

FREEZE DRYING WITH OSMOTIC PRETREATMENT AS A METHOD FOR PRESERVATION OF LONGKONG (*Lansium Parasiticum* THICK-SKINNED CULTIVAR) FRUIT

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Abstract

In southern provinces of Thailand, when seasonal yield of longkong outpaces market demand its price sinks suddenly and directly affects farmers. Therefore, the objective of the study was focused on developing dried longkong using osmotic dehydration as a pre-treatment followed by freeze-drying to prolong the shelf life of longkong. The effects of the concentration (1, 2, 3, and 4% w/v) and type (calcium chloride and calcium lactate) of firming agent on the firmness were studied. The effect of the concentrations (30, 40, and 50°Brix) and soaking times (24 and 48 h) of sucrose solution on customers' satisfaction were also investigated. The nutritional values of the freeze-dried products were analyzed and their shelf life in aluminum foiled bags and PET bottles were investigated at room temperature (25-30°C) for 24 weeks. The results showed that peeled longkong immersed in 1% (w/v) calcium chloride solution had the highest firmness of 35.430±5.521 g. Sensory characteristics of the finished product were evaluated and the results revealed that soaking longkong in sucrose solution of 30°Brix for 24 h represented the most satisfying qualities and overall consumer liking. Study of the product shelf life showed that dried longkong packed in both aluminum foil bags and plastic bottles (PET) could be kept at room temperature for 24 weeks. Microbiological qualities including total bacterial count, *Salmonella* spp., *Staphylococcus aureus*, *Escherichia coli*, as well as yeast and mold count were tested; negative results were obtained for these tests and the standards according to TIS 919-2532 were met. It can be concluded that freeze-drying with osmotic pretreatment can be efficiently used as a method to prolong the shelf life of fresh longkong fruit and create a product with satisfactory qualities.

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Introduction

Due to a rapid growth in the healthy food trend, fresh fruit consumption has increased dramatically and Thailand can produce a wide variety tropical fruits with high quality, attractive appearances, and unrivaled distinct flavors throughout the year (Thai National Food Institute, 2018). The Thai National Food Institute reported that the export value of fruit and its products in 2016 increased by 19% to 119,630 million baht of which 27% was fresh fruit (32,412 million baht). Moreover, the export of dried fruit sharply increased by 53% to 10,910 million baht (Thansettakij, 2017). Thus, in future years the market for processed fruits such as fruit candy, fried fruit, and freeze-dried fruit will significantly increase.

Longkong is a tropical fruit that originated in Malaysia and is commercially grown mostly in Southeast Asian countries including Thailand (Morton, 2013). Longkong fruit is an abundant source of vitamins and minerals as well as proteins and carbohydrates (Sangkasanya and Meenune, 2010). It has a unique taste and offers a variety of health benefits, particularly antimicrobial and antioxidant activities (Venkatachalam and Meenune, 2012). However, the short shelf life of fresh longkong has restricted its export to other regions of the world, and over-supply of longkong in the harvesting season consequently pushes its price down. The largest longkong growing area in Thailand is in the group of 5 southernmost provinces bordering Malaysia comprising Narathiwat, Yala, Pattani, Songkhla, and Satun totaling one-third of the overall cultivation area countrywide (Thai Department of Agricultural Extension, 2017). Local administrative organizations and farmers' representatives in this area have long expressed concerns over the shelf life and price issues of longkong and the need to increase the value of fresh longkong using food processing techniques (Center for Megacity and City Studies Rangsit University and Yala City Municipality, 2016). The contribution of this

research will provide useful knowledge about inexpensive and efficient techniques to extend the shelf life and allow the export of longkong worldwide.

To increase the shelf life and the value of the fruit, freeze-drying is a promising method by freezing the fruit samples, and reducing the pressure and subsequent water removal by sublimation (primary drying) and then by desorption (secondary drying) (Inyang *et al.*, 2017). The freeze-dried fruits have a crispy texture while retaining their characteristic and delicious flavors. In addition, the nutritional value is kept at the maximum level so people can feel safe about eating the fruit. Freeze-drying is a drying process in which water is sublimated from the product after it is frozen. This consumes a lot of energy and time and, therefore, a pretreatment process using osmotic dehydration is normally employed for raw material preparation. Osmotic pretreatment will definitely reduce the amount of water in the fruit, enhancing the drying operation and improving the fruit's qualities (Singh *et al.*, 2006; Ciurzynska *et al.*, 2014; Prosapio and Norton, 2017).

Osmotic dehydration is a dynamic process that works on the principle of osmotic pressure by partial removal of the water content from the cells of fruit and vegetables. The cell membranes are semi-permeable which allows water to migrate through them rapidly. By slowly increasing the concentration of a hypertonic solution of salt, sugar, or a combined solution when soaking, the concentration gradient between the cells and the hypertonic solution allows the water to be removed (Singh *et al.*, 2006; Falade and Igbeka, 2007; Chavan and Amarowicz, 2012; Zeeshan *et al.*, 2016; Ramya and Jain, 2017).

Thus, the objective of this research was to develop a freeze-drying process for peeled longkong by treatment in different amounts of calcium salts. Customers' satisfaction following soaking longkong in sucrose

solution was also determined. The nutritional values of the final product as well as the shelf life of the dried longkong kept in PET bottles and aluminum foil bags were analyzed.

Materials and Methods

Materials

Fresh longkong was obtained from Mueang Yala district of Yala province in southern Thailand and stored at $6\pm1^{\circ}\text{C}$ at the Food Processing Pilot Plant, Rangsit University before the experiment. Citric acid (Crisco) from J.M. Smucker Co., Ltd. (Orlando, FL, USA) was used to protect color change and reduce the microbial load. Potassium metabisulfite, calcium chloride, and calcium lactate (Univar) were purchased from Ajax Finechem Pty Ltd. (Taren Point, NSW, Australia). Potassium metabisulfite was used as a preservative and anti-enzymatic browning agent. A calcium salt solution was prepared with either calcium chloride or calcium lactate and used as a firming agent. A sucrose solution was prepared by mixing sugar (Mitr Phol Sugar Corporation, Bangkok, Thailand) with water in different concentrations for the water removal process of the longkong.

Aluminum foil bags with a size 12×20 cm and 100 micron in thickness were purchased from Tk Foil Co., Ltd. (Pathum Thani, Thailand). The bags have a 3-layer lamination with an outer layer made of polyester (PET), the middle layer is aluminum foil (AL), and the inside layer is linear low density polyethylene (LLDPE). PET bottles with a diameter of 83.3 mm, 92 mm in height, and 380 ml in capacity enclosed by an aluminum lid were purchased from Laz Step Ltd. (Bangkok, Thailand).

Sample Preparation and Osmotic Dehydration

The longkong fruit was first washed with tap water and peeled. The peeled longkong was soaked in a mixture of 0.5% citric acid and 0.1% potassium metabisulfite solution, which contained the calcium salt solution (calcium chloride or calcium lactate) in the range of 1, 2, 3, and 4% (w/v). The weight ratio of the longkong to the mixture solution was 1:1 and the soaking time was 15 min. The soaked

longkong was then air-dried for about 1 h at room temperature and the firmness was tested using a texture analyzer (TA.XTplus, Stable Micro Systems, Godalming, UK). Longkong with the highest firmness was weighed and osmotically dehydrated in different sucrose solutions in the range of 30, 40, and 50°Brix and soaking times of 24 and 48 h. The weight ratio of longkong to the sucrose solution was 1:1.

Freeze Drying Process

The osmotic pretreated longkong samples (with different sucrose concentrations and soaking times) were rapidly frozen by being subjected to dry ice at -78°C and then freeze-dried using an 8 liter freeze dryer (Durian Freeze Dry Co., Ltd., Lumlukka, Pathumtani, Thailand). The conditions of the freeze-drying process were primary drying at 45°C followed by secondary drying at 60°C . Primary drying was designed to remove the frozen water by sublimation, while secondary drying at the elevated temperature was devised for removal of the remaining water and further reducing the product moisture content to a safe level for long-term storage. The freeze-drying process continued until the water activity (a_w) of the samples was less than 0.6. The dried products were packed in tightly sealed aluminum foil bags filled with nitrogen gas.

Physicochemical Properties

The firmness and diameter of the longkong soaked in a calcium salt solution was tested using a texture analyzer (TA.XTplus, Stable Micro Systems, Godalming, UK) and digital vernier caliper (Mitutoyo Corp., Kawasaki, Japan). The firmness measurement was analyzed by puncturing with a 2 mm needle into the cloves of longkong flesh (3 cloves for 1 fruit) at a position approximately 1 cm from the bottom of the clove. The diameter was measured at the center position of the longkong.

The physicochemical properties of the longkong soaked in a sucrose solution were investigated including the pH, a_w , total soluble solid, and water loss. The pH was measured with a pH meter (SI Analytics Lab 860, Xylem Inc., Rye Brook, NY, USA). Water activity was measured with a water activity meter

(AquaLab Series 3TE, Decagon Devices Inc., Pullman, WA, USA). The total soluble solid was measured with a digital refractometer (MA871, Milwaukee Instruments Inc., Rocky Mount, NC, USA). Water loss was calculated from the difference in weight of the longkong before and after soaking in the sucrose solution (modified from El-Aouar *et al.*, 2006) by the following equation:

$$\text{Water loss (\%)} = [(w_i - w_f) / w_i] \times 100$$

where w_i and w_f are the weight (g) of the longkong samples before and after soaking, respectively.

Sensory Quality

The dried longkong samples were evaluated by 60 untrained panelists who were staff members and students of Rangsit University. They were different in gender, age ranges, education levels, and incomes and liked to consume longkong regularly. The sensory characteristics were evaluated for texture, color, odor, sweetness, sourness, and overall liking using a 7-point hedonic scale ranged from “1 = Dislike a lot” to “7 = Like a lot” (Stone *et al.*, 2012). The dried longkong sample with the highest satisfaction score was selected for determination of nutritional value, shelf life, and microbiological qualities.

Nutritional Value

The nutritional values of the dried longkong comprising energy, protein, fat, carbohydrate, ash, minerals (calcium, phosphorous, and iron), and vitamins (A, B1, B2, and C) were analyzed by a certified laboratory (Central Laboratory Co., Ltd., Bangkok, Thailand). The methods used were according to the AOAC method (AOAC, 2016) and Compendium of Methods for Food Analysis (Thai Department of Medical Sciences and Thai National Bureau of Agricultural Commodity and Food Standards, 2003).

Shelf Life

Twenty-five grams of dried longkong was packed in 2 types of containers: aluminum

foil bags and PET bottles. The packed dried longkong was kept at room temperature (25–30°C) for 24 weeks. The samples were analyzed every 2 weeks for a_w , moisture content, and microbiological qualities as required by the Thai Industrial Standard TIS 919-2532 (Thai Industrial Standards Institute, 1989). For the microbiological qualities, the samples were analyzed for total bacterial count, yeast and mold count, and pathogenic bacteria (*Salmonella* spp., *Staphylococcus aureus*, and *Escherichia coli*) according to the AOAC method (AOAC, 2016).

Experimental Design and Statistical Analysis

The experimental design was a completely randomized design where a randomized completed block design was used for quality and sensory investigation. Values were presented as the means of 3 replications. The data were analyzed by analysis of variance to determine if significant differences existed among the sucrose solution treatments. Duncan's new multiple range test was used to separate the means where significant ($p < 0.05$) differences existed. Statistical software was used to perform the analysis.

Results and Discussion

Effect of Type and Concentration of Calcium Salt Solution on Firmness of Longkong

The results of the firmness analysis of the soaked longkong samples (Table 1) showed a trend toward the increase of firmness values compared with the control (fresh unsoaked longkong). The firmness of the longkong samples soaked in 2% calcium chloride solution was significantly higher than the control ($p \leq 0.05$). However, when the longkong was soaked in 2, 3, and 4% calcium chloride solutions, their firmness was not significantly different from the control sample and from those obtained when soaked in every concentration (1 to 4%) of calcium lactate solution. The diameters of all the soaked longkong samples in this study were similar ranging between 25.55–27.82 mm (Table 1).

Table 1. Firmness of longkong soaked in various concentrations of calcium chloride and calcium lactate solutions compared with control sample

Solution	Concentration (%)	Firmness (g)	Diameter (mm)
Control	-	23.786 ± 5.351 ^b	26.44 ± 1.77 ^a
Calcium chloride	1%	35.430 ± 5.521 ^a	26.17 ± 2.60 ^a
	2%	24.725 ± 7.943 ^b	26.34 ± 1.68 ^a
	3%	26.046 ± 4.369 ^{ab}	26.39 ± 1.96 ^a
	4%	28.793 ± 8.413 ^{ab}	27.82 ± 2.19 ^a
Calcium lactate	1%	26.930 ± 6.957 ^{ab}	26.54 ± 1.63 ^a
	2%	28.435 ± 3.968 ^{ab}	27.54 ± 0.99 ^a
	3%	28.752 ± 4.893 ^{ab}	25.55 ± 1.91 ^a
	4%	25.822 ± 8.916 ^b	26.76 ± 1.51 ^a

Note: Different letters in the same column indicate significant differences ($p < 0.05$).

Table 2. Physicochemical properties of longkong soaked in different sucrose solution concentrations for 24 and 48 h

Soaking time (h)	Sucrose concentration (°Brix)	pH	a_w	°Brix	Water loss (%)
24	30	3.92 ± 0.02 ^b	0.979 ± 0.004 ^{ab}	22.17 ± 0.06 ^b	23.26 ± 0.23 ^e
	40	3.65 ± 0.00 ^c	0.983 ± 0.001 ^a	23.03 ± 0.06 ^b	12.40 ± 0.74 ^c
	50	3.63 ± 0.01 ^c	0.983 ± 0.001 ^a	20.00 ± 0.00 ^d	15.00 ± 0.01 ^d
48	30	4.36 ± 0.18 ^a	0.971 ± 0.012 ^b	21.33 ± 0.06 ^c	-7.61 ± 0.26 ^a
	40	3.61 ± 0.15 ^c	0.982 ± 0.001 ^a	23.77 ± 0.23 ^a	2.06 ± 0.06 ^b
	50	3.28 ± 0.07 ^d	0.982 ± 0.001 ^a	23.97 ± 0.06 ^a	-7.68 ± 0.11 ^a

Note: Different letters in the same column indicate significant differences ($p < 0.05$).

The appearance of the skin and the color of the unsoaked and soaked longkong in 1% calcium salt solution are shown in Figure 1. The results revealed that the skin characteristics and color of these 2 samples were apparently different. The soaked longkong possessed a tight smooth skin that was whiter and more consistent than the skin from unsoaked longkong (control). This may be a result of immersion of the fruit in the citric acid solution that has prevented the color change by inhibition of the enzymatic browning reaction. Citric acid is an anti-browning agent that directly limits polyphenol oxidase (PPO) activity by 2 inhibitory mechanisms. First, it lowers the pH of the fruit to minimize the activity of the PPO due to the loss of copper at the active site when the pH is below 4. Secondly, it acts as a chelating agent binding

**Figure 1. Appearance of unsoaked longkong (a) and longkong soaked in 1% (w/v) calcium chloride solution (b)**

with copper at the active site of the PPO (Suttirak and Manurakchinakorn, 2010). When considering the production cost (the price of calcium salt) and the firmness of the soaked longkong, the most suitable type and concentration of salt solution was 1% calcium chloride solution.

Table 3. Sensory evaluation of freeze dried longkong after soaking in different sucrose concentration for 24 h

Concen-tration (°Brix)	Sensory marks					
	Texture	Color	Odor	Sweetness	Sour	Overall liking
30	5.30±1.42 ^a	5.60±0.95 ^a	5.50±0.85 ^a	5.40±1.43 ^a	5.40±1.17 ^a	5.50±1.27 ^a
40	4.80±1.40 ^a	5.50±0.85 ^a	5.70±0.95 ^a	5.20±1.55 ^a	5.30±1.77 ^a	5.40±1.35 ^a
50	2.80±1.40 ^b	4.80±1.23 ^a	4.60±0.97 ^b	4.50±1.08 ^a	5.00±1.33 ^a	4.00±1.56 ^b

Note: Different letters in the same column indicate significant differences ($p < 0.05$).

Table 4. Nutritional value of freeze dried longkong

List	per 100 g	Reference Methods
Calories (Kcal)	375.60	CMFA (2003)
Calories from Fat (Kcal)	28.44	CMFA (2003)
Total Fat (g)	3.16	AOAC (2016)
Saturated fat (g)	1.64	CMFA (2003)
Trans Fat (g)	Not Detected	CMFA (2003)
Cholesterol (mg)	Not Detected	CMFA (2003)
Sodium (mg)	18.03	AOAC (2016)
Total Carbohydrate (g)	80.80	CMFA (2003)
Dietary Fiber (g)	8.30	AOAC (2016)
Total Sugar (g)	55.70	CMFA (2003)
Protein (g) (%N x 6.25)	5.99	AOAC (2016)
Vitamin A (µg)	Not Detected	CMFA (2003)
Vitamin B1 (mg)	<0.030	CMFA (2003)
Vitamin C (mg)	7.30	CMFA (2003)
Calcium (mg)	102.23	AOAC (2016)
Iron (mg)	1.20	AOAC (2016)
Phosphorus (mg)	134.80	AOAC (2016)
Ash (g)	3.06	AOAC (2016)
Moisture (g)	6.99	AOAC (2016)

CMFA refers to Compendium of Methods for Food Analysis (DMSc and ACFS, 2003)

Effect of Sucrose Solution Concentration and Soaking Time on Physicochemical Properties of Osmotic Dehydrated Longkong

Table 2 shows the physicochemical properties of longkong soaked in different concentrations of sucrose and at different soaking times. The water loss of the longkong soaked in 30°Brix sucrose solution for 24 h was 23.26% which was significantly higher than for those soaked in 40 and 50°Brix solutions ($p \leq 0.05$). Furthermore, data also show that the water loss of the longkong soaking in every concentration of sucrose solution for 48 h was significantly lower than soaking for 24 h

($p \leq 0.05$). This was because the longer soaking time may lead to higher sucrose absorption, since during the osmotic dehydration process solute transfer from the solution to the product can also occur in addition to the main water flux from the product to the solution (Park *et al.*, 2002). Hence, to reduce the processing time, the longkong soaked in 30, 40, and 50°Brix for 24 h were chosen for further investigation of suitable freeze-drying condition and sensory evaluation.

Sensory Evaluation

The freeze-dried longkong samples were further evaluated by 60 panelists to assess the

Table 5. Moisture content and a_w of freeze dried longkong packed in PET bottle and aluminum foil bag

Week(s)	Moisture Content (%wb)		a_w	
	PET bottle	Aluminum foil bag	PET bottle	Aluminum foil bag
0	2.36±0.22 ^{ab}	1.83±0.61 ^a	0.283±0.02 ^a	0.283±0.021 ^a
2	2.14±0.10 ^a	2.12±0.13 ^{ab}	0.409±0.003 ^b	0.331±0.012 ^{bc}
4	2.16±0.08 ^a	2.25±0.11 ^{bc}	0.400±0.006 ^b	0.334±0.010 ^{bcd}
6	2.57±0.52 ^{ab}	2.36±0.22 ^{bc}	0.395±0.009 ^b	0.332±0.012 ^{bc}
8	2.43±0.10 ^{ab}	2.39±0.07 ^{bc}	0.451±0.004 ^{cd}	0.371±0.007 ^f
10	2.66±0.13 ^b	2.41±0.08 ^{bc}	0.446±0.005 ^{cd}	0.355±0.008 ^{defg}
12	3.32±0.15 ^{cd}	2.43±0.11 ^{bc}	0.435±0.005 ^c	0.339±0.010 ^{bcd}
14	3.14±0.07 ^c	2.38±0.05 ^{bc}	0.448±0.008 ^{cd}	0.321±0.009 ^b
16	3.21±0.29 ^c	2.63±0.31 ^c	0.457±0.003 ^{cd}	0.348±0.005 ^{cdef}
18	3.69±0.06 ^{de}	2.58±0.26 ^c	0.459±0.005 ^{cd}	0.321±0.015 ^b
20	2.71±0.37 ^b	2.51±0.21 ^{bc}	0.470±0.007 ^{de}	0.357±0.016 ^{efg}
22	3.17±0.44 ^c	2.54±0.08 ^{bc}	0.485±0.008 ^{ef}	0.362±0.014 ^{fg}
24	3.78±0.08 ^e	2.57±0.07 ^{bc}	0.498±0.039 ^f	0.356±0.005 ^{efg}
Average	2.87±0.02	2.38±0.07	0.434±0.005	0.339±0.004

Note: Different letters in the same column indicate significant differences ($p < 0.05$).

sensory qualities. From Table 3, the sensory evaluation suggested that the testers equally liked the color, sweetness, and sourness of all samples. On the other hand, the testers contrarily felt satisfied in regards to texture, odor, and overall liking of the freeze-dried longkong that were soaked in sucrose solutions at different concentrations, with the results being significantly different ($p \leq 0.05$). According to the sensory evaluation, the 30°Brix sucrose solution and soaking time of 24 h were chosen before the freeze-drying process due to the time reduction, cost saving, and having the highest overall satisfaction scores.

Nutritional Value

The nutritional values of the freeze-dried longkong including energy, protein, fat, carbohydrate, ash, minerals (calcium, phosphorous, and iron), and vitamins (A, B1, B2, and C) are shown in Table 4.

Shelf Life

To determine that the product will have a long enough shelf life for export, distribution, and sale as well as meeting the consumer safety requirements throughout its shelf life, storage stability testing was conducted over

a period of 24 weeks. Freeze-dried longkong (soaked in 1% calcium chloride solution and osmotically pretreated in 30°Brix sucrose solution for 24 h) were packed in aluminum foil bags and PET bottles and kept in a dry place at room temperature. The microbial quality, moisture content, and a_w of the stored samples were investigated every 2 weeks. The moisture content and a_w data are shown in Table 5. The moisture content ranged from 2.14 to 3.78% and 1.83 to 2.63% for the samples packed in PET bottles and aluminum foil bags, respectively. The water activity of all samples was lower than 0.6, ranging from 0.283 to 0.498 and 0.283 to 0.371 for the samples packed in PET bottles and aluminum foil bags, respectively. The water activities of the samples were similar to other freeze-dried fruit with osmotic pretreatment such as strawberry (Prosapio and Norton, 2017). The changes in moisture content and a_w during storage were significantly different ($p < 0.05$) in both containers. However, the moisture content and a_w of the freeze-dried longkong packed in PET bottles and aluminum foil bags were in accordance with the criteria of TIS 919-2532 (Thai Industrial Standards Institute, 1989). For the microbiological qualities were also tested

according to TIS 919- 2532 and the results showed that all microbial parameters of the product complied with the specified standard (data not shown). This was because the a_w of the product was lower than 0.6 which is the lowest value for microbial growth (Wattanasin, 2002). The total bacterial count was less than 1×10^4 CFU/g. The yeast and mold count was less than 100 CFU/g; *Escherichia coli* was less than 3 MPN/g; and no *Salmonella* spp. or *Staphylococcus aureus* were found in 25 g and 0.1 g of the sample, respectively. The results confirmed that the reduction of a_w was able to control both spoilage and the pathogenic microorganisms. Hence, the product packed in either aluminum foil bags or PET bottles could be kept at room temperature for up to 24 weeks. However, the color of the product packed in PET bottles was darker than that packed in aluminum foil bags, as shown in Figure 2. This was because the PET bottle is a transparent material, directly exposing the product to the light that affected the color of the product. Therefore, there is a chance that consumers will reject the product if packed in PET bottles and stored for 24 weeks due to this color alteration in comparison to the product packed in aluminum foil bags in which the color only slightly changed.

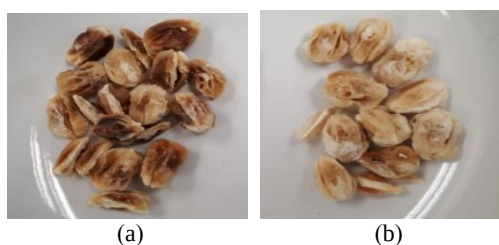


Figure 2. Color of longkong packed in PET bottle (a) or aluminum foil bag (b) after 24 weeks in storage

Conclusions

Freeze-dried longkong with osmotic dehydration as a pretreatment was successfully developed in this study, which confirms the usefulness of the food processing techniques in preservation

of longkong fruit, increases its value, and creates a new alternative for consumers. The results from this study could hopefully help longkong farmers to overcome their 2 biggest problems of oversupply and a price slump. Immersing fresh longkong fruit in a mixture of 0.5% citric acid, 0.1% potassium metabisulfite, and 1% calcium chloride solution for 15 min followed by osmotic dehydration in 30°Brix sucrose solution for 24 h before freeze-drying was the appropriate processing method resulting in the highest consumer satisfaction scores. The final product could be kept for 24 weeks and all microbial qualities, moisture content, and a_w complied with the TIS 919-2532 standard for dehydrated fruit. However, the color of the product packed in aluminum foil bags was more appealing than that packed in PET bottles.

This study also pointed out that osmotic dehydration could be used as a simple method for partial removal of moisture from fresh fruit. Farmers may apply this method in combination with the freeze-drying for other tropical fruits such as mangosteen, rambutan, banana, or durian to create varieties of dehydrated fruit products with improved texture and rehydration properties which will expand both the domestic and international markets.

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