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Review paper

A review on Co-Digestion of Vegetable waste with Organic wastes for Energy Generation

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Abstract

Fossil fuels, a non-renewable energy resource provides 80 per cent of the world's primary energy supply today. Several environmental and social costs are associated with the heavy dependence on fossil fuels for energy. The sustainable development of the environment requires use of renewable energy alternatives. Solar energy, wind energy, small hydropower, biomass, and municipal and industrial wastes are the freely available major renewable sources of energy. The use of waste biomass for renewable energy offers several benefits and thus the use of agricultural waste becomes a brilliant spot for generation of energy. Vegetable waste represents a major share of agricultural wastes. A Hugh quantity of vegetable waste is produced in market every day. Vegetable wastes are perishable and cause nuisance. The present inappropriate vegetable waste management systems results in loss of potentially valuable materials that can be processed to generate fuel and fertilizer. Hence, appropriate vegetable waste management system is needed for environment protection. Anaerobic digestion results in generation of biogas and effluent which serve as a natural fertilizer. Co-digestion is preferred over anaerobic digestion because of several benefits associated with it. Thus, the aim of the present review paper is to focus onto detailed aspects of co-digestion of vegetable waste with other organic wastes for energy generation.

Keywords: Co-digestion, energy generation, organic wastes, vegetable wastes, etc.

Introduction

Biomethanation is the anaerobic digestion of biodegradable organic waste under controlled temperature, moisture and pH conditions in an enclosed space to generate biogas comprising mainly methane and carbon dioxide[1,2]. Methane, a source of renewable energy can be converted into electricity[2,3] and effluent from biomethanation plant can be used as soil conditioner[2,4,5].

Co-digestion, also called as co-fermentation is the mixing of different wastes together and its anaerobic digestion to produce energy[6]. Co-digestion is preferred over anaerobic digestion of waste alone due to its several advantages[7,8]. Co-digestion increases the load of mixed nutrients and thus accelerates biodegradation rate by biostimulation[9]. Beacause of increased biodegradable organic matter, the rate of digestion increases which results in higher biogas yield[10]. Better biogas yield in co-digestion is associated with the synergistic effect of microorganisms. The sludge of better quality is also produced in co-digstion process. Co-digestion results in dilution of toxic compounds if any one of substrate has high associated toxicity. It also improves carbon to nitrogen ratio of substrate[11].

Co-digestion of vegetable waste (VW) with fruit waste

Co-digestion of vegetable waste with fruit waste (FW) has been carried out by several workers. Das and Mondal[12] studied the anaerobic digestion of fruit and vegetable waste in batch reactors at 15 days hydraulic retention time (HRT) and 27°C. The yield of biogas and HRT was studied for individual anaerobic digestion processes at varying organic loading rates (OLR) and catalyst concentrations to observe the best concentration for maximum biogas production. Maximum yield of biogas was obtained with OLR as 5% slurry concentration and optimal catalyst concentration as 1.5g/l. Sagagi et al[13] studied biogas production from fruits and vegetables waste materials and their effect on plants for determining its manural value. The highest weekly individual production rate was recorded for the cow dung slurry (1554 cm3 biogas), followed by pineapple waste (965 cm3), orange waste (612cm3), lastly, 373 cm3 and 269 cm3 biogas yield was associated with pumpkin and spinach wastes respectively. Alvarez[14] reported 0.07 m^3 biogas/ kg VS added from anaerobic digestion of FVW in mesophilic digester with HRT 30 days and OLR 0.3-1.3 kg VS/m^3 day. Gunaseelan[15] studied the biochemical methane potential (BMP) of 54 fruits and vegetable wastes samples and eight standard biomass samples for determining the methane yield. The ultimate methane yields and kinetics of fruit wastes ranged from 0.18 to 0:732 l /g VS added and 0.016 to 0.122 /d, respectively, and that of vegetable wastes ranged from 0.19 to 0:4 l /gVS added and 0.053 to 0.125 /d, respectively. The biogas yield in the range of 0.18-0.732 L/g VS and 0.19-0.4 L/g VS was reported for fruit and vegetable wastes respectively[15]. Bouallagui et al[16] studied anaerobic digestion of fruit-vegetable wastes (FVW) under thermophilic conditions in tubular digester at 20 days HRT, Feeding concentration 6% total solids (TS), the biogas yield was 603.46 l/kg VS added. Bouallagui, et al[17] studied anaerobic digestion of FVW (from fruit market) under mesophilic conditions in two phases reactor at OLR 7.5 g COD/ l.d, the biogas yield was 450.3 L ± 22.3 /kg COD added. Bouallagui et al.[18] reported the biogas yield of 452.6 liter per kg VS through fruit and vegetable waste biomethanation using tubular digester run in mesophilic conditions at 20 days HRT and OLR of 6% TS.

The co-digestion of fruit -vegetable waste with other organic waste has been attempted by few workers. Earnest and Singh[19] studied the co-digestion of vegetable and fruit waste for its biomethanation potential using cow dung in various proportions. The lab scale study was conducted using anaerobic digester of capacity 1.5L run in ambient temperature conditions at 15 days HRT. The biogas yield of 245 ml was observed as maximum with 1:1 (VW: CD) and 230 ml biogas yield with 1:2 (FW: CD). Callaghan et al[20] studied co-digestion of cattle slurry with fruit and vegetable waste and chicken manure. Co-digestion of 20% FVW in 9 fractions with 80% cattle slurry under mesophilic conditions at 21 days HRT and OLR 3.19- 5.01 kg VS/m^3 day produced the biogas 0.23 m3/kg VS added. Liu et al[21] studied anaerobic co-digestion of food waste, fruit–vegetable waste and dewatered sewage sludge using a continuous stirred-tank reactor at pilot scale for energy generation. The maximum and stable biogas was produced at the rate of 4.25 m^3 /m^3 d at OLR of 6.0 kgVS /m^3 d and HRT of 20 days. Garcia-Pena et al[22] studied biomethanation potential of fruit and vegetable waste (FVW) from the central food distribution market in Mexico City. The biogas production, methane yield and volatile solids removal from the FVW was found to be 0.42 mbiogas3/kg VS, 50%, and 80%, respectively was obtained with batch systems. Co-digestion of the FVW was studied with meat residues at 30 L anaerobic digestion system. The methane yield obtained was 0.25 m^3/kg TS and reduction of chemical oxygen demand (COD) was found to be 65%. Voegeli et al[23] studied biomethanation of kitchen waste in Tanzania. The average daily biogas yield of 290 L/d and 130 L/d was observed with the daily feeding of 2 kg wet weight of food waste and market waste respectively. TS reduction of 84.9% and 72.8% was obtained with food waste and market waste respectively. The reduction of organic load was described by measuring the input and output of volatile solids. Food waste and market waste exhibited the average VS reduction of 92.2% and 85.3% respectively.

Co-digestion of vegetable waste (VW) with animal wastes

Beatriz et al[24] evaluated co-digestion of animal wastes- swine manure (SM), poultry litter (PL) and vegetable processing wastes (VPW) mixtures to determine its biomethanation potential. In SM-VPW co-digestions, CH_4 yield increased from 111 to 244 mL CH_4/ g VS added with the VS reduction from 50% to 86%. For PL-VPW co-digestions, the biogas yield reported was 158 to 223 mL CH_4/ g VS added and VS reduction was found to be 70% to 92%. Beatriz et al[25] studied anaerobic digestion of animal wastes with vegetable processing wastes. Islam et al[26] studied the effect of co-digestion of vegetable waste and cow-dung in various proportions using 4 L capacity laboratory scale digesters. Vegetable waste was used from 200 gm to 300 gm, and cow-dung was used from 0 gm to 300 gm to make vegetable waste to cow dung ratios from 1:0 to 1:1.5. From 2 to 3 mm sized vegetable waste was used in the experiment. The digester was feed on batch mode and operated at ambient temperature and HRT of 15 days. In the slurry, total solid concentration was maintained 8% by mass for all of the observations. The maximum amount of biogas yield was 1200 ml/Kg of wastes at the vegetable waste and cow dung ratio 1:1. Alvarez and Liden[14] evaluated the biomethanation potential of solid slaughterhouse waste, fruit-vegetable wastes, and manure in semi-continuous manner under mesophilic temperature conditions. The present biomethanation study was conducted in semi-continuous manner at 35 °C using four laboratory scale 2 L reactors. The methane yields of 0.3 m^3 /kg VS with 54–56% methane content was obtained with the OLR of 0.3–1.3 kg VS /m^3 d. They also studied co-digestion in a mixture experiment using 10 different feed compositions. Biogas yield after 60 days for the mixture was in the range 1.1–1.6 L /d. The methane content was found to be 50–57%. The methane yields and VS reductions were found to be 0.27–0.35 m^3 /kg VS and 50%-67% respectively. Alvarez[27] studied co-digestion of 67% FVW, 17% solid slaughterhouse waste and 17% manure in mesophilic digester with HRT 30 days and OLR 0.3-1.3 kg/ VS/m^3 day. The biogas yield reported was found to be 0.35±0.02 m^3 / kg VS.

Kim et al[28] developed a modified three-stage methane fermentation system for the treatment of food waste. They studied the effect of temperature and HRT on the methanogenesis. The biogas yields with its methane content and Soluble COD removal rate was found to be higher with reactor fed with liquor food waste and run in thermophilic conditions than the reactor run in mesophilic conditions. The methane yield was found to be highest in the reactor at 12 d HRT (223 l CH4/kg sCOD degraded).

Kumar et al[29] studied the biomethanation potential of potato waste and cattle manure admixture at 37±1°C. Potato waste and cattle manure was taken in various proportions for biomethanation. Biogas production rate was higher with (1:1) potato waste and cattle manure. They determined the effect of 2.5 and 5.0 ppm concentrations of three heavy metals (Cd, Ni and Zn) on biogassification of substrate. All three heavy metals enhanced biogas yield as compared to control set at 2.5 ppm concentration. Heavy metal in order of Cd, Ni and followed by Zn increased the biogas yield. The 2.5 ppm concentration of Cd was found to produce highest biogas yield as compared to other two heavy metals. Kale and Mehetre[30] studied the production of biogas from Kitchen waste, dry leaves, green grass, animal remains, paper etc. Aerobic and anaerobic digestion was carried out for about 10-12 days. The biogas produced had 70-75% methane content. Lastella et al[31] determined the effects of different bacteria inoculums on the biomethanation process based on organic waste which was obtained from the orthofruit market. Fruteau de Laclos et al[32] studied the biomethanation potential of municipal solid wastes at a OLR 2.5 kg VS/m^3.d.The biogas yield obtained was 0.38 m3/kg VS with 61 methane and 70% VS degradation.

Co-digestion of vegetable waste (VW) with sewage sludge

Kuglarz and Mrowiec[33] studied the co-digestion of organic fraction of solid municipal waste (OFMSW) and sewage sludge. They investigated the effect of kitchen remnants on the biomethanation of OFMSW. Bouallagui et al[34] studied the co-digestion of mixture of fish waste (FW), abattoir wastewater (AW) and waste activated sludge (WAS) as co-substrates on the FVW anaerobic digestion. Four anaerobic sequencing batch reactors (ASBR) were run at 10 days HRT under mesophilic conditions. The reactors were loaded with OLR of 2.46–2.51 /g VS. l. d·, of which 90% share of substrate were from FVW. For the biomethanation of FVW with other organic wastes, carbon to nitrogen ratio (C/N) of 22-25 was found to be optimal. Panyue Z et al[35] studied biomethanation potential of biosolids and OFMSW admixture and compared it with the biomethanation of biosolids alone. Carbon to nitrogen ratio of the feed material was increased from 8.10 to 17.68. The total and volatile solid reductions reported during the present study were over 30% and 65% respectively. Gomez et al[36] studied the biomethanation of primary sludge (PS) and admixture of PS and fruit and vegetable fraction of municipal solid wastes (FVFMSW) in a reactor run under mesophilic conditions. The biogas yield obtained during the two digestion processes reported were 0.6–0.8 l /g VS and 0.4–0.6 l /g VS added for the first and second parameter respectively.

Conclusion

Biogas yield and volatile solids removal efficiency in co-digestion of vegetable waste with other organic wastes is higher than the anaerobic digestion of vegetable waste alone. Vegetable waste and animal waste combination is found to be better since it yields high amount of biogas. Thus co-digestion appears to be a potential economically viable option for the generation of renewable source of energy. It also controls environmental pollution by treating the waste in an eco-friendly manner.

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