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# Processing anaerobic sludge for extended storage as anaerobic digester inoculum

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## HIGHLIGHTS

- Different methods were used to reduce MC of sludge for storage as digester inoculum.
- The methanogenic activity of sludge at different MC levels was assessed and compared.
- Effect of storage time of up to 4 months on methanogenic activity was evaluated.
- Processed and stored sludge retained between 76% and 99% of fresh sludge methane yield.

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## ABSTRACT

Thermophilic anaerobic sludge was processed to reduce the volume and moisture content in order to reduce costs for storing and transporting the sludge as microbial inoculum for anaerobic digester startup. The moisture content of the sludge was reduced from 98.7% to 82.0% via centrifugation and further to 71.5% via vacuum evaporation. The processed sludge was stored for 2 and 4 months and compared with the fresh sludge for the biogas and methane production using food waste and non-fat dry milk as substrates. It was found that fresh unprocessed sludge had the highest methane yield and the yields of both unprocessed and processed sludges decreased during storage by 1–34%, however processed sludges seemed to regain some activity after 4 months of storage as compared to samples stored for only 2 months. Maximum methane production rates obtained from modified Gompertz model application also increased between the 2-month and 4-month processed samples.



## 1. Introduction

Anaerobic digestion (AD) is becoming increasingly popular as an efficient method for converting a wide range of organic materials into biogas (primarily methane) and digested sludge (or digestate). Many countries have developed incentive policies to promote the development of anaerobic digesters for waste treatment and energy recovery. For example, the European Union requires at least 25% of bioenergy to be produced via biogas in the future (Holm-Nielsen et al., 2009). In the United States, there are various incentive programs at both federal and state levels for anaerobic digestion projects. The California Bioenergy Action Plan recently has set a goal of producing 95 MW electricity from dairy manure and 250 MW electricity from other organic wastes.

Successful development of anaerobic digesters involves the startup of new digesters, which requires establishment of suitable environment and microbial populations needed to achieve the desired performance. Commonly, anaerobic sludge from an existing anaerobic digester is used as inoculum for a new digester. When there are no digesters nearby, animal manure or wastewater lagoon sludge are used as sources of microbes but the enrichment process can take considerable time as the methanogenic populations and activities are low, requiring a period of weeks to months to cultivate a healthy population of methanogens and other microorganisms needed for efficient full-scale digester operation

*Abbreviations:* OS, original sludge effluent from an operational anaerobic digester; CS, centrifuged original sludge; CES, centrifuged and further evaporated original sludge; MC, moisture content; FW, food waste; NFDM, non-fat dry milk; BMP, biochemical methane potential; BD, biodegradability; Fresh sludge, sludge without storage; TS, total solids; VS, volatile solids; F/M ratio, food to microorganism ratio; EBY, experimental biogas yield; EMY, experimental methane yield; TMY, theoretical methane yield; DBY, daily biogas yield; DMY, daily methane yield.

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**Table 1**
Characteristics of anaerobic sludge and substrates.

| Sample | OS | CS | CES | FW | NFDM |
|---|---|---|---|---|---|
| MC (%)[a] | 98.7 ± 0.2 | 82.0 ± 0.4 | 71.5 ± 3.2 | 76.6 ± 0.4 | 4.1 ± 0.1 |
| TS (%)[a] | 1.3 ± 0.2 | 18.0 ± 0.4 | 28.5 ± 3.2 | 23.4 ± 0.4 | 95.9 ± 0.1 |
| VS (%)[a] | 0.9 ± 0.1 | 14.7 ± 0.3 | 22.4 ± 2.6 | 22.0 ± 0.3 | 88.0 ± 0.1 |
| VS/TS (%) | 67.4 ± 0.2 | 81.5 ± 0.4 | 78.6 ± 0.5 | 94.0 ± 0.2 | 91.8 ± 0.1 |
| Ash (%)[a] | 0.4 ± 0.1 | 3.3 ± 0.1 | 6.1 ± 0.6 | 1.4 ± 0.2 | 7.8 ± 0.1 |
| C (%)[b] | ND | ND | ND | 48.9 ± 0.2 | 42.9 ± 0.1 |
| H (%)[b] | ND | ND | ND | 7.7 ± 0.1 | 6.0 ± 0.1 |
| O (%)[b] | ND | ND | ND | 34.7 ± 0.1 | 44.1 ± 0.3 |
| N (%)[b] | ND | ND | ND | 2.7 ± 0.1 | 1.8 ± 0.1 |

ND, not determined; OS, original sludge; CS, centrifuged original sludge; CES, centrifuged and further evaporated original sludge; FW, food waste; NFDM, non-fat dry milk.
[a] As total weight of sample.
[b] As TS of sample.

(Zeeman et al., 1988; Zhao et al., 2013). A recent review of thermophilic anaerobic digestion systems indicated that many operational problems associated with thermophilic systems might be attributed to inconsistencies in the common practice of adapting mesophilic inoculum to thermophilic conditions (De la Rubia et al., 2013). For low solids digesters, recommended inoculum rates may range from 0.5% to 15% of the operating total solids (TS) content by mass, and research on high solids anaerobic digestion indicates that up to 50% of TS may be required as inoculum to achieve a rapid start-up (Li et al., 2011; Brown and Li, 2013; Zhu et al., 2014). Therefore, it would mark a significant time and cost savings to develop a proper method to produce concentrated anaerobic sludge that can both be stored and transported economically while retaining the methanogenic activities in the sludge for efficient start-up of new digesters.

Considerable past research has focused on treatment options for separation and dewatering of anaerobic sludge or digestate, such as centrifugation and vacuum evaporation (Mihoubi, 2004; Rehl and Müller, 2011; Chiumenti et al., 2013). It was also reported by Agrawal et al. (1997) that dried pelletized anaerobic sludge containing only 12% moisture content (MC) achieved stable performance during mesophilic wastewater digestion with variations in organic loading rates. Other studies have reported that reducing MC in anaerobic digestion systems can lead to decreasing methanogenic activities. Lay et al. (1997) found methanogenic activity of mesophilic sludge dropped by 47% when MC decreased from

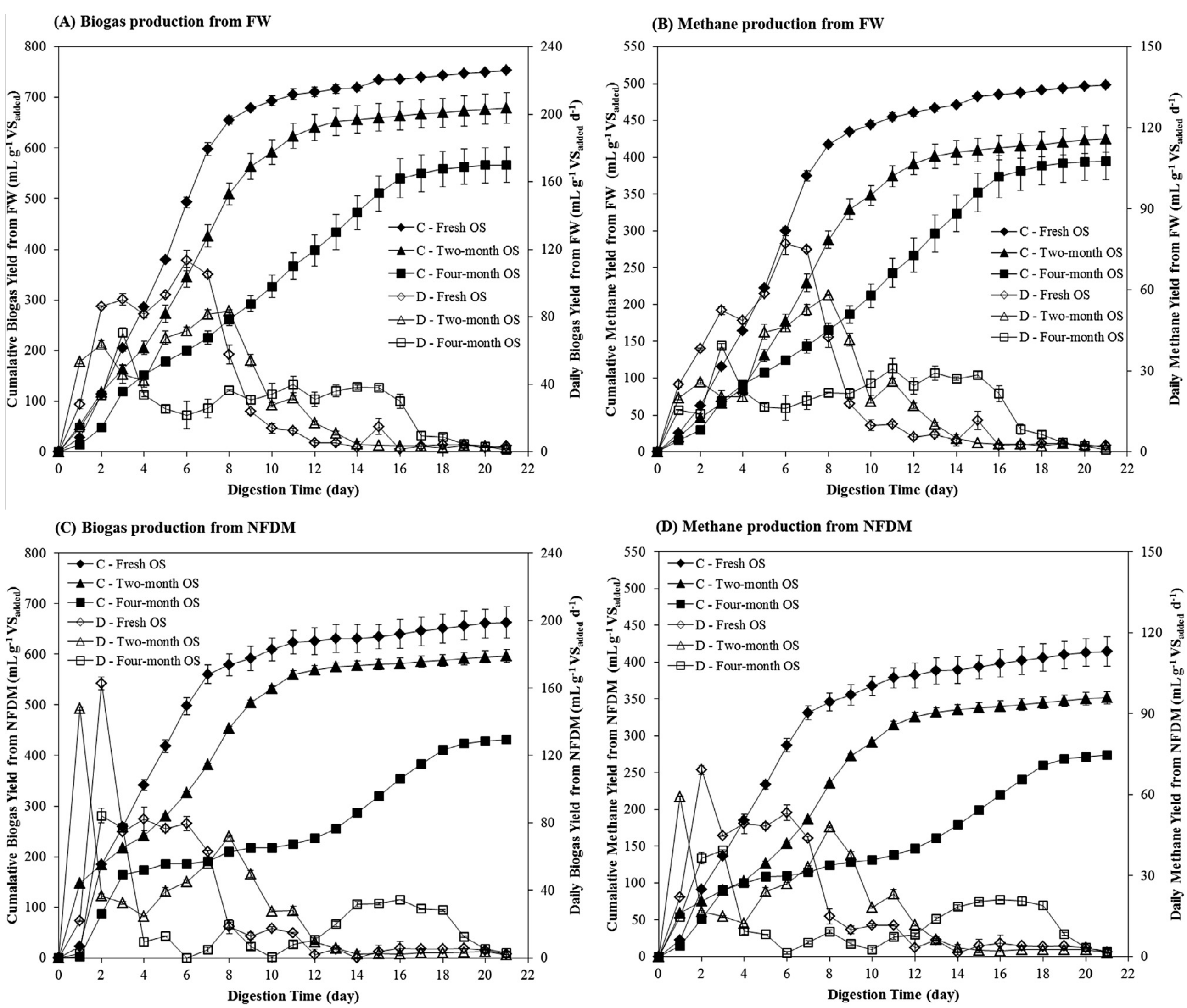


**Fig. 1.** Daily and cumulative biogas production from FW and NFDM with fresh and stored original sludge. FW, food waste; NFDM, non-fat dry milk; OS, original sludge; C, cumulative gas yield; D, daily gas yield.