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CHARACTERIZATION OF SUBSTRATE (FOOD WASTE,AZOLLIA AND SLUDGE) FOR CO-DIGESTION IN ANAEROBIC DIGESTION TO PRODUCE BIOGAS

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Abstract

Food waste collected was collected from multiple household's hostels, restaurants and canteens of Greater Noida area. Green waste (Azolla) was collected from Dal Lake of Kashmir Valley. It was characterized for its potential for use as a feedstock for anaerobic digestion processes. The substrate was analyzed for pH , Moisture Content (%),TS (%),VS (%),VS/TS ratio (%),COD (mg/gm), Alkalinity (mg/l), VFA (mg/l), Carbon (% db), Nitrogen (% db), C/N ratio and total phosphorous (ppm or mg/gm). The results of this study indicate that the food waste, Azollia and activated sludge are a highly desirable substrate in co-digestion for anaerobic digesters with regards to its high biodegradability and methane yield.

1. Introduction

Food waste with high decomposition potential can be successfully degraded anaerobically for the production of biogas (Kondusamy and Kalamdhad, 2014) due to having high moisture content and readily biodegradability (Zhou *et al*., 2014). The use of food waste may also improve the overall economic benefits of anaerobic digestion process because low or zero cost associated with collecting this substrate (Chen *et al*., 2014).

The main sources of food waste are hotels, restaurants and canteens of universities and enterprises etc. (Zhou *et al*., 2014). Roughly 33% of all food produced for human consumption is wasted yearly totaling 1.3 billion tones, as reported by Food and Agricultural Organization of the United Nation (Kondusamy and Kalamdhad, 2014). However this waste is evenly distributed between developing and industrialized nation with 40% of the food waste in the developing nations occurring in the production and processing phases of consumption while in the industrialized nation, 40% occurs at the retail and consumer level consumption. By such amount of FW is digested anaerobically it has the potential to generate 367 m^3 of biogas per dry tonne at about 65% CH_4 with an energy content of 6.025×10^{-9} TWh/m^3, much amount of energy can be recovered. Further, transportation of FW to landfills and greenhouse gas emission from the landfill sites will be reduced by implementing anaerobic digestion. The anaerobic digestion of food waste required few pre-treatments and optimum conditions for efficient digestion and to recover maximum biogas production due to its readily available organics and highly complex oil contents (Kondusamy and Kalamdhad, 2014).

Food waste comprises rich nutrients and is a superior substrate for anaerobic digestion. However, as a single organic waste stream, food waste is rich in nitrogen sources such as protein, leading to low carbon-nitrogen ratio (C/N) (Khalid *et al*., 2011). Usually, low C/N ratio is not proper for high efficient anaerobic process due to inhibition from extra total ammonia nitrogen in the food waste (Pan *et al*., 2008). Contrary, anaerobic digestion of mono-substrate food waste could also suffer sensitive acidification and instability as organic loading rate (OLR) increased (Liu and Liu, 2011). Anaerobic digestion could offer the possibility of balancing carbon and nitrogen in the system when food waste is digested in co-digestion with other substrate. Correspondingly, the digestion efficiency and operations could be maintained more accurately and stably (Ganesh *et al*., 2013). For some stable carbon sources, lingo cellulosic biomass may be better option, especially for plant residues, because of their easy availability and collectivity. Thus, the co-digestion of food waste with plant residues could be potentially digested to improve the efficiency of digestion system. However, plant residues are lingo cellulosic biomass, which presented the characteristics and composition of difficult digestibility comparing with food waste. When co-digested, each substrate would pose different biodegradable rate, which could cause asynchronism of digestion rate, and may potentially affect mass bioconversion and biogas production adversely (Zhou *et al*., 2014). Worldwide the anaerobic stabilization of sewage sludge is probably the most prevalent anaerobic digestion activity. Sewage sludge is produced in large quantities in urban areas all over the world. It is a vast resource that has high

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biodegradability. Wastewater treatment facilities use anaerobic digesters to break down sewage sludge and eliminate pathogens in wastewater (Scaglia et al., 2014).

Azolla may be a better option for co-digestion purpose due to its unique composition. The chemical composition of *Azolla* comprises a mixture of key molecules found in lingo cellulosic, starch and-oil-producing terrestrial bioenergy crops. *Azolla* contains starch (up to 6 % dw), cellulose/hemicelluloses (up to 35 % dw) and lipids (8 % dw). *Azolla* biomass can accumulate up to 6 t dw/ha-year of starch and 34 t dw/ha-year of cellulose/hemicelluloses. The *Azolla* biomass can also accumulate up to 8 t/ha-year of neutral (Miranda *et al*., 2016).

Biochemical methane potential is an important and valuable assay for the interpretation of anaerobic digestion (Zhang *et al*., 2007). In the present study a laboratory test was conducted to the potential biogas yield of food waste as a feed stock. Anaerobic co-digestion could offer the possibility of balancing carbon and nitrogen in the system when food waste is digested with other substrate (Ganesh *et al*., 2013). Thus, the co-digestion of food waste with *Azolla* (green waste), has also been tested for its potential of methane generation.

The main objective of this paper was to analyze the physio chemical characteristics like pH, Moisture Content (%), TS (%) , VS (%), VS/TS ratio (%), COD (mg/gm), Alkalinity (mg/l) , VFA (mg/l) ,Carbon (% db) , Nitrogen (% db), C/N ratio, Total Phosphorous (ppm or mg/gm) of food waste(substrate), azolla(enhancer), activated sludge(seed)

2. Methodology

2.1Sample collection

The food waste was collected from multiple household's hostels, restaurants and canteens of Greater Noida area. Green waste (Azolla) was collected from Dal Lake of Kashmir Valley. For facilitating effective degradation and start up Inoculum or seed sludge was collected from sewage treatment plant, Indrapuram, Ghaziabad. The samples were preserved at 4 degree centigrade in order to reduce the chances of decomposition, to make the sample homogenous it was crushed, grinded and reduced to powder form. Fig 1.1

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(a) (b)

Fig. 1.1 crushing of sample

2.2. Sample Characterization

Physico chemical characteristic of food waste, inoculum and Azolla was carried out prior to experimental setup; the values of all parameters were analyzed and measured as per standard methods. Initially before the start-up of each experiment the characteristics of food waste in terms of moisture content, pH, COD, TS, TVS, VFA, TOC TKN and Phosphorus are being determined every time before start the digestion and after at the end of the digestion period. Initial and final TS, TVS and COD were used to determine solid reduction during the digestion period. The characteristic of substrate should be high in solid content, high organic content and the volatile solid at less than 60% of total solid.

Concentrated stock solution and defined media containing nutrients was prepared as per method prescribed by researchers (Owen *et al*., 1979) and was used in each batch bioassay test. Defined media was stored in 2-1 glass bottles after purging the N2 gas through the media and sealed in order to prevent oxygen interference (Owen *et al* 1979). For preparation of defined media, the tap water supplied in Institute laboratory of Gautum Budha University Campus was used. pH, COD, microbial concentration in terms of VSS, TSS, nitrogen and phosphorus were determined as per standard methods (Apha *et al* .,2005). Biomass was digested to determine the percentage of N and P. First of substrate and inoculum were investigated by following parameter as shown in table 1.1. The results were illustrated it‘s characteristic and potential to digest under anaerobic condition. Organic matter is presented by percentage of volatile fatty acid, Carbon and Nitrogen showed the chemical characteristic of substrate which has enough nutrients for microorganism growth. In Table 1.1 represent the parameters analyzed methodologies.

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Table 1.1 Parameters analyzed

S.No.	Parameters	Instruments and Models	Methods	Interference	Reference
1	Moisture Content (%)	Oven	Gravimetric Method	High moisture contents usually facilitate the AD ≥70%	APHA et al., 2005
2	pH	Digital pH meter (Hech edition 1)	Electrometric method	Sodium if pH>10 and temperature	APHA et al., 2005
3	Alkalinity (mg/L as $CaCO_3$)	Glass wares and burate for titration	Titration Methods	Soap, oily matter, suspended solids	APHA et al., 2005
4	COD (mg/L)	UV-VIS Spectro-photometer	Close Reflex (colorimetric) Method	Fatty acids, chlorides, nitrite and iron	APHA et al., 2005
5	Total Solids (g/L)	Oven	Gravimetric Method	Loss of volatile OM during Drying	APHA et al., 2005
6	Total Volatile Solids (g/L)	Muffle Furnace	Gravimetric Method	Loss of volatile inorganic salts like (NH4)2CO3	APHA et al., 2005
7	Volatile Fatty Acids (mg/L)	Digital pH meter and glasswares, burate for titration	Titration Methods	Eluting organic acids and some synthetic detergents	Orris E. Albertson et al., (1949)
8	Total Organic Carbon	Glasswares and Burate for titration	Walkley and Black Method	TOC = TC-IC TC: 0-500 mg/L IC: 0-200 mg/L	Walkley, A.and Black, I.A. 1934

9	Total Kjeldahl Nitrogen (mg/g TS)	Digestion unit distillation unit (Hach VDK 139, semi-automatic Distillation Unit)	Titration method	Sulphuric acid, potassium sulphate and cupric sulphate (caatalysts). Excess of alkali property is the interference of TKN.	APHA et al., 2005
10	Total Phosphorus (mg/g TS)	Digestion unit distillation unit (Hach VDK 139, semi- automatic Distillation Unit)	Titration method	Organic matter, moisture content and temperature. (for bacteria cell 2.6% is the maximum level)	APHA et al., 2005

2.3. Result and discussion

pH value in AD is very important factor as methanogenic bacteria are sensitive to acidic environment by which growth and gas production is inhabited. The pH value varies along the different stages of anaerobic digestion (Zhang *et al*., 2011). The pH variation is caused by volatile fatty acids, bicarbonates, alkalinity and CO_2. Chemicals like NaOH and $NaHCO_3$ are used to maintain the pH value (Goel *et al*., 2003). The hydrolysis and acetogenesis occur at pH between 5.5 and 6.5, respectively (Xiaojiao *et al*., 2012). pH value for anaerobic digestion was discussed by various researchers but optimal range was found around 7.0 (Sosnowski *et al*., 2002). More over in any anaerobic digestion process, adequate alkalinity is required to maintain stable pH and optimal biological activity Methanogens mainly prefer nearly neutral pH conditions with the optimum range being between 6.5 and 8.2 (Ag˘dag˘ and Sponza, 2005). This is due to the fact that pH is not sensitive to fluctuations in alkalinity once the pH and alkalinity are about 7.4 and 5000 mg CaCO3/l, respectively (Rittmann and McCarty, 2001).The pH was found to be the highest in Azolla (7.65 ± 0.21) and found dropped in Inoculum and Food waste i.e. (6.7±0.20) and (5.75±0.21) respectively, alkanity of 708.12±11.64 was found in azolla and that of food waste and inoculum was found to be 630.96±89.24 and 676.14±41.73 respectively.

High moisture contents usually facilitate the anaerobic digestion; however, it is difficult to maintain the same availability of water throughout the digestion cycle (Hernandez-Berriel, Benavides, Perez, & Delgado, 2008). Initially water added at a high rate is dropped to a

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certain lower level as the process of anaerobic digestion proceeds. High water contents are likely to affect the process performance by dissolving readily degradable organic matter. Moisture content has profound effect on anaerobic digestion. An anaerobic process was carried out at different moisture levels i.e. 70 and 80%. It was found that bioreactor operated at 70% moisture content produces more methane than the bioreactor operated at 80% moisture content. However, the ratio of BOD and COD remained the same (Hernandez-Berriel et al., 2008). The moisture content of Azolla was found to be in the range of (81.85±4.81) and that of food waste was found as (74.14±4.31).

For food waste TS and VS were found to be 35.92±4.40 and 28.13±3.10, for Inoculum TS and VS were found to be 10.46±0.92 and 4.50±1.50 respectively and finally for azolla TS and VS were as 14.14±2.33 and 11.74±1.77 respectively. Furthermore COD was found to be highest in azolla i.e 1503.91±33.05 and comparatively small in food waste i.e. 718.23±14.48 and smallest in inoculum i.e. 286.19±21.06. Comparing the above results VS/TS ratio was found highest in azolla i.e. 83.14, little less in food waste i.e. 78.54 and comparatively less in inoculum i.e. 22.88. These results well matched with the literature reports (Han and Shin, 2004; Zhang et al., 2007) , where the moisture content and VS/TS ratio of the food wastes was 69–93% and 0.85–0.95, respectively. By contrast, the piggery wastewaters contained 6.37–7.62% of TS and 0.72 of VS/TS ratio (Ahn et al., 2006).

The different concentrations of VFA (equivalent to acetic acid) in an anaerobic batch system is found to have a derivative effect on each phase of the hydrolysis, acidogenesis and biogas production related to the AD process (Siegert *et al*., 2005). Komisar *et al.* (1998) have been reported that in case of glucose as primary substrate biogas production was more than halved when VFA was above 8 g/L which indicated that digestion process was less sensitive to inhibition by VFA. The accumulation of VFA in specific place results in deranged microbial consortia, which leads to failure of the anaerobic digestion process operation (Vijayaraghavan *et al*., 2012). The VFA of food waste was found highest i.e. 234.79±43.29 and comparatively low in inoculum and azolla i.e. (71.18±6.98) and (80.66±8.46) respectively.

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The C on a dry weight basis (dwb) was found to vary in food waste, inoculums and azolla i.e. (55.89±2.78), (31.86±1.90) and (86.41±2.74), being highest in azolla. Highest Nitrogen content was found in azolla i.e. 3.07±0.13, for food waste it was found to be 2.65±0.22 and lowest in inoculum i.e. 1.79±0.05. Thus, the C/N ratio was found to decrease in Inoculum (17.76), for food waste (20.86) and maximum in azolla i.e. 28.09, thus satisfying the study which concludes that though the gas production will be low at high C/N ratio due to rapid consumption of nitrogen (Khalid *et al*., 2011). Optimum C/N ratio is reported to be between 20-30 (Vandevivere *et al*., 2000). Optimum C/N ratio can be achieved by mixing substrate of low and high C/N ratio (Khalid *et al*., 2011).

Table 2.1 Waste characteristics

Parameters	**Food Waste**	**Inoculum**	**Azolla**
pH	5.75±0.21	6.7±0.20	7.65±0.21
Moisture Content (%)	74.14±4.31	-	81.85±4.81
TS (%)	35.92±4.40	10.46±0.92	14.14±2.33
VS (%)	28.13±3.10	4.50±1.50	11.74±1.77
VS/TS ratio (%)	78.54	22.88	83.14
COD (mg/gm)	718.23±14.48	286.19±21.06	1503.91±33.05
Alkalinity (mg/l)	630.96±89.24	676.14±41.73	708.12±11.64
VFA (mg/l)	234.79±43.29	71.18±6.98	80.66±8.46
Carbon (% db)	55.89±2.78	31.86±1.90	86.41±2.74
Nitrogen (% db)	2.65±0.22	1.79±0.05	3.07±0.13
C/N ratio	20.86	17.76	28.09
Total Phosphorous (ppm or mg/gm)	3.8±0.30	2.77±0.10	0.85±0.12

Conclusion

The anaerobic biodegradability of an waste depends upon the physio-chemical parameters like for pH , Moisture Content (%),TS (%),VS (%),VS/TS ratio (%),COD (mg/gm), Alkalinity (mg/l), VFA (mg/l), Carbon (% db), Nitrogen (% db), C/N ratio and total phosphorous (ppm or mg/gm).The current research paper was focused to show suitability of food waste, Azollia and activated sludge as the substrate for co-digestion in an aerobic digestion. All the parameters were found in acceptable range for conducting different experiments for production of biogas. The results shows that Azollia,an aquatic weed can be used an enhancer during the co-digestion of food waste.

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