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One chicken, one Watt... Poultry litter as an alternative fuel

In the third excerpt from MVW Lechtenberg & Partner's Alternative Fuels & Raw Materials Handbook, Dirk Lechtenberg describes the use of poultry litter as an alternative fuel for cement and lime. Due to be published in the summer of 2011, the handbook will give an insight into over 80 different types of alternative fuels and raw materials with detailed descriptions of the availability, common use and practice in the cement industry.

Above: A hen running through grass.

More than 50 billion chickens are reared annually as a source of food for their meat and eggs. Chickens farmed for meat are called broiler chickens, whilst those farmed for eggs are called egg-laying hens or layers. The UK alone consumes over 29 million eggs every *day* and some hens can produce over 300 eggs a year. Chickens will naturally live for six or more years, but after 12 months, the hen's productivity will start to decline and this the point when most commercial laying hens are slaughtered.

In egg-producing farms, birds are typically housed in rows of cages, called batteries. Environmental conditions are automatically controlled, including light duration, which mimics summer day length. This stimulates the birds to continue to lay eggs all year.

Broilers

Meat chickens, commonly called broilers, are floor-raised on litter such as wood shavings or rice hulls. They are raised indoors in climate-controlled housing. Poultry producers may use nationally-approved medications in feed or drinking water, to prevent or treat disease. In the US, as well as in many other countries, laws prohibit the use of hormones or steroids in poultry production. After a period of approx. 27- 30 days, the broilers will be slaughtered and the stables are cleaned. A typical shed has a volume of 150t of shavings and litter.

Below - Table 1: Estimated amounts of cake/crust and litter + cake/crust produced by various types of poultry.

Bird type	Cake/crust per 1000 birds by flock* (t)	Litter + cake/crust per 1000 birds by flock* (t)
Broiler	0.2	1.1
Roaster	0.2	1.5
Cornish	0.04	0.5
Breeder	-	24.0
Pullet	-	6.7
Layer	-	19.7
Turkey	-	10.0

Quantity and availability

The average chicken generates its weight in excrement during its life - just six weeks. The amount available in a given region can be worked out using Table 1.

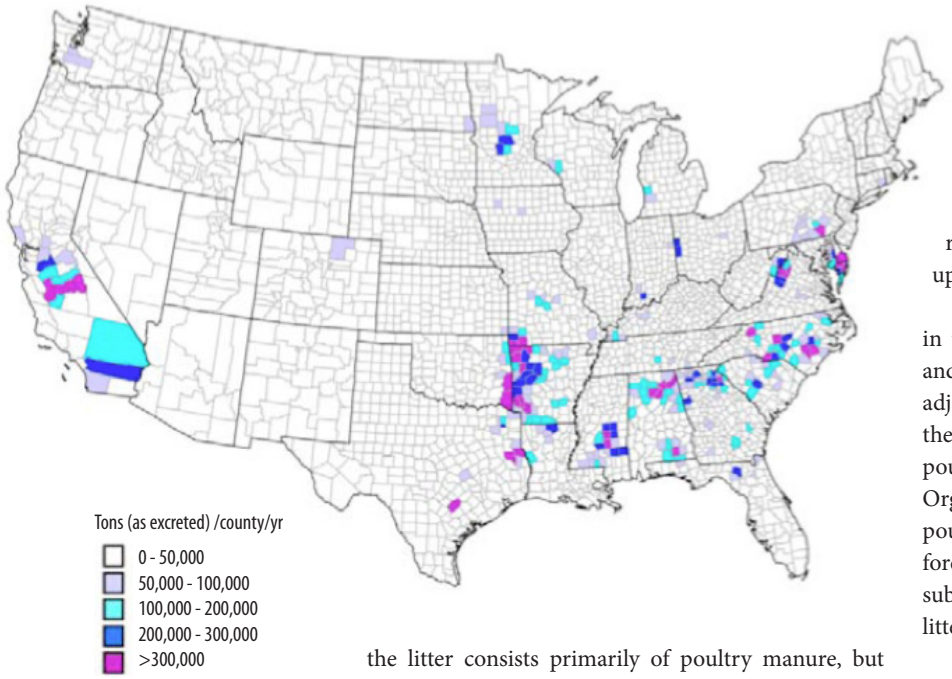
Global production of broiler meat has been growing since the 1960s, faster than that of any other meat due to cost, percieved health advantages and good versatility. Despite these advantages, the broiler industry increasingly faces pressure to improve its production methods, with consumers and government citing health, environmental responsibility and animal welfare as the areas for improvement.

The US is expected to maintain its position as the world's largest poultry producer. Although production fell to 16.38Mt in 2010, production is forecast to expand by 1.3%/yr to reach 18.83Mt/yr by 2018. A map of poultry litter production in the US is seen in Figure 1. China is expected to achieve almost double this growth rate over the same period. With annual expansion forecast at 2.5%, by 2018 the country will be producing 16.3Mt.The world's third largest producer, Brazil, is forecasted to expand by some 2%/yr over the same period, bringing its 2018 production to 13.1Mt.

Other countries that are expecting to see rapid broiler industry expansion include Russia, India, Thailand, Brazil and Argentina. In the EU the growth rate is expected to be just 0.5%/yr. Total output will rise over the period by 414,000Mt to reach 8.81Mt/yr by 2018.

Waste composition

Common litter materials are wood shavings, sawdust, peanut hulls, shredded sugar cane, straw and other dry, absorbent, low-cost organic materials. After use,



Above - Figure 1: US poultry litter production by county. Source: M. Freeman.

the litter consists primarily of poultry manure, but also contains the original litter material, feathers and spilled feed. A breakdown of the litter/manure mixture is given in Table 2. The composition of poultry litter ash is shown in Table 3.

Right - Table 2: Median composition of poultry litter. **Source:** MVW Lechtenberg & Partner.

Parameter	Unit	Median
Moisture	%	38.7
Ash	%	9.1
Volatiles	%	38.1
Sulphur	%	0.3
Carbon (total)	%	23.2
Hydrogen	%	2.9
Nitrogen	%	2.8
Oxygen (from subtraction)	%	17.2
Chlorine	%	0.3
Fluorine	%	0.007
Net calorific value	kJ/kg	11,364
Antimony	mg/kg	<4
Arsenic	mg/kg	0.7
Lead	mg/kg	3.9
Cadmium	mg/kg	<0.4
Calcium	mg/kg	15,200
Chomium	mg/kg	7
Cobalt	mg/kg	1
Potassium	mg/kg	16,700
Copper	mg/kg	37
Magnesium	mg/kg	4075
Manganese	mg/kg	213
Sodium	mg/kg	2060
Nickel	mg/kg	6.1
Mercury	mg/kg	0.05
Titanium	mg/kg	0.4
Vanadium	mg/kg	3.4
Zinc	mg/kg	192

Harmful substances

Much litter comes from commercial broiler operations, which use arsenic as a feed additive to control parasites and increase weight gain. Most of this arsenic does not accumulate in the poultry meat, but is excreted by the birds. As a result, almost 90% of the arsenic fed to poultry ends up in the litter.

As this heavy metal has the potential to build up in the soil, cause health problems for farm workers and consumers of produce and can be transported to adjacent lakes or streams, many organic farmers and their certifiers are concerned that using commercial poultry litter is not compliant with the US National Organic Standard. Copper sulphate is also used in poultry farms in order to avoid aspergillosis. Therefore a continuous measurement of possible hazardous substances has to be implemented while using poultry litter as a fuel for cement plants.

Bio-security is an important issue for poultry producers. Disease can be transmitted between farms or houses by contaminated litter transport. Some disease-causing organisms can live for weeks, months or even years away from the birds. As litter transport has been a source of disease when delivering litter from several houses to a single end-use, traffic poses one of the greatest risks to bird health. Traffic control and sanitation are two methods that poultry producers use to protect their farms from infectious disease.

Traffic control includes both the traffic onto the farm and the traffic patterns within the farm. Litter removal must be organised to prevent contact with live birds. Delivery trucks may also need to be sanitised between farms sufficiently to convince growers that their flocks will be protected. These practices will affect the use of litter as an alternative fuel.

Hazardous characteristics

Dust and odour associated with litter is another critical issue. Excessive dust in poultry houses is also a detriment to house environment and may adversely affect health of birds and workers. Several sources in the poultry house can contribute to dust generation including bedding, manure, feed, dander, feathers and bacteria.[3]

Collection, recycling and disposal

Collection: Poultry litter from industrial farming is available after the breeding period of broilers, hens and turkeys. The poultry is taken out of the farms and then the litter has to be removed from the farms in order to initiate a new breeding period.

As the poultry farmers have a detailed breeding and slaughtering plan, the collection time is foreseen for a while and can be well organised. The bio security is one of the most important issues. Therefore a detailed health and safety management has to take place. Poultry litter will be loaded into covered containers or trucks for further transport. A logistic scheme that considers disinfection and agreed transport routes has to be developed.

Element	%	Element	ppm
Calcium	16.68	Selenium	2.4
Phosphorous	10.08	Fluorine	436
Copper	0.17	Aluminium	7260
Iron	0.59	Antimony	<5
Magnesium	2.65	Arsenic	52
Potassium	7.64	Cadmium	0.8
Sodium	4.34	Chromium	34
Chloride	0.99	Lead	4.4
Zinc	0.14	Mercury	<0.1
		Vanadium	26

Right- Table 3: Chemical analysis of poultry litter ash. **Source:** Blake, J.P., Hess, J.B. Department of Poultry Science, Auburn University, Alabama, USA.

Transport: Poultry litter has to be delivered only in covered trucks. It has to be received, stored, and handled in totally enclosed structures, maintained under negative air pressure. Bulk density is similar to wet sawdust, between 450kg/m^3 and 600kg/m^3. It can be transported by truck at about 20t per load. Automated unloading requires either a truck tipper at the energy facility or use of live-bottom vans. The unloading area and trucks must be cleaned or disinfected to protect litter suppliers from disease.

Recycling: Poultry litter is traditionally used as a fertiliser. As with other manures, the fertilising value of poultry litter is excellent, but it is less concentrated than chemical fertilisers, giving it a relatively low value per ton. This makes it uneconomic to ship long distances and extracting its full value requires that it be used on nearby farms. In regions where there are more poultry farms than suitable nearby farmland, the litter tends to go to waste by one route or another.

In the UK and the US there are several small scale power plants of between 10–30MW that use poultry litter as a fuel. In some regions, poultry litter is used in small combustion chambers without any flue gas cleaning systems.

Use as alternative fuels in the cement plant

Poultry litter, mainly from broiler and turkey production, on wood or other biomass shavings is a 100% biogenic fuel source for cement plants. Preferably, poultry litter can be introduced at the precalciner. Due to the higher ammonia content, a reduction of NO_x can be realised.

	Calorific value (kcal/kg)	Substitution factor compared to coal	Substitution factor compared to petcoke
Poultry litter with shavings	3000	2.03	2.73
Coal	6100	1	*
Petcoke	8200	*	1

Above- Table 4: Substitution factors for poultry litter as an alternative fuel. **Source:** Fibrowatt.

Value as an alternative fuel

Calorific value: Poultry litter has a potential energy content. Its calorific value is around 3000kcal/kg. Therefore, 2.03t and 2.73t are needed to substitute for 1t of coal and 1t of pet coke respectively. Table 4 shows an economic calculation of poultry litter regarding the calorific value in comparison with pet coke and coal without any handling and operational costs and capital investment.

Biomass & CO_2-value

Due to the source of the poultry litter the emitted CO_2 is 100% environmentally neutral when poultry litter is used as an alternative fuel. according to Table 4, 1t of coal is substituted by 3.47t of poultry litter. Hence the emission of approximately 2.45t of fossil CO_2 from coal is saved completely.

Pre-processing

The physical characteristics of the litter are similar to those of the wood, sawdust and shavings that are used for the bedding. The cake or crust may need to be sized in a hammer mill but the bulk of the litter is suited to reclaim and feed directly from a storage bin or silo. Wood chips from nutrient filter biomass could be used to add bulk to the litter to improve handling.

Storage at the plant site

Fuel selection for cement kilns often results from availability and reliability of supply first and price and fuel quality second. Most cement plants have found it beneficial to have some fuel processing on site for reprocessing off-spec fuel and handling special circumstances. Fuel receiving and handling is a major source of fugitive emissions from poultry litter. Odour, dust and health considerations suggest that litter should be received and fired in as coarse and unprocessed a form as possible with a minimum of fuel handling.

Designers of poultry litter plants in the UK have taken a simple approach to fuel receiving. The poultry litter is collected in enclosed vehicles each carrying about 20t. The loads are weighed on site and analysed for moisture content, ash and calorific value, before the litter is tipped into enclosed reception pits. Loads with excessive moisture content are rejected. The litter is stored under negative pressure, maintained by induced draft fans, to prevent noxious odours from escaping into the atmosphere. The litter is discharged into reinforced concrete pits that can store a 10 day supply, corresponding to 11,300m^3 (400,000ft^3) or about 5600t. It is sorted by moisture content, enabling an overhead grab crane to recover a consistent blend of wet and dry material, thus giving a reasonably constant heating value at the kiln. Receiving systems should handle unloading without delay, handle dust control for dry fuels and preliminary processing to separate oversize material and waste materials such as metal objects or rocks. Since a variety of qualities of litter will be received, it may be necessary to:

- have a versatile receiving facility,
- be capable of sorting into different storage bins,
- provide bypass capability for special conditions,
- be able to selectively blend from storage,
- accommodate unpredictable quantities of oversize and fine fuel.

Ventilation air used as combustion air can be used to thermally destroy odorants. Routine site odour monitoring is advised!

Dosing and feeding systems

The receiving design capacity should be sized to reduce delay in truck unloading and may include live-bottom receiving capacity, primary disc screen, self-cleaning magnetic separation, oversize feed to a hammer mill, a possible bypass to alternate bins, means to reintroduce fuel to screen from yard and a dust collection system.

Storage and reclaim can be based on the amount of processing required for the fuel (segregation, screening, drying, resizing) and the number of very different fuels to be blended. The ability to separately vary a marginal fuel that contains sulphur or other contaminants can reduce operational and emissions problems. Poultry litter is a very difficult material for handling, as the gases are acid and need special requirements for dosing and feeding.

Quality influence on clinker

A good suspension burner will sustain ignition without a pilot flame if the fuel is milled so that at least 25% will pass through a 100 mesh screen (<150µm). The theoretical burning time for fuel particles of this size is 2s, 0.5s to devolatilise and 1.5s for char combustion.

In practice most burner designs, like those used with litter, only partially burn fuel in suspension and depend on sufficient residence time at high temperatures to complete combustion.

Particle size must be controlled if nutrient biomass wood chips or straws are blended with poultry litter. A kiln operates best with a uniform range of fuel sizes that can be controlled by processing on site. When fine particles are introduced with larger sized chip fuel into the kiln (kiln burner), the difference in size can create emissions. The fines devolatilise rapidly in the high-velocity air which is needed to burn the chip-sized fuel, but the char elutriates out of the high-temperature zone of the kiln producing carbon particles and excess CO in the flue gas. Foreign (three dimenntional) particles will fall into the clinker bed, will be encapsulated and create brown coloured clinker as well as CO problems.

The poultry litter contains phosphorous which is incorporated into the clinker minerals to form calcium phosphates. The input of phosphorous is low due to the low ash content of poultry litter. But especially in accumulation with the use of animal meal as fuel phosphorous could influence the setting time and the early strength (S. Puntke).

Recommendations

Depending on the origin of poultry litter and composition (preferably from broiler and turkey production on wood or straw), poultry litter can be a sustainable fuel for cement plants.

The farming industry is concentrated by a few big and multinational companies with a different mentality from the cement industry.

Fuel sourcing and contracting is one of the major issues in order to secure a long term supply. MVW Lechtenberg & Partner has a long track record in working with the farming industry. Germany is one of the major locations for poultry farming in Europe, and can support cement plants in fuel sourcing and developing local equipments for storage, dosing and feeding.

References

Blake, J.P; Hess, J.B. *'Direct Substitution of Dicalcium Phosphate with Poultry Litter Ash in Broiler Diets.'* Department of Poultry Science Auburn University. Symposia Annual meeting, 2005.

'Economic and Technical Feasibility of Energy Production from Poultry Litter and Nutrient Filter Biomass on the Lower Delmarva Peninsula.'

Freeman, M. *'Power From Poultry Litter. Agricultural Waste-To-Energy,' 1st Annual Waste to Fuels Conference and Trade Show,* Orlando Florida, April 7, 2008.

Lechtenberg, D. Various studies about poultry farming in the UK, Germany, Turkey and USA.

Tabler, G. T; Liang, Y. *'Poultry Litter: Issues and Opportunities,' Avian Advice*, Summer 2008. (http://www.thepoultrysite.com/articles/1127/poultry-litter-issues-and-opportunities).

Parker, D; Lichtenberg, E; Lynch, L. *'Environmentally Sound Uses for Poultry Litter,'* Agricultural and Resource Economics, University of Maryland, USA.

Puntke, S. *'Auswirkungen des Phosphateintrages in Drehofenanlagen der Zementindustrie auf Klinkermineralogie und Zementeigenschaften,'* PhD Thesis University of Clausthal, Germany, 2004.

Walmsley, T. *'Power from Poultry Litter Regional-Scale Renewable Energy Plant. Waste-to-Energy Workshop For the Farm, Food Processing, & Wood Industries,'* Huntingburg, Indiana, 11 December 2006.

Left - Figure 2: Poultry litter with coin for scale.