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Anaerobic co-digestion of potato tuber and its industrial by-products with pig manure

Prasad Kaparaju*, Jukka Rintala

Department of Biological and Environmental Science, University of Jyväskylä, P.O. Box 35, FIN-40014, Finland

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Abstract

The possible use of potato tuber and its industrial by-products (potato stillage and potato peels) on farm-scale co-digestion with pig manure was evaluated in a laboratory study. The methane yields ($m^3\,kg^{-1}$ volatile solids $(VS)_{added\,waste}$) achieved on semi-continuous co-digestion at loading rate of $2\,kg\,VS\,m^{-3}\,day^{-1}$ in continuously stirred tank reactors at 35 °C were 0.13–0.15 at 100:0 (VS% pig manure to VS% potato co-substrate), 0.21–0.24 at 85:15 and 0.30–0.33 at 80:20 feed ratio. Increasing the loading rate from 2 to $3\,kg\,VS\,m^{-3}\,day^{-1}$ at a feed VS ratio of 80:20 (pig manure to potato waste) produced methane yields of $0.28–0.30\,m^3\,kg^{-1}\,VS_{added\,waste}$. Post-digestion (60 days) of the digested materials in batches produced $0.12–0.15\,m^3\,kg^{-1}\,VS_{added\,waste}$ of methane at 35 °C. The results suggest that successful digester operation can be achieved with feed containing potato material up to 15–20% of the feed VS and that under similar feed VS, loading rate, retention time and feed VS ratio, the methane yields and process performance for potato tuber would be similar to that of its industrial residues. Thus, co-digestion of potatoes and/or its industrial by-products with manures on a farm-scale level would generate renewable energy and provide a means of waste treatment for industry.

Keywords: Agro-industrial waste; Ammonia; Anaerobic digestion; Co-digestion; Methane; Pig manure; Potato peel; Potato stillage; Potato tuber

1. Introduction

Interest has recently been growing in the anaerobic digestion of organic waste of farm origin e.g. manures, surplus crop and crop residues as well as organic residues from food

* Corresponding author. Tel.: +358 14 2602231; fax: +358 14 2602321.
E-mail address: prasad.kaparaju@bytl.jyu.fi (P. Kaparaju).

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and other agro-industries as an on-site treatment and source of renewable energy (Braun et al., 2002; Weiland and Hassan, 2001). Apart from biotechnological advantages (Callaghan et al., 1999; Lafitte-Trouque and Forster, 2000; Mata-Alvarez et al., 2000), the co-digestion of different materials may have some organisational and economical benefits too. Besides the energy balance, farm-scale co-digestion can also decrease considerably the investment costs per unit of energy. Indeed, co-digestion may even result in an energy surplus, providing additional income to the biogas plants from the sale of electricity produced or even surplus heat to the grid or by storing the upgraded biogas as vehicle fuel (Brolin and Kättström, 2000; Wellinger, 2000). The surplus crop produced in agriculture and/or its organic residues created during industrial processing can thus form a source of renewable energy and aid in generating additional revenue and diversifying the agricultural activity (Nordberg, 1996).

The major biotechnical advantage of the co-digestion of manures and co-substrates is overcoming the problem in the digestion of agro-residues alone of maintaining a stable pH within the methanogenesis range (Brummeler and Koster, 1990) which is associated with low pH of the substrate itself, poor buffering capacity and the possibility in potential of high volatile fatty acid (VFA) accumulation during digestion (Banks and Humphreys, 1998; Campos et al., 1999). Moreover, co-digestion of manures with agro-residues will also aid in overcoming ammonia inhibition related to pure manure digestion. In general, co-substrates such as agro-industrial residues benefit more from the association of manure (Molnar and Bartha, 1998), as manures can be excellent base substrates due to their inherent high buffering capacity, high ammonia content and a wide range of nutrients needed by the methanogens (Angelidaki and Ahring, 1997; Wilkie et al., 1986).

The potato, a staple food in many European countries, has been chosen among the various agricultural crops produced worldwide, because it is produced in surplus quantities. Estimated potato tuber production in Europe was 307 million metric tons in the year 2002 (FAOSTAT, 2002). Potato tuber in general contains 70–80% water and the main dry matter component is starch. Potato is processed into several industrial products ranging from dietary products such as potato crisps, deep-frozen French fries, dehydrated potatoes and canned new products to alcoholic beverages and industrial starch. In one industrial process, the chemical structure of the starch is altered to obtain glue, used primarily as a raw material in the paper industry. During the sedimentation of this starch residue a thick stillage of no commercial interest is produced.

To our knowledge, there is no literature on the co-digestion of potato and its industrial by-products with manure. Potato and its industrial by-products in general contain high quantities of soluble organics that would rapidly be converted into VFA. If sufficient buffering capacity is not present in single stage digesters, the pH would be depressed and methanogenesis might be inhibited (Kang and Weiland, 1993). However, previous studies on successful digestion of potato pulp (total solids (TS) 18–21%) or potato thick stillage (14–18% TS) produced 300–500 m^3 of biogas per ton of dry matter with a 50–70% degradation (Weiland, 1993). Whereas, the ultimate biodegradability reported for potato peel in a 37–85 days (35 °C) batch digestion at a substrate to inoculum ratio of 0.8 was 86–91% (Kang and Weiland, 1993). Stewart et al. (1984) on the other hand, reported a methane yield of 0.426 $m^3\,kg^{-1}$ (VS) with complete destruction of solids under continuous digestion of potato waste (peel and rejects) at loading rate of 2.5 kg VS $m^{-3}\,day^{-1}$ in a continuously stirred tank reactor (CSTR) at 35 °C and 20 days hydraulic retention time (HRT).