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The anaerobic digestion of pig carcase with or without sugar beet pulp, as a novel on-farm disposal method

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ABSTRACT

Anaerobic digestion was investigated as a potential method for on-farm disposal of fallen stock (pig carcases), degrading the carcase material to produce biogas and digestate. The effects of feedstock (sugar beet pulp or pig carcase material or a 50:50 mix) and organic loading rate (50 g-TS L^{-1} or 100 g-TS L^{-1}), during mesophilic (35 °C) anaerobic digestion were investigated. Anaerobic digestion was achieved for all experimental treatments, however the pig carcase material at the higher organic loading rate produced the second highest methane yield (0.56 Nm^3 kg-VS^{-1} versus a range of 0.14–0.58 Nm^3 kg-VS^{-1} for other treatments), with the highest percentage of methane in total biogas (61.6% versus a range of 36.1–55.2% for all other treatments). Satisfactory pathogen reduction is a legislative requirement for disposal of carcase material. Pathogens were quantified throughout the anaerobic digestion process. *Enterococcus faecalis* concentrations decreased to negligible levels (2.8 $\log_{10}$ CFU g-TS^{-1}), whilst *Clostridium perfringens* levels remained unaffected by treatment throughout the digestion process (5.3 ± 0.2 $\log_{10}$ CFU g-TS^{-1}).

1. Introduction

In 2016, there were approximately 147 million pigs in Europe (Eurostat, 2017), with 4.4 million pigs (DEFRA, 2016) farmed in the United Kingdom (UK). Fallen stock are defined as livestock which have died of natural causes or euthanised on-farm, and are therefore not fit for human consumption. The average mortality rates on UK pig farms are 5.4% sows, 12.2% pre-weanlings, 2.8% during rearing and 2.7% in the finishing herd (AHDB Pork, 2016). This results in a substantial quantity of fallen stock annually which requires safe, legal disposal.

Traditionally, European livestock farmers disposed of fallen stock and animal by-products (ABP) by on-farm open-burning and/or burial (Bansback, 2006). In 1984, bovine spongiform encephalopathy (BSE) appeared in UK cattle (Bansback, 2006) and in 1991, it was established that prions (the BSE causing agent) could remain infective within the soil for up to 3 years following carcase burial (Brown and Gajdusek, 1991). Subsequently, the ingestion of BSE-infected material was linked to the development of variant Creutzfeldt-Jakob disease in humans (Fox and Peterson, 2004). In order to reduce the risk of transmission within the cattle population and to humans, in 2002 the Commission Regulation (European Commission (EC)) No. 1774/2002 prohibited on-farm burning and burial for all fallen stock, irrespective of species susceptibility to prion diseases. This legislation required farmers to use alternative methods of disposal; either on-farm incineration, off-site incineration or off-site rendering. These methods (a) increased the cost of fallen stock disposal to farmers, (b) raised concerns regarding their negative environmental impact and (c) reduced farm biosecurity due to frequent movement of potentially contaminated vehicles between farms and fallen stock collection centres (Massé et al., 2008).

Kirby et al. (2010) surveyed UK livestock (dairy, beef, sheep and pig) farmers to assess their compliance with EU fallen stock regulations and concluded that illegal disposal occurred for 13.7% for fallen stock, 19.5% for aborted foetuses/stillborns and 57.6% for placentas. The European Food Safety Authority (EFSA) provides scope for consideration and approval of new/novel methods for carcase disposal and storage. For a method to be considered, it must

Abbreviations: AD, anaerobic digestion; ABP, animal by-products; BSE, bovine spongiform encephalopathy; CFU, colony-forming units; C:N, carbon:nitrogen ratio; EC, European Commission; EFSA, European Food Safety Authority; FS, feedstock; FW, fresh weight; -H, higher organic loading rate; -L, lower organic loading rate; M, mixed feedstock; OLR, organic loading rate; PCM, pig carcase material; SBP, sugar beet pulp; TS, total solids; UK, United Kingdom; VFA, volatile fatty acids; VS, volatile solids.

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provide scientific evidence to demonstrate a sufficient reduction in disease risk (of 5.0 $\log_{10}$ orders of magnitude), in specific key animal and human health pathogens (EFSA, 2010).

Anaerobic digestion (AD) is commonly used to treat animal slurries, human sewage (wastewater), municipal wastes and food wastes (Alvarez and Lidén, 2008). The AD pasteurisation process can also destroy some pathogens (Escudero et al., 2014) and subsequently if compliant with legislation, the pasteurised digestate can be applied to agricultural land as a fertiliser/soil conditioner (Salminen and Rintala, 2002). In relation to protein-rich feedstocks, a number of investigators have examined the feasibility of using AD for the treatment of slaughterhouse wastes (Jensen et al., 2014; Ortner et al., 2015), specified risk material (potentially prion-infected spinal cord material) (Gilroyed et al., 2010) and rendered ABP (Bayr et al., 2012). Carcase material and slaughterhouse wastes are ideal substrates for AD due to the high contents of organic matter, protein and lipids (Palatsi et al., 2011, Bayr et al., 2012). However, the digestion of high protein content feedstocks can produce high ammonia and volatile fatty acids (VFA) concentrations, which can inhibit biogas production (Sung and Lui, 2003; Nielsen et al., 2007). Moreover, carcase material differs from these previously examined feedstocks, as complete carcases also contains bones, teeth and intestinal content. Few authors have considered the possibility of using the AD process on-farm to digest whole animal carcases. Massé et al. (2014) used AD at psychrophilic temperatures (20 and 25 °C) to successfully digested whole porcine carcases. Yuan et al. (2012) digested carcase fractions, mixed with macerated carcase trimmings (without intestinal contents) at mesophilic temperatures and demonstrated limited methane yields.

Anaerobic digestion is currently not an EFSA approved carcase disposal method as the AD process conditions are unlikely to destroy prions. However, pigs and poultry are not susceptible to prion-infection via natural, oral infection routes (Ryder et al., 2000), although experimental transmission can occur using artificial transmission routes (intracranial, intravenous and intraperitoneal) (Groschup et al., 2007). Therefore, the AD process may be a suitable method for on-farm disposal of pig and poultry carcases. There is a research gap associated with the effective digestion of porcine carcases at mesophilic temperatures, particularly where co-digestion with carbohydrate-rich feedstocks are used to improve process stability and biogas yields. The objective of this research was to investigate the potential of AD for the disposal of pig carcase material (PCM), with and without sugar beet pulp (SBP) as an additional, highly-digestible carbon source. To establish if the AD process would be a suitable novel method for fallen stock on-farm, the research also investigated the potential for destruction of key indicator pathogens (*Enterococcus faecalis*, *Clostridium perfringens* and *Salmonella* spp.), i.e., those described as pathogens in Commission Regulation (EC) No. 1774/2002 and Commission regulation (EC) No. 142/2011.

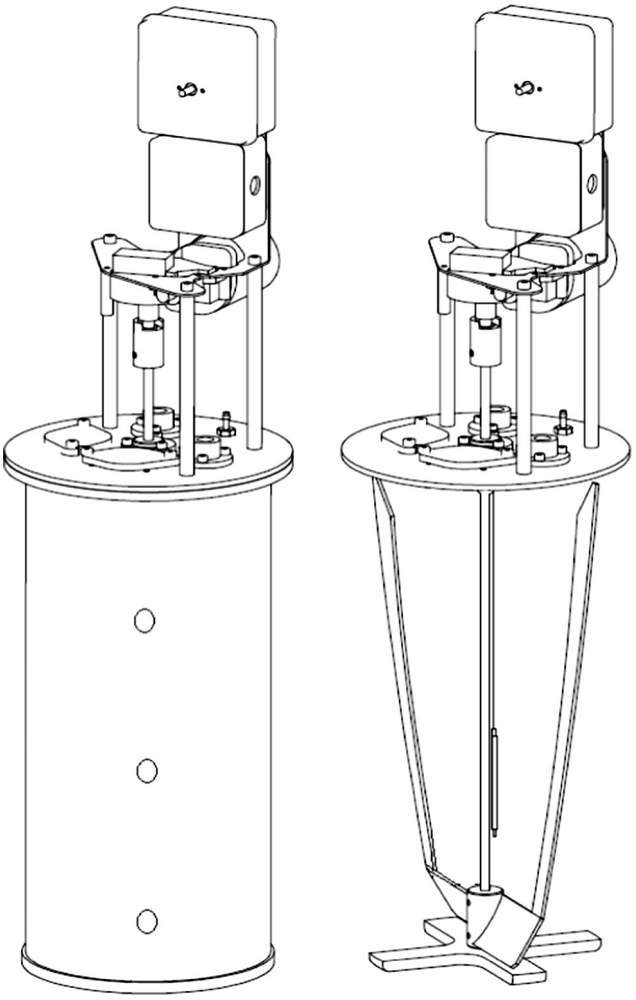

Fig. 1a. Schematic diagram of the exterior surface and internal paddle stirrer configuration of the 12.6 L anaerobic reactors.

Fig. 1b. Photograph of the six operating reactors.

2. Materials and methods

2.1. Reactor design

Six, cylindrical stainless steel bench-top AD reactors (458 mm height, 210 mm diameter), each with a working volume of 10L and head-space capacity of 2.6L (total volume 12.6L) were used for digestion studies. A schematic diagram of the exterior surface and interior paddle stirrer configuration of a reactor is shown in Fig. 1a and the reactors are shown photographically in Fig. 1b. The reactors had 3 wall ports spaced evenly down the cylindrical wall to allow digestate sampling from different levels (top, middle and bottom). The head plate contained a feed port, sampling ports, a gas nipple and a gas-tight paddle stirrer. The gas nipple permitted biogas from the reaction vessel to be collected via tubing into a 5L capacity gas-tight Teflon bag (35 × 26.5 cm) that was both sealable and detachable such that it could be removed for gas analyses. When biogas production was excessive, more than 1 bag could be connected to each reactor. Reactors were intermittently mixed (for fifteen minutes in every hour, except during feeding) using a paddle stirrer connected to a direct current motor (TGE 511, Denso,

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