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DEGRADATION OF BIOWASTE LIQUID FRACTION IN ANAEROB BATCH REACTOR

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ABSTRACT

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 or composting, because of their biodegradability. In order to resolve the problem and reduce the biodegradability of organic fraction 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 Caringin market in 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. This research used a substrate liquid fraction of the original biowaste, artificial, vegetables, fruits and variations of pretreatment sedimentation and without pretreatment. Physical-chemical parameters analyzed in this research are pH,VSS, volatile fatty acid (FVA), chemical oxygen demand (COD), ethanol, and biogas. The results show that the efficiency of COD removal at higer s pretreatment edimantation than without pretretment. COD removal efficiency in substrat with pretreatment sedimentation 81.82% the biowaste original reactor, 72.73% the biowaste artificial reactor, 81.97% the vegetable reactor and 59.90% the fruit reactor. Methan produced 2.11% day-to-10 in the biowaste original reactor without pretreatment, and with pretreatment 0,16% the vegetable reactor and 0,019% the fruit reactor, which both occurred on the fourth day.

Keywords: anaerobic digestion, batch, biowaste.

INTRODUCTION

Waste problems in Indonesia until now has not get adequate attention. The studies on waste treatment is very little done, but more on aspects of management. Market waste contributor around 18.77% of municipal waste[1], and the problem of aesthetics, the environment and health, because it is concentrated in one place is massive. Waste

generation of Caringin Market is 1.22 liter/m^2/day with biowaste composition of 85.31% [(1)], and the composition of vegetables and fruits from the traditional market reached 84.6%.
In general, market waste in Indonesia immediately transported to a landfill (operated open dumping). The problem of open dumping is the production of biogas as one of the causes of global warming. One of the biogas recently suspected as the cause of global warming is methane gas. Activity of methanogenic landfills produce 6-12% methane released into the atmosphere[(2)]. This is a big concern because of global warming potential of methane reached 5-35 times the CO_2[(2)]. So that need reduce the organic compounds that enter the landfill for the formation of methane gas to be reduced. In developed countries, reduction of organic waste solids before dispose off becomes a necessity, such as methods of MBT (Mechanical Biological Treatment) applied in European countries. MBT is divided into 2 (two) stages, mechanical and biological treatment, generally MBT uses the concept of pretreatment before treated by composting. Composting is a very generally alternative suggested in Indonesia, but composting will be found barriers by high water content of the waste will be processed, so reducing the water content need be done to market waste biodegradable (biowaste), for the solid can treated in a more optimum. Reduction of waste to be transported to a landfill is a referrals that mandated by the Law of the Republic of Indonesia No. 18 of 2008[(3)], so treatment waste in the market is in line with the law.

Especially wet fermentation of household waste that is characterized by high levels of water will produce a reject water, and very few are learning how to treat wastewater generated from this process[(4)]. Estimating about 500 liters of waste water leaving the system per-ton wet fermentation biowaste are processed[(4)]. In recent years, a number of reactor designs adapted and developed for anaerobic treatment for fruit and vegetable solid waste, such as batch and continuous [(5)]. Biometan process of fruit and vegetable solid waste occurs in the presence of a series of biochemical transformations, which consist of 4 (four) stages [(5)]. First, organic materials from solid waste fruit and vegetables such as cellulose, hemicellulose, pectin, lignin, will experience liquefaction in the presence of extracellular enzymes before being used by bacteria asidogenik. The rate of hydrolysis stage is a function of several factors such as pH, temperature, composition, substrate particle size and concentration of intermediate products. After that, the dissolved organic components include the hydrolysis products will be converted into organic acids, alcohols, hydrogen, and carbon dioxide by bacteria asidogenik. The product of the process asidogenesis converted into acetic acid, hydrogen, and carbon dioxide. Then the methane produced by bacteria metanogenik of acetic acid, hydrogen, and carbon dioxide along with the reactions of other substrates such as formic acid and methanol.

Anaerobic process has the advantage that it can remove organic compounds and produce methane gas that can be utilized as an energy source. Market organic waste, solid waste vegetables and fruits that are produced periodically every day, is a renewable biomass energy source, because the content of nutrient-rich material and potentially be used as raw material for the formation of energy (biogas). The purpose of this study was to determine the degradation process biowaste fraction of the solid waste liquid and artifial original market and solid waste vegetables and fruits in anaerobic batch reactor.

METHOD

Sampling methode which used in this research was grab sampling. Biowastes which used in this research were original biowastes, Fruit wastes, vegetable wastes, artificial biowastes from Caringin market. After collected, each biowaste goes to 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 made slurry to reduce organic materials and nutrient in biowaste. Slurry undergo separation process by screening fabric to result liquid and solid fraction. These liquid fraction became a substrate for each reactor. The research used four anaerobic batch reactors with substrate sedimentation and without sedimentation before the input reactors. The substrate composition of liquid fraction is 100% original biowaste, 100% artificial biowaste, vegetable 75% : fruit 25% (vegetables reactor) and vegetables 25%: fruit75% (fruit reactor).

The substrates were inoculated with seeding from rumen, cow manure and sludge from anaerobic pond IPAL (Instalasi Pengolahan Air Limbah) which had been aclimated with the same kind of substrate used in experiment. The ratio of biowaste substrate and seeding is 9:1. This mixture was adjusted to reach neutral pH (7) before added to reactor.

Reactors used in this experimental were an anaerob batch reactor with operational volume 4 L, showed in Figure 1. At the reactor cover, there are silicon hose for gas sampling and substances addition, thermometer, and mixer. After the substrates and inoculum added to reator, it is covered and sealed. N_2 is flowed to remove oxygen in the reactor so that the anaerob condition was created.

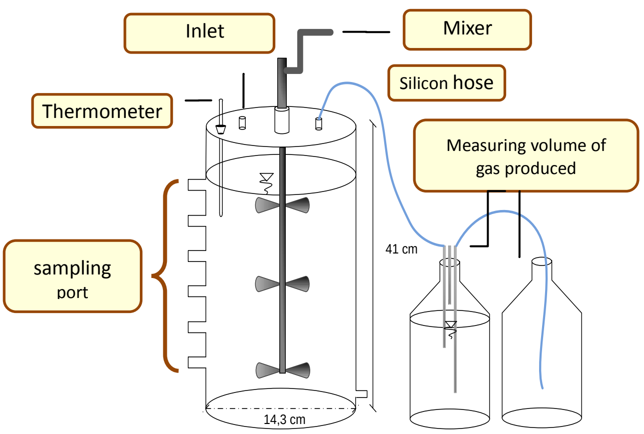


Figure 1. Reactor Scheme

Temperature, pH, VSS, total volatile acid (TVA), chemical oxygen demand (COD) and etanol were determined according to Standar Methods for Waste and Wastewater Treatment [6]. Biogas was analysed by gas chromatography.

RESULT AND DISCUSSION

The characteristic of substarte showed in Tabel 1 and 2. pH of original and artificial substrate is 4.7-5.45, whereas vegetables and fruits substrate are more acidic pH of 2.82-4.02. pH for each liquid fraction under neutral pH conditions, so that said liquid fraction to the original substrate, artificial, vegetables and fruits are acidic samples[7]. (Hammer and Hammer Jr. 2005).

Bicarbonate alkalinity in the range of 2500-5000 mg/l may function as buffer to handle the increased concentration of volatile acid that can decrease the pH[8]. Liquid fraction of the original biowaste alkalinity, artificial with pretreatment and without pretreatment, as well as for vegetable 1 is in the range of alkalinity so that they can function as a buffer against pH changes.

Anaerobic treatment is suitable for waste water with biodegradable COD of the medium range (around 2000 mg/l) to high (> 20,000 mg/l) [9]. COD of liquid fraction of substrates in Table 1 and Table 2 has a value greater than 2000 mg/l, so that the liquid fraction can be treated with anaerobic system.

Table 1. Characteristic Substrate of Liquid Fraction Original and Artificial Biowaste

Parameter	**Unit**	**Variation**			
		Original 1	Original 2	Artificial 1	Artificial 2
pH	-	5.3	5.45	5	4.7
Alkalinity	mg/L $CaCO_3$	2,606	3,016	2,503	2,786
Temperatur	^{o} C	26	26	25	26
COD total	mg/L	9,164	8,592	12,888	11,456
VFA	mg/L acetat	3,267	1,653	4,967	1,397
Phosphat Total	mg/L	8.7	8.4	11.7	6.8
NTK	mg/L	9,051	7,230	9,427	6,697
TSS	mg/L	7,200	5,600	7,220	5,530
VSS	mg/L	5,893	4,875	5,683	3,540
Selulose	% w/w	0.79	0.52	0.78	0.67
Carbohidrat	% w/w	0.28	0.108	0.37	0.385
Lipid	% w/w	0.1878	0.1075	0.1976	0.1687

Note : 1-Without *Pre-treatment* sedimentation
2-With *Pre-treatment* sedimentation

Table 2. Charakteristic Substrate of Liquid Fraction from Vegetable and Fruit *Biowaste*

Parameter	Unit	Variation			
		(vegetables 75% : fruits 25%) or vegetables 1	(vegetables 75% : fruits 25%) or vegetables 2	(vegetables 25% : fruits 75%) or fruits 1	(vegetables 25% : fruits 75%) or fruits 2
pH	-	4.02	3.64	3.32	2.82
Alkalinity	mg/l $CaCO_3$	4,602	5,137	7,705	7,384
VFA	mg/l Asetat	2,463	1,537	1,806	683
TSS	mg/l	4,940	728	4,370	636
VSS	mg/l	4,040	708	3,870	584
COD total	mg/l	28,800	13,017	33,600	17,898
Phosphat total	mg/l	64	36	44	45
NTK	mg/l	158	150	127	114
Carbohidrat	% w/w	0.1676	0.0798	0.4543	0.2397
Lipid	% w/w	0.2481	0.1945	0.2824	0.2471
Selulose	% w/w	0.60	0.60	0.76	0.66

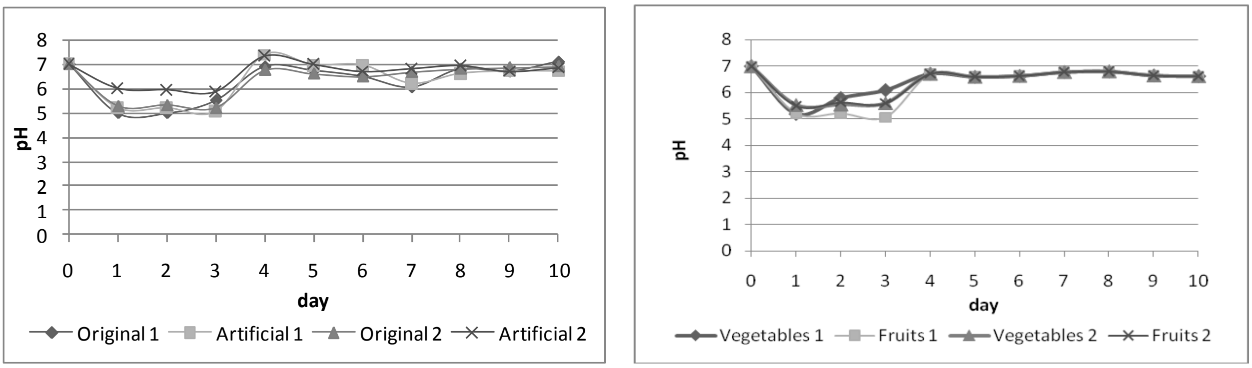
Note: 1-Without *Pre-treatment* sedimentation
2-With *Pre-treatment* sedimentation

Cellulose is a biodegradable polymer but has a low level of solubility[10]. With the treatment of sedimentation, suspended particles will be removed including cellulose, whereas cellulose content in the liquid fraction was lower in the pretreatment sedimentation.

Carbohydrates are measured as the starch is a polysaccharide which degradable the monosaccharides, glucose and fructose[11]. The highest carbohydrate content present in the fruit 1 (Tabel 2).

Environmental conditions of temperature and 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[20]. The optimal pH required for asidogenic bacteria is between 5 and 6.5, while the optimal pH for methanogenesis is above 6.5[9].

Based on this research, Figure 2 shows the pH profiles in all reactors. initial pH of all reactors around 7 but continued to decrease, then day-to-4 pH increased again and began to stabilize at pH 6.2 to 7.1 until the end of the research.

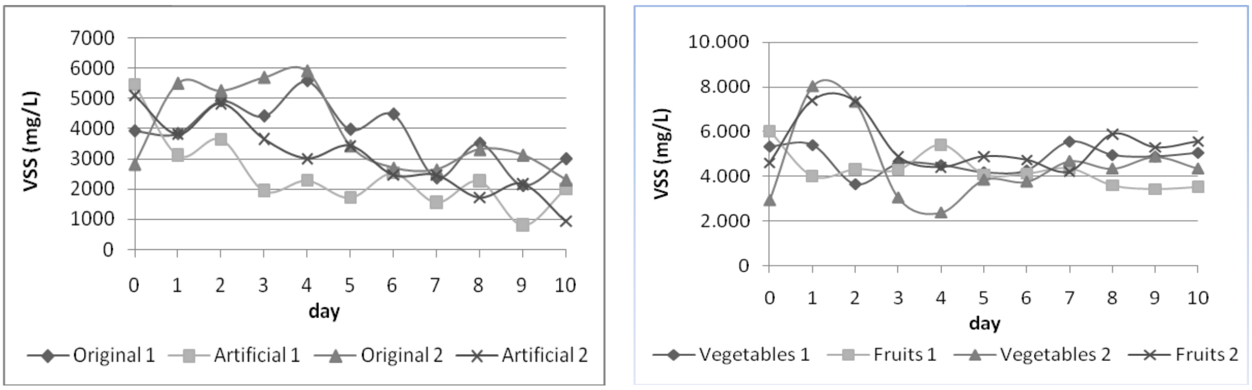


(a) (b)

Figure 2. pH of *batch* reactor anaerob from substrate with p*retreatment* and without p*retreatment.* (a) Original and Artificial B*iowaste*, (b) Vegetables and Fruits *Biowaste.*

Decreasing pH indicate the accumulation of acids, due to high concentrations of volatile acids in a reactor. When bacteria asidogenik work, the more organic acids reproduced and cause a decline in pH(12). With decreasing pH, which indicated all the reactors, suggesting asidogenesis process. After a day-to-4, the pH of the reactor began to stabilize. Increasing the pH value indicates the occurrence of phase decomposition asidogenesis toward methanogenesis.

Volatile suspended solids (VSS) shows the organic content of suspended solids, while also as the amount of biomass contained in reactor. The concentration of VSS is the number of active biomass and inert biomass contained in the reactor (13). From the profile obtained through the VSS measurement results can be seen the growth of biomass in anaerobic batch reactor. **Figure 3** shows the profile of VSS in the liquid fraction by pretreatment and without pretreatment sedimentation.

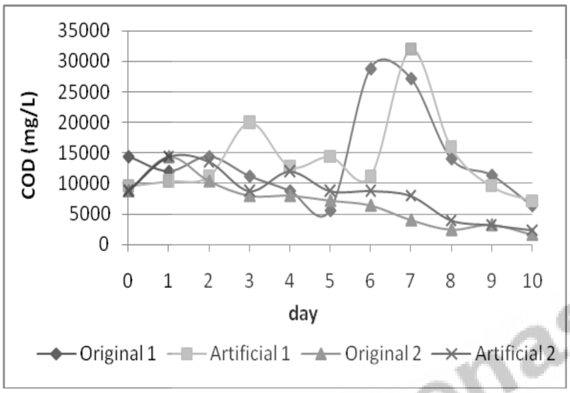


(a) (b)

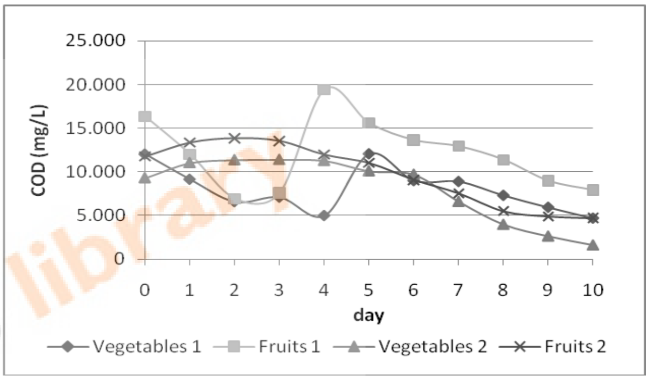
Fig 3. VSS of reactor *batch* anaerob from substrate with p*retreatment* and without p*retreatment.* (a) Original and Artificial B*iowaste*, (b) Vegetables and Fruits *Biowaste*

Figure 3(a) shows the measurement results VSS, VSS tends to decrease during the research, original and artificial reactor VSS is 5570-820 mg/l. Figure 3(b), the reactor vegetables and fruit treated with pretreatment, the VSS increase until day 2 at 8000 mg/L and then decrease to 2000 mg/l until day 4, then tend to stabilize. As for the reactor without pretreatment of vegetables and fruits tend to be fixed from the start to the end of the research with VSS of 8029-2386 mg/l.

Soluble chemical oxygen demand (COD dissolved) is a value that indicates the need oxygen to oxidize dissolved organic compounds. In batch conditions where there is no influent or effluent in the system, and organic content measured as soluble COD continued to decrease[14]. Figure 4 shows profiles of dissolved COD in the reactor liquid fraction of original waste, artifial, vegetables and fruits with and without pretreatment sedimentation.



(a)



(b)

Figure 4. Concentration soluble COD in reactor batch anaerob from substrate with p*retreatment* and without p*retreatment.* (a) Original and Artificial B*iowaste*, (b) Vegetables and Fruits *Biowaste*

In Figure 4 shows the COD tends to decline in all reactors, but to original reactor 1, an artificial 1, fruit 1 and vegetable 1, an increase in concentration of about 1-2 days then decrease.

Soluble COD reduction associated with the activity of microorganisms in degrading organic content of the substrate into energy sources, such as methane CH_4[11]. Things that affect the increase in soluble COD in anaerobic batch reactor is soluble microbial products (SMP). SMP produced by microorganisms into organic content so that the measured soluble COD increased [15]. In a review[16], generally defined as compounds dissolved SMP contained in the effluent, but not found in the influent. SMP can be classified into two groups, namely utilization associated products (UAP) and biomass associated products (BAP), where UAP is a SMP associated with the use of the substrate and the growth of microorganisms, so the rate of its formation proportional to the rate of use of the substrate. BAP is a SMP associated with the decay of microorganisms, where the rate of formation of BAP proportional to concentration of biomass[16]. The content of soluble compounds were detected in SMP increased soluble COD can be classified as UAP, because occurs early in the anaerobic batch reactor operation.

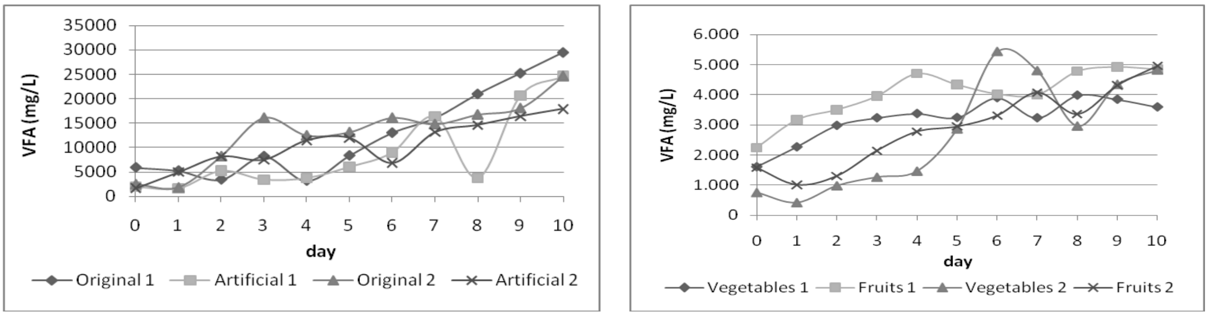
COD removal efficiency at higher substrate pretreatment than without pretreatment, COD removal of each reactor are listed in Table 3 and the highest COD removal occurred in vegetable reactor 2 is 81.97%, while for the highest removal occurred in the fruit 1 reactor reached 840 mg/l/day.

Table 3. Rate Removal and Removal efficiency dissolved COD in reactor batch anaerob

Reactor	**Input (mg/l)**	**Output (mg/l)**	**Removal Rate (mg/l/day)**	**Removal Efficiency (%)**
Without *Pretretment*:				
- Original 1	14.400	6.400	800	55,56
- Artificial 1	9.600	7.200	240	25,00
- Vegetables 1	11.993	4.702	729	60,79
- Fruits 1	16.311	7.910	840	51,51
Reactor	**Input (mg/l)**	**Output (mg/l)**	**Removal Rate (mg/l/day)**	**Removal Efficiency (%)**
With *Pretretment*:				
- Original 2	8.800	1.600	720	81,82
- Artificial 2	8.800	2.400	640	72,73
- Vegetables 2	9.027	1.628	740	81,97
- Fruits 2	11.762	4.716	705	59,90

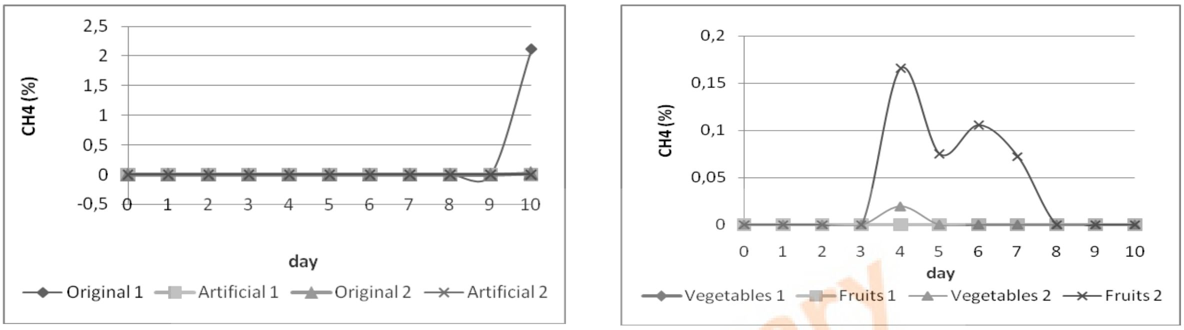
COD concentrations related with the formation of methane and total volatile acid (TVA). Substrate hydrolyzed into shorter organic chain, and then fermented into volatile acids by bacteria asidogenik. Volatile acids which have more than two carbon chain, will be converted to acetate and H_2 by H_2 -producing bacteria (obligate hydrogen-producing acetogens) and then changed to CH_4 by methanogenic bacteria.

During the the research TVA concentration in all reactors showed an increase as shown in Figure 5, and at the end of the experiment reached 17900-30000 mg/l acetate in the reactor with substrate fraction of original waste liquid and the artificial, whereas for the reactor of vegetables and fruits reach 3591-4959 mg/l acetate . If the accumulation of volatile acids exceed 2000 mg/l cause inhibition of methane fermentation[17]. TVA values in the whole reactor exceed 2000 mg/l, so that when connected with Figure 6 shows the inhibition the formation of methane, methane is formed only on original biowaste reactor liquid fraction at day-10 of 2.11%, and day-to-4 formation of methane in the reactor fruit 2 is 0.16% and vegetable 2 reactor equal to 0.019%.



(a) (b)

Fig 5. TVA in reactor batch anaerob from substrate with p*retreatment* and without p*retreatment*. (a) Original and Artificial B*iowaste*, (b) Vegetables and Fruits *Biowaste*

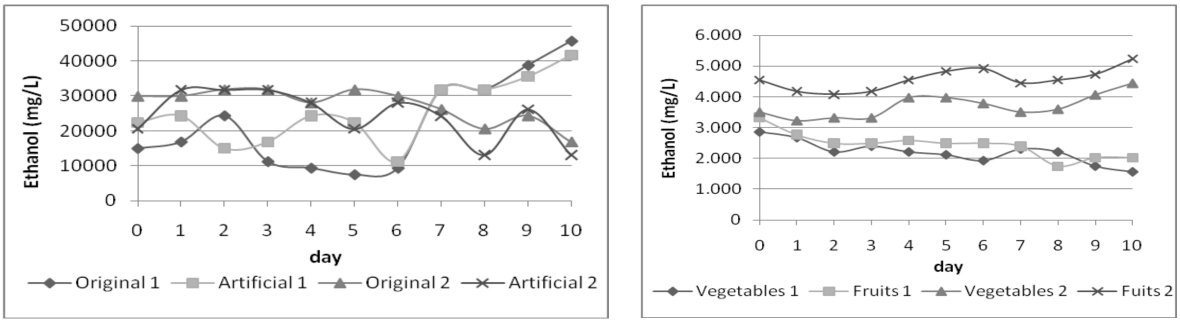


(a) (b)

Fig 6. Metan in reactor batch anaerob from substrate with p*retreatment* and without p*retreatment*. (a) Original and Artificial B*iowaste*, (b) Vegetables and Fruits *Biowaste*

Methanogenic bacteria tend to be more influenced by the inhibition than the bacteria that work on the fermentation process[9]. Inhibition is a low pH, and accumulation of excess acid product. Bacterial fermentation can continue to produce fatty acids although the pH has decreased. This can cause the continued problems of environmental conditions. TVA decrease of measurable in the reactor caused by the products asidogenesis that are used for stage acetogenesis. Propionic acid, butyric can be degraded into acetate[18]. TVA decrease followed by an increase which indicates that the acetate has been produced, and measured the accumulation of such products as TVA. Total volatile acid profiles for each reactor tend to show an increase for 10 days. The increase and decrease in TVA profile related with the rate of production and consumption rate of volatile acid. In the research done [19], TVA reduction occurred after 10 days, in which acetic acid, butyric and proprionat consumed as a substrate on the stage of methanogenesis. Based on the results obtained from TVA measurement which tends to increase, concluded that the degradation of all the reactors are still in the stage asidogenesis.

Ethanol is a product resulting from the process asidogenesa. In this research ethanol measurements done by the method of refractive index refraktometri. The results for ethanol content can be seen in Figure 7.



(a) (b)

Fig 7. Etanol in reactor batch anaerob from substrate with p*retreatment* and without p*retreatment.* (a) Original and Artificial B*iowaste*, (b) Vegetables and Fruits *Biowaste*

Figure 7 shows the profile of ethanol produced in the reactor decreased concentration of original 2, artificial 2, vegetables and fruit a 1, while the other reactor tends to increase. In the process of anaerobic fermentation, fatty acids, amino acids and monosaccharides converted into various fermentation products including ethanol. Ethanol is produced is then used by methanogenic bacteria as a substrate metanogenik[20]. Increasing the amount of ethanol concentration showed that the non-methanogenic bacteria to produce ethanol is still active on stage asidogenesa. During operation of batch reactors occur ethanol removal in original reactor 2 and artificial 2 is 43.75% and 36.36%. Removal of ethanol in the reactor 1 and fruit vegetable 1 is 45.74% and 38.79%.

CONCLUSION

Based on the research, there is removal organic matter a higher on the substrate with a pretreatment sedimentation. Removal efficiency of liquid fraction of original biowaste 81.82% and biowaste artificial 72.73%, while the liquid fraction vegetable biowaste are 81.97% and 59.90% fruit liquid fraction biowaste. On the substrate without pretreatment sedimentation, occur removal of organic matter in liquid fraction biowaste original and the artificial are 55.56% and 25%, while the liquid fraction of biowaste vegetables and fruits are 60.79% and 51.51%. The formation of methane at 2.11% on day 10 occur at f liquid reaction of original waste without pretreatment sedimentation, while the substrate with pretreatment sedimentation the formation of methane of 0.16% in the liquid fraction of biowaste vegetables and 0.019% in liquid fraction biowaste of the fruit, which both occur on the fourth day.

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