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Review Paper

Anaerobic digestion of Vegetable waste for Biogas generation: A Review

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Abstract

World's vegetable production is strongly concentrated in Asia. India is next only to China in area and production of vegetables in the world. Vegetable waste is produced in huge quantities during the harvesting, poor and inadequate transportation, storage facilities, marketing practices and processing of vegetables. These serve as source of nuisance. The present methods used to dispose the vegetable wastes are inappropriate and cause environmental pollution. Biomethanation is an attractive option for vegetable waste treatment. Biomethanation is the anaerobic digestion of organic matter under controlled conditions of temperature, moisture and pH in an enclosed space to generate generates energy and nutrient rich effluent. The purpose of this review paper is to focus onto biomethanation studies on vegetable waste with respect to yield of biogas and pollution abatement studies.

Keywords: Anaerobic digestion, biogas, vegetable waste, environmental pollution, etc.

Introduction

Vegetables in our daily diet are the source of proteins, vitamins, minerals, dietary fibers, micronutrients, antioxidants and phytochemicals. The diverse soil and climatic conditions in the country makes it possible to grow variety of vegetables. More than 40 kinds of vegetables belonging to different groups are grown in tropical, sub-tropical and temperate regions of the country.

The vegetable markets produce plenty of vegetable waste per day. The disposal of these wastes is a very serious issue. The present vegetable waste disposal methods include dumping in municipal landfills, spreading on land and by feeding to animals. These unscientific methods results in environmental pollution. These methods results in land, water and air pollution[1]. The treatment of vegetable wastes with the biological methods appears to be economical and also controls environmental pollution[2].

Biomethanation is an attractive option among the biological methods since it generates biogas comprising mainly methane and carbon dioxide[3]. Methane can be converted into electricity[4,5] and effluent from biomethanation plant have nutritive value[6,7].

Biogas yield and pollution abatement studies during anaerobic digestion of vegetable waste

There are several reports on anaerobic digestion of vegetable waste for biomethanation potential. The anaerobic digestion of mixture of vegetable wastes was performed by Dhanalakshmi et al in a 2 L capacity single stage mesophilic anaerobic reactor[8]. They operated the reactors at two different organic loading rates (OLR) 0.25 and 0.5gVS/l.d, with the HRT of 25days. The average biogas production was 0.150 and 0.300 L/day for two OLR rates respectively. Percent conversion of TS and VS was in the range of 53-62% and 62-67% respectively for two OLRs. The biogas yield was, 0.383 and 0.522 l/g TS added and 0.423 and 0.576 l/g VS added for the two OLR respectively. The methane content in the gas was around 63% and methane yield was 0.226 and 0.362 l CH4 / g VS added for the selected vegetables for the two OLR respectively. Dhanalakshmi and Ramanujam[9] analyzed the performance of the vegetable waste based batch reactor and for determining cumulative biogas production for a given organic loading rate. The OLR used in experiment was in the range of 0.06 gm VS to 0.47 gm VS. Biogas production increased from OLR 0.06 gm VS to 0.26 gm VS and thereafter quantity decreased. Maximum Cumulative gas produced was found to be 3764 ml for 0.26 gm VS OLR. Babaee and Shayegan[10] conducted experiment to investigate the production of biogas from vegetable wastes by using anaerobic digestion process. They operated the digester at different organic feeding rates of 1.4, 2 and 2.75 kg VS/ m^3.d. The methane content of biogas was in the range of 49.7- 64% and biogas production rates was in the range of 0.12-0.4 m^3 biogas/ (kg VS input). The methane yield was found to be 0.25 m^3CH4/kg VS with 88% VS reduction at OLR of 1.4 kg VS/ m^3.d. Biomethanation of vegetable waste was carried out in mesophilic conditions by Velmurugan and Ramanujam[11] using a fed-batch laboratory scale reactor. The average methane content in the biogas was 65% and the Methane yield was 0.387 l CH4/g VS added for the selected types of wastes. Kumar et al[12] carried out a batch digestion of mixed vegetable market waste using 5% Total Solid (TS) concentration in a laboratory-scale digester of 10 L capacity. The biogas yield of 0.15 m³ / kg TS was observed after 41 days. The maximum biogas production rate of 650 ml/hour was observed on day 25. The Chemical Oxygen Demand (COD) reduction observed during the present study was found to be about 65%.

Biomethanation of vegetable waste at scale up studies has been carried by several workers. Kameswari et al[13] studied biomethanation of vegetable market waste using bioreactor of capacity 30 tonnes per day. The biomethanation plant was designed for 30 tonnes per day, organic loading rate of 2.5 kg of VS/day/m3 with biogas generation of 2500 m3 of biogas per day. Biswas et al[14] studied the anaerobic digestion of vegetable market waste in anaerobic digester of 10 dm3 capacities in a batch mode at an optimum temperature of 40^{o}C and 6.8 pH. They studied the effect of slurry concentration and that of the concentration of carbohydrate, protein and fat in the slurry on the biogas production rate and methane concentration in the biogas. A maximum concentration of methane in the order of 80% was obtained. Shashikant et al[15] used 5 L capacity pyrex glass aspirator bottles for vegetable waste based Biomethanation. Biogas yield was 0.9 L/g VS added. Ranade et al[16] studied biomethanation using market waste consisting of rotten vegetables using 25 L capacity lab scale biogas plant of floating dome design. The biogas yield was 175 L/day corresponding to 35 L/kg/day. Scale up studies on 200 L capacity biogas plant produced 302 L/kg/day.

Several reports are available on biomethanation studies on vegetable component of kitchen waste. Lama et al[17]conducted a study at Kathmandu University, Nepal to determine the biomethanation potential of biodegradable portion of kitchen wastes from Kathmandu University Premises. Modified ARTI model compact biogas plant of 1 m^3 digester and 0.75 m gasholder was used for biomethanation. The maximum methane gas and average maximum carbon dioxide recorded was found to be 65% and 58% respectively. The average gas production was found to be 173 L/day. Liu et al[18] studied biomethanation of vegetable wastes collected from school canteen and vegetable leaves, stems and roots were mixed with the ratio of 1:1:1 using 15L capacity reactor made of plexiglass. The operational parameters for biomethanation were 100 to 128:4:1 C: N: P ratio, 35^{0}C temperature, OLR of 2.0 gVS/l.d. Biogas yield was in the range of 3.0 L /d to 3.5 L/d with 55% and 58% methane. Kitchen waste was used for biogas production by Voegeli et al[19]. The average daily gas production amount was found to be 290 L/d and 130 L/d when fed daily with 2 kg market waste. TS reduction of 84.9% for food waste and 72.8% for market waste with feeding period with 2 kg/d. VS reduction 92.2% and 85.3% for food and market waste respectively with 42.5 days HRT. COD reduction was approx. 83%. Chen et al[20] established a 15 m3 capacity two-phase anaerobic digestion pilot plant for kitchen waste. They observed more than 80% VS reduction with the biogas yield of 0.6 m3/ kg VS.

Biochemical methane potential (BMP) of vegetable waste is determined by several researchers. Labatut et al[21] determined the BMP and biodegradability of an array of substrates with highly heterogeneous characteristics, with dairy manure. The results of about 175 individual BMP assays indicate that substrates rich in easily degradable carbohydrates yield the highest methane potential whereas the high lignocellulosic fraction exhibited the lowest yield. Co-digestion of dairy manure with easily degradable substrates increased the specific methane yields as compared to manure digestion only. Nguyen et al[22] studied anaerobic digestion of organic fraction of municipal solid waste at a OLR 0.8kg VS/m3.d.The biogas yield obtained was 0.26m3/kg VS with 60 methane and 61% degradation of VS. Selina and Joseph[23] studied batch digestion of vegetable waste slurry in the laboratory using 2.5 L capacity bottle reactors for 60 days at ambient temperature conditions. The biogas yield from vegetable waste was found to be 0.391L/g of VS added. The methane content of the biogas was in the range of 67% during the first ten days and afterwards 68%-70%. The BMP was found to be 0.269 L CH4/g VS added.

Ojolo et al[24] examined the potential of vegetable component of municipal solid wastes. The batch fed 200dm^3 capacity anaerobic digester was fed with 10-20 kg of vegetable and operated at 8-10 % TS of substrate, 40 days HRT and temperature of the fed substrate was within 29ºC and 33ºC. The average biogas yield varied from 5.15 dm^3/kg TS to 5.83 dm^3/kg TS. Davidsson et al[25] determined the methane yield from 17 types of domestically organic fraction of municipal solid waste (OFMSW) in thermophilic digestion. The VS reduction was 80% and a methane yield of 300–400 Nm^3 CH_4/ton VS_{in} was obtained with 15 days HRT corresponding to about 70% of the methane potential.

Many workers have used two phase anaerobic processes during the biomethanation studies on vegetable wastes. Zhu et al[26] studied biomethanation of Vegetable wastes using anaerobic sludge bed reactors (ASBR). The experiment was carried out at mesophilic temperature conditions (35^{0}C), HRT was 4 days and 20 days for hydrolytic reactor(HR) and methanogenic reactor(MR) respectively, OLR in HR and MR was 10/ g VS L and 5 g VS L-1 respectively. The biogas yield was about 660/g VS with 60±3% methane. Kamaraj[27] studied vegetable market waste biomethanation process using biphasic anaerobic systems. The biogas and methane yields recorded were 511.8 and 352.7 l/ kg COD des respectively with a COD reduction of 75.6 % and 29.9 l/kg VMW fed. Rajeshwari et al[28] studied biomethanation of solid vegetable market waste using two-stage digester: 100 L solid bed digester for hydrolysis and acidification and 24.6L Upflow anaerobic sludge blanket (UASB) reactor for biogas production. The COD reduction of 94% was achieved during UASB reactor operation at organic loading rate of 19.6 kg COD m day^{-3}.

Biswas et al[29] developed a deterministic mathematical model to predict the characteristics of an anaerobic digester of biogas generation satisfactorily. Mondal and Biswas[30] performed comparative study on production of biogas from green vegetables wastes and dried vegetable wastes at different temperatures viz.20 °C, 28 °C and 38 °C and solid concentrations (4%-8 %) in slurry by using two identical anaerobic bio digesters run in batch mode at pH 6.9. Maximum biogas (0.8 L/Kg DM/day) was produced at 6% solids conc. Dried vegetable waste showed 11.0 L biogas /Kg and green vegetable waste showed 6.5 L biogas /kg at 38 ° C. Study showed high biogas yield and methane yield with the dried grinded vegetable was as compared to green vegetable wastes.

The effect of catalysts on biogas yield by anaerobic digestion is studied by several scientists. Duran-Garcia et al[31] assessed biogas production from peeling residues of potatoes, cabbage and carrots using several anaerobic digesters. They estimated the biogas yield, substrate pH and substrate concentration, using different types of catalysts. Kumar et al[32] studied the effect of Ni(II), Zn(II) and Cd(II) on biogas production from potato waste and cattle manure mixture using fixed anaerobic batch digester. Maximum biogas was produced with 0.5:0.5 combination of potato waste and cattle manure. All the three heavy metals increased biogas yield over the control at 2.5 ppm concentration. The Cd^{++} at 2.5 ppm was found to produce maximum biogas in terms of volume.

Conclusion

Vegetable wastes have high carbohydrate and high moisture content and thus are a good substrate for the production of biogas through biomethanation process. Several researchers have studied biogas production from mixture of vegetable waste. Biogas yield reported by researchers is in the range of 0.360 L/g of VS to 0.9 L/g VS added. The temperature, pH and organic loading rates have a pronounced effect of vegetable waste biomethanation. The reactors of different designs also influence on the biogas yield. The use of appropriate catalysts is found to increase the biogas yield from anaerobic digestion of vegetable waste. Biomethanation process also reduces the load of organic pollutants in terms of reduction of TS, VS, BOD and COD. Thus, biomethanation appears to be an eco-friendly technology for the treatment of vegetable waste.

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