

Effect of osmotic dehydration process using sucrose solution at mild temperature on mass transfer and quality attributes of red pitaya (*Hylocereus polyrhizus*)

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Abstract

In the current research, osmotic dehydration of red pitaya (*Hylocereus polyrhizus*) cubes using sucrose solution at mild temperature (35°C) was investigated. Sucrose solution (40, 50 and 60% w/w) was employed for osmotic dehydration process. Responses of weight reduction (WR), solid gain (SG), water loss (WL), color (L^* , a^* and b^*) and texture (hardness) were evaluated. It was found that sucrose concentration significantly ($p < 0.05$) affected the mass transfer terms during osmosis process. The results obtained revealed an increase in yellowness (b^*), decrease in lightness (L^*) and redness (a^*) as the sucrose concentration increased. Furthermore, osmotically dehydrated samples were considerably softer than untreated samples. Increasing of sucrose concentration and dehydration time caused softer tissue of dehydrated product compared with the fresh red pitaya.

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Introduction

Red pitaya, *Hylocereus polyrhizus* L., a member of the *Cactaceae* family is native to the Central and South America (Haber, 1983). The fruit which is cultivated on a large scale in Malaysia, Vietnam, Thailand and Taiwan has great amount of vitamin C (Rui *et al.*, 2009). The most important pitaya pigments are the red-violet betacyanins and the yellow betaxanthins which belong to the betalain pigments (Wybraniec *et al.*, 2001). Pitayas are useful sources of fiber, minerals and phytoalbumin which are highly appreciated for its antioxidant properties. The fruit is juicy with a subtle fruity flavor. Pitaya fruit, like other tropical fruit, is highly perishable and needs preservation methods to increase its shelf life. Drying is one of the oldest methods of food preservation mainly because of moisture removal from the food which resulted in slow down the rate of bacteria, yeast and molds growth (Mandala *et al.*, 2005). In recent years, osmotic dehydration has been widely used for fruits and vegetables preservation due to its potential to keep sensory and nutritional properties similar to fresh fruits and vegetables (Prothon *et al.*, 2001). Osmotic dehydration is process of immersing cellular materials into a concentrated solution for partial removal of water while increasing

soluble solid content (Corzo and Bracho, 2005). The mass transfer rate depends on some factors like temperature, solution concentration, immersion time, size and geometry of sample and amount of sample to solution ratio (Panades *et al.*, 2008). On the other hand, depending on characteristics of sample and conditions of osmotic process many changes in macro- and microscopic properties of sample including porosity/volume changes and alteration in quality attributes (i.e. mechanical and optical properties) (Telis *et al.*, 2005) to varying degrees take place which associated mass and heat transfer during the process. To date no work can be found in the literature on osmotic dehydration of red pitaya. Therefore, this study was dedicated to evaluate the influence of sucrose concentration on weight reduction (WR), solid gain (SG), and water loss (WL) as well as optical (color) and mechanical (texture) properties during osmotic dehydration of red pitaya at mild temperature (35°C).

Materials and Methods

Sample preparation

Fresh red pitayas (*Hylocereus polyrhizus*) were obtained from a local market at Serdang, Malaysia. The fruits were chosen at commercial maturity according to their similarity of color, size and absence

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of surface defects. Fruits were washed, peeled and then cut into 2.0 ± 0.1 cm cubes manually using sharp stainless steel knife.

Osmotic dehydration procedure

Osmotic solution was prepared using commercial grade sucrose and distilled water. The solution concentrations (40%, 50%, and 60% w/w) throughout each experiment were monitored by refractometer (Atago-Master-20M, Japan). Experiments were performed at $35 \pm 0.5^\circ\text{C}$ using an agitated water bath (Memmert, WNE14. Memmert GmbH Co. KG, Germany). The temperature was monitored using a digital thermometer (Ellab CTD-85, Ellab, Denmark) and a thermocouple (1.2 mm needle diameter constantan type T). According to preliminary studies, the mass ratio of osmotic solution to sample was kept constant at 10:1 (w/w) to avoid significant dilution of the osmotic solution. Sampling was performed in time intervals of 15, 30, 45, 60, 75, 90, 105, and 120 min, and then the samples rinsed quickly with distilled water (below 30 s) to eliminate the solution from the surface and carefully blotted with tissue paper to remove the excess surface water. All experiments were performed triplicate.

Analytical determination

Before and after treatment, when the temperature of samples reached to 25°C , weights of red pitaya cubes were measured using an analytical Mettler Toledo balance (± 0.0001 g) (Mettler Toledo GmbH, Greifensee, Switzerland) to determine mass changes. Moisture and solid contents were determined by the gravimetric method in oven (Heraeus Vacutherm VT6025, Germany) at 105°C until a constant weight (24 h) was obtained (AOAC, 1990). All measurements were carried out triplicate.

Determination of weight reduction, solid gain and water loss

The fresh and dehydrated red pitaya cubes after each contact times were placed in oven (Heraeus Vacutherm VT6025, Germany) at 105°C until constant weight (24 h) in order to measure the moisture and solids content according to Association of Official Analytical Chemists (AOAC) method 931.04 (AOAC, 1990). From these data, weight reduction (WR), solid gain (SG) and water loss (WL) were determined in all the cases at different times, t , in agreement with the following equations (Panagiotou *et al.*, 1999).

$$\text{WR} = \frac{M_0 - M}{M_0}, \quad (1)$$

$$\text{SG} = \frac{m - m_0}{M_0}, \quad (2)$$

$$\text{WL} = \frac{(M_0 - m_0) - (M - m)}{M_0}, \quad (3)$$

Where M_0 is the initial mass of fresh sample (g), M is the mass of sample after time (t) of osmotic dehydration (g), m is the dry mass of sample (g) after time (t) of osmotic dehydration, m_0 is the initial dry mass of sample (g).

Color measurement

Color analyses were carried out using a Minolta CR-300 portable colorimeter (illuminant D 65) in terms of L^* (lightness), a^* (redness or greenness) and b^* (blueness or yellowness) as an average of three measurements at three different locations. CIE- $L^*a^*b^*$ coordinates were obtained using D65 illuminant. From these values, total color differences (TCD) with regards to initial fresh samples were calculated according to the following equation:

$$\text{TCD} = [(L^* - L_0^*)^2 + (a^* - a_0^*)^2 + (b^* - b_0^*)^2]^{1/2} \quad (4)$$

Where L_0^* , a_0^* and b_0^* are the readings at time zero, and L^* , a^* and b^* the individual readings at each processing time.

Texture measurement

Texture measurement of fresh and osmotically dehydrated cubes of red pitaya was performed using a universal test machine (TA.XT.PLUS Stable Micro Systems Ltd, Godalming, UK) with a 30 N load cell and an aluminum probe of 50 mm diameter at room temperature of 25°C . The program was set to measure force in compression mode, considering a 60% relative deformation. The test parameters were 1.00 mm/s of pre-test and post-speed, 0.5 mm/s of test speed and 10 g of trigger force. Hardness was measured as peak maximum force. Data were analyzed using Windows based software, Texture Expert version 1.19 (Stable Micro Systems Ltd, Godalming, UK). All of the measurements were replicated thrice at different locations and the mean values were reported.

Statistical analysis

Data were subjected to analysis of variance (ANOVA) and mean comparison test were carried out using Tukey's test with a 95% of confidence level ($p < 0.05$). All the analysis was carried out using MINITAB V. 14 (Minitab Inc., PA, USA).

Results and Discussion

Effect of sucrose concentration on weight reduction, solid gain and water loss

Figures 1-3 show the WR, SG and WL of red pitaya during osmotic dehydration at different sucrose solution concentrations, respectively. Sucrose concentration had significant ($p < 0.05$) effect on the WR, SG and WL. The higher extent of mass transfer in terms of WR, SG and WL during osmotic dehydration of red pitaya was achieved by using more concentrated osmotic solution. This can be attributed to the large osmotic driving force between the fruit and the surrounding hypertonic medium (Azoubel and Murr, 2004; Falade *et al.*, 2007). This result corroborates those obtained by several research groups for osmotic dehydration of cantaloupe, mango slices, apricot and guava cubes (Fermin and Corzo, 2005; Mastrantonio *et al.*, 2005; Ito *et al.*, 2007; Ispir and Togrul, 2009; Ganjloo *et al.*, 2011). These results indicate that some benefits in terms of faster WR and WL could be achieved by choosing a higher concentration of medium. However, a much greater SG is also observed (Azoubel and Murr, 2004). This finding also confirmed that highly concentrated sucrose solution ($>60\%$ w/w) is a mass transfer rate limiting parameter during osmotic dehydration process (Khoiyi and Hesar, 2007)

Changes in color parameters of red pitaya

Color is an attribute of food quality which initially being judged by a consumer at the point of purchasing food products. Loss of color during osmotic dehydration process is one of the most significant changes (Osorio *et al.*, 2007). Physical and chemical factors responsible for loss of color during osmotic process are degradation, loss or concentration of fruit pigments and development of browning. Ames (2003) indicated that color degradation of dehydrated foods related to the browning reaction such as enzymatic or non-enzymatic browning. Therefore, the color parameters of red pitayas were measured before and after osmotic dehydration process.

The Lightness (L^*), redness (a^*) and yellowness (b^*) values of fresh red pitaya were 26.97 ± 1.27 , 32.7 ± 1.99 and 5.5 ± 0.4 , respectively. Typical plots of variation of color parameters with dehydration time at different sucrose concentrations and constant temperature of 35°C were illustrated in Figures 4-7. It was revealed that the b^* value increase ($p < 0.05$) with increase in dehydration time and solution concentration, while both L^* and a^* values decreased ($p < 0.05$). The increase in b^* value may be related to concentration of betaxanthins. The decrease in

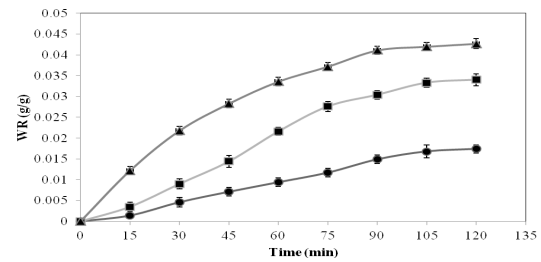


Figure 1. Weight reduction (WR) of red pitaya during osmotic dehydration using three different sucrose concentrations (●) 40.0% (w/w); (■) 50.0% (w/w); (▲) 60.0% (w/w) at mild temperature of 35°C

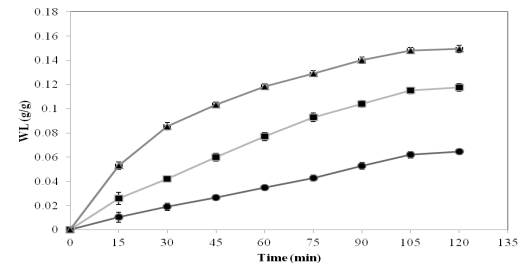


Figure 2. Water loss (WL) of red pitaya during osmotic dehydration using three different sucrose concentrations (◆) 40.0% (w/w); (■) 50.0% (w/w); (▲) 60.0% (w/w) at mild temperature of 35°C

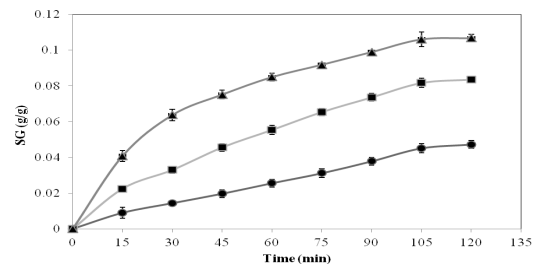


Figure 3. Solid gain (SG) of red pitaya during osmotic dehydration using three different sucrose concentrations (●) 40.0% (w/w); (■) 50.0% (w/w); (▲) 60.0% (w/w) at mild temperature of 35°C

L^* value for red pitayas may be attributed to brown pigment formation during process due to high levels of reducing sugars and air loss of osmodehydrated red pitayas (Moreno *et al.*, 2000). Increasing in total color difference (TCD) suggesting that red pitaya lose lightness, redness and yellowness. These results are in agreement with Forni *et al.* (1997), Waliszewski *et al.* (1999) and Moreira *et al.* (2010) who observed similar behavior in color changes of osmotically treated apricots, banana and chestnuts. Generally, " L^* " and " a^* " parameters are well correlated to browning reaction (Medina-Torresa *et al.*, 2008). Enzymatic and non-enzymatic reactions are the most important reason of browning development in fruits and vegetables during dehydration. Polyphenoloxidase and peroxidase which is present in low acid fruits involved in enzymatic browning (Moreno-Castillo *et al.*, 2005). This reduction of lightness values (Figure 4) could also be attributed to the shrinkage of plant

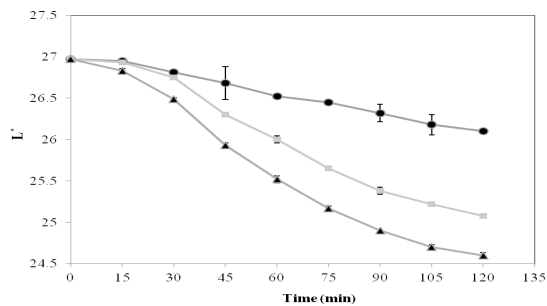


Figure 4. Plot of L^* value changes of red pitaya using three different sucrose concentrations (●) 40.0% (w/w); (■) 50.0% (w/w); (▲) 60.0% (w/w) at mild temperature of 35°C

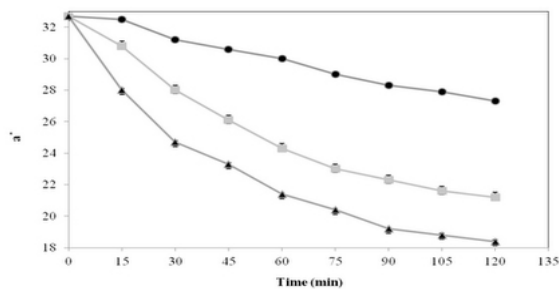


Figure 5. Plot of a^* value changes of red pitaya using three different sucrose concentrations (●) 40.0% (w/w); (■) 50.0% (w/w); (▲) 60.0% (w/w) at mild temperature of 35°C

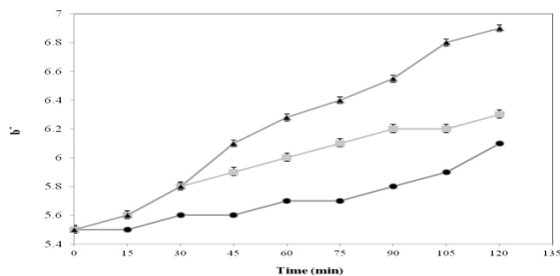


Figure 6. Plot of b^* value changes of red pitaya using three different sucrose concentrations (●) 40.0% (w/w); (■) 50.0% (w/w); (▲) 60.0% (w/w) at mild temperature of 35°C

tissue which leads to increase in samples opacity (Contreras *et al.*, 2008; Heredia *et al.*, 2009). The changes of redness and yellowness (Figures 5-6) are clear and seem to be relevant to alteration of fruit pigments and solids uptake (Forni *et al.*, 1997; Rodrigues *et al.*, 2003; Falade and Igbeka, 2007).

Changes in hardness of red pitaya

The texture perception of foods receives through biting, chewing and swallowing providing information which are very useful to assess the quality of consumed food. Instrumental texture analysis describes physical characteristics of food products in both quality and quantity. According to Raoult-Wack (1994) limitations of textural evaluation of osmotically dehydrated sample using texture analyzer are related to lack of uniform shape and size of fruit and vegetables. Thus, in this

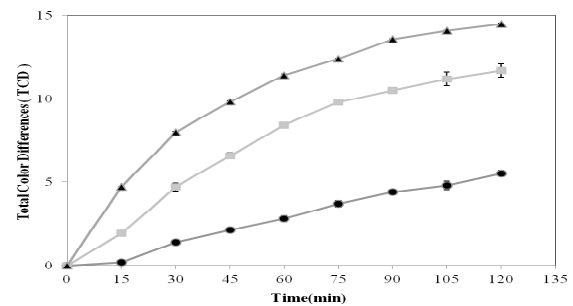


Figure 7. Plot of TCD value changes of red pitaya using three different sucrose concentrations (●) 40.0% (w/w); (■) 50.0% (w/w); (▲) 60.0% (w/w) at mild temperature of 35°C

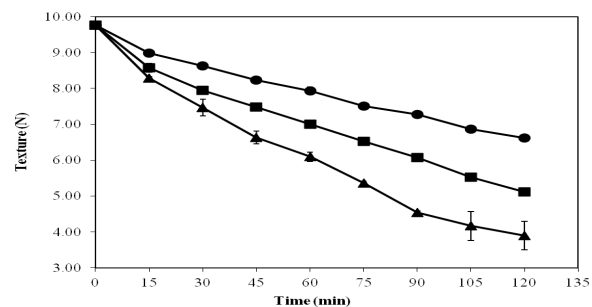


Figure 8. Plot of Hardness value changes of red pitaya using three different sucrose concentrations (●) 40.0% (w/w); (■) 50.0% (w/w); (▲) 60.0% (w/w) at mild temperature of 35°C

study, care was exercised to select only cubes that have same shape and size to minimize the effect of sample shape and size on the experimental data. The hardness value of fresh red pitaya was 9.76 ± 0.02 N (Figure 8). The variations of hardness during osmotic dehydration of red pitayas using different sucrose concentrations were presented in Figure 8. It is clear that osmosed samples were considerably softer than untreated samples and as sucrose concentration and time increased the hardness of the samples decreased gradually. This was explained by substantial changes in cellular tissues including loss of cell turgor (plasmolysis), filling of air spaces with hypertonic solution and degradation of the middle lamellae during osmosis of fruits and vegetables (Lewicki and Lukaszuk, 2000). Similar observations were reported by Lewicki and Lukaszuk (2000), Chirlat and Talens (2005) and Katsiferis *et al.* (2008) and Castello *et al.* (2010) working on apples, orange, Granny Smith apple slices and strawberries.

Conclusion

In current research, the effects of sucrose concentrations on mass transfer in terms of WR, WL and SG were investigated during osmotic dehydration of red pitaya. It was revealed that the higher values of solution concentration resulted in higher flows of water and solids and loss of weight through the red

pitaya cubes. Tristimulus colorimetry and texture analysis made it possible to perform a qualitative analysis during the osmotic process performed under different solution concentrations. It was showed that an increase in yellowness (b^*) coordinate and a decrease in lightness (L^*) and redness (a^*) was achieved as the sucrose concentration increased. This could be attributed to the shrinkage of plant tissue which leads to increase in samples opacity, alteration of fruit pigments and solids uptake. Finally, it was found that osmosed samples were considerably softer than untreated samples. As the concentration of the osmosed samples increase, the hardness decrease which led to produce softer product texture.

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