



Osmotic Dehydration to Accelerate Bio-Drying Process of Food Scrap Waste

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Abstract. The increasing municipal solid waste can cause environmental pollution problems. The organic fraction is the largest component of municipal solid waste, reaching 75%, mostly around 61% from kitchen waste. One method to reduce the impact of pollution from municipal waste by processing it into Refused Derived Fuel (RDF) with bio-drying method. The combination of osmosis process treatment by soaking organic waste in a NaCl solution before the bio-drying process can speed up the drying process. Immersion was carried out for four days. Every day the water content analysis was carried out by weighing. This paper provides an effect evaluation of 5%, 15%, and 25% NaCl solution as osmosis media on reducing the organic waste's water content. The organic waste are simulated using tomatoes, water spinach, cooked rice, and tofu. The higher the NaCl concentration (maximum 25% studied), the greater the ability to reduce the water content, 25% in water spinach and 40% in tomatoes. In tofu and cooked rice, soaking in NaCl solution increased the water content by 20% and 100%, respectively.

Keywords: Bio-Drying, Food Scrap Waste, Dehydration, Osmosis, RDF

1 Introduction

Municipal solid waste in Indonesia mostly comes from kitchen waste. For example, in Malang city, around 75% comes from kitchen waste. The components that makeup kitchen waste are dominated by organic solid waste, including solid food waste, reaching 61.5% [1]. The high organic fraction causes high water content in municipal solid waste, reaching 49.5% to 60% with calorific value 1272.22 cal/gram [2].

The municipal solid waste organic fraction can be used for Refuse Derived Fuel (RDF) which can be used as solid fuel. RDF is a type of product from municipal solid waste which is dried to reduce its water content and increase the calorific value of the waste.

The dried RDF product has a calorific value of 4335 kcal/kg with water content below 20% [3], the characteristics of RDF vary. There is no specific standard, the main specifications that become requirements are the calorific value and water content. One example of RDF specifications is the lowest calorific value of 11-18 MJ/kg and water content of 10 - 30 % [4]. Another example is RDF fuel specifications for kiln

combustion in a cement industry are : caloric value ≥ 2500 Kcal/kg, moisture content ≤ 20 % [5].

Bio-drying is a method that is widely used to dry municipal solid waste to make RDF and bio-stabilization. This method is to dry solid waste by utilizing the heat of biological microorganisms activity, bacteria, and fungi to evaporate and reduce the water content in organic solid waste [6]. The mechanism of the bio-drying process is similar to that of composting but has a different purpose. Bio-drying aims to reduce the water content more significantly than composting and reduce the volatile solid content to a lesser extent. In composting, the decrease in water content is smaller, while the decrease in volatile content is more significant than in bio-drying. Composting requires a longer drying time of 4 weeks - 50 days, while bio-drying is only about 7 - 15 days [7]. The bio-drying product can be used for solid fuel called RDF, while the composting product can be used for compost.

The disadvantage of drying solid waste using the bio-drying process is that it takes too long. The time depends on the type of solid waste. The impact requires a process equipment (reactor) with a large volume and energy requirements to circulate air for drying. Another impact is that the longer the bio-drying time, the lower the carbon content due to decomposition. The decomposition process can occur due to the activity of heterotrophic microorganisms that require carbon from the organic compounds they occupy. Several studies have been carried out by previous researchers. Research conducted by [8] experimented on bio-drying canteens waste in windrow pile and aerated pile. It took 17-22 days to reach 20-30% water content.

Osmosis is a phenomenon of the transfer of substances contained in the material from a lower concentration (hypotonic) to a higher concentration (hypertonic) through a semipermeable membrane [9]. NaCl solution can be used as a hypertonic solution to absorb water in material with semipermeable membrane, such as fruits and vegetables. A semipermeable membrane is a separate membrane which only water and its molecules can pass through. Organic waste from kitchen waste is a material with a low salt concentration (hypotonic). When this material is immersed in a salt solution (hypertonic), the water in the material tissue will move to a salt solution. This water transfer causes a decrease in the availability of water in the material and can reduce the water activity (so the growth of microorganisms that decompose organic waste is inhibited. Reducing the can be done with removing the water content partially or entirely by adding hydrophilic solution or through drying [10].

Water transfer from plant tissue causes the water content decreasing of organic waste. Theoretically, the osmosis mechanism's decrease in water in plant tissues can reach 50%, depending on the hydrophilic solution used. The initial treatment of soaking organic waste using a solution of NaCl before the bio-drying process can reduce water content and waste decomposition. Thus, it can speed up the bio-drying process and minimize the decomposition process of organic waste for RDF materials. This study aims to analyze the effectiveness of reducing water content and decomposition in tomatoes, vegetables, cooked rice, and tofu after soaking in NaCl solution.

2 Experimental

2.1 2.1 Measurement of the water content of the sample in the osmosis process

Samples of tomatoes, water spinach, cooked rice, and tofu 250 grams were soaked in 5%, 15%, and 25% (m/m) NaCl solution for 4 days in a plastic container, shown in Figure 1. Every day, the appearance (color and turbidity) of the immersion water was observed, and samples taken from the immersion water were drained and placed on a cloth to remove adhering water and then weighed. The change in sample mass is calculated as a decrease or increase in water from the sample when observing clear immersion water, shown in Figure 2. If the immersion water is cloudy (Figure 3) the decrease in sample mass is calculated as a decrease in mass due to decomposition and a decrease in the sample's water content.



Fig 1. Cooked rice, tomatoes, water spinach in plastic container



Fig 2. Clear immersion water



Fig 3. Cloudy immersion water

2.2 Measurement the water content of the bio-drying process and the combination of osmosis-bio-drying

Two samples of a mixture of tomatoes, water spinach, cooked rice, and tofu were made with a mass ratio of 4:4:1:1 each with a total of 2000 grams (Figure 4). The First sample was directly processed in the 30 liters volume of bio-drying reactor (Figure 5), aeration rate 25 l/minute, at temperature 33-35o C for 5 days. The second sample was first immersed in a NaCl solution with a concentration of 25% (m/m) for 2 days, drained, and then continued with the bio-drying process same as the first sample. After 5 days of the

bio-drying process, each 2 grams of sample was taken to analyze its water content by gravimetric method.

2.3 Gravimetric Analysis

A total 2 grams of the sample in a porcelain dish was put into a furnace at a temperature of 110°C then weighed until a constant mass is obtained, which takes about an hour. The sample was cooled in a desiccator for 15 minutes. Then the sample was weighed using an analytical balance.

$$\text{moisture content (\%)} = \frac{m_2 - m_1}{m_3 - m_1} \times 100\% \quad (1)$$

m_1 = empty cup mass (gram)

m_2 = the mass of the cup + pre-oven contents (gram)

m_3 = the mass of the cup + the contents after being in the oven (gram)



Fig 4. Mixture sample



Fig 5. Bio-drying reactor

3 Result And Discussion

The types of organic waste used in this study were vegetables (water spinach), fruit (chopped tomatoes), carbohydrates (cooked rice), and protein (tofu). Each of the materials, a total of 250 grams, was immersed in a NaCl solution whose concentration was varied with the ratio of 1:3 for 4 days. To determine the occurrence of a decrease in water content is done by weighing. Every day the sample was taken from the NaCl solution, drained and covered with a cloth to dry the water adhering to the surface, then weighed. The difference between the initial mass and the mass of the material after soaking in NaCl solution is considered a decrease or increase in water after the soaking process. This assumption was validated based on observations of the turbidity of the immersion water. If the immersion water is clear, it is justified that the change in the mass of the materials due to the mass transfer of the water. On the other hand, if the immersion water is cloudy, it is justified that the change in the mass of the material is due to the decomposition of the material and the mass transfer of the water. Turbidity can indicate that the activity of microorganisms is high, which causes the

decomposition process. Heterotrophic microorganisms require carbon compounds from organic materials for their growth [11]. Microorganism activity can be measured from the value of [12]. The value ranges from 0, which indicates the absence of water to 1, which is pure water [13]. Although the addition of a hypertonic solution can reduce a_w , several types of yeasts such as *Debaryomyces hanseii*, *Hemymysis anomela*, *Candida pseudotropicalis*, and some mold types can grow in media with high salt and sugar concentrations [14].

3.1 Effects of NaCl concentration on tomato soaking

The effect of NaCl concentration on the percent decrease in cumulative mass of tomato soaking can be seen in Figure 6. Soaking tomatoes using NaCl solution with a concentration of 5% on the first day showed that the liquid was cloudy and formed bubbles. Until the fourth day, the liquid is getting cloudy. It indicates that the activity of microorganisms is high, which causes the decomposition process. In Figure 6, it is shown that the decrease in the cumulative mass of the material from the first to the fourth day was highest at a concentration of 5% compared to immersion with a concentration of 15% and 25%. This high decrease was due to the decomposition process of tomatoes. Tomatoes have a high sugar content so they are easy to ferment and 5% NaCl concentration could not kill microbes as described by [14].

Comparison of the concentration of 15 and 25% NaCl solution immersion, from the first day to the second day, the 15% immersion water was clear, and turbidity was seen on the third day. In comparison, at 25%, the turbidity began to appear on day four. The percent decrease in tomato mass for three days of immersion was more immersed in a 25% saline solution compared to 15%. The justification is that the decrease in mass is due to the decrease in the water content of tomatoes. The higher the NaCl concentration, the higher the cumulative decrease in the water content per unit of time

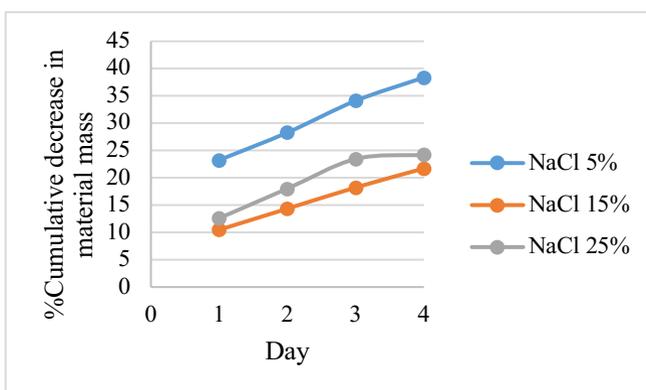


Fig 6. Effect of NaCl concentration on percent cumulative tomato mass decrease

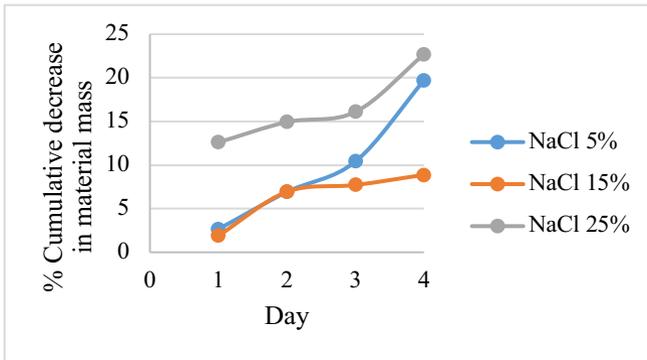


Fig 7. Effect of NaCl concentration on percent cumulative water spinach mass decrease

3.2 Effects of NaCl concentration on Water Spinach soaking

The effect of NaCl concentration on the percent decrease in cumulative mass of water spinach soaking can be seen in Figure 7. Water Spinach has more robust cell structure with a lower water content than tomatoes. The decrease in mass of water spinach per unit time after soaking was lower than that of tomatoes. Soaking water spinach using NaCl with a concentration of 5% on the first day, showed that the liquid was not cloudy and remained clear, and the color was light brown. It is due water spinach has low sugar content and high in cellulose, that not easy to ferment by microbes. On the third day, the fluid remained clear but was browner than on the first day and became darker brown and cloudy on the fourth day. This condition indicates that the decomposition process of water spinach soaked in NaCl solution with a concentration of 5% begins on the third day. Water spinach immersion with NaCl solution at a concentration of 15% and 25% remains clear with a light brown color. This condition, showed no decomposition of water spinach soaked in NaCl solution at both concentrations. In Figure 7, the percent cumulative decrease in the mass of water spinach for three days of immersion, was higher when soaked in 25% NaCl solution than 15%. The Justification is the mass decrease due to the decrease of the water spinach's water content. The higher the NaCl concentration, the higher the cumulative decrease in water content per unit time.

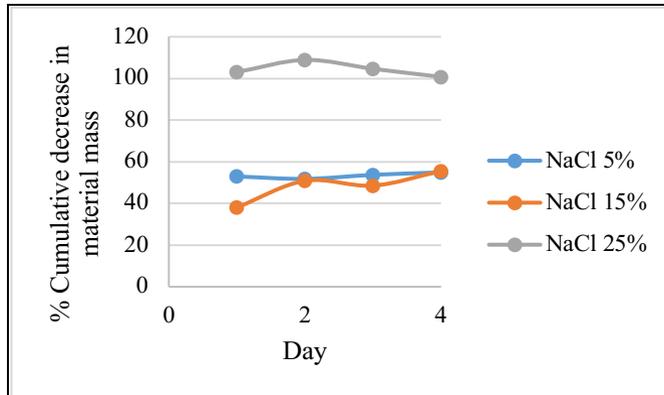


Fig 8. Effect of NaCl concentration on percent cumulative cooked rice mass decrease

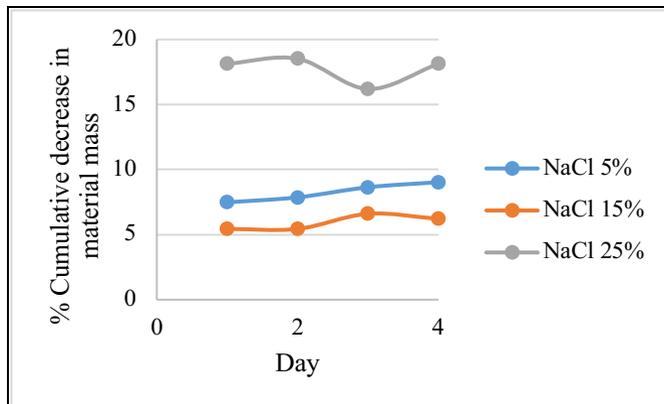


Fig 9. Effect of NaCl concentration on percent cumulative tofu mass decrease

3.3 Effects of NaCl concentration on cooked rice and tofu soaking

Unlike tomatoes and water spinach, cooked rice and tofu do not have a semipermeable cell structure. The mass transfer of water from these two materials to a NaCl solution or vice versa is not through osmosis but through adsorption and absorption mechanism. After soaking in NaCl solution, the mass of cooked rice and tofu increases. It is due to the mass transfer of NaCl solution through the pores into the cooked rice and tofu. At Figure 8 and 9, soaking tofu and cooked rice with concentrations of 5 and 15% NaCl solution shows an increase in the mass of the two ingredients. The increase in cooked rice mass after soaking in 5 and 15% NaCl solution for 4 days was higher than the increase in tofu mass. It caused by the porosity of the tofu is smaller than that of cooked rice. The NaCl solution absorbed by the cooked rice is greater than that of the tofu. The water soaked in cooked rice and tofu at concentrations of 5% and 15% from

the first to the fourth day was cloudy. It indicates that decomposition had occurred. The immersion water of two materials in 25% NaCl solution, remains clear, it indicating no decomposition occurs. The mass addition of cooked rice and tofu in NaCl concentration of 25%, was higher than of 5% and 15% NaCl immersion. It is because the immersion at the two latter of concentrations causes decomposition, and so decrease in the mass of the material immersed. The cooked rice has high sugar content, and tofu has high protein content. Both of the ingredients are easy to ferment, and at 5-15% NaCl concentration could not killed microbes.

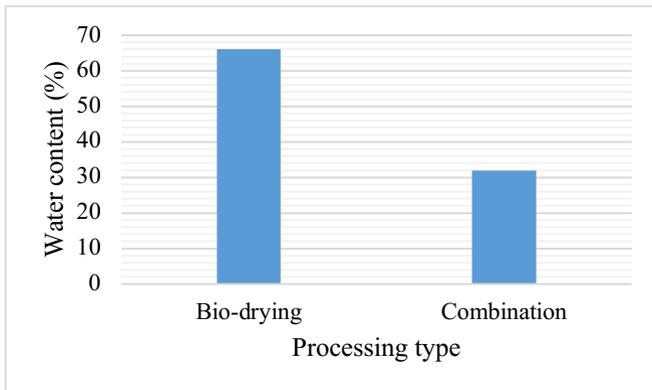


Fig 10. Water content of bio-drying and combination of osmosis-bio-drying process

3.4 Comparison of the drying time of the bio-drying process and the combination of osmosis-bio-drying

Tests effect the drying time of the bio-drying process and the combination of osmosis-bio-drying on the water content was carried out by making two of mixed samples of water spinach, tomatoes, cooked rice, and tofu in a mass ratio of 4:4:1:1, of 2000 grams each. First sample was directly processed by bio-drying for five days, and second sample was soaked in 25% NaCl solution first for two days, then drained and processed by bio-drying at same duration as first sample. The volume of bio-drying reactor is 30 liters, with temperature 33-35oC and aeration air flow 25 l/minute. Figure 10 shows the comparison water content in both samples after five days bio-drying. During the five days drying process, the moisture content of the samples in the bio-drying process was 68%, while those processed using the combined osmosis-bio-drying process were 38%.

The initial water content of sample was 90.1% so it decreased 32% for bio-drying and 52% for combination process. These indicate that the osmosis process using NaCl solution can reduce the water content of organic material before bio-drying. The advantage of osmosis process can reduce the water activity, thereby minimizing the decomposition of organic matter. The disadvantage of the combination process is the

dilution of the NaCl solution. It requires additional treatment to increase the concentration of NaCl solution so that it can be reused.

4 Conclusion

In this paper, an evaluation of the effect of NaCl solution as osmotic agent to accelerate the bio-drying process of simulated food waste has been presented. The process of osmosis using a NaCl solution can reduce the water content of tomatoes and water spinach, but in cooked rice and tofu the water content increases. The process of osmosis using a NaCl solution with a concentration of 25% for one, two, three, and four days can reduce the tomatoes, water spinach, without decomposition. Osmotic dehydration before bio-drying can speed up the drying process and minimize the decomposition of organic matter. The disadvantage of the combination process is that it requires an additional process to concentrate the NaCl solution so that it can be reused.

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References

1. Dinas Kebersihan dan pertamanan. *Pengelolaan Sampah di Kota Malang*. 2013.
2. G.A. Kristanto, I. Hanany, "Effect of air-flow on biodrying method of municipal solid waste in Indonesia," *AIP Conf Proc*, vol 1903 (040004), 2017, pp. 1-8.
3. F. Tambone, B. Scaglia, S. Scotti, and F. Adani, "Effects of biodrying process on municipal solid waste properties," *Bioresour Technology*, vol. 102(16), 2011, pp. 7443-7450.
4. C.S. Psomopoulos, "Residue derived fuels as an alternative fuel for the hellenic power generation sector and their potential for emissions reduction," *AIMS Energy*, vol. 2(3), pp. 321-341.
5. K.K. Ummatin and N. Faria, "Simulation of tipping fee policy to support municipal waste management into alternative fuel in the cement industry: A case study of Tuban landfill Indonesia," *IOP Conf Ser Earth Environ*, vol.753(012041), 2021, pp.1-7.
6. S. Sadaka, K. Vandevender, T. Costello, and M. Sharara, "Partial Composting for Biodrying Organic Materials," *Agriculture and Natural Resources*, 2011, pp.1-4,
7. M.M. Tun, and D. Juchelková, "Drying methods for municipal solid waste quality improvement in the developed and developing countries: A review," *Environ Eng Res*, vol.24(4), 2019, pp.529-42.
8. M. Chaerul and A. Fakhrunnisa, "Refuse derived fuel production through biodrying process (case study: solid waste from canteens)," *J. bahan alam terbarukan*, vol. 9 (1), 2020, pp. 69-80.
9. H.L. Ulfa, R. Falahiyah, and S. Singgih, "Uji osmosis pada kentang dan wortel menggunakan larutan NaCl," "Osmosis test on potatoes and carrots using a solution of NaCl," *J Sainsmat*, vol. IX(2), 2020, pp. 110-116.
10. P. Pittia and A.Paparella, "Safety by control of water activity: drying, smoking, and salt or sugar addition," chap 2 of *Regulating Safety of Traditional and Ethnic Foods*, Elsevier:Academic Press, 2016. pp.7-28.
11. R.J. Patil, G.A. Kaygude, S.K. Atole, and P.A. Muley, "Role of microbes in organic matter decomposition and sustains the soil health," *IJRSET*, vol. 8(7), 2019, pp.7753-7762.
12. E. Sandulachi and P. Tatarov, "Water activity concept and its role in strawberries food," *Chem J Mold*, vol. 7(2), 2021, pp.103-15.
13. E. Sandulachi, "Water activity concept and its role in food preservation," *Water Act Concept its role food Preserv*, 2010, pp.40-48.
14. L. Petruzzi, M.R. Corbo, M. Sinigaglia, and A. Bevilacqua. "Microbial spoilage of foods: fundamentals," chap 1 of *The Microbiological Quality of Food: Foodborne Spoilers*, Elsevier Ltd, 2017, pp.1-21.

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