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# Preparation and some physicochemical properties of freeze-dried vegetables carving

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## Abstract

Freeze-drying is a very gentle dehydration method to preserve the highest quality and give the final product a longer shelf-life, based on the principle of removing the ice by sublimation. This research aimed to study freeze-dried manufacturing processes of vegetable carving for application in the foodservice industry. Plant materials used in this study were pumpkin, carrot and Chinese radish which were carved into a rose shape. To prepare, all carved-rose vegetables were dipped in 1.0% $CaCl_2$ solution as a firming agent for 5 mins before freeze-dried operations at the temperature of –50°C under vacuum (~30 Pa) for 50 hrs. Dyeing operation was conducted specifically in carved-rose Chinese radish using pink (0.05 and 0.1%) and red (0.05 and 0.1%) food-grade colour after pretreatment with $CaCl_2$. The results showed that dried carved-rose vegetables had low water activity (0.32-0.42) and moisture content (8.01-11.44%). The physical properties of freeze-dried pumpkin and carrot carving were firmed and presented a spongy texture with small bubbles spread continuously throughout the piece which helps protect the structural collapse. However, carved-rose radish had a slight shrinkage but it was restored as fresh after immersing in water. Rehydration time was 5 mins for pumpkin and carrot, and 10 mins for Chinese radish which showed remarkable that firm-liked fresh vegetables. Then, freeze-dried vegetables were packed in an aluminum bag filled with nitrogen gas and kept at 25±1°C for 2-months storage. The sensory characteristics evaluated by specialists were ranged in the medium to very like throughout the storage periods. Thus, freeze-dried carved-rose vegetable seems to be very interesting, moreover, conduction on a larger scale for the foodservice industry was particularly noticeable.

## 1. Introduction

The art of carving fruit and vegetables is a very common technique pervasive in Europe and Asian countries, to decorate plates of food, enhancing their beauty and edibility found in a variety of restaurants, hotels, catering halls, exhibitions and cruises (Panprom *et al*., 2013). However, vegetable and fruit carving are living tissues that still remain breathing and produces ethylene, accumulated nutrients and are used for respiration metabolism resulting in short shelf-life (Suwannarak *et al*., 2014a). Therefore, the application on a commercial scale is difficult because it is a craftsmanship work that takes a long time to produce. Finding the preservation methods to maintain the physical properties and fresh-like appearance is a challenge. In addition, the production of ready-to-use fruits and vegetable carving is very attractive. It can reduce the shortage of highly skilled personnel and applies on various occasions both domestically and abroad.

Many techniques of hurdle technology have been used to improve and prolong the qualities and shelf-life of vegetable and fruit carvings, such as firming agents, edible coating (Suwannarak *et al*., 2015) and various sanitisers (Suwannarak *et al*., 2014b). Unfortunately, the shelf-life of vegetable and fruit carving was not exceeded than 1 week at the temperature of 4°C, a look-liked fresh appearance was declined along with long time storage. Recently, the authors had studied the method of acid conditioning of vegetable and fruit carving under atmospheric pressure (Suwannarak *et al*., 2017) cooperated with temperature and pressure control

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conditions (Suwannarak *et al*., 2020) which were packed in hermetically sealed containers. It was found that the limitation of both methods results in a difference in flavor, texture and appearance from the fresh carved fruit and vegetables. Moreover, the carved fruit and vegetables must be stored under the pickle until used.

Freeze-drying or lyophilization is the one technique of dehydration process based on the principle of water is removed by sublimation of ice from frozen materials (below -30°C) by reducing the system pressure below the normal atmosphere. Vaporized water is condensed at a temperature around -60°C and then transported through the porous layer of the dried material (George and Datta, 2002). The chamber pressure and freeze-drying time are important factors that affected the key qualities (texture, colour, moisture content, water activity and colour) of fruit and vegetable products (Guiné and Barrosa, 2012; Ciurzyńska *et al*., 2014). Moreover, sample size preparation is another supporting role in process conditions. A 10 mm pumpkin cube required 24 h for freeze-drying operation under the pressure of 63 Pa (Ciurzyńska *et al*., 2014), while the 2 cm cubes used 38 h under 0.666 Pa (Guiné and Barrosa, 2012). Moreover, a porous provided a sponge-like texture in the final product which acted as an insulation body and helped slow down the rate of heat transfer into the food, increasing of drying time (Yeom and Song, 2010).

The freeze-drying process is conducted at low temperature, thus reducing the qualities loss reasoned by heat. The product also maintains its initial shape and dimensions, good rehydration and preserves product quality such as colour, flavour, taste, and texture, compared to other drying methods. As above advantages, there are several applications of freeze-drying in minimally-processed fruits and vegetables, such as pumpkin cubes, carrot slices, tomato slices, apple cubes and various kinds of tropical fruits (Bhatta *et al*., 2020) and dices strawberry (Lammerskitten *et al*., 2020). From this perspective, the market of freeze-dried foods is diversifying nowadays, for example, vegetable snacks (Ciurzynska *et al*., 2020), edible rose flowers (Hnin *et al*., 2021) and ready-to-eat food products (meal boxes, bakeries, soups, confectionaries and breakfast cereals) (Bhatta *et al*., 2020). However, this technique has not been reported on the application in vegetable carving. The objective of this study was to consider some physicochemical properties and sensory evaluation of freeze-dried vegetable carving.

## 2. Material and methods

### *2.1 Plants materials*

Mature, commercial cultivars of pumpkin (*Cucurbita moschata* Decne.) *cv*. Kangkok, carrot (*Daucus carota* subsp. sativus) and Chinese radish (*Raphanus sativus* Linn.) were purchased from a Suvarnabhumi Market, Lat Krabang District, Bangkok, Thailand in April 2019. Vegetables were transferred to the Center of Food Development and Innovation, King Mongkut's Institute of Technology Ladkrabang, washed with tap water and air-dried.

### *2.2 Sample preparation*

Pumpkin, carrot, and Chinese radish were carved into rose shapes according to the method of Suwannarak *et al*. (2014a). For briefly, samples were trimmed into a semi-circle shape with a diameter of approximately 7 cm. and carved manually into a rose shape with a sharp carving knife. The initial weight of the carved-rose pumpkin, carrot and Chinese radish were in the range of 8-11, 8-11 and 9-12 g, respectively. Then, all carved-rose vegetables were dipped in 1.0% (w/w) calcium chloride ($CaCl_2$) solution for 5 mins as a pre-treatment step. For carved-rose Chinese radish, the samples were dyed into pink (PK; Erythrosine, INS No. 127) and red colour (RD; Kingkol Ponceau 4 R, Ins No. 124) using food colouring powder (Dow, Adinop Company Limited, Thailand) at the concentration of 0.05 (PK 0.05 and RD 0.05) and 0.10% (w/w) (PK 0.1 and RD 0.1), respectively. After $CaCl_2$ treatment, samples were immersed in colour solutions for 5 mins and drained to remove excessed colour.

### *2.3 Freeze-drying process*

The freeze-drying process of carved-rose pumpkin, carrot, and Chinese radish was performed using Kryo.D’. Fz freeze dryer (Model KD-330 CR, I.T.C. (1993), Co., Ltd, Thailand) with 150 kg capacities consisting of eight shelves. Samples were arranged in an aluminium tray (16 ×24-inch dimension) by 50-55 carved-rose samples per tray with a distance between the pieces approximately 5 cm followed by being placed on a drying shelf. The thermocouple was installed on each drying shelf by inserting it into the centre of the sample. Freezing and drying procedures were conducted in the same chamber, divided into 3 stages including freezing, primary- and secondary drying. The drying conditions were: temperature –50°C, pressure less than 40 Pa, and time 50 hrs. The freezing rate (°C/min) was calculated using equation (1) in accordance with the recommendation in Charoenrein and Owcharoen (2016).

$$\text{Freezing rate} = \frac{\text{initial temperature } (T_i) - \text{final temperature } (T_f)}{\text{freezing time } (t_f)} \qquad (1)$$

The freezing rate of the experiment was 0.88°C/min for bringing an initial product temperature of 26.4 to -15.7°C within 0.8 hrs. The change of parameters in terms of product temperature, shelf temperature and pressure are shown in Figure 1. After that, samples were removed and individually packed in a zip lock bag before repacked in an aluminium bag (15×22 cm. with 9 pieces per bag), filled with nitrogen gas using Brother continuous sealer (Model SF150W, China) and then stored at room temperature until the experiment.

*2.4 Colour measurement*

The colour of the dried samples was measured using a colourimeter (ColourQuest XE, HunterLab, USA) and expressed as L*, a*, and b* values. L* for the lightness which ranged from black (0) to white (100), a* from green (−) to red (+), and b* from blue (−) to yellow (+). For total colour change (ΔE) between freeze-dried or rehydrated sample (L, a and b) and fresh sample ($L_0$, $a_0$, and $b_0$) was calculated using equation (2). Hue angle (H°) was defined in equation (3) as suggested by Guiné and Barrosa (2012). The absolute colour difference (ΔH), hue difference, was reported in comparison to fresh samples.

$$\Delta E = \sqrt{(L_0 - L)^2 (a_0 - a)^2 (b_0 - b)^2} \quad (2)$$

$$H^\circ = \mathrm{arctg}(b^*/a^*) \quad (3)$$

*2.5 Moisture content and water activity*

The moisture content of freeze-dried vegetable carving was examined according to AOAC (2000) and reported on a wet basis. Water activity ($a_w$) was analysed using a dew point water activity meter (4TE, Aqualab, USA) at 25°C. All samples were analysed with three replications.

*2.6 Rehydration capabilities*

The rehydration capabilities of freeze-dried samples were investigated by the method recommended by Meda and Ratti (2005) with some modifications. The experiment was operated at 25°C by immersing in distilled water (100 mL). The sample was let to drain for 5 mins then the weight of rehydrated samples was recorded using a two-digits digital scale at the interval of 5 mins until the difference weight was not exceeded than ±0.01g. All samples were analysed with three replications. The rehydration ratio was calculated by the following equation (Al-Amin *et al*., 2015):

$$\text{Rehydration ratio} = \frac{\text{Wt. of rehydrated material}}{\text{Wt. of dehydrated material}} \quad (4)$$

*2.7 Sensory evaluation*

For the sensory evaluation, freeze-dried materials of carved-rose pumpkin, carrot and Chinese radish (dyed with 0.1% pink colour) were studied, using the sample that was not treated with 1.0% calcium chloride as a control. Sensory evaluation was studied by an unconventional approach. A small group of three members was chosen from a different restaurant chef located in Bangkok, Thailand, which was highly familiar and experienced in vegetables carving in food service management. The panels were suggested to immerse a dried vegetable carving in drinking water for 10 mins before the experiment and then noted the score in terms of appearance, colour, texture and overall acceptability using 9-point hedonic scales. This experiment was done on 0, 1 and 2-month storage periods. Appearance profiles were described by visual quality after rehydration, size, shape, and product shrinkage. Colour properties were a visual shade with no defect such as dullness or browning. Texture quality in reference to firmness was performed by compression test using the finger (Chen and Opara, 2013). Finally, overall acceptability was explained by the whole satisfaction of cared-rose vegetables after trial used in a dish.

*2.8 Statistical analysis*

There were three replications per treatment. Data were analysed using the SPSS program (V.26; IBM, Ontario, Canada) for analysis of variance at $P \leq 0.05$. Duncan's multiple range test was used to compare mean values to determine the difference between treatments.

## 3. Results and discussion

*3.1 Freeze-drying processes*

The variation of process parameters, product and shelf temperature, and pressure throughout the freeze-drying period of 50 hrs are shown in Figure 1. Overall, it can be seen from the graph that the cycle of freeze-dried operation was comprised of three stages including freezing, primary- and secondary-drying. The first stage was freezing, requiring approximately 10 hrs which reduced product temperature to lower than the freezing point in order to bring water in plant cells to become ice crystals (Bhatta *et al*., 2020). According to Figure 2, a rapid freezing rate was observed and the freezing point of the product dropped to around -16°C within 1 hr. In the second stage, the pressure of the system was reduced to lower at the vacuum (~ 30 Pa), while shelf temperature was rose (from -50 to 10°C) which induced the dehydration by sublimed ice crystals in plant cells to become a gas (Bhatta *et al*., 2020). The remarkable rise of product temperature, from -15 to above 0°C, was used to investigate the endpoint of this stage which was around 22 hrs (Figure 1). In secondary drying, an evaluated shelf temperature was performed by gradually increasing by level until reached 40°C (Figure 1). This stage results in more efficiently eliminating product humidity which helps maintain product structure caused by collapse (Patel *et al.*, 2010).

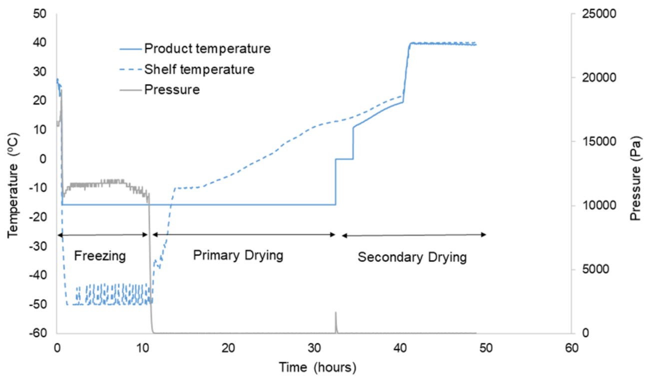


Figure 1. Freeze-drying cycles of carved-rose vegetables are comprised of three stages.

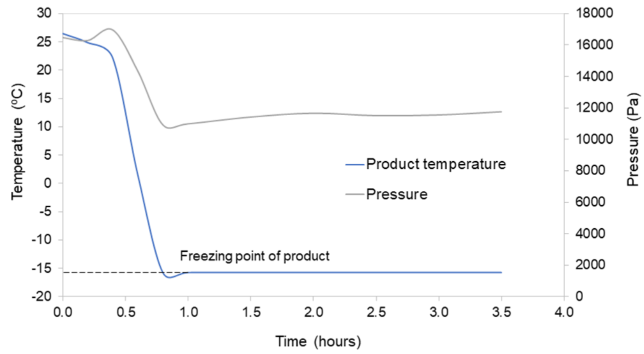


Figure 2. Changes in product temperature and pressure in freezing stage.

*3.2 Physical characteristics of freeze-dried vegetable carving*

*3.2.1 Moisture content and water activity*

The key quality of three kinds of carved-rose vegetables underwent freeze-drying explained by moisture content and water activity as shown in Table 1. The results showed that the final product was lightweight which was reduced approximately 84-94%, and had low moisture content. The moisture content of freeze-dried vegetable carving presented in the range of 8.01-11.44%. A similar pattern was observed in water activity ($a_w$) for all kinds of plant which were about 0.316-0.407. The data from this experiment were in the criteria of a standard created by The Food and Agriculture Organization of the United Nations (FAO) which should be lower than 12% (w.b.) (FAO, 2020). To explain, freeze-drying is based on the principle of water sublimation from the product. Composition, structure and porosity of raw material are influenced on drying in terms of product moisture content which are able to move through the pores from inside to the product surface with the more open structure (Mercer, 2014). For this reason, carved-rose Chinese radish with a less dense fibrous structure observed a low moisture content and water activity when compared with pumpkin and carrot.

*3.2.2 Colour and appearance*

The colour and visual appearance of fresh, freeze-dried, and rehydrated vegetables carving of three kinds of plant are shown in Table 2-3 and Figure 3-5. As illustrated in Figure 3, the appearance of freeze-dried pumpkin (A2) and carrot (B2) had structural strength as complete as fresh samples (A1 and B1) with the spongy texture. Rapid freezing (0.88°C/min) affects the structure which provides small porosity for dried samples (Patel *et al.*, 2010). Therefore, the structure of the final product does not collapse due to the numerous small porous help supporting it. Moreover, a plant cell wall, cellulose and non-cellulose (hemicellulose and pectic), are abundant compositions that give product integrity and maintain the structural strength of dried materials (Bhatta *et al.*, 2020). However, some shrinkage was slightly observed in carved-rose Chinese radish around the edge of the petal (Figure 4-A2 and B2). This phenomenon was described by the loss of microscopic structure of freeze-dried plant materials involved with the effect of the temperature of product which was higher above collapse temperature (Tc), which Tc could be 2°C to 20°C higher than glass transition temperature, depending on compositions of plant material (Bhatta *et al.*, 2020).

Moreover, the colour of freeze-dried carved-rose pumpkin and carrot faded into white (Figure 3-A2 and

Table 1. Moisture content, water activity and rehydration ratio of freeze-dried vegetables carving.

| Vegetables | Moisture content (%) | Water activity (Aw) | Rehydration ratio for maximum water absorption |
|---|---|---|---|
| Pumpkin | $9.98\pm0.22^{b}$ | $0.354\pm0.007^{b}$ | 4.07 |
| Carrot | $11.44\pm1.03^{a}$ | $0.407\pm0.018^{a}$ | 6.17 |
| PK 0.05 | $8.50\pm1.13^{c}$ | $0.319\pm0.014^{c}$ | 8.55 |
| PK 0.1 | $8.51\pm1.05^{c}$ | $0.316\pm0.005^{c}$ | 10.14 |
| RD 0.05 | $8.01\pm0.69^{bc}$ | $0.333\pm0.026^{bc}$ | 7.72 |
| RD 0.1 | $9.63\pm0.63^{bc}$ | $0.327\pm0.006^{bc}$ | 8.43 |

Values are presented as mean±SD, n = 3. Values with different superscripts within the same column are significantly different ($p\leq0.05$).

PK 0.05: carved-rose Chinese radish dyed with 0.05% pink colour, PK 0.1: carved-rose Chinese radish dyed with 0.1% pink colour, RD 0.05: carved-rose Chinese radish dyed with 0.05% red colour, RD 0.1: carved-rose Chinese radish dyed with 0.1% red colour.

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Table 2. The colour (L*, a*, b*, ΔE and ΔH) of fresh, freeze-dried, and rehydrated vegetable carving.

| Vegetables | Experimental unit | L* | a* | b* | ΔE | ΔH |
|---|---|---|---|---|---|---|
| Pumpkin | Fresh | 69.10±1.89$^{c}$ | 12.14±0.41$^{a}$ | 75.75±1.37$^{a}$ | | |
| | Freeze dry | 83.67±0.87$^{a}$ | 2.41±0.44$^{b}$ | 31.39±2.51$^{c}$ | 47.75±3.05$^{a}$ | 4.65±1.15$^{ns}$ |
| | Rehydrate | 73.12±2.11$^{b}$ | 10.88±2.63$^{a}$ | 65.94±3.48$^{b}$ | 9.03±3.62$^{b}$ | 0.93±0.69$^{ns}$ |
| Carrot | Fresh | 57.67±0.14$^{c}$ | 38.32±0.67$^{a}$ | 45.95±1.70$^{a}$ | | |
| | Freeze dry | 71.08±1.61$^{a}$ | 26.40±0.81$^{c}$ | 32.81±2.40$^{c}$ | 22.26±2.77$^{a}$ | 1.64±0.75$^{ns}$ |
| | Rehydrate | 64.54±0.18$^{b}$ | 35.84±1.47$^{b}$ | 41.58±0.89$^{b}$ | 8.62±0.95$^{b}$ | 0.90±0.75$^{ns}$ |
| PK 0.05 | Fresh | 63.78±1.95$^{ns}$ | 39.19±3.19$^{b}$ | -4.73±0.94$^{b}$ | | |
| | Freeze dry | 64.84±0.54$^{ns}$ | 46.79±1.42$^{a}$ | 1.58±0.82$^{a}$ | 9.95±1.57$^{ns}$ | 7.28±0.78$^{ns}$ |
| | Rehydrate | 64.23±0.10$^{ns}$ | 49.33±0.94$^{a}$ | 0.27±0.25$^{a}$ | 11.32±0.91$^{ns}$ | 6.48±0.15$^{ns}$ |
| PK 0.1 | Fresh | 58.80±1.10$^{ns}$ | 49.17±6.27$^{ns}$ | -4.64±0.72$^{b}$ | | |
| | Freeze dry | 60.75±0.21$^{ns}$ | 47.24±0.11$^{ns}$ | 1.43±1.23$^{a}$ | 6.68±1.10$^{ns}$ | 7.12±0.61$^{ns}$ |
| | Rehydrate | 60.52±1.79$^{ns}$ | 49.82±1.99$^{ns}$ | 1.09±1.21$^{a}$ | 6.02±1.04$^{ns}$ | 6.68±0.72$^{ns}$ |
| RD 0.05 | Fresh | 50.94±1.81$^{c}$ | 41.76±4.53$^{a}$ | 6.68±0.76$^{b}$ | | |
| | Freeze dry | 62.67±1.96$^{b}$ | 30.59±3.23$^{b}$ | 9.88±1.05$^{b}$ | 16.56±3.65$^{ns}$ | 8.99±2.98$^{ns}$ |
| | Rehydrate | 66.92±1.40$^{a}$ | 26.60±2.14$^{b}$ | 11.28±1.10$^{a}$ | 22.54±2.42$^{ns}$ | 13.93±2.28$^{ns}$ |
| RD 0.1 | Fresh | 40.08±3.67$^{b}$ | 46.23±2.77$^{a}$ | 9.83±2.22$^{ns}$ | | |
| | Freeze dry | 53.62±1.55$^{a}$ | 35.80±2.94$^{b}$ | 8.20±0.98$^{ns}$ | 17.31±2.51$^{ns}$ | 1.13±2.54$^{ns}$ |
| | Rehydrate | 57.05±0.90$^{a}$ | 34.30±2.77$^{b}$ | 9.24±0.71$^{ns}$ | 20.90±1.35$^{ns}$ | 3.30±2.33$^{ns}$ |

Values are presented as mean±SD, n = 3. Values with different superscripts within the same column are significantly different ($p \leq 0.05$).
PK 0.05: carved-rose Chinese radish dyed with 0.05% pink colour, PK 0.1: carved-rose Chinese radish dyed with 0.1% pink colour, RD 0.05: carved-rose Chinese radish dyed with 0.05% red colour, RD 0.1: carved-rose Chinese radish dyed with 0.1% red colour.

Table 3. Consensus attribute lists of fresh, freeze-dried, and rehydrated carved-rose vegetables.

| Plants | Attributes | Fresh | Freeze dried | Rehydrated | Cross section of rehydrated sample |
|---|---|---|---|---|---|
| Pumpkin | Colour<br>Texture<br>Shape | Bright orange<br>Firm flesh<br>Rose carving | Pale orange<br>Firm and spongy<br>Still maintained | Bright orange as fresh<br>Firm and not crispy<br>Still maintained as fresh |  |
| Carrot | Colour<br>Texture<br>Shape | Yellow<br>Firm flesh<br>Rose carving | Pale yellow<br>Firm and spongy<br>Still maintained | Yellow as fresh<br>Firm and not crispy<br>Still maintained as fresh |  |
| Chinese radish (PK 0.05, 0.1) | Colour<br>Texture<br>Shape | Pink and translucent<br>Firm flesh<br>Rose carving | Light pink and opaque<br>Soft and spongy<br>Maintain rose shape and slightly shrinkage around the edge | Pink as fresh, reduced transparency<br>Firm and not crispy<br>Restored as fresh and not presented shrinkage |  |
| Chinese radish (RD 0.05, 0.1) | Colour<br>Texture<br>Shape | Red and translucent<br>Firm flesh<br>Rose carving | Light red, irregular and opaque<br>Soft and spongy<br>Maintain rose shape and slightly shrinkage around the edge | Pale red<br>Firm and not crispy<br>Restored as fresh and not presented shrinkage |  |


Figure 3. Appearance of fresh (1), freeze-dried (2), and rehydrated (3) carved-rose pumpkin (A) and carrot (B).

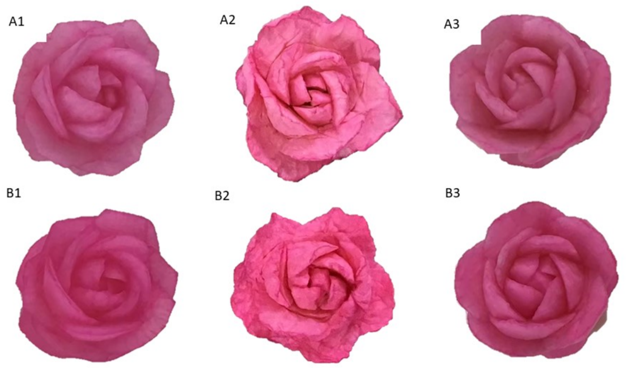


Figure 4. Appearance of fresh (1), freeze-dried (2), and rehydrated (3) carved-rose Chinese radish which was dyed with 0.05% (A) and 0.1% (B) pink colour.


Figure 5. Appearance of fresh (1), freeze-dried (2), and rehydrated (3) carved-rose Chinese radish which was dyed with 0.05% (A) and 0.1% (B) red colour.

B2) as investigated by higher L* value and ΔE (Table 2). Carved-rose pumpkin and carrots after rehydration in water showed a slightly increased brightness (L*), redness (a*) and yellowness (b*) compared to fresh samples (Table 2). As for the visual aspect, rehydrated samples (Figure 3-A3 and B3) were similar to the fresh samples (Figure 3-A1 and B1) which induced a decrease in ΔE and ΔH (Table 2). Colour characteristic of rehydrated dried-carrot correlated with the degradation of carotenoid and beta-carotene contents which was noted by Zielinska and Markowski (2012). Dried-carrot exhibited the highest a* value which was attributed to the highest content of carotenoids. In this study, freeze-dried carved-rose carrots could recover their original colour after rehydration similar to those of fresh samples.

The carved-rose Chinese radish dyed with both concentrations of pink colour (PK 0.05 and PK 0.1) showed no significant ($p>0.05$) changes in total colour difference (ΔE) and hue (ΔH) between freeze-dried and rehydrated samples. For red cared-rose Chinese radish, the rehydrated samples had a significantly declined in a* value when compared to fresh samples (Table 2). This was due to a releasing of colour into the water during rehydration as observed in an appearance as shown in Figure 5-B3, which results in a dramatic colour change in ΔE and ΔH (Table 2).

*3.2.3 Rehydration capabilities*

Rehydration capabilities of three kinds of freeze-dried vegetable carving are shown in Figure 6 including pumpkin, carrot and Chinese radish (pink and red-dyed). The initial weight of dried materials was shown in the range of 0.7 – 2.3 g. After being immersed in water, carved-rose pumpkin and carrot absorbed water quickly and required the time to reach equilibrium about 5 mins. Normally, freeze-dried foods are vulnerable to moisture or high relative humidity environments. The sponge-like characteristics allow them to rehydrate quickly by moisture pick-up results in volume changes (Valentina *et al*., 2016). Moreover, it might depend on the shape, size, and cell wall composition of individual cultivars and the capacity of the dried cell to reabsorb water after rehydration (Gandavvagol *et al*., 2018). The weight of samples after rehydration was increased 75.42 and 83.78% for pumpkin and carrot, respectively. Similar observation reported by Vergeldt *et al*. (2014) that non-blanched carrot cylinders frozen at −28°C before freeze-drying exhibited rehydration faster compared to those frozen at −150°C, due to blocking of smaller pores by swelling. On the contrary, a slow rehydration rate was observed in carved-rose Chinese radish for both pink (PK 0.05 and PK 0.1) and red colour (RD 0.05 and RD 0.1) which the weight increased continuously during the first 10 min. After that, the rate of weight gain decreased and was not significantly different ($P>0.05$) until the end of the experiment. Percentage of samples weight was increased to a range of 87.05-90.14% compared to initial weight (0 min). Product shrinkage or volume reduction after freeze-drying leads to poor rehydration characteristics (Fauster *et al*., 2020). Moreover, a less density of fibrous components in the cell wall may affect a loss of dried product integrity by collapse. Even though a carved-rose Chinese radish required a long time (10 mins) for rehydration, however, a high rehydration ratio (7.72-10.14; Table 1) which observed at maximum water absorption indicated that dried material could restore a cell structure as fresh and not presented cell shrinkage

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after immersing in water (Figure 4. A3, B3 and Figure 5. A3, B3).

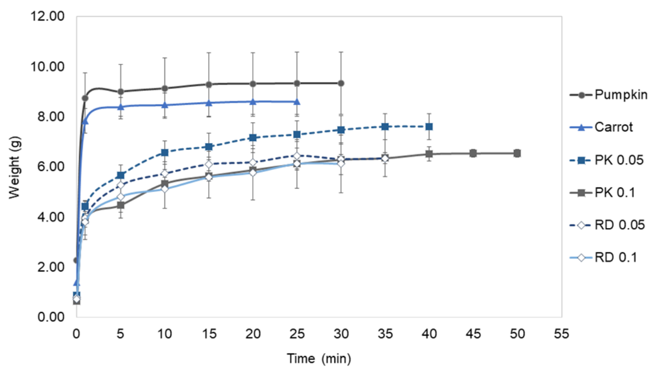


Figure 6. Changes in weight of carved-rose vegetables during rehydration in water at 25±1°C.

*3.3 Sensory evaluation*

Sensory evaluation for three kinds of carved-rose vegetables is shown in Table 4-6. The general overview here is that all carved-rose vegetables achieved a high level of acceptance score (7-9) throughout 2 months of storage in both control and treatment samples. For treatment sample of carved-rose pumpkin, application of 1.0% calcium chloride as a firming agent responded to a positive effect which showed significantly higher texture and overall quality scores ($p\leq0.05$) than those of the control treatment throughout 2-months storage, with the table being 8.33-9.00 (Table 4). The qualities characteristics of carved-rose carrot and Chinese radish followed a similar pattern over the periods, however no

Table 4. User acceptance score of freeze-dried pumpkin carving into rose shape at an initial (0 month) and after storage for 1 and 2 months in an aluminium bag filled with nitrogen gas at 25±1ºC.

| Storage time (month) | Sensory characteristic | Control | Treatment |
|---|---|---|---|
| 0 | Appearance | $8.00\pm0.89^{ns*}$ | $7.33\pm0.52^{ns*}$ |
| | Colour | $9.00\pm0.00^{a*}$ | $7.67\pm1.03^{b*}$ |
| | Texture | $7.67\pm0.52^{ns*}$ | $8.33\pm1.03^{ns*}$ |
| | Overall acceptability | $8.67\pm0.52^{ns*}$ | $7.67\pm1.03^{ns*}$ |
| 1 | Appearance | $8.00\pm0.89^{ns}$ | $8.33\pm0.52^{ns}$ |
| | Colour | $8.33\pm1.03^{ns}$ | $7.33\pm1.03^{ns}$ |
| | Texture | $7.33\pm1.03^{b}$ | $9.00\pm0.00^{a}$ |
| | Overall acceptability | $7.67\pm1.03^{ns}$ | $8.33\pm1.03^{ns}$ |
| 2 | Appearance | $8.33\pm0.52^{ns}$ | $8.33\pm1.03^{ns}$ |
| | Colour | $8.33\pm1.03^{ns}$ | $7.33\pm0.52^{ns}$ |
| | Texture | $6.67\pm1.37^{b}$ | $9.00\pm0.00^{a}$ |
| | Overall acceptability | $7.67\pm0.52^{ns}$ | $8.67\pm0.52^{ns}$ |

Values are presented as mean±SD, n = 3. Values with different superscripts within the same row are significantly different ($p\leq0.05$).
$^{ns}$no significant difference between treatments, *no significance difference in each sensory characteristic among storage time.

Table 5. User acceptance score of freeze-dried carrot carving into rose shape at an initial (0 month) and after storage for 1 and 2 months in an aluminium bag filled with nitrogen gas at 25±1°C.

| Storage time (month) | Sensory characteristic | Control | Treatment |
|---|---|---|---|
| 0 | Appearance | $8.00\pm0.89^{ns*}$ | $7.33\pm0.52^{ns*}$ |
| | Colour | $7.67\pm1.37^{a*}$ | $7.33\pm0.52^{b*}$ |
| | Texture | $6.33\pm0.52^{ns*}$ | $6.67\pm1.03^{ns*}$ |
| | Overall acceptability | $8.00\pm0.89^{a*}$ | $7.00\pm0.00^{b*}$ |
| 1 | Appearance | $8.67\pm0.52^{ns}$ | $7.67\pm0.52^{ns}$ |
| | Colour | $8.67\pm0.52^{ns}$ | $7.67\pm0.52^{ns}$ |
| | Texture | $7.33\pm1.37^{ns}$ | $8.33\pm0.52^{ns}$ |
| | Overall acceptability | $8.33\pm0.52^{ns}$ | $8.00\pm0.89^{ns}$ |
| 2 | Appearance | $8.33\pm0.52^{ns}$ | $8.00\pm0.52^{ns}$ |
| | Colour | $8.33\pm1.03^{ns}$ | $8.00\pm0.52^{ns}$ |
| | Texture | $7.33\pm1.37^{ns}$ | $7.83\pm0.52^{ns}$ |
| | Overall acceptability | $8.00\pm0.89^{ns}$ | $8.00\pm0.52^{ns}$ |

Values are presented as mean±SD, n = 3. Values with different superscripts within the same row are significantly different ($p\leq0.05$).
$^{ns}$no significant difference between treatments, *no significance difference in each sensory characteristic among storage time.

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Table 6. User acceptance score of freeze-dried Chinese radish carving into rose shape at an initial (0 month) and after storage for 1 and 2 months in an aluminum bag filled with nitrogen gas at 25±1°C.

| Storage time (month) | Sensory characteristic | Control | Treatment |
|---|---|---|---|
| 0 | Appearance | $8.00±0.89^{ns*}$ | $6.67±0.52^{ns*}$ |
| | Colour | $9.00±0.00^{ns*}$ | $7.33±1.37^{ns*}$ |
| | Texture | $7.33±0.52^{ns*}$ | $7.33±0.52^{ns*}$ |
| | Overall acceptability | $8.00±0.00^{ns*}$ | $7.33±0.52^{ns*}$ |
| 1 | Appearance | $8.33±1.03^{ns}$ | $8.00±0.89^{ns}$ |
| | Colour | $8.33±1.03^{ns}$ | $8.00±0.89^{ns}$ |
| | Texture | $7.67±1.37^{ns}$ | $8.33±0.52^{ns}$ |
| | Overall acceptability | $8.00±0.89^{ns}$ | $8.00±0.89^{ns}$ |
| 2 | Appearance | $8.67±0.52^{ns}$ | $8.00±0.89^{ns}$ |
| | Colour | $8.33±1.03^{ns}$ | $7.33±1.03^{ns}$ |
| | Texture | $7.33±1.37^{ns}$ | $8.00±0.89^{ns}$ |
| | Overall acceptability | $8.00±0.89^{ns}$ | $8.33±0.52^{ns}$ |

Values are presented as mean±SD, n = 3. Values with different superscripts within the same row are significantly different ($p≤0.05$).

$^{ns}$no significant difference between treatments, *no significance difference in each sensory characteristic among storage time.

statistically ($p>0.05$) significant difference in firmness was observed during storage. Interestingly, control samples of carved-rose carrot got the key quality score especially colour greater than the treatment during the storage period (Table 5). For carved-rose Chinese radish, the overall quality between both treatments seems not distinct and showed no statistically significant difference ($p>0.05$) in all characteristics throughout the storage period (Table 6).

## 4. Conclusion

Application of freeze-drying for carved-rose pumpkin and carrot offered a good characteristic in terms of visual structural strength and no visual collapse. The small porous texture helps absorb water quickly (within 5 min) and is restored as a fresh vegetable, described by colour ($\Delta E$ and $\Delta H$) and sensory score. Some product shrinkage presented in dried Chinese radish results in a longer time (10 min) for rehydration. The overall acceptance of all rehydrated vegetable carving was ranged from moderately to extremely like throughout 2-months observation. Further study should be investigated on the changes in chemical and microbiological properties which were not reported in this work.

## Conflict of Interest

The authors declared no conflict of interest.

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