Appendix 5.

Advances in waste treatment

Increasing environmental pressures and economic incentives to reduce greenhouse gas (GHG) emissions are raising interest in waste-to-energy projects.

CONTENTS

Introduction

Increasing environmental pressures and economic incentives for industries and enterprises to reduce greenhouse gas (GHG) emissions have boosted interest in waste-to-energy projects.

The success of these types of projects in other industries such as intensive pig farming, and economic drivers to save money through power creation, possible trading of carbon credits and the potential to produce more 'fertiliser-type' products from manure, are driving interest in advanced waste treatment strategies.

Fresh beef feedlot manure has a relatively high energy content and offers the potential for energy recovery. However, factors that can reduce the energy potential of feedlot manure include the breakdown on the feedlot pad, high moisture content and contamination by soil and gravel. To date there is no full-scale example in Australia of energy recovery from feedlot manure and only limited data is available from overseas.

Advanced treatment of manure

A range of advanced technologies could be used to generate power and extract nutrients from beef cattle manure. These technologies usually fall into one of three categories

- anaerobic digestion
- thermal treatment
- diet modifications.

Of the three categories, anaerobic digestion has shown the most potential to date for extensive use in Australian livestock manure management for both capture and reuse of methane and for flaring unwanted biogas.

Dietary modification and thermal treatments could be used with anaerobic digestion as part of an overall GHG mitigation strategy.

Thermal treatments are energy intensive and require significant investment in engineering technology; there have been some successes but also large-scale failures.

Thermal treatments such as gasification, pyrolysis and direct combustion have been used in the US and Europe but have had only limited application in Australia. An Australian desktop study identified that energy recovery from harvested manure using thermal techniques appeared to offer attractive economics even for medium-sized feedlots of 10,000 SCU (Bridle 2011), but the study was based on using freshly harvested manure which may not be practical for commercial feedlots.

Anaerobic digestion of beef feedlot manure

Anaerobic digestion is one of the more promising waste-to-energy techniques. The biogas generated is readily used as an energy source while digestate from this process is often rich in ammonium and phosphate that can be recovered via crystallisation, potentially for conversion into marketable fertilisers (Gaterell et al. 2000). Anaerobic digestion also has other advantages such as the destruction of pathogenic and parasitic organisms, low biomass production, good process stability and relatively low treatment cost (Quan et al. 2010).

Basically, anaerobic digestion involves mixing manure with water and storing it in a closed space; microbial digestion of organic matter in the absence of oxygen produces biogas consisting mostly of methane and carbon dioxide.

Anaerobic digestion systems include

- High-rate anaerobic digesters – these normally operate with short hydraulic retention times (typically <48 hours) but can extend solids retention times by integrating solids retention within the main digester. The most common type is an upflow anaerobic sludge blanket (UASB) reactor. These require a low solids feed with relatively high levels of soluble material. They are most often used for domestic sewage treatment and industrial wastewaters (van Lier 2008)
- Covered anaerobic ponds – a heavily loaded pond is covered and the biogas collected from under the cover. This has a low capital cost but relatively large footprint. Regular pond desludging is needed which can be difficult and costly. Because of the large volumes, failure correction can be expensive or impractical
- Liquid mixed digesters – these operate as a fully mixed system with either gas recirculation or mechanical mixing. The maximum in-reactor solids concentration is around 6%
- Liquid plug flow – in this system, semi-solid liquids (10–20% dry matter) pass through a long polyethylene tube or concrete facility. As these systems are not mixed, contact with biomass is poor

- Solid phase (leach bed) – material is loaded into a reactor with leachate liquid circulated through it. Leach beds can operate as either batch or continuous systems with the latter being considerably more expensive (Pavlostathis and Giraldo-Gomez 1991).

Anaerobic digestion of feedlot manure on a commercial scale is yet to be implemented in Australia. Various anaerobic digestion technologies including liquid mixed digesters, covered anaerobic ponds, liquid plug flow and mixed plug flow digestion have been applied to cattle manure in North America (Pillars 2003).

There are significant issues with anaerobic digestion of feedlot manure. In particular, the biological methane potential of harvested manure is relatively low due to its rapid deterioration on the feedlot pad. Optimising the solids concentration for conventional digestion would also require a significant volume of water during the drier months. Nevertheless, a conventional anaerobic digestion system could operate economically in Australian beef feedlots if water were available. The disposal of the resultant saline effluent is an issue (Hertle 2008).

Combustion

Direct combustion is the simplest method of converting waste to energy. It involves burning material in the presence of oxygen to produce heat energy. This heat can then create other forms of energy including steam, hot water or hot air. Direct combustion is also one of the most commonly used technologies, particularly in developing countries where dry cattle dung is used as fuel for domestic cooking.

Typical combustion temperatures for biomass from a livestock origin are 300–550°C. In most direct combustion operations heat energy is used to turn water into steam. Steam may be used to create electricity or a transportable form of heat (Baranyai and Bradley 2008). Waste-to-energy systems that generate both electricity and a source of heat are called cogeneration facilities. The most common method of producing steam is the direct combustion of a fuel beneath boilers.

The moisture content of the biomass being burnt is a major determinant of the efficiency of combustion systems. As the initial phase of combustion involves water evaporation, a lower moisture content means less heat is required to achieve combustion. The suggested optimal moisture content is between 15 and 20%. Wet materials also cause large variations in temperature, leading to inefficient energy conversion, incomplete combustion and the potential build-up of combustible gases (Antares Group Incorporated et al. 1999).

Combustion is a relatively inefficient method of converting biomass into energy, with small combustion systems having heat losses of 30–90% of the original energy potential. Unlike the digestion process not all the nutrients are retained during combustion. Although more than 90% of both phosphorus and potassium remain in the ash after combustion at both 300°C and 550°C, about 44% of the nitrogen is lost at 300°C and 94% at 550°C (Roberts et al. 2009).

Despite promising initial desktop studies, preliminary Australian trials of combustion of harvested beef feedlot manure were unable to demonstrate that this was viable. Further research is required before it is dismissed altogether (Watts et al. 2012).

Pyrolysis

Pyrolysis is the chemical decomposition of a material by heat in the absence of oxygen or oxidising agents. Pyrolysis converts the organic portion of the biomass into a mixture of char and volatile gases containing non-condensable vapours and condensable tars (oxygenated hydrocarbons) which form a pyrolytic oil or bio-oil (Bridgewater 2003). Gases including methane, ethane and acetylene are produced by the process along with ash.

Pyrolysis can be divided broadly into slow or fast pyrolysis, or by the operating temperature. Low temperature slow pyrolysis produces more biochar (and less energy) and is commonly promoted for biochar production. High temperature (approximately 500°C), fast pyrolysis produces more liquid and gas from the same product and less biochar.

Pyrolysis conditions such as temperature and feedstock properties of particle size, lignin and inorganic matter content are key factors influencing the quality of the biochar produced (Demirbas 2004).

Bio-oil has been successfully fired in several diesel test engines where it behaves similarly to diesel in terms of engine parameters, performance and emissions. Work in this area is still in its infancy but there is a considerable effort currently occurring to improve the technology.

Gasification

Gasification is the process of converting materials into a hydrocarbon gas (syngas) through the application of very high temperatures in the absence of oxygen. Syngas consists of carbon monoxide, hydrogen, carbon dioxide and methane. It can be burnt to produce steam or electricity and has the potential to be used in normal combustion engines. Compared to direct combustion, gasification produces carbon and hydrogen-rich fuels which provide more flexibility for energy generation, often with improved efficiencies and environmental performance.

Gasifiers can be categorised into four separate systems

- *Downdraft* – the most common system. Biomass enters the system at the top of the unit and proceeds downwards. Air is fed into the unit above the point where syngas exits (Lynch 2006)
- *Updraft* – the simplest system to operate. Biomass is added to the top of the unit and air is added at the base. The updraft causes ash to settle downwards while the syngas exits near the top. This system has greater tar and failure problems (FAO 1986)
- *Crossdraft* – this type of system pushes air flow across the chamber. Biomass is still added at the top of the unit but the reactions occur sequentially between the air inlet and gas outlet. The proximity of the inlet and outlet increases tar collection problems and requires high quality material to be used. This type of system can be highly economical (FAO 1986)
- *Fluidised bed* – the most complex of the four systems, but it can manage a much wider range of biomass materials. Air is blown through a uniform, heated bedding material causing the material to remain in a suspended state. Biomass added to the bedding material reaches pyrolysis temperature quickly, significantly increasing the amount of syngas generated.

Conventional gasifiers are not compatible with the high silica and ash content in feedlot manure so specialised equipment would need to be developed (Madden 2011).

A major advantage of gasification over direct combustion is lower GHG emissions (including nitrous oxide) with some nitrogen retained and the remainder lost as ammonia. The retention of nitrogen increases the nutrient value and potential price of the resultant by-products. However, gasification is an expensive technology to design, construct, operate and maintain. Gasification facilities require considerable preparation and drying of biomass fuels and substantial heat inputs. Studies have indicated that biomass gasification facilities, especially ethanol production facilities, benefit from economies of scale and need to be large to be viable (Yakima County Public Works 2003).

There has been limited research involving gasification of feedlot manure. For example in Texas, feedlot manure and chicken litter were used as inputs to a fixed bed gasification system (Priyadarsan et al. 2004). The feedlot manure was a blend of 70% manure from a soil-surfaced feedlot and 30% manure from a fly-ash bedded feedlot. The resulting manure had an ash content of around 45% by weight. Three different fuels were tested: the feedlot manure blend, chicken litter and a 50:50 blend of feedlot manure and chicken litter. Both the feedlot manure and the chicken litter could be gasified to produce low-BTU gas with a heating range of 4-4.8 MJ/m^3. However, the high-alkaline chicken litter resulted in agglomeration in the bed which reduced the bed's peak temperature and peak-temperature propagation rate. Blending it with feedlot manure addressed this issue without significantly reducing the heating value of the gas produced.

In Australia, gasification trials using beef feedlot manure have so far been unable to demonstrate that harvested pen manure is suitable for conversion into syngas (Watts et al. 2012). Further research is warranted.

The future

Renewable energy technologies can be cost-competitive in providing energy and industrial heat for Australian agribusinesses but the scale and mix of technologies will be different for each business (Edgerton 2012).

Covered anaerobic ponds or purpose-built anaerobic digesters could possibly be viable systems for beef feedlot manure but there are significant issues to address, including ensuring a regular supply stream of relatively fresh manure. Covering feedlot holding ponds to capture biogas for use as an energy source is not economically attractive, even for large feedlots (Bridle Consulting 2011).

To date, Australian farm-scale trials have been unable to demonstrate that combustion and gasification technologies can be feasibly used to process beef feedlot manure (Watts et al. 2012).

Advanced treatment of effluent

In response to changes in water availability and cost of supply, the industry has expressed interest in treating and reusing effluent as part of the water supply for feedlots.

The major water use within feedlots is drinking water for cattle but significant amounts can be used to wash the animals. In most locations the long-term sustainable effluent yield is around 2.5–5 ML/1000 head/year (Tucker et al. 2011b). Reuse of treated effluent within the feedlot could meet 20–30% of the total drinking water requirement.

Feedlot effluent is a reasonably concentrated wastewater with considerable colour and high concentrations of both inorganic and organic nutrients. Microbiological contamination is a key parameter pertaining to the treatment requirements and safe reuse of effluent, since the pathogen load in raw effluent can be quite high.

Effluent would need extensive tertiary treatment to allow for safe consumption by cattle. Treatments would need to dilute or partially remove salt and considerably reduce organic matter, colour and nutrients to ensure effluent stability and efficient disinfection. At present, the high cost of treating water to this standard would put those installing such a plant at a commercial disadvantage compared to feedlots that have access to cheaper water (Tucker et al. 2011b).

As the recent public debates about recycled water have shown there are other factors to be considered, regardless of whether the risks associated with recycled water are perceived or real. Water recycling in the beef industry is unlikely to be an option for most of the industry unless water prices increase considerably.

Further reading

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