as changes in fertiliser use (and hence production) which could considerably change the emissions of greenhouse gases. They considered that such quantification should

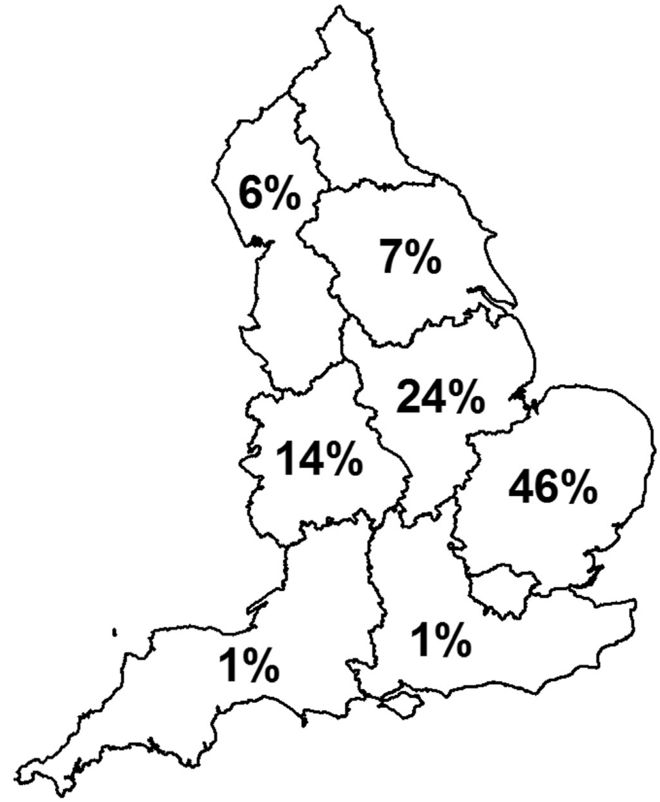

Fig. 1. Distribution of turkey farms in England showing regional concentration in the east.

be the subject of further research. Billen et al. (2015) compared poultry litter being applied to land as a fertiliser with combustion for electricity generation, in The Netherlands using LCA. Main impacts (and benefits for electricity production) related mainly to reduced greenhouse gas from fossil fuel use and emissions of ammonia, nitrous oxide. Further benefits arose from the enhanced ability to export P and K fertiliser in ash away from areas that were potentially over-supplied.

The aim of the current study was to apply a life cycle assessment (LCA), "from cradle to gate" to quantify the potential changes in environmental burdens when the turkey litter is used as fuel to generate electricity instead of its traditional use as a fertiliser. A typical UK turkey production system was used as a framework of the analysis (Leinonen et al., 2016).

2. Methods

2.1. Scope of the LCA

The system boundary included all feed production (with associated upstream inputs) and husbandry activities to produce turkeys up to the farm gate. The alternative approaches to manure management were included within the system boundary. The functional unit (FU) was 1000 kg turkey live weight at the farm, ready for slaughter.

2.2. Systems approach and the turkey production data

Some empirical activity data was supplied from the turkey industry and other partners, but systems modelling was used to provide most the inputs for life cycle assessment This included structural models of the industry, process models and simulation