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Vegetable Waste Biodrying Treatment for Energy Recovery as Refuse Derived Fuel Potential

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ABSTRAK

Sampah sayuran merupakan jenis sampah organik *biodegradable* yang dapat ditemukan di setiap lokasi di Indonesia. Selain itu, timbunan sampah sayuran juga mendominasi sampah makanan. Pemanfaatan lebih lanjut sampah sayuran salah satunya dapat menggunakan pemulihan energi. Pemulihan energi sampah sayuran dapat dilakukan dengan *biodrying* yang tergantung dengan waktu dan bioaktivator. Tujuan dari studi ini adalah untuk mengetahui pengaruh waktu dan pemberian aktivator pada proses *biodrying* sampah sayuran. Penelitian ini menggunakan sampah seberat 0,5 kg dengan pemberian laju alir udara 15 liter/menit, suhu pada proses berada pada rentang 28,4-34,1°C. Biodaktivator yang digunakan dalam penelitian ini adalah ragi roti, tempe, dan tape. Penurunan massa maksimum terjadi pada proses biodrying dengan penambahan bioaktivator. Hasil uji pengaruh pada multivariate menunjukkan adanya pengaruh waktu dan bioaktivator pada perubahan nilai kadar air dan nilai kalor. Akan tetapi, interaksi antara waktu dan bioaktivator hanya berpengaruh pada kadar air. Hal ini karena proses degradasi terjadi memanfaatkan mikroorganisma yang tersimpan di dalam cairan bioaktivator dan air dalam sampah sayuran. Penelitian lebih lanjut diperlukan untuk mengetaui lebih jelas pengaruh variabel lain dalam proses *biodrying* terutama pada waktu detensi yang tepat dan bioaktivator yang mempercepat laju degradasi.

***Kata kunci*:** Sampah sayuran, biodrying, waktu detensi, bioaktivator.

ABSTRACT

Vegetable waste is a type of biodegradable organic waste found in every location in Indonesia. In addition, vegetable waste also dominates food waste. One of the ways to use vegetable waste is to use energy recovery. Energy recovery of vegetable waste can be done by time-dependent biodrying and bioactivator. This study aimed to determine the effect of time and activator application on the vegetable waste biodrying process. In this study, 0.5 kg of waste is used with an airflow rate of 15 liters/minute, the temperature in the process is in the range of 28.4-34.1°C. The bioactivators used in this study were baker's yeast, tempeh, and tape. The maximum decrease in mass occurs in the biodrying process with the addition of a bioactivator. The multivariate effect test results showed an effect of time and bioactivator on changes in water content and caloric value. However, the interaction between time and bioactivator only affects the water content. This is because the degradation process occurs utilizing microorganisms stored in the bioactivator liquid and water in vegetable waste. Further research is needed to know the effect of other variables in the biodrying process, especially the right detention time and bioactivators that accelerate the rate of degradation.

***Keywords*:** Vegetable waste, biodrying, detention time, bioactivator.

1. INTRODUCTION

With the increasing number of household activities being carried out, the more vegetable waste produced will cause piles of rotting garbage, causing unpleasant odors, polluting the environment, and becoming a source of disease that impacts public health [1,2]. The accumulation of waste, especially

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vegetable waste, needs to be treated properly and correctly [3]. Waste processing carried out by the community is still conventional and requires a long time. So, innovation can be required by reprocessing waste simply by reusing it [4].

The lack of efforts to utilize waste impacts the increasing volume of waste [5]. For example, the average amount of waste in Surabaya per day is 8700 m^3, with 87% of organic waste found in the Surabaya Wonokromo Market, which is dominated by vegetable and fruit waste [6]. Therefore, efforts need to be made to utilize waste into something valuable, namely waste to energy, as an alternative to overcome the problem of increasingly limited fuel [7-9].

The thermal method is very efficient for reducing volume in a short time and recovering energy as renewable energy [10]. Biodrying is an alternative to mechanical-biological bioconversion to treat waste with high water content [11], such as vegetable waste. This process can be applied in a reactor to treat vegetable waste. Biodrying integrates mechanical processes (waste counting and air circulation) and bioconversion (composting and anaerobic treatment) [12]. In practice, biodrying reactors process waste with high moisture content that has been chopped and produces an output of dry waste (dried) which will undergo further mechanical processing. The heat generated from the aerobic decomposition process of organic compounds is combined with excess air. This study aimed to determine the effect of time and activator application on the vegetable waste biodrying process.

2. RESEARCH METHODS

2.1. Time and Location

The researchers carried out several activities to complete this research, starting with discussing research ideas, collecting raw materials, making briquette pellets, processing test data, and compiling research reports mainly carried out in South Jakarta from September 20, 2020 to January 30, 2021.

In this study, temperature control was carried out every day. At the end of the retention period, the decrease in water content, solid volatile value, carbon value, and caloric value analysis was carried out. The weight of the mud used in the experiment was 0.5 kg with a variation of the water flow rate of 15 liters/minute. The temperature in the biodrying process is in the range of 28.4-34.1°C. This was done following several previous studies using a range of 30-40°C [13,14]. The variations used in this biodrying research was shown in Table 1 and the image of vegetable waste used in this work was displayed in Figure 1.

Table 1. Variations used in biodrying research.

Code	Variation
SS1	Vegetable trash
SS2	Vegetable waste + baker's yeast
SS3	Vegetable waste + tempeh yeast
SS4	Vegetable waste + tape yeast

Figure 1. Vegetable waste to be processed by biodrying.

2.2. Sample Measurement

The researcher's method of data collection was through several tests of the effectiveness of RDF to obtain the desired results, namely the weight test, water content test, caloric value test, and ash content test.

The method used to measure the sample's water content is the gravimetric method. Gravimetry in chemistry is one of the analytical chemistry methods to determine the quantity of a substance or component that has been known by measuring the weight of the component in a pure state after going through the separation process. Gravimetric analysis or quantitative analysis by weight is a process of isolating and weighing a certain element or compound in the purest possible condition. The moisture content of the sample material is determined by the weight loss during drying. Samples of materials are airtight packed after being weighed. The sample was then dried in a drying oven at about 105°C until a constant weight was reached during successive weighing. The drying time and temperature depend on the material and are specified in the relevant standards. After drying, the sample material was weighed again. The difference in weighing can determine the moisture content of the sample material. The ash content test is carried out to measure the total mineral content in an object. Determining the total ash is usually used to determine the quality of processing and determine the type of material.

The method used to measure the caloric value of samples in Balitnak is to use of a bomb calorimeter. A bomb calorimeter is a tool used to measure the amount of heat (caloric value) released during incomplete combustion (in excess O_2) of a compound, food, or fuel. A number of samples are placed in an oxygenated tube immersed in a heat-absorbing medium (calorimeter) and an electric fire will burn the sample from a metal wire attached to the tube. The caloric value is obtained through experiments using a bomb calorimeter, which is part of the heat released from the combustion of a number of units of fuel.

2.3. Data Analysis

As for the inferential analysis using multivariate analysis (MANOVA). However, before performing the hypothesis analysis, the analysis prerequisite test consists of the normality test, the data homogeneity test, and the test between the dependent variables. From the requirements analysis test, it was found that the data were normally distributed and homogeneous.

3. RESULTS AND DISCUSSION

The weight test was carried out to determine the value of the reduction in weight or weight of each type of pellet briquette after going through several work steps and the testing process. From the weight test results, the data obtained after the drying process, both the natural drying process with biodrying and the natural drying process without biodrying carried out for 5 days are shown in Figure 2. The masses in SS1 and SS2 along with SS3 and SS4 have different values due to different treatments for the mass of bioactivator and the amount of vegetable waste. This does not affect because what is important is the rate and amount of water reduction in the biodrying process [15,16].

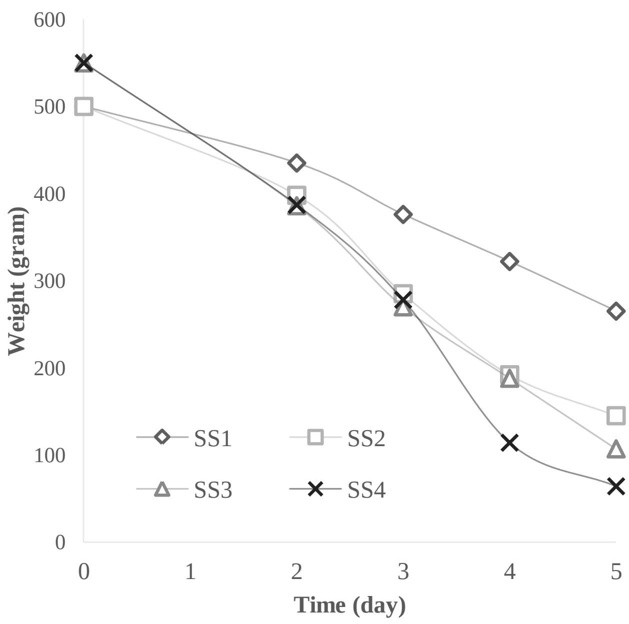

Figure 2. Changes in mass during the five-day biodrying process.

The comparison graph between moisture and ash content from laboratory tests can be seen in Figure 3 and Figure 4. The initial water content contained in the final biodrying product greatly affects the caloric value contained [15]. In the dry caloric value of laboratory test results, the graph trend has decreased, while in the actual caloric value (including moisture content), the graph trend has increased (Figure 5).

Ash is an inorganic residue from the combustion process or the oxidation of organic components of food. Total ash content is part of a proximate analysis that aims to evaluate the nutritional value of a food product, especially total minerals [17]. Therefore, the ash content of material shows the total minerals contained in the material that must handle after thermal processes [18 -20].

The caloric value of the laboratory test is the caloric value obtained on the sample under dry conditions (without any moisture content). Even though the final product of biodrying in this study still contained several percent water content. To determine the actual caloric value of the final product, the caloric value was calculated without any reduction in moisture content. The calculation results of the actual caloric value (including moisture content) can be seen in Figure 5.

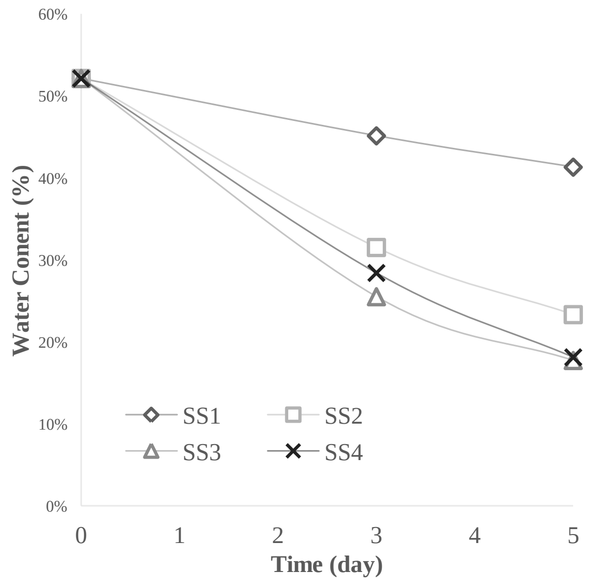

Figure 3. Changes in water content during the five-day biodrying process.

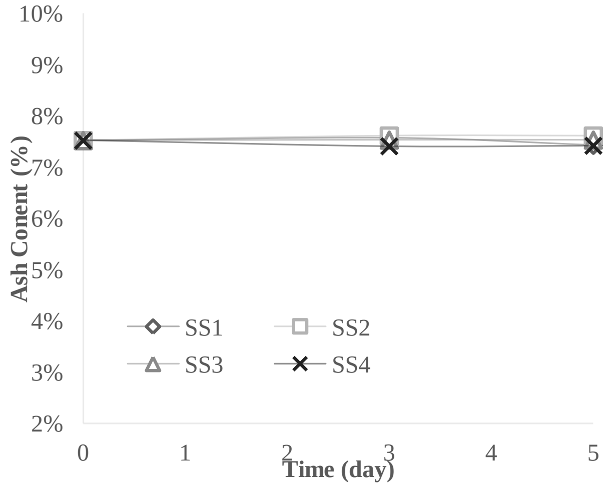

Figure 4. Changes in ash content during the five-day biodrying process.

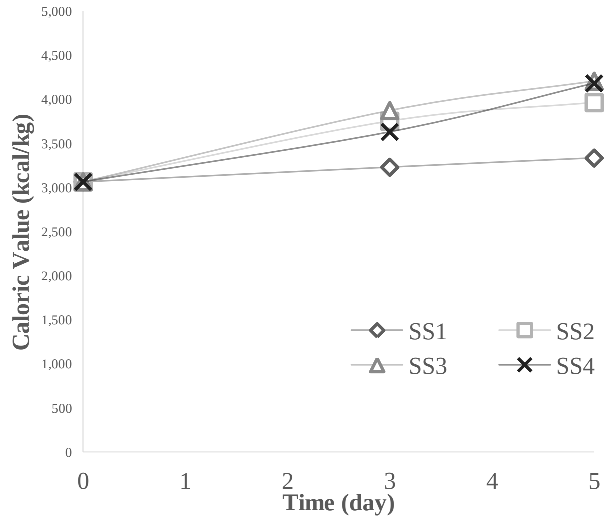

Figure 5. Changes in caloric value during the five-day biodrying process.

The first hypothesis test in this study used a multivariate test using Pillai's Trace, Wilks' Lambda, Hotelling's Trace, Roy's Largest Root tests. From the results of hypothesis testing, a significance level of 0.000 was obtained for all variables. Because this significance level is less than 0.05, there is no effect of the results on time and bioactivators in the biodrying process. A summary of the multivariate test results using Pillai's Trace, Wilks' Lambda, Hotelling's Trace, Roy's Largest Root tests shown in Table 2.

Table 2. The results of the influence test on each variation.

Effect		Value	F	Hypothesis df	Error df	P-value
Intercept	Pillai's Trace	1	4442.178	3	6	0.000
	Wilks' Lambda	0	4442.178	3	6	0.000
	Hotelling's Trace	2221.089	4442.178	3	6	0.000
	Roy's Largest Root	2221.089	4442.178	3	6	0.000
Time	Pillai's Trace	0.998	1263.472	3	6	0.000
	Wilks' Lambda	0.002	1263.472	3	6	0.000
	Hotelling's Trace	631.736	1263.472	3	6	0.000
	Roy's Largest Root	631.736	1263.472	3	6	0.000
Bioactivator	Pillai's Trace	1.948	4.939	9	24	0.001
	Wilks' Lambda	0	85.897	9	14.753	0.000
	Hotelling's Trace	1427.923	740.405	9	14	0.000
	Roy's Largest Root	1418.063	3781.502	3	8	0.000
Time * Bioactivator	Pillai's Trace	1.904	4.63	9	24	0.001
	Wilks' Lambda	0	43.304	9	14.753	0.000
	Hotelling's Trace	305.352	158.331	9	14	0.000
	Roy's Largest Root	295.709	788.557	3	8	0.000

The final results of MANOVA in time variation and bioactivator have the same effect on moisture content and caloric value, while no effect on ash content. Meanwhile, the interaction between time and the biactivator only significantly affected the water content. The overall results can be seen in Table 3.

The biodrying technique used utilizes microorganisms stored in the bioactivator liquid [12,21]. Aerobic microbes will carry out the activity of decomposing organic matter. This activity will release heat, reducing the water content in the material but still maintaining the caloric value in the organic material. Therefore, in the biodrying process, it does not significantly affect the decrease in ash content. Meanwhile, the interaction of time and bioactivator only affects the degradation process, especially the use of water by microorganisms. The biodrying process focuses on aerobic technology, namely removing water, especially steam, due to the composting temperature and adequate ventilation. Proper aeration and temperature settings can increase drying efficiency by 66.7% of the initial moisture content [22]. When the water content ratio to biodegradable organic matter is too high, the heat generated from the biodegradation process is insufficient to evaporate the water. On the other hand, the waste degradation process (high water content) will produce more leachate and decrease caloric value [23-25].

A desirable aerobic treatment technique for removing moisture from food waste and creating refuse-derived fuel (RDF) that is advantageous for using trash as an energy source is bio-drying [26]. Optimizing the parameters to increase the water removal rate requires an understanding of the mechanism of the process and the interactions of important variables [26]. Heat is produced as part of the metabolic processes as the nutrients, carbon (C), nitrogen (N), and other elements needed for microbes are fed from the vegetable waste. This heat can be used for drying. RDF is a clean and effective way to provide an eco-friendly alternative fuel for sectors that generate electricity using coal fuel (RDF is mostly used for pulp, paper, and wood industry waste, with the sawmill industry coming in second) [27]. As a result, the RDF facilities are somewhat tiny and are only used by the industrial sector.

Table 3. MANOVA test results for each variation.

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	Water	0.132[a]	7	0.019	183.219	0.000
	Ash	9.276E-6[b]	7	1.33E-06	0.188	0.98
	Caloric	1730474.802[c]	7	247210.686	13.76	0.001
Intercept	Water	1.276	1	1.276	12356.13	0.000
	Ash	0.086	1	0.086	12166.69	0.000
	Caloric	2.16E+08	1	216453978.1	12048.29	0.000
Time	Water	0.021	1	0.021	200.833	0.000
	Ash	4.02E-07	1	4.02E-07	0.057	0.817
	Caloric	342663.9	1	342663.891	19.073	0.002
Bioactivator	Water	0.11	3	0.037	354.584	0.000
	Ash	7.40E-06	3	2.47E-06	0.35	0.791
	Caloric	1282781	3	427593.694	23.801	0.000
Time * Bioactivator	Water	0.002	3	0.001	5.984	0.019
	Ash	1.47E-06	3	4.90E-07	0.069	0.975
	Caloric	105029.8	3	35009.944	1.949	0.2
Error	Water	0.001	8	0		
	Ash	5.65E-05	8	7.06E-06		
	Caloric	143724.3	8	17965.543		
Total	Water	1.409	16			
	Ash	0.086	16			
	Caloric	2.18E+08	16			
Corrected Total	Water	0.133	15			
	Ash	6.57E-05	15			
	Caloric	1874199	15			

[a]R Squared = .994 (Adjusted R Squared = .988)
[b]R Squared = .141 (Adjusted R Squared = -.610)
[c]R Squared = .923 (Adjusted R Squared = .856)

4. CONCLUSION

The biodrying process in this study can occur within 5 days of processing with the highest mass reduction in the administration of bioactivators. The effect test results showed an effect of time and bioactivator on changes in water content and caloric value. However, the interaction between time and bioactivator only affects the water content. This is because the degradation process occurs utilizing microorganisms stored in the bioactivator liquid and water in vegetable waste. Further research is needed to know the effect of other variables in the biodrying process, especially the right detention time and bioactivators that accelerate the rate of degradation.

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