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RESEARCH ARTICLE

Comparison of Weight Reduction and Water Loss for Convective and Osmo-convective Dehydrated Breadfruit (*Artocarpus altilis* (Parkinson) Fosberg)

Muhammad Abdurrahman Mas [1*], Laurensia Citra Larasati [1]

[1]Department of Food Technology, Indonesia International Institute for Life-Sciences (i3L), Jakarta, Indonesia
**corresponding author: muhammad.mas@i3l.ac.id*

ABSTRACT

Breadfruit (*Artocarpus altilis* (Parkinson) Fosberg), a tropical fruit commonly found in Indonesia, contains a well-balanced nutritional content. However, breadfruit has a rapid respiration rate which causes the fruit to be underutilized, leading to breadfruit becoming food waste. Convective dehydration is an effective method in slowing down the respiration rate; however, heat exposure can reduce the nutritional content of the breadfruit. The combination of osmotic pre-treatment and convective dehydration act as an alternative to achieve a similar outcome with a shorter amount of thermal exposure. This study determined the effectiveness of an osmotic treatment with 50° Brix sugar solution compared to convective dehydration on breadfruit. The results indicate that, as expected, the weight reduction (WR) of the osmo-convective samples is lower where the WR is 80.680% for convective dehydrated samples and 57.190% osmo-convective dehydrated samples. The water loss (WL) is statistically similar where WL of osmo-convective dehydrated samples was 18.315% compared to WL of the convective dehydrated samples 19.836%. The higher WR in the osmo-convective treatments shows sugar uptake into the fruit, while the similar water loss indicates the same reduction in moisture content between treatments. These results show the potential benefit of applying osmo-convective treatments to breadfruit. However, the research is still in the early stages of development. Additional parts of the research and parameters need to be optimized and explored in the future.

Keywords: ***breadfruit; osmo-convective dehydration; water loss; weight reduction***

HIGHLIGHTS

- Breadfruit spoils really quickly which leads to food waste.
- Convective and osmo-convective dehydration can slow down spoilage.
- Convective dehydration reduces breadfruit's weight more than osmo-convective dehydration.
- Water loss is similar for both treatments.
- Osmo-convective dehydration shows potential to slow down breadfruit spoilage.

INTRODUCTION

Out of millions of tons of food produced every day, one-third of the total food produced is wasted or lost during transport. During this era where climate change is becoming more and more apparent, it is imperative that preservation techniques are applied to foods to reduce the possibility of food waste and/or food loss. Food loss and waste percentages are calculated from the difference in the amount of food from the harvest of fresh commodities compared to the amount of food that reaches the consumer. One of the most critical steps in the farm to plate continuum is the post-harvest treatment of fresh commodities. This step plays a crucial role in determining the shelf life of the food. Improper treatments would eventually lead to foods being wasted. Taking the worldwide trend into consideration, fruits and vegetables are the second groups that accounted for 22% of the world's food loss and waste. This means that fruits and vegetables are a significant contributor to the world's food waste issue. However, even with thorough research, these data could not be considered accurate due to the lack of information from the still-developing areas (FAO, 2019).

As a developing country, the amount of research regarding food waste in Indonesia is still insufficient. According to Bisara (2017), current estimates suggest that each person could squander about 300 kg of food per year. In addition, Indonesia faced other challenges that increased the inefficiency of its food supply chain, such as poor infrastructure, leading to an increasing amount of food loss just through inefficient transportation of foods. These factors made Indonesia the second largest producer of food waste in 2016 (Bisara, 2017).

To solve this food waste issue while also providing suburban and rural areas with nutritious food, we have decided to focus on one particular fruit commonly produced in Indonesia, the breadfruit. Breadfruit (*Artocarpus altilis* (Parkinson) Fosberg) is a staple food native to the Pacific region widely cultivated in Indonesia for food purposes. Breadfruit gained its name due to the fact that it has a similar texture to bread; this is due to the sufficient carbohydrate (27.12 g/ 100 g) and starch (15.5 g/ 100 g) content. Breadfruit can be considered a superfruit as it serves high energy (103 kcal/ 100 g) and potassium content (490 mg/100 g). However, as a climacteric fruit, breadfruit has a rapid respiration rate at 20°C, quickly reaching spoilage in 3-5 days (Thompson, 2015). Due to the short shelf life, breadfruit is usually fried shortly after harvesting or processed into flour. If these processing methods are not available or are not able to process all of the ripe breadfruits, breadfruit often becomes food waste. Aside from the few efforts in preservation, Fardiana, Ningsih, & Mustapa (2018) also stated that each breadfruit plant produced ±350 kg of waste from the skin to the seed per year.

Post-harvest treatments are designed to minimize the loss from various physiological processes of fresh products such as respiration and ethylene production. The dehydration process is one of the oldest yet most reliable preservation techniques to extend the shelf life of fruits and vegetables. Convective or conventional dehydration processes apply heated unsaturated air to drive the diffusion of water from within the sample to the outside air. Meanwhile, osmotic dehydration (OD) uses a high osmotic pressure solution to drive the removal of water from within the cell to the surrounding saturated solution and solutes from the solution into the cell (Sandarani, Dasanayaka, & Jayasinghe, 2018). The driving force of osmotic dehydration is dependent on the concentration gradient between the osmotic solution and the fluid contained in the cell. Intracellular fluid would diffuse to the hypertonic solution, creating an equilibrium state on both sides between membranes. It should be mentioned that osmotic dehydration can only achieve up to 50% water removal, depending on the fruit. Further processing is still required to lower both moisture content and water activity to a safe level (Ramya & Jain, 2016). Convective dehydration is, therefore, often combined with an osmotic process to remove the bulk of the moisture content of the food. By adding osmotic dehydration as a pre-treatment to convective, a wide range of beneficial effects can be gained, such as nutrients, color, aroma, and flavor preservation due to the lower amount of heating applied to the product as opposed to just the application of convective dehydration. The use of sugar and/or salt as the hypotonic solution also offers cost-efficient technology (Yadav & Singh, 2012).

Osmotic dehydration, therefore, may be effective as a pre-treatment to shorten the dehydration time; however, it still requires much research to be applied to any individual fruit (Akharume *et al*., 2020). Various factors need to be investigated to find the optimal conditions for application. In this study, we compared the one concentration of sugar for osmotic dehydration, determined to be the most effective through our initial studies, for 2 hours at room temperature, followed by convective dehydration for 5 hours compared to convective dehydration for 7 hours without the osmotic pre-treatment. This study was designed as an initial study to determine the effectiveness of an osmotic treatment with sugar compared to convective dehydration. The benefit of this research is to potentially apply an alternative method of food preservation to breadfruit. Further studies will be aimed to investigate the application of heat to osmotic dehydration and to use other osmotic agents to increase the effectiveness of the process.

MATERIAL AND METHODS

Materials

Breadfruit was purchased online from a local supplier and bought in an unripe state to control the ripening condition. Breadfruit was let sit at 25°C for two days until ripe (external dried latex, brown-colored skin, soft-textured flesh (Thompson, 2015; Tamegnon *et al*., 2017)). Breadfruit was peeled and cut into eight pieces, then sliced into 0.5 cm thickness. Sliced breadfruits were immediately immersed in 2% ascorbic acid solution for 5 seconds to prevent any enzymatic reaction.

Sucrose was selected as the osmotic agent in the dehydration process. A total volume of 1500 mL 50° Brix solution was prepared based on the USDA's Sucrose Conversion Table (Downing, 2012). The solution was then split evenly into three pickling jars (Lock & Lock 1.4L Pickling Containers).

Dehydration treatments

a. Convective dehydration

Convective dehydration was conducted in a home scale food dehydrator (Bee C3) using methodology adapted from (Mercer 2014) for Apple Ring Drying. Instead of apples, breadfruit was sliced to 0.5cm thickness and dipped into 2% ascorbic acid instead of lemon juice. These dipped slices were then dried using a convective dehydration machine, a home scale food dehydrator (Bee C3), at 50°C for 7 hours. To ensure breadfruit slices would evenly dry, they were separated on different drying trays to ensure that slices did not stick together or clump. Each tray was rotated every 15 minutes to achieve an even dehydration rate during drying.

b. Osmo-convective dehydration

The methodology used in this study follows the general process outlined in (Ramya *et al.* 2016). Fresh fruit was washed, then peeled and sliced to 0.5 cm thickness slices and immediately immersed in 2% ascorbic acid solution as an osmotic pre-treatment for 5 seconds to prevent enzymatic browning. The sliced breadfruits were weighed and the mass data was collected. Breadfruits were divided equally into three pickling jars filled with 50° Brix sugar solution for each replication to undergo osmotic treatment. The osmotic dehydration consisted of a 2 hours period, whose chosen period was based on the pre-trial result where no significant changes were observed after the 2-hour treatment period. The osmotically treated breadfruit slices were drained and then placed on drying trays. This convective dehydration step was run in a home scale food dehydrator (Bee C3) with 50°C for 5 hours in a similar method with the previous convective method.

Physicochemical measurements

a. Weight measurement

The weight of breadfruit of each treatment was measured on an OHAUS balance. The measurement was taken per hour.

b. Moisture content

Moisture content was carried out using OHAUS rapid moisture analyzer (RMA) with specific requirements for different breadfruit states. Wet breadfruit setting was applied for the fruit before its intended drying treatment, while dried breadfruit setting was intended for fruits at the end of each treatment. All samples were cut into smaller pieces then crushed using a mortar and pestle to optimize the moisture content analysis.

Table 1. Rapid Moisture Analyzer Settings

Sample	Setting	Requirement
Wet breadfruit	Sample weight	3 g
	Temperature program	Step
	Drying temperature	180°C, 3 min. 120°C, 3min, 105°C
	Switch-off criterion	A30
Dry breadfruit	Sample weight	2 g
	Temperature program	Fast
	Drying temperature	105°C
	Switch-off criterion	A30

Mass balance / Mass exchange / Mass transfer parameters

Weight reduction (WR) and water loss (WL) were the parameters taken for mass balance. Both parameters were calculated using the formula below:

$$\% \, WR = \frac{(W_0 - W_1)}{W_0} \times 100\%$$

$$\% \, WL = \frac{(W_0 \times MC_0 - W_1 \times MC_1)}{W_0} \times 100\%$$

Where,

W_0	weight of control breadfruit (g)
W_1	weight of dried breadfruit (g)
MC_0	moisture content of control breadfruit (%)
MC_1	moisture content of dried breadfruit (%)

Statistical analysis

Normal data distribution was shown for WR and WL on the Shapiro-Wilk test. The sample size for this study was (n=27) for each treatment, where three replications were done for each treatment, and each replication had a sample size of 9. Mann-Whitney U test was selected due to the lack of biological replication and small sample size (Weaver *et al.*, 2017).

(p < 95%) and presented in box plots. All data measured for this study were measured in triplicate.

RESULTS AND DISCUSSION

Weight Reduction

Weight reduction is a measure of weight loss during the process. On its own, this parameter can be used to approximate the change in the mass balance of a dehydration system. However, the weight reduction needs to be accompanied by water loss when observing the convective dehydration as it signifies the reduction in mass for all components of the system combined, not just the water lost during the dehydration process. Therefore, weight reduction is still necessary to observe, especially as a measure of completeness for the osmotic dehydration process. It is expected that during the osmotic process, there should be no or close to zero net weight gain or loss during the process as the solutes and water are being moved by osmotic forces present between the product and the high osmotic solution (Fernandes & Rodrigues, 2007).

The weight reduction obtained in this experiment can be seen in figure 1. where the two treatments show a clear difference where it can be seen that the median for convective and combination processes for WR is 80.680% and 57.190%, respectively. Furthermore, the median for the weight reduction shows a significant difference (p = 0.049) through the Mann-Whitney U test.

This result is not as expected; as mentioned earlier, during the osmotic phase of the combination treatment, there should be zero to a close to zero net change in the weight reduction as the equilibrium between the product and saturated osmotic solution is being achieved throughout the osmotic dehydration process. This results in a lower weight reduction after the osmo-convective process compared to the conventional process. This study shows that although the weight reduction of the combination process is smaller than the convective dehydration process, it is not yet close to zero as expected. These results are in line with the review paper written by Ramya & Jain (2016), stating that osmo-convective treatments increased the yield compared to conventional treatments only. However, we currently do not know if the sugars in the saturated osmotic solution entered the product. To prove this weight gain, there need to be additional tests to determine the product's sugar content and/or the solution before and after the osmotic process. Because of this difference between the osmotic and convective processes in terms of mass balance changes, it confirms that an osmotic pre-treatment will affect the weight reduction of the breadfruit slices during dehydration.

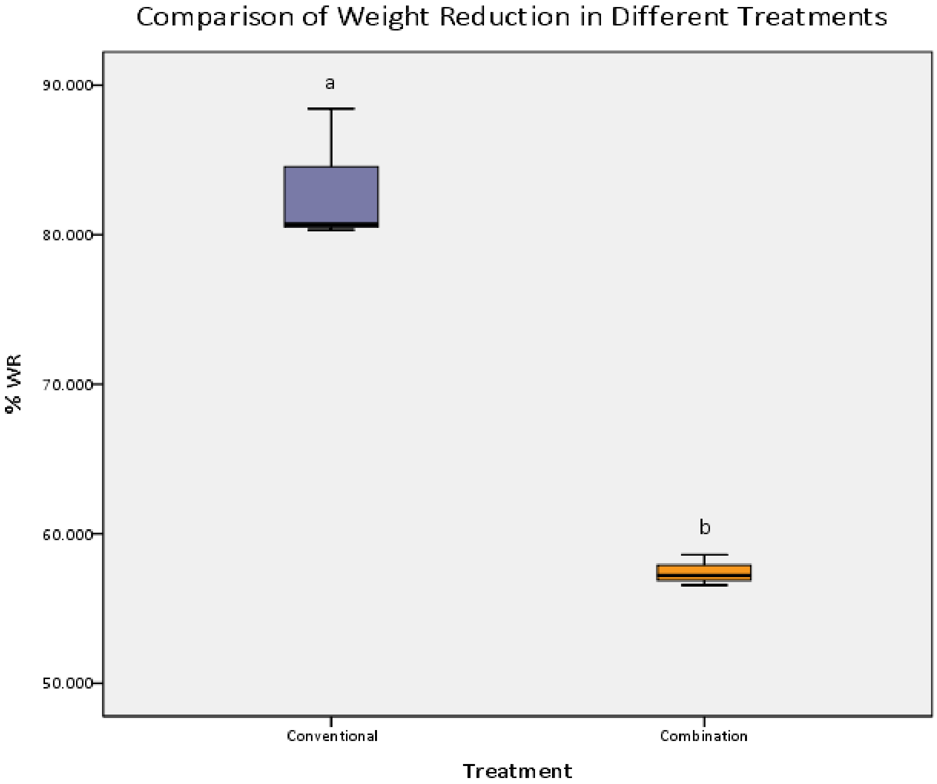

Figure 1. Weight Reduction of Different Treatments

Water Loss

Water loss is another significant parameter in determining the effectiveness of convective and combination processes. The calculation is obtained by subtracting the output of water loss multiplied by the weight reduction value before and after treatments. It is hypothesized that the combination process would yield similar to or more water loss due to the combination of processing methods. Osmotic dehydration acts as a partial water removal method through achieving equilibrium mass transfer. Some studies show up to 50% of water removal, though it is less likely to be because of the decreasing removal rate with time (Ramya & Jain, 2016). In this experiment, figure 2 shows that convective dehydration generates more water loss than the combination, where the median is 19.836% and 18.315% for convective and osmo-convective dehydrated samples, respectively. However, the statistical analysis indicates an insignificant effect ($p = 0.275$) through the Mann-Whitney U test. This result is as expected, indicating that convective drying and a combination of osmo-convective drying can achieve a similar water loss after seven total hours of processing. This shows that an osmotic treatment may be a suitable method to reduce the time breadfruit is exposed to a thermal treatment. Therefore, an osmo-convective combination treatment is a promising treatment that could potentially reduce costs and preserve nutrients found in the breadfruit.

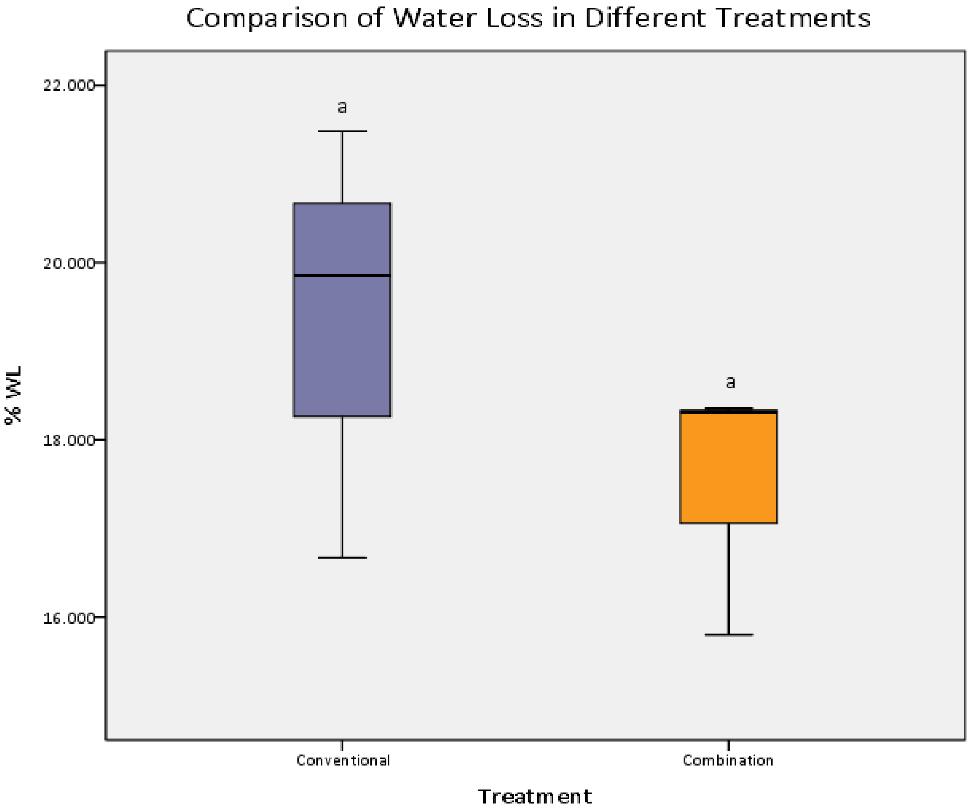

Figure 2. Water Loss of Different Treatments

CONCLUSION

This study aims to perform a study to determine the effectiveness of an osmotic treatment with sugar compared to convective dehydration on breadfruit. The results seemed to indicate that although not as close to zero as expected, the weight reduction of the sample is significantly lower and the water loss is statistically similar in the osmo-convective dehydrated samples compared to the conventional dehydrated samples. These results show the potential benefit of applying osmo-convective treatments to breadfruit. However, the research is still in the early stages of development; some parts of the research need to be optimized such as the temperature of the osmotic pre-treatment, the time of conventional dehydration, and the types of dehydration applied. Furthermore, some additional parameters should be considered during the experiment, such as measuring the density of the fruit slices and increasing the data points in moisture content analysis and the total amount of solute in the fruit at any given time to define the mass transfer kinetics of this process. Additionally, increasing the number of biological replicates that are done could increase the accuracy of the data and provide more accurate results and better insight into the trends that could potentially be observed in this study.

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