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PREFACE

Sustainable development that meets the needs of the present without compromising the ability of future generations to meet their own needs should be implemented in all countries. The implementation is of importance especially with the presence of alarming local to global scale anthropogenic environmental problems and how the countries are connected through the earth's natural system. It is thus imperative that countries collaboratively working together to tackle and prevent the problems in order to warrant the successful implementation of sustainable development in the countries.

It is under the above mentioned spirit that the Environmental Technology and Management Conference (ETMC) was initiated. Held every 4 years since 1997 and with growing numbers of participant and expertise, the ETMC brings together policy makers, scientists, engineers, industries, and field expertise in environmental technology and management to discuss current and future local, regional, and global environmental issues. The ETMC is aimed to provide a forum to discuss and disseminate advances in research, technologies, and management, for improving the quality of the environment. Past participants of the conference include researchers, academic staffs, students, industries, public, and government officials.

With theme "Present and Future Challenges in Environmental Sustainability", the 4th ETMC is a global momentum for sustainable development that will lead to practical applications of the engineering and science of sustainability. Participating industries, academics, and governmental bodies will acquire information on the state of the art in environmental technology and management.

Plenary sessions of the 4th ETMC include presentations by:

- **Prof. Toshihiro Kitada**
  Toyohashi University of Technology, Japan
- **Prof. (Hon) Rachmat Witoelar**
  President's Special Envoy for Climate Change Indonesia.

There are invited international distinguished speakers:

- **Prof. Yen Peng Ting**
  National University of Singapore, Singapore
- **Prof. Rudy Sayoga**
  Institut Teknologi Bandung, Indonesia
- **Prof. Naoyoki Funamizu**
  Hokkaido University, Japan
- **Prof. Michael Sturm**
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- **Prof. Kim Oanh**
  Asian Institute of Technology, Thailand
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  Okayama University, Japan

- **Ir. H. Mulyadi Afmar**
  PT. Benefita, Indonesia
- **Moekti Handajani Soejachmoen**
  Special Assistant to the President's Special Envoy for Climate Change Indonesia
- **Dr. Setiawan Wangsaatmadja**
  Environmental Management Agencyof West Java, Indonesia
- **Dr. Indra Budiman Syawmil**
  Institut Teknologi Bandung, Indonesia

Contributed oral (114 contributions) and poster (26 contributions) presentations are divided into 6 major sessions:

A. Eco-industries
B. Natural Resources Management
C. Water Resources Management
D. Environmental Engineering and Technology
E. Green Cities
F. Climate Change and Air Pollution

Finally, the Organizing Committee wishes that this conference is able to provide beneficial scientific information to the participants and other concerned readers.

Bandung, November 2011

Ir. Edwan Kardena, PhD
Chair of Organizing Committee

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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 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/m^2/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 compostingis 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 under went 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 anaerob batch reactors with an operational volume 5 L, and made of from material flixyglass.

The substrates were inoculated with seeding from rumen and cow manure which had been aclimated 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. N_2 is circulated to remove oxygen in the reactor,thus creating an anaerob condition.

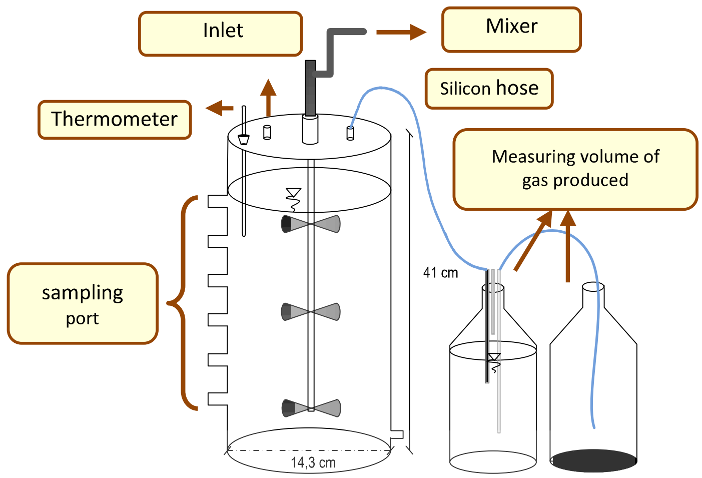


Fig 1. Reactor scheme.

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.

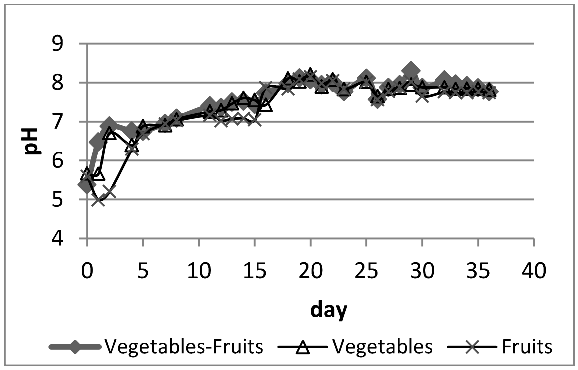


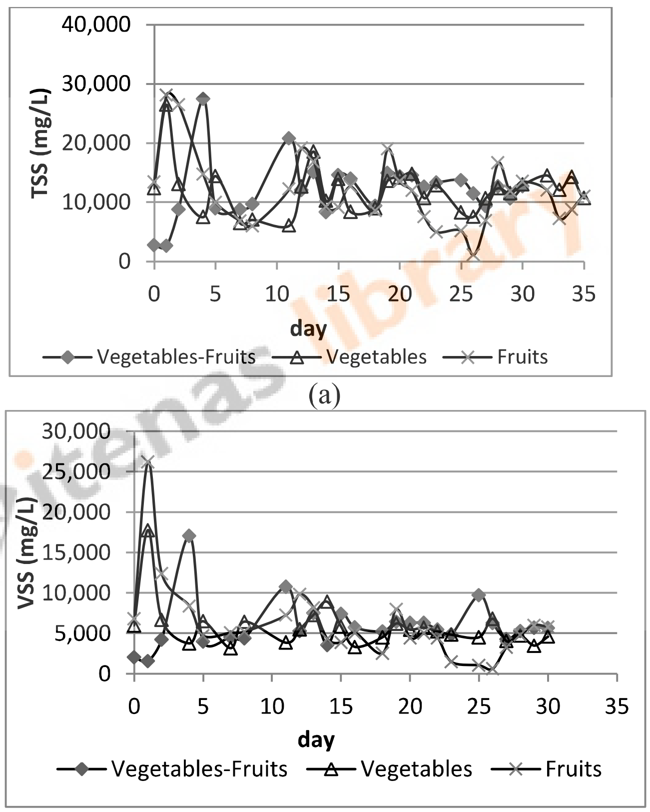
Fig2. pH from vegetables-fruits, vegetables, and fruits reactor.

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 asidogenesis phase. After 17 days, the third reactor began to stablize (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 intially 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 enironmental conditions.

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 biomassa 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 intial operation of this experiment.



(b)

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

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**.

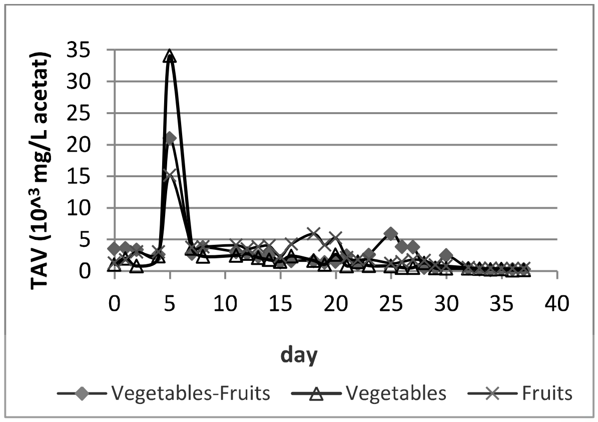


Fig 4. Total Volatile Acid.

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 21.02x10^3 mg/l in vegetables-fruits reactor, 34.07x10^3 mg/l in vegetables reactor and 15.14x10^3 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 representated by the five-day BOD concentration of the wastewater [6]. COD concentration show the organic matter content which still remain in reactor.

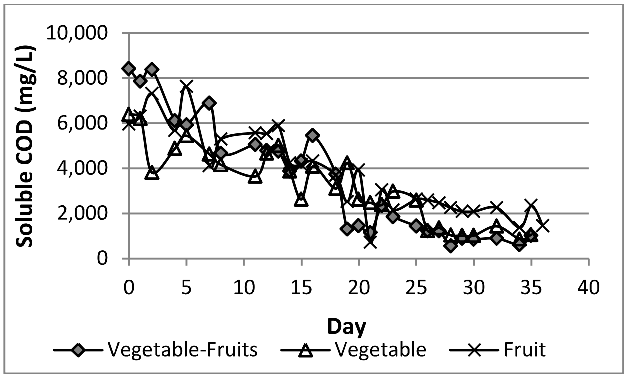


Fig 5. Soluble COD from vegetables-fruits, vegetables, and fruits reactor**.**

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.

3.5 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 CO_2 or sulfate as their electron acceptors. CO_2 reduction results in CH_4 production [8]. Methane is mostly produced from acetate or hydrogen (H_2) and carbon dioxide (CO_2) or formate. The process of gas formation affected several factors, including pH, temperature and volatile acid. pH condition of acidic would distrub 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	1.0199	96.0536	-	3.9714	0.8764	95.1254	-	8.4803	2.5494	88.9703	-
4	23.9241	1.274	46.3229	28.479	35.2339	12.5399	52.2226	-	36.328	43.162	-	20.51
7	33.96	0.3421	25.9706	39.7273	46.8387	-	15.6246	37.5366	34.6615	-	16.9168	48.4216
11	24.765	-	28.9111	46.8387	32.4116	-	14.9328	52.6556	34.798	-	15.1645	50.0375
14	16.2336	-	56.9694	26.797	20.4254	-	24.0719	55.5027	28.0229	-	32.8744	39.1026
18	11.6141	-	70.2962	18.0897	17.5064	-	43.0945	39.3991	24.5803	-	27.2813	48.1384
21	9.5417	-	71.1515	19.3068	18.4183	-	48.0788	33.5029	18.7925	-	28.711	52.4965
28	1.9361	-	98.0639	-	16.8268	-	61.0598	24.1133	15.7067	-	16.1193	68.174
36	1.9361	-	98.0639	-	7.8367	-	92.1633	-	14.6605	-	19.8888	65.4507

From Table 2, in all three reactors, H_2 increases and then decreases. This indicates the occurrence of asidogenesis. The early process that produces H_2 and CO_2, and organic acids that the chain is longer than acetate. H_2 is formed when organic acids are converted to acetate by bacteria asetogen. During the process asidogenesis-asetogenesis, high levels of H_2 is produced. Homoasetogen bacteria will convert most of H_2 and CO_2, 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 H_2 must be in condition that is very low (below 100 ppm) to enable the conversion of organic acids (mainly propionate) to acetate is thermodynamically.

H_2 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 CO_2. Bacteria of acidogen and acetogen can use the CO_2 into methane gas products. In all three reactors, the concentration of CO_2 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 H_2-utilizing bacteria, using H_2 and CO_2 to form methane and acetoclastic methanogens, which use acetate to form methane. According to [7], formation of CH_4 and CO_2 as a final product methanogenesis by 72% derived from acetate, while 28% derived from the use of H_2 and CO_2. Figure 6 shows the methane production from all three reactors.

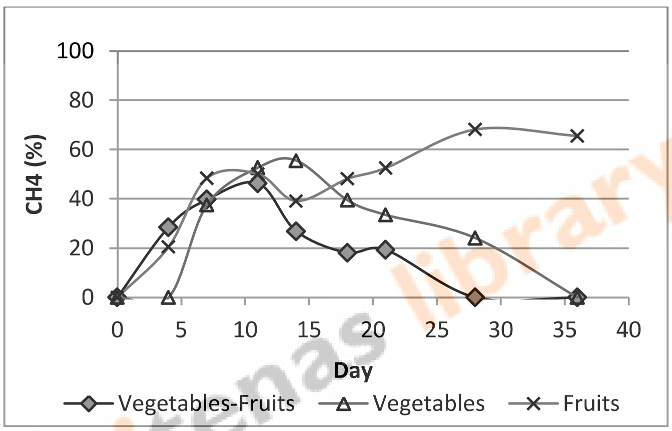


Fig 6. Methane produce from vegetables-fruits, vegetables, and fruits reactors

In all three reactors methane production occured, 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, occuring 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.

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 Acknowlegdement

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