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Degradation of Biowaste Liquid Fraction Vegetables and Fruits in Anaerob Batch Reactor

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Abstract: The escalation of population in Indonesia affects the increase of solidwaste generation. Biodegradable constituents of municipal solid wastes such as fruit and vegetable wastes are produced in large quantities in markets. The waste generally contains high level of organic matters (70 – 80)%, so it is possible to be treated by biological treatments such as composting or anaerobic treatment. The solid waste has a high water content and is very expensive to incinerate, hence it is not suitable for thermal processing. Biodegradable constituents of municipal solid wastes, such as fruit and vegetable wastes, are produced in large quantities in markets, and become a source of nuisance in municipal landfills because of their biodegradability. In order to resolve the problem and reduce the biodegradability of the organic fraction in municipal solid wastes, mechanical and biological treatment are applied. The aim of this research is to evaluate the biodegradation process of biowaste in liquid fraction made from vegetable and fruit substrate in an anaerobic batch reactor. Furthermore, the production of biogas from the reactor is also being monitored. Biowaste used in this research were taken from Caringin Market, Bandung. Mechanical treatment used include sorting, grinding and separating, while biological treatment used in this research was by anaerobic digestion using a batch reactor operated at a volume of 4 L. By mechanical treatment, the liquid fraction of the biowaste was obtained. Physical-chemical parameters analyzed in this research are pH, total volatile acid (TVA), chemical oxygen demand (COD), and biogas. The results show that the efficiency of COD removal in the vegetable reactor was 86,97%, the fruit reactor and vegetable-fruit reactor were 88.82% and 93.39%. Methane produced in the vegetable reactor reached 55.5% at day 14, the fruit reactor was 68.17% at day 28, and the vegetable-fruit reactor was 46.32% at day11.

Keywords: *anaerob, batch reactor, biowaste fruit and vegetable*

1 Introduction

The amount of domestic waste which is generated from human activities has increased due to an increase in human population. Municipal Solid Waste in Indonesia mainly consist of organic materials. Biowaste is the separately collected biodegradable fraction of municipal solid waste and includes food

4 Conclusion

Based on this research, the vegetables-fruits reactor, vegetables reactor and fruits reactor has pH value between 4.99 until 8.3. The efficiency of COD removal in vegetables-fruits reactor was 93.39%, vegetables reactor and fruits reactor were 86.96% and 88.82%, respectively. Methane production occurs in all three reactors. Methane produced in vegetables-fruits reactor reached 46.32% on day 11, 55.50% on day 14 in the vegetables reactor and in the fruits reactor, methane production reached 68.17% on day 28.

5 Acknowledgement

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H₂ production stopped at day 7 in the vegetables reactor and the fruits reactor, whereas in the vegetables-fruits reactor it stopped on day 11. Biogas production can also be seen from the increase of CO₂. Bacteria of acidogen and acetogen can use the CO₂ into methane gas products. In all three reactors, the concentration of CO₂ increased in the beginning process and then declined towards the end of the observation, and peaked on day 7 to 11.

Methane formed from the activity of H₂-utilizing bacteria, using H₂ and CO₂ to form methane and acetoclastic methanogens, which use acetate to form methane. According to [7], formation of CH₄ and CO₂ as a final product methanogenesis by 72% derived from acetate, while 28% derived from the use of H₂ and CO₂. Figure 6 shows the methane production from all three reactors.

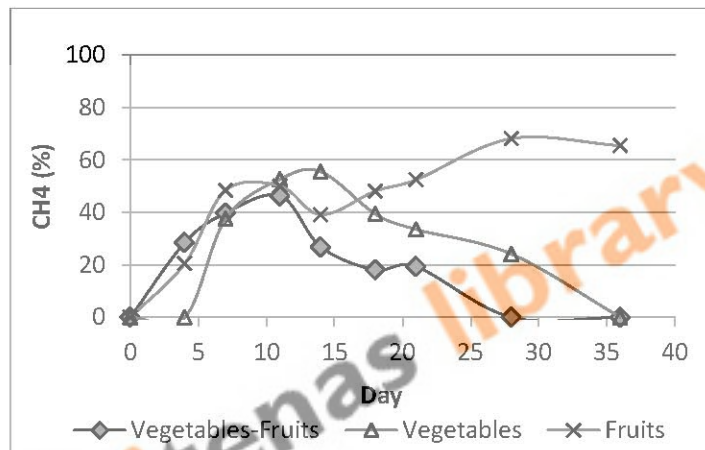


Fig 6. Methane produce from vegetables-fruits, vegetables, and fruits reactors

In all three reactors methane production occurred, and less methane was formed in the vegetables-fruits reactor compared to other reactors. In day-4, vegetable-fruits reactor and fruits reactor methane is formed increasing then decreasing, whereas in the vegetable reactor methane took longer to form, occurring on day-7. Methane in the vegetable-fruit reactor reached a maximum on day 11 at 46.32%, whereas in the vegetable reactor it reach a maximum on day 14 at 55.5%. In the fruits reactor, methane production continued to increase to reach 68.17% on day 28.

3.5 Biogas Production

Gas production is the only parameter that shows digester instability faster than pH monitoring [3]. Anaerobic systems operate in the absence of oxygen and utilize CO₂ or sulfate as their electron acceptors. CO₂ reduction results in CH₄ production [8]. Methane is mostly produced from acetate or hydrogen (H₂) and carbon dioxide (CO₂) or formate. The process of gas formation affected several factors, including pH, temperature and volatile acid. pH condition of acidic would disturb the formation of methane. The result gas measure shown in Table 2.

Table 2. Gas composition in vegetables-fruits reactor, vegetables reactor, and fruits reactor (% volume).

Day	Vegetables-Fruits Reactor				Vegetables Reactor				Fruits Reactor			
	CO ₂	H ₂	N ₂	CH ₄	CO ₂	H ₂	N ₂	CH ₄	CO ₂	H ₂	N ₂	CH ₄
0	2.9265	1.01	96.05	-	3.971	0.876	95.12	-	8.480	2.54	88.97	-
		99	36		4	4	54		3	94	03	
4	23.92	1.27	46.32	28.47	35.23	12.53	52.22	-	36.32	43.1	-	20.51
	41	4	29	9	39	99	26		8	62		
7	33.96	0.34	25.97	39.72	46.83	-	15.62	37.53	34.66	-	16.91	48.42
		21	06	73	87		46	66	15		68	16
11	24.76	-	28.91	46.83	32.41	-	14.93	52.65	34.79	-	15.16	50.03
	5		11	87	16		28	56	8		45	75
14	16.23	-	56.96	26.79	20.42	-	24.07	55.50	28.02	-	32.87	39.10
	36		94	7	54		19	27	29		44	26
18	11.61	-	70.29	18.08	17.50	-	43.09	39.39	24.58	-	27.28	48.13
	41		62	97	64		45	91	03		13	84
21	9.541	-	71.15	19.30	18.41	-	48.07	33.50	18.79	-	28.71	52.49
	7		15	68	83		88	29	25		1	65
28	1.936	-	98.06	-	16.82	-	61.05	24.11	15.70	-	16.11	68.17
	1		39		68		98	33	67		93	4
36	1.936	-	98.06	-	7.836	-	92.16	-	14.66	-	19.88	65.45
	1		39		7		33		05		88	07

From Table 2, in all three reactors, H₂ increases and then decreases. This indicates the occurrence of asidogenesis. The early process that produces H₂ and CO₂, and organic acids that the chain is longer than acetate. H₂ is formed when organic acids are converted to acetate by bacteria asetogen. During the process asidogenesis-asetogenesis, high levels of H₂ is produced. Homoasetogen bacteria will convert most of H₂ and CO₂, and acetate into methane (CH₄). So there is cooperation between the hydrogen-producing bacteria and bacterial acetone users of hydrogen, the hydrogen level can be set in their environment. According to [8], the concentration of H₂ must be in condition that is very low (below 100 ppm) to enable the conversion of organic acids (mainly propionate) to acetate is thermodynamically.

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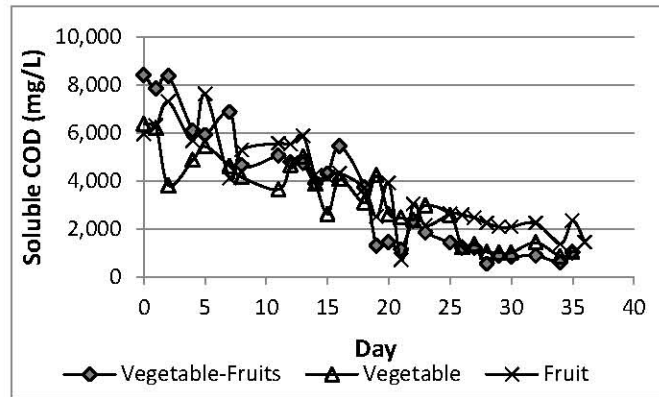


Fig 5. Soluble COD from vegetables-fruits, vegetables, and fruits reactor.

Figure 5 shows that the COD concentration has a range between 8421-557 mg/l in vegetables-fruits reactor, 6395-1013 mg/l in vegetables reactor, and 7626-706 mg/l in fruits reactor. At the beginning of operation, COD concentration of vegetable-fruit reactor 8421mg/l, while in vegetables reactor 6395 mg/l, and fruit reactor 5958 mg/l. After those days, the COD concentrations tended to decrease. In day-36 reach 724 mg/l in vegetable-fruit reactor, 833 mg/l in vegetables reactor and 1448 mg/l in fruits reactor. These conditions indicate the biodegradation process had been running well in all three reactors. The efficiency of soluble COD removal in vegetables-fruits reactor was 93.39%, in vegetables reactor and fruits reactor were 86.96% and 88.82%, respectively. Removal rate of soluble COD from the three reactors shown in Table 1.

Table 1. Removal rate of soluble COD on vegetables-fruits reactor, vegetables reactor and fruits reactor.

Reactor	COD in (mg/l)	COD out (mg/l)	Operation time (day)	Removal rate COD (mg/l/day)
vegetables-fruits	8421	724	36	213,81
Vegetables	6395	833	36	154,50
Fruits	5958	1448	36	125,28

From Table 1, removal rate of soluble COD in vegetables-fruits reactor is the highest at 213.81 mg/l/day, then followed by vegetables reactor and fruits reactor at 154.50 mg/l/day and 125.28 mg/l/day, respectively.

3.3 Total Volatile Acid

When substrate was degraded and enter the acidogenic phase, the total volatile acid (TVA) was increasing. Total volatile acids concentration was shown in Figure 4.

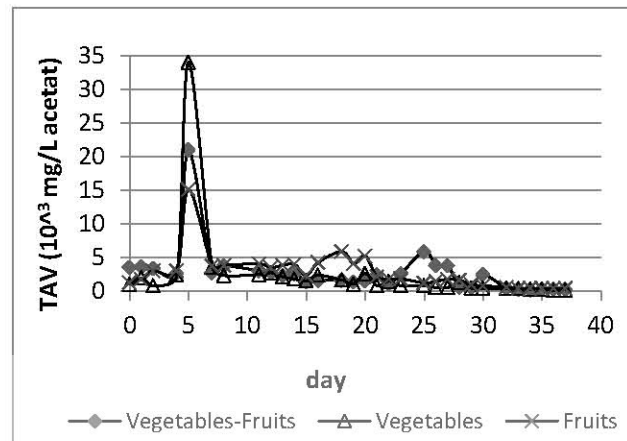


Fig 4. Total Volatile Acid.

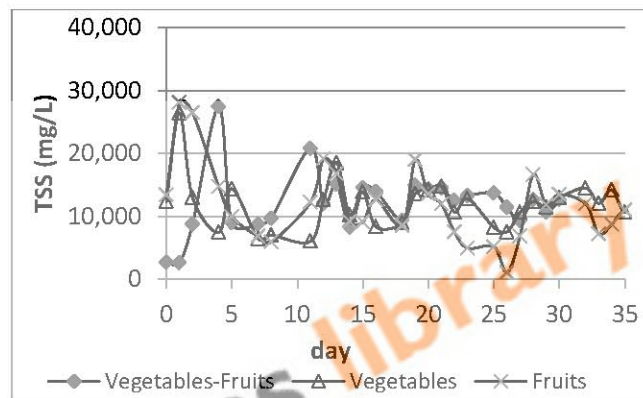
Figure 4 shows that on day-1, TVA concentration in the third reactor has a value between $(1.06-5.53)10^3$ mg/l. This concentration reached its peak on day-5 at 21.02×10^3 mg/l in vegetables-fruits reactor, 34.07×10^3 mg/l in vegetables reactor and 15.14×10^3 mg/l in fruits reactor. This shows that the degradation of organic substrates into volatile acids or in other words asidogenesis. High TVA concentration on day-5 shows that the rate of acid formation is not comparable with conversion rate of acid into methane. After day-5, TVA concentration decrease with methane formation. The maximum methane measured on day-11 was 46.32% in vegetables-fruits reactor, 55.50% on day-14 from vegetables reactor and 68.17% on day-28 from fruits reactor.

3.4 COD

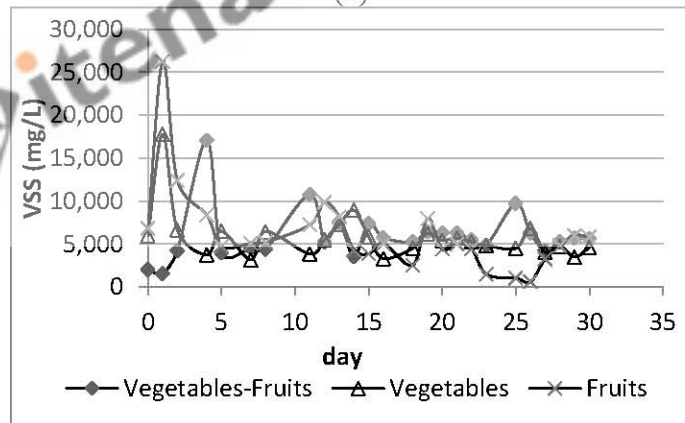
COD is a parameter that shows the amount of total oxygen which is needed to oxidize organic matter in solid waste. Under anaerobic condition, the amount of material that can be degraded biologically is usually greater than that represented by the five-day BOD concentration of the wastewater [6]. COD concentration show the organic matter content which still remain in reactor.

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The growth of microorganisms can be viewed using the parameters as the VSS approach. If a system had increasing VSS denotes the microorganisms grow well because the environment was adequate. In the vegetable-fruits reactor, VSS concentration on day 0 was 2060 mg/l, and increased to reach 17070 mg/l on day 4. The increasing TSS concentration in the sample was also caused by the biomass growth which was in the suspended solid. In the fruits reactor, VSS concentration on day 0 was 5975 mg/l, and increase to reach 17775 mg/l on day 1, then decrease at day 2 to 6680 mg/l. In the fruits reactor VSS on day 0 was 6820 mg/l and increased to reach 26240 mg/l on day 1. VSS concentration in the fruits reactor had a higher increase than the vegetables reactor and vegetable-fruits reactors. Microorganisms in all three reactors relatively grew well in the initial operation of this experiment.



(a)



(b)

Fig3. (a) Total Suspended Solid and (b) Volatile Suspended Solid.

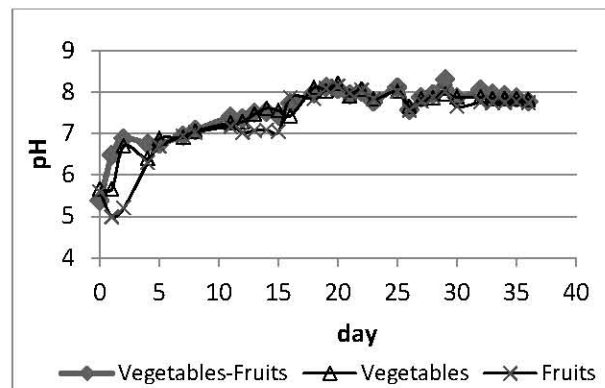


Fig2. pH from vegetables-fruits, vegetables, and fruits reactor.

Based on this research (Figure 2), the third reactor showed a decrease of pH when the process in reactor began. Vegetables-fruits reactor had pH value between 5.37 and 8.3, vegetables reactor had pH value between 5.66 and 8.21, and fruits reactor had pH value between 4.99 and 8.15. A decreasing pH can point toward acid accumulation, which typically occurs if there is an overload of volatile acids in the digester. The acidogenic bacteria then thrive, producing more organic acids and lowering the pH [3]. The decrease of pH in the three reactors signifies the presence of the acidogenesis phase. After 17 days, the third reactor began to stabilize (based on pH value). The increases of pH value indicates the change of decomposition from acidogen phase into methane phase.

3.2 Total Suspended Solid (TSS) and Volatile Suspended Solid (VSS)

TSS and VSS are closely related with the growth of microorganisms in reactor. This research used a source of high anaerobic microbes to start up an anaerobic system called inoculation. The anaerobic microbes used are from rumen and cow manure. In manures and some wastes, the microbes needed for the digestion may already be present in the wastes in small numbers, but sufficient enough to act as an inoculum, and will develop into a fully functional bacterial population if the right conditions are provided, including a suitable temperature. TSS and VSS value are shown in Figure 3(a) and (b). TSS parameter determine the total solid suspended in wastewater. Overall, the TSS values tended to initially increase then decrease. The increasing TSS concentration in the sample is caused by the biomass growth which was in the suspended solid form. The growth of microorganisms can be viewed using the parameters as the VSS approach. If a system had a low VSS denotes the microorganisms did not grow well because of in adequate environmental conditions.

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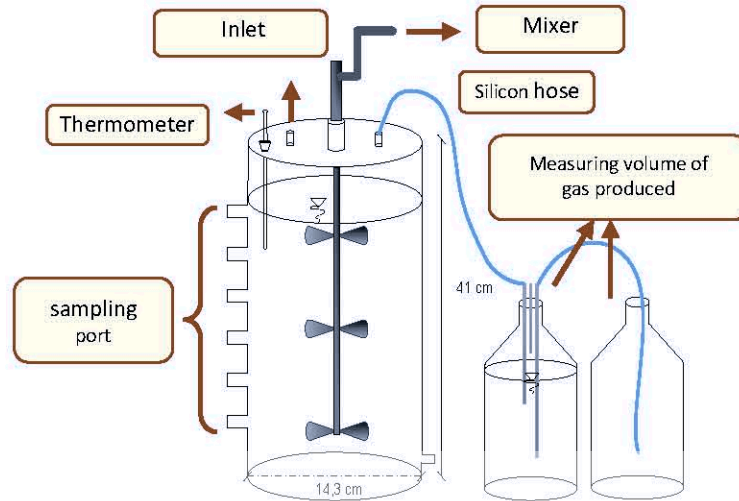


Fig 1. Reactor scheme.

Temperature, pH, alkalinity, total volatile acid (TVA), chemical oxygen demand (COD) are determined in accordance to Standar Methods for Waste and Wastewater Treatment [1]. Biogas was analysed by gas chromatography.

3 Result and Discussion

3.1 pH

Environmental conditions such as pH have an important effect on the survival and growth of microorganism in anaerob degradation organic matter. Bacteria will be active in specific pH range and show the maximum activities at optimum pH [9]. The optimal pH required for asidogenic bacteria is between 5 and 6.5, while the optimal pH for methanogenesis is above 6.5 [6]. Before it is filled into the reactor, biowaste liquid fraction is mixed with inoculum and adjusted to reach neutral pH (± 7). pH condition during the operation of reactor shown in Figure 2.

waste, garden waste and kitchen waste [5]. Biodegradable components of municipal solid wastes (MSW) such as fruit and vegetable wastes (FVW) are produced in large quantities in markets, and constitute a source of nuisance in municipal landfills because of their biodegradability [2]. Based on data from PD Kebersihan Bandung City (2005), solid waste volume of Caringin market is 1.22 liter/m²/day with an organic waste composition of 72.42%. The increasing amount of waste is not followed by the availability of land for final disposal, so the appropriate process is necessary to reduce the domestic waste volume that must be removed to final disposal.

Mechanical Biological Treatment (MBT) is a pretreatment technology which contributes to reducing MSW and biowaste organic content that go into landfill [4]. Organic waste of market can be processed by composting with sufficient oxygen (aerobic), but its high water content at 88.7%, can interfere with the composting process. The optimum moisture for composting is 40-60%. This condition is necessary for handling the water content of biowaste. The aim of this study is to review the degradation process of biowaste liquid fraction in anaerobic batch reactors and biogas production.

2 Methodology

Biowastes used in this research were organic wastes consisting of vegetables and fruits from Caringin market, and collected by grab sampling method. After collected, biowaste goes through grinding process by SHREDDER FT0101-2HP type from normal size into small size (± 1 cm). The waste was stored at 4°C until it was used in the experiment. Any non-organic contamination was removed by hand before use. After grinding process, the biowaste was processed into a slurry. Slurry underwent separation process by screening fabric to result liquid and solid fraction. The liquid fraction became a substrate for each batch reactor. Reactors used in this experiment were anaerobic batch reactors with an operational volume 5 L, and made of from material flint glass.

The substrates were inoculated with seeding from rumen and cow manure which had been acclimated with the same kind of substrate used in experiment. The ratio of biowaste substrate and seeding is 90%:10%. This mixture was adjusted to reach neutral pH (around 7) before added to reactor.

The reactor used in this experiment is shown in Figure 1. At the reactor cover, there are silicon hoses for gas sampling and substances addition, thermometer, and mixer. After the substrates and inoculum are added to the reactor, it is covered and sealed. N₂ is circulated to remove oxygen in the reactor, thus creating an anaerobic condition.