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Biomethanation Potential Study of Individual and Combined Vegetable Market Wastes

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Abstract

The vegetable markets produce plenty of vegetable waste per day. Vegetable wastes are perishable and are responsible for great amount of environmental pollution. Biomethanation is an attractive option for vegetable waste treatment. Several studies have been reported on the biomethanation of mixture of vegetable wastes by different researchers using anaerobic digesters of different designs and capacities. There are very few reports on biomethanation potential of individual vegetable waste types. Thus, the purpose of this study was to determine the biogas yield and volatile solids removal efficiency using individual vegetable waste types and combination of these individual vegetable wastes in equal proportions using floating dome design type of reactor of 1 liter capacity. The daily biogas yield in terms of gm VS/l.d added from individual vegetable waste ranged from 0.483 L/gm VS to 0.674 L/gm VS. Potato waste and Onion waste exhibited highest and lowest biogas yield respectively. Mixture of vegetable waste exhibited the biogas yield of 0.654 L/gm VS. Maximum VS and BOD reduction was associated with the tomato waste whereas cauliflower waste exhibited minimum VS and BOD reduction.

Keywords: Vegetable waste, pollution, biomethanation, energy generation, etc.

Introduction

Vegetables serve as sources of important nutrients such as proteins, vitamins, minerals, dietary fibers, micronutrients, antioxidants and phytochemicals in our daily diet. India is rich in biodiversity of vegetables and is the primary and secondary center of origin of many vegetables. India (162.19 million tonnes vegetables from 9.21 million hectares) is next only to China (573.94 million tonnes of vegetables from 24.56 million hectares) in area and production of vegetables in the world.

Vegetable waste is produced in large quantities during harvesting, poor and inadequate transportation, storage facilities, marketing practices and processing of vegetables. The vegetable markets produce plenty of vegetable waste per day. Vegetable wastes are perishable and voluminous. The collection, transportation and disposal of vegetable waste is a very serious problem today. The present vegetable waste management systems includes disposal by dumping in municipal landfills, spreading on land or by feeding to animals.

Vegetable wastes are responsible for great amount of environmental pollution. Uncontrolled dumping in municipal landfills and spreading on land bears several adverse consequences such as air, land and water pollution[1]. It further promotes the breeding disease vectors at the disposal site. These unscientific disposal methods result in loss of potentially valuable materials that can be processed to generate fuel and fertilizer[2]. Hence, appropriate treatment system is needed vegetable waste management. Biomethanation is the anaerobic digestion of organic matter to generate biogas and nutrient rich effluent. It appears to be highly economical and eco-friendly treatment option[3].

Several studies have been reported on the biomethanation of mixture of vegetable waste by different researchers[4-8]. Anaerobic co-digestion of vegetable waste with other agricultural wastes also has been studied for biogas generation by several workers[9-14].

There are very few reports on biomethanation potential of individual vegetable waste types. Thus the purpose of this study was to determine the biogas yield and volatile solids removal efficiency during anaerobic digestion of individual vegetable waste types such as Potato *(Solanum tuberosum* L.), Onion (*Allium cepa* L.), Cabbage *(Brassica oleracea* L. var. capitata*)*, Cauliflower (*Brassica oleraceae* L. var. botrytis), Tomato (*Lycopersicon esculentum* Mill.) and Brinjal (*Solanum melongena* L.) and combination of these individual vegetable wastes in equal proportions (i.e. mixture) in a floating dome design type of reactor of 1liter capacity.

Material and Methods

Materials: Wet vegetable waste, Inoculum from cattle dung based biomethanation plant, L capacity biogas digester (KVIC design of floating dome type), Combustibility testing assembly, Gas measurement assembly, Gas chromatography assembly.

Methods: Collections and preparations of samples: Wet vegetable wastes for the present study were collected from the local vegetable market. The collected wastes were further segregated into individual vegetable waste types. Potato, Onion, Cabbage, Cauliflower, Tomato and Brinjal dominated the composition of vegetable waste. These individual vegetable wastes were segregated, shredded separately and ground in a kitchen blender to make paste of the individual vegetable wastes. The paste of mixed vegetable waste was prepared in the same way combining equal proportions of individual vegetable wastes. They were kept in refrigerator at 4^0C until used.

Inoculum : Inoculum was obtained from an active mesophilic digester of cattle dung based biomethanation plant located at Degaon village, M.I.D.C., Satara (M.S.), India.

Experimental Procedure: Biomethanation studies were carried out in a floating dome design type of 1 liter capacity laboratory scale reactors. The reactors were provided with suitable arrangements for feeding, gas collection and draining of residues. The effective volume of each of the reactor was maintained at 600 ml by diluting 200 ml inoculum with 400 ml tap water. Acclimatization of inoculums was done before initiation of the experiment. The reactors were daily fed with the individual vegetable waste slurry and mixture of vegetable wastes in separate reactors and operated at 20 days HRT, pH 7.0 of the substrate and ambient temperature conditions. The reactors were mixed manually by means of shaking and swirling once in a day to break the scum.

Analytical methods: The physico-chemical characteristics of the vegetable wastes, inoculum and effluent were determined according to Standard Methods[15]. Biogas production from the reactors was monitored at a fixed time each day by water displacement method. The volume of water displaced from the glass beaker was equivalent to the volume of gas generated. Analysis of biogas was carried on Michro 9100 Gas chromatograph by using TCD and nitrogen as carrier gas.

Results and Discussion

Potato *(Solanum tuberosum* L.), Onion (*Allium cepa* L.), Cabbage *(Brassica oleracea* L. var. capitata*)*, Cauliflower (*Brassica oleraceae* L. var. botrytis), Tomato (*Lycopersicon esculentum* Mill.) and Brinjal (*Solanum melongena* L.) wastes dominated the composition of vegetable waste. These individual vegetable wastes separately and their mixture were used for biomethanation study (figure-1).

The physico-chemical characteristics of the substrates used for biomethanation are represented in table-1.

The inoculum obtained from an active mesophilic digester of cattle dung based biomethanation plant contains all the required microbes essential for biomethanation process. The physico-chemical characteristics of the inoculum are represented in table-2.

Figure-1
Substrate used for Biomethanation

Table-1
Physico-chemical analysis of substrates used

Parameter	Unit	Potato waste	Tomato waste	Onion waste	Brinjal waste	Cabbage waste	Cauliflower waste	Mixture of vegetable waste
pH	-	6.49	4.10	5.18	4.30	4.19	4.91	4.70
Moisture	%	83.74	95.32	86.76	91.55	90.73	89.28	89.50
Carbohydrates	%	11.80	2.53	8.52	5.25	6.09	4.65	6.45
Dietary fiber	%	0.67	0.53	0.98	0.92	0.79	1.53	0.90
Crude protein	%	2.88	1.32	3.14	1.80	1.86	3.68	2.40
Fat	%	0.07	0.03	0.13	0.01	0.05	0.09	0.06

Table-2
Physico-chemical analysis of inoculum

Parameter	Value
pH	6.25
BOD 5 days at 20^0C (mg/l)	7980
COD(mg/l)	16800
Total solids (mg/l)	15160
Total volatile solids (mg/l)	10260
Total dissolved solids (mg/l)	1480

Biomethanation studies on individual and mixed vegetable wastes were carried out using 1 liter capacity digesters, operated at 20 days HRT, pH 7.0 of the fed substrate and ambient temperature conditions (30-35^0C). The daily biogas yield in terms of volume from individual vegetable waste and mixed vegetable wastes are represented in figure-2.

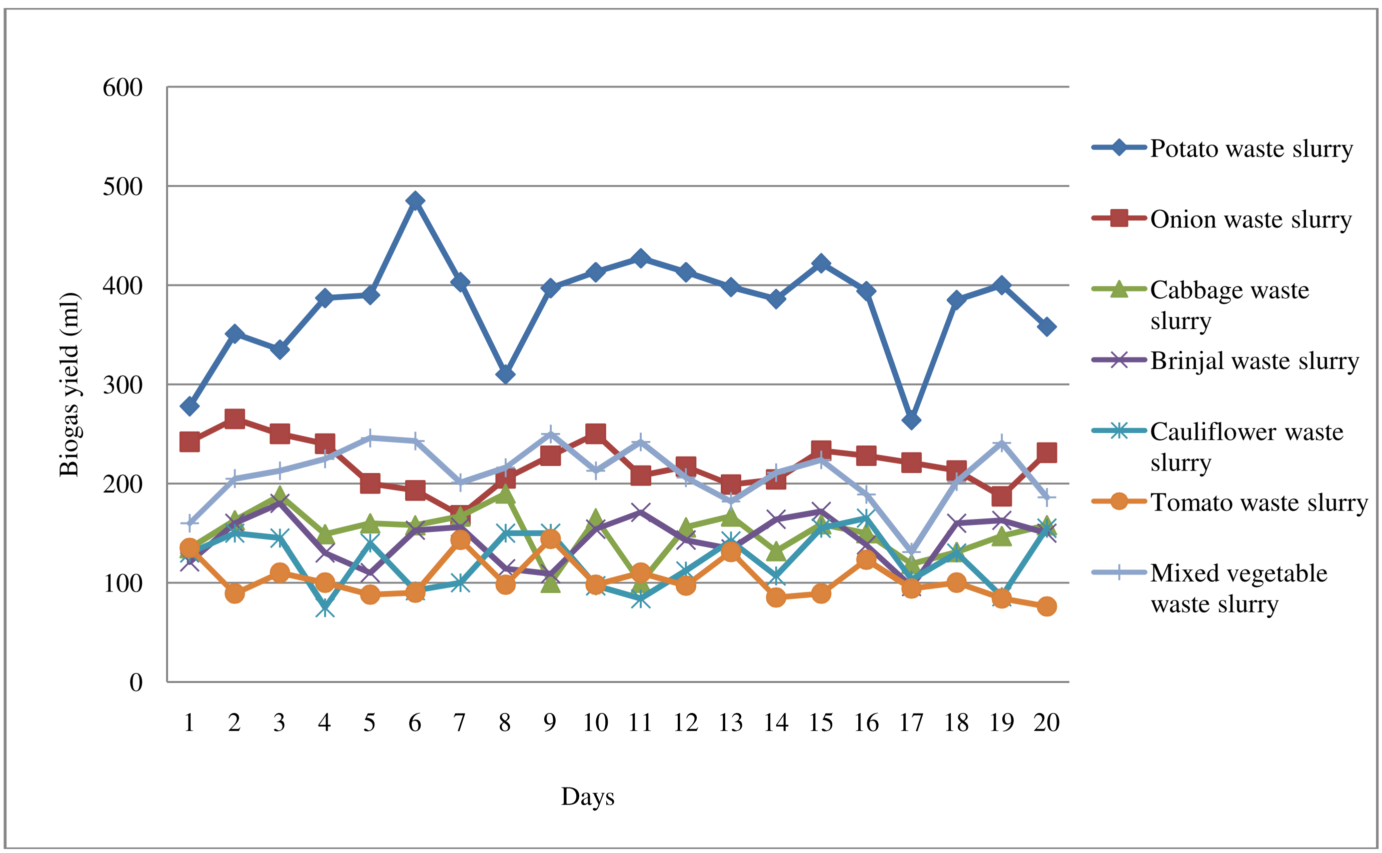

Figure-2
Daily biogas yield (ml) from individual vegetable waste and mixed vegetable waste

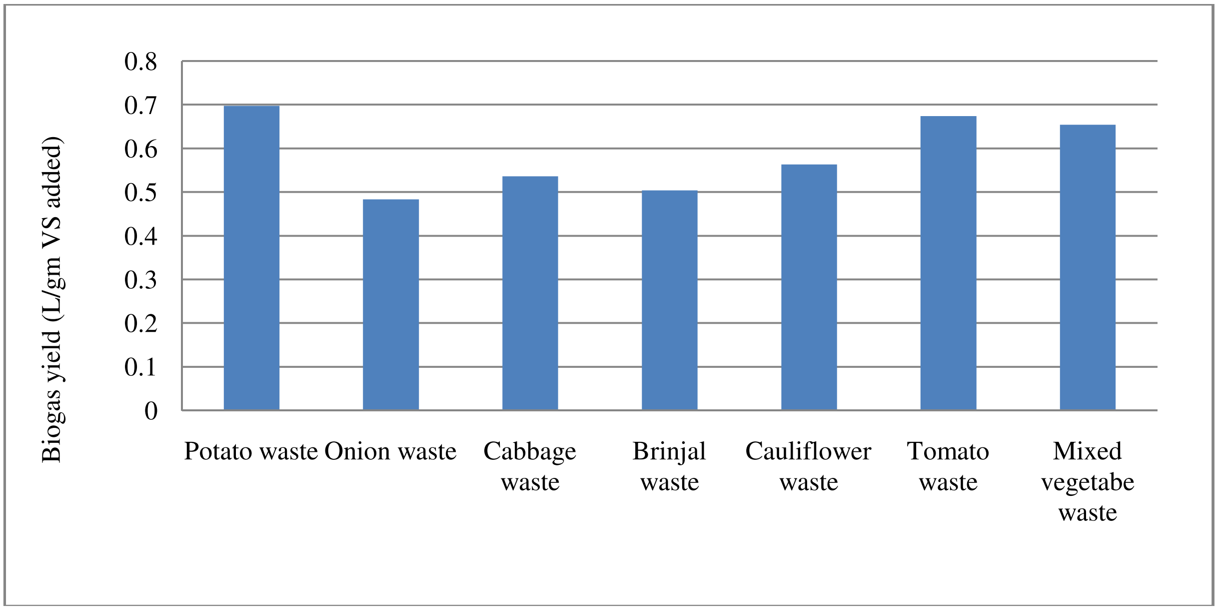

Figure-3

Average daily biogas yield (L/gm VS added) from individual vegetable waste and mixed vegetable waste in 20 days

The biogas yield for individual vegetable waste ranged from 0.483-0.697L/gm VS added whereas 0.654L/gm VS added was exhibited by mixed vegetable waste.

Total solids (TS), volatile solids (VS), biological oxygen demand (BOD) and chemical oxygen demand (COD) removal during biomethanation of individual vegetable waste types and mixed vegetable wastes is represented in figure-4.

The daily biogas yield for potato waste ranged from 278 ml-485 ml. The maximum amount of biogas (485 ml) was produced on day 6 of digestion. The lowest daily biogas yield in terms of volume was exhibited by tomato waste which ranged 76-144 ml. The daily biogas yield from mixed vegetable waste slurry in terms of volume ranged 131-250 ml. Maximum biogas was produced on 9th day as 250 ml.

The daily biogas yield in terms of gm VS/l.d added from individual vegetable waste and mixed vegetable wastes are represented in figure-3.

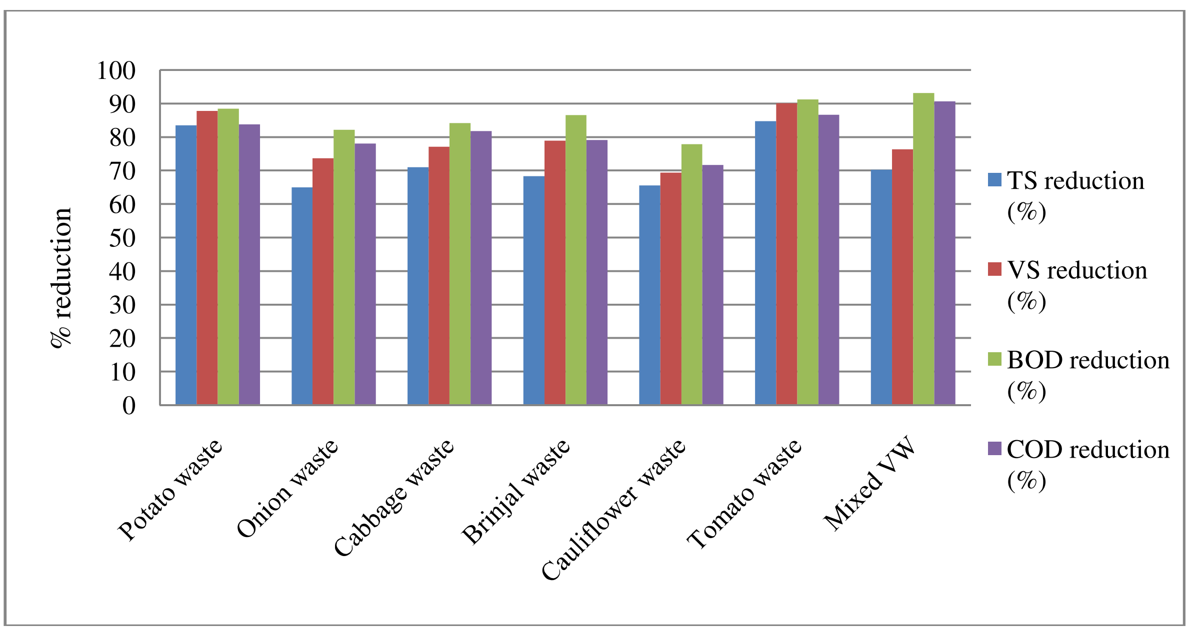

Figure-4

TS and VS reduction during biomethanation of individual and mixed vegetable wastes

It is evident that TS, VS, BOD and COD reduction of individual vegetable waste types ranged from 65-83.5%, 69.4-90.1%, 77.84-91.26 % and 71.68-86.63% respectively. Maximum VS and BOD reduction was associated with the tomato waste whereas minimum VS and BOD reduction was associated with Cauliflower waste. The TS, VS, BOD and COD reduction associated with the mixed vegetable wastes biomethanation was found to be 70.2%, 76.3%, 93.16% and 90.64% respectively.

The average biogas yield in terms of gm VS added/l.d by Potato waste was found to be 0.697 L which was higher than the other vegetable waste types. The methane content in biogas obtained from potato waste was found to be 60 %. The VS and BOD reduction during potato waste biomethanation was found to be 87.8% and 88.41% respectively. The biogas yield from potato waste in the present vegetable waste biomethanation study is higher than reported by previous researchers. Gunaseelan et al., reported the biogas yield as 0.267L/gm VS/l.d[16]. The high biogas yield associated with the Potato waste could be due to its relatively high nutritive value. It contains high amounts of starch (11.80 %), dietary fiber (0.67%) and Crude proteins (2.88%). The proteins contain high percentage of essential amino acids. It also contains trace quantities of minerals and B vitamins, C vitamins and fat soluble vitamins[17].

Tomato waste produced biogas yield as 0.674 L/gm VS added which is also high as compared to previous reports. The VS reduction (90.1%) was found to be comparable with the previous reports. Gunaseelan et al. reported 0.384 L biogas/gm VS with 98.1%VS reduction from rotten tomato waste[16]. Brinjal waste produced 0.504 L biogas /gm VS added which is also higher as compared to yield previously reported. Volatile solids and BOD reduction during the present study was78.9% and 86.53% respectively. Gunaseelan et al reported biogas yield of 0.396 L/gm VS with 91.1% VS reduction of brinjal waste[16]. Cauliflower waste obtained the biogas yield of 0.563L/gm VS degraded which is superior to previous reports but VS reduction (69.4%) was less as compared to previous report. Gunaseelan et al. reported the biogas yield as0.190 L/gm VS with the 82.0% reduction of VS[16]. Cabbage leaves produced biogas as 0.536 L/gm VS degraded which is also superior to previous reports. The VS and BOD reduction was found to be 77.1% and 84.13% respectively. Gunaseelan et al. reported biogas yield of 0.309 L/gm VS with 91.2% VS reduction[16].

The lowest average daily biogas in terms of gm VS added/l.d among the individual vegetable waste types was exhibited by Onion waste which was found to be 0.483 L. The yield obtained in the present study is comparable with previous reports. Gunaseelan et al. reported the biogas yield from onion waste as 0.400L/gm VS degraded with 88.2% VS reduction[16]. The low biogas yield from Onion waste could be related to its composition. It is found to be rich in bioactive constituents that have antibacterial activities[18].

The average daily biogas yield in terms of gm VS/l.d added from the biomethanation of mixed vegetable waste at ambient temperature conditions (30-35^{0}C) was found to be 0.654 L. The results of biogas yield from the present vegetable waste mixture are higher as compared to those reported by previous researchers. The biogas yields reported from mixture of vegetable waste by previous researchers are 0.423 L/gm VS added[4], 0.400 L/gm VS added[19], 0.600 L/gm VS added[20], etc.

Conclusion

The biomethanation potential of individual vegetable waste types and mixture of these vegetable wastes has been carried out in a laboratory scale 1 L capacity floating dome design type of reactor for 20 days at ambient temperature conditions (30-35^{0}C). Potato waste produced highest average daily biogas yield (0.697 L/gm VS added) with 87.8% VS reduction. Tomato waste produced biogas yield 0.674 L/gm VS added produced and exhibited 90.1% VS reduction. Cauliflower waste produced biogas yield 0.563 L/gm VS added and exhibited 69.4% VS reduction. Cabbage waste produced biogas yield 0.536 L/gm VS added and exhibited 77.1% VS reduction. Brinjal waste produced biogas yield 0.504 L/gm VS added and exhibited 78.9% VS reduction. Onion waste produced biogas yield 0.483 L/gm VS added and exhibited 73.7% VS reduction. Mixed vegetable waste produced biogas yield 0.654 L/gm VS added and exhibited 76.3% VS reduction. It is evident from the results obtained that the vegetable wastes containing high moisture and high nutrients are good substrate for biomethanation process. Biomethanation of vegetable wastes produces a renewable energy source (biogas) and nutrient rich effluent that can be used as natural fertilizer. In addition, the biomethanation process controls the environmental pollution by preventing soil, water and air pollution.

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