A comparative study based on anaerobic digestion of kitchen waste with wastewater and freshwater

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The anaerobic co-digestion of kitchen waste with wastewater is a promising approach for biogas, methane yield improvement and the trace elements supplement. The trace elements in the kitchen, vegetable, and fruit wastes are usually insufficient. Due to the increase in the human population throughout the world, the amount of wastewater generated is also on the constant rise. The inherent nutrients (trace elements) available in wastewater are useful for enhancing methane production and play a major role in increasing the volatile solid conversion efficiency. The paper presents the results of the study, conducted on two pilot-scale anaerobic digesters I and II at 5 % total solids. Digester I was fed with kitchen waste along with wastewater and digester II was fed with kitchen waste along with freshwater to produce renewable methane and produce bio-fertilizer. The study was carried out at mesophilic temperature with a hydraulic retention time of 35 days. The study was conducted for 55 days. During the entire operation, the average methane content for digesters I and II were recorded as 57.4 % and 54.4 %, respectively. The cumulative volume of biogas produced from digesters I and II were found as 5888 L and 5485 L, respectively. The average specific methane production yield from digester I and digester II was estimated as158.48 L/kg VS and 139.76 L/kg VS, respectively.

Material and methods

The wastewater was collected from the drainage line at IIT Delhi, India. After collection, the raw wastewater was first filtered using sieves (0.45 mm) and then centrifuged at 10,000 rpm for 10 min to remove solid particles. The determination of chemical oxygen demand (COD), nitrate-nitrogen (NO3-N), total dissolved phosphorus (TDP), and total ammonical-nitrogen (TAN), Total suspended solids (TSS) were based on the APHA method at IIT Delhi, India. The mixed kitchen waste (consisting of rotten/damaged fruits and vegetables) was regularly (as and when required during the investigation) collected from residential apartments and hostels of the Indian Institute of Technology Delhi. The pH value of kitchen waste was measured separately using a digital portable pH meter (Make: Horiba–Laqua D-74-AK) at Biogas Laboratory, IIT Delhi. The proximate properties of kitchen waste were determined using standard protocols reported in APHA [1]. The ultimate analysis of kitchen waste was carried out by using an automated instrument ‘Vario EL’ elemental analyzer (Make: PerkinElmer, USA).

Results and Discussion

The proximate analysis revealed that the total solids (TS) and volatile solids (VS) content in kitchen waste substrate on a wet basis was 10% and 90%, respectively. The ultimate analysis revealed the C/N ratio in kitchen waste substrate was 20.54. The wastewater pH was around 7.8, Chemical oxygen demand (COD) was found around 150-190 mg/L, Total ammonical nitrogen (TAN) 25-26 mg/L, Total dissolved phosphate (TAP) measured in the range of 20-24 mg/L, Nitrate- Nitrogen (NO3-N) 10-11 mg/L and Total suspended solids was found around 55-70 mg/L.

During the entire operation, the average methane content for digesters I and II were recorded as 57.4 % and 54.4 %, respectively. **Fig 1**. shows the variation of methane content for 55 days study period in digesters I and II. The range of methane content for digesters I and II was observed as 52.3-62.6 and 52.8-55.7, respectively. The range of carbon dioxide for digester I was observed as 33.1-43.7 %. The average carbon dioxide content was recorded as 37.7%. The range of carbon dioxide for digester II was observed as 37.9-43.0%. The average carbon dioxide content was recorded as 40.4%. The cumulative volume of biogas produced from digesters I and II were found as 5888 L and 5485 L, respectively. The specific biogas production for digester I was found that the ranges of specific biogas production yield during the 55 days were observed as 46.34-334.52 L/kg TS and 51.48-371.69 L/kg VS. For the same time period, the average specific biogas production was found as 246.13 L/kg TS and 273.48 L/kg VS. The specific biogas production for digester II was found that the ranges of specific biogas production yield during the 55 days were observed as 27.80-311.64 L/kg TS and 30.89-346.26 L/kg VS. For the same time period, the average specific biogas production was found as 232.53 L/kg TS and 258.37 L/kg VS. The specific methane production yield from digester I was estimated based on daily methane production yield over a period of 55 days, regarding methane yield per unit input mass of total solids and volatile solids (L/kg TS and L/kg VS). It was found that the range of specific methane yield for 55 days period was 24.23-192.12 L/kg TS and 26.93-213.47 Lm^3/kg VS. For the same duration, the average specific methane production was found as 142.63 Lm^3/kg TS and 158.48 L/kg VS. The specific methane production yield from digester II was estimated based on daily methane production yield over a period of 55 days, regarding methane yield per unit input mass of total solids and volatile solids (m^3/kg TS and m^3/kg VS). The specific methane production from digester II per unit TS and VS was found that the range of specific methane yield for 55 days period was 14.76-170.24 L/kg TS and 16.40-189.15 L/kg VS. For the same duration, the average specific methane production was found as 125.79 L/kg TS and 139.76 L/kg VS. The variation of specific methane yield of digester I and II is shown in **Fig. 2**. The total volatile solid removal efficiency for digester I was found that the range of 5.22-43.00 % and an average value of 35.17 %. The total volatile solid removal efficiency for digester II was found that the range of 3.11-40.49 % and an average value of 33.7 %. The energy analysis of biogas produced during the whole 55 days of the study period from the digesters I and II are shown in **Table 1**. The energy balance calculation was considered by Isha et al., 2021[2]. The produced energy output was 108.26 MJ in digester I, and 95.58 MJ in digester II. The net energy output was 104.66 and 91.98 MJ for digesters I and II, respectively. The overall energy efficiency achieved in each digester was 96.67% for digester I and 96.23% for digester II.

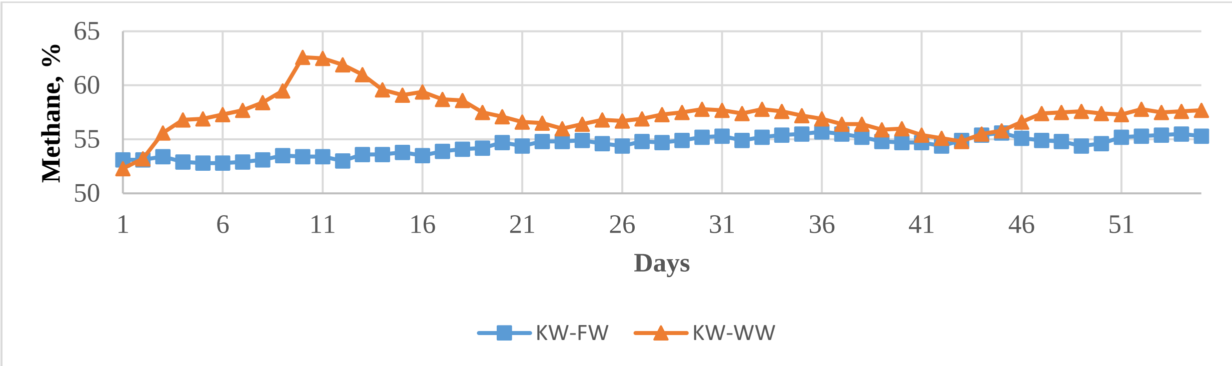

Fig. 1. Variation in methane content in biogas in digesters I and II.

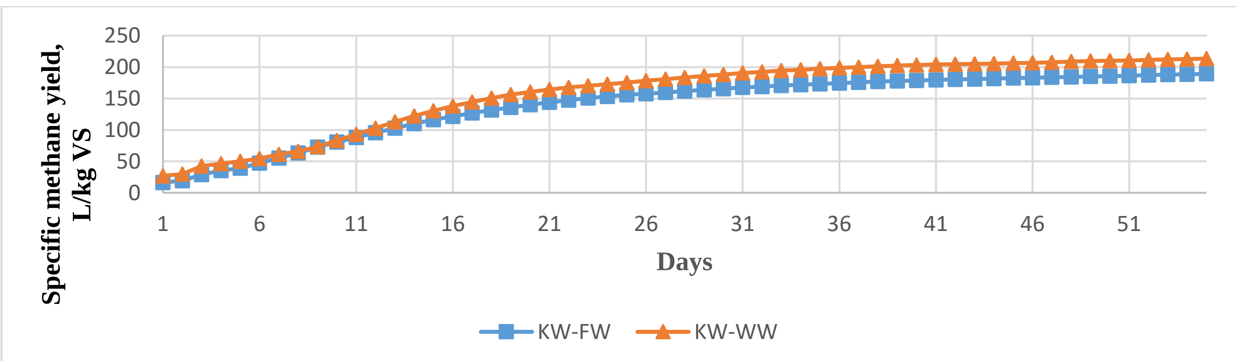

Fig. 2. Variation in specific methane production (VS basis) in digesters I and II.

Conclusion

The anaerobic digestion process needs lots of freshwaters for the hydrolysis step. Due to the scarcity of freshwater, the researchers in this study searched for alternative use of freshwater with wastewater for the anaerobic digestion process. The study showed the use of wastewater performed better results than using freshwater.

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