OSMO-CONVECTIVE DEHYDRATION OF SWEET POTATO (IPOMOEA BATATAS L.)

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ABSTRACT

The effect of sugar concentration and different drying temperatures on the quality of osmotically dehydrated sweet potato was determined. Sweet potato cubes were osmotically dehydrated in sugar syrup concentrations of 50, 60 and 70°Brix for 48 hours and thereafter samples were dried using tray drier at temperatures of 55, 65 and 75 °C. The quality of the samples was determined in terms of bulk density, water activity, sugar gain, hardness, shrinkage ratio and color. The drying rate decreased with increase in drying time and became uniform for 55, 65 and 75 °C drying temperature irrespective of concentration of sugar solutions, whereas at initial stage higher decrease in drying rate was found in 75 °C at 50 °Brix. Bulk density was maximum for sugar solution concentration of 60°Brix at 65°C (46.52 kg/m^3). The maximum water activity was found for sample having sugar concentration of 50 °Brix and drying temperature of 55°C and the minimum value of water activity was attained for sliced sample at a drying temperature of 75°C and sugar concentrations of 60°Brix. It was observed that the sugar gain was highest in samples dipped in sugar solutions of concentration 70 °Brix and lowest in the samples of sugar solution concentration of 50°Brix.

Key words: Drying temperature, Osmotic dehydration, Sugar, Sweet potato.

INTRODUCTION

The sweet potato (Ipomoea batatas L.) is a dicotyledonous plant of Convolvulaceae family. Its large, starchy, sweet-tasting and tuberous roots make it an important root vegetable. In India, the total production of sweet potato was 1.090 million Mt from 112 thousand ha area (Anonymous 2014). Sweet potato is one of the five most important food crops in developing countries. Tuber crops achieve levels of importance as great as cereal grains in providing the greater part of people’s daily caloric needs in the tropics. Sweet potato provides at least 90% of human requirements, except for protein and niacin, since the root part is rich in ɑ-carotene, food fiber, and potassium etc. Sweet potato is used widely in ready-to-eat foods such as noodles, Chinese style french fries, canned foods, etc.

The use of artificial drying to preserve agricultural products has been expanding, creating a need for more rapid and efficient drying techniques and methods that reduce energy consumption and costs in the drying processes. Innovative techniques that increase drying rates and enhance product quality have acquired considerable attention. Water is usually removed by evaporation (air drying, sun drying, smoking or wind drying) but, in the case of freeze-drying, food is first frozen and then the water is removed by sublimation. Bacteria, yeasts and molds need the water in the food to grow, and drying effectively prevents them from surviving in the food.

Osmotic dehydration is used for partial removal of water from plant tissues by immersion in a hyper-tonic osmotic solution. Water removal is based on the natural and non-destructive phenomenon of osmosis across cell membranes. The driving force for the diffusion of water from the tissue into the solution is provided by the higher osmotic pressure of the hyper-tonic solution. The diffusion of water is accompanied by the simultaneous counter diffusion of solutes from the osmotic solution into the tissue. Since the cell membrane responsible for
osmotic transport is not perfectly selective, solutes present in the cells (organic acids, reducing sugars, minerals, flavors and pigment compounds) can also be leached into the osmotic solution, which affect the organoleptic and nutritional characteristics of the product.

Recently, many studies have been conducted on the osmotic dehydration of different vegetable and fruits. Kar and Gupta (2001) studied the osmotic drying behaviour of button mushrooms in relation to temperature (25, 40 and 55°C); Valdez and Mujica (2002) proposed pilot plant scale equipment for osmotic dehydration (OD) of apple cubes; Alam (2007) carried out osmotic dehydration kinetics of anola fruit in solution of different osmotic agents; Baik and Taiwo (2007) studied the effects of various pre-treatments (blanching, freezing, air drying, osmotic dehydration and control) on the shrinkage and textural properties of fried sweet potatoes; Antonio et al (2008) studied the influence of osmotic dehydration and high temperature short time processes on dried sweet potato; Yang et al (2010) studied the effects of drying processes on the antioxidant properties in sweet potatoes; Silva et al (2011) investigated the influence of stepwise blanching over the kinetics of osmotic dehydration process and over the physical characteristics of pumpkin. Kaur and Singh (2013) studied absent mass transfer kinetics and optimization during osmotic dehydration of beetroot.

The present study was carried out with the objectives to study the drying behavior of osmotically dehydrated sweet potato using tray drier and also to determine the quality of dehydrated sweet potato slices.

MATERIALS AND METHODS

Fresh sweet potatoes were purchased locally from the vegetable market. The fresh and healthy sweet potatoes of about equal size and shape were manually sorted and then washed under running tap water to remove adhering soil and other debris. They were then peeled with peeler and cut into cuboidal shapes of 3.0x1.0x1.0 cm size.

Osmotic dehydration: Sweet potato sample was dipped in 1% acetic acid solution for 1 hour and then pricking was done by piercing a pin uniformly through each piece for faster removal of moisture. The solution/sugar syrups prepared were of strength 50, 60 and 70°Bx. The osmotic dehydration was carried out using sugar solution. The prepared lots of sweet potato samples were dipped/soaked in the sugar syrup in the ratio 1:4 (1 part fruit and 4 parts of sugar syrup) in airtight boxes. Proper care was taken so that whole lot of fruit remains submerged in the sugar syrup for uniform removal of moisture. These airtight boxes were kept at room temperature for 48hr. The intermediate moisture samples were then taken out from sugar syrup and cleaned with filter paper to remove the sugar syrup sticking on its surface so as to ensure proper moisture removal during drying. Three samples of 100g each were then loaded in tray drier where further convection drying at three different temperatures viz. 55, 65° and 75°C was carried out. The weights of the samples were recorded manually at regular interval of 30 min. Drying was continued till the weight of the sample reached a desired moisture content of about 20% on dry basis.

Drying rate: Drying rate was determined by moisture content (db) decrease of the sample per unit time as given by Brooker et al (1997).

\[
\frac{dM}{dt} = \frac{(M_i - M_{i+1})}{(t_{i+1} - t_i)}
\]

Where,

\[
\frac{dM}{dt} = \text{drying rate, moisture loss per minute (gms/min)}
\]

\[
M_i = \text{Moisture content (db) of sample at time } t_i
\]

\[
M_{i+1} = \text{Moisture content (db) of sample at time } t_{i+1}
\]

Estimation of moisture content: Known weights of samples were taken in Petri dishes and dried in an oven at a temperature of 103 ± 2 (AOAC, 2000).

Estimation of total soluble solids (TSS): The TSS of fresh as well as osmotically dried sweet potato samples was determined using hand refractrometer (make: ERMA).

Bulk density: The density of dried sweet potato samples was determined using method given by Mohsenin (1986).

Estimation of water activity: Water activity of the processed samples was measured directly using water activity meter. One piece of dried sweet potato from each sample was taken and placed in a standard measuring cup provided with the water activity meter, and sealed against a sensor block.
Texture: Hardness of the dried sweet potato samples was determined using the texture analyzer.

Estimation of water loss: Water loss (WL) during the osmosis process was the net moisture lost from the fruit after time ‘t’ on an initial mass basis (Pokharkar and Prasad, 1998). It was calculated using the given relationship:

\[ WL = \left( \frac{W_i \times X_{wi} - W_o \times X_{wo}}{W_i \times X_{wi}} \right) \times 100 \]

Where,
- \( W_i \) = initial mass of fruit, gms
- \( X_{wi} \) = water content as a fraction of the initial mass of fruit
- \( W_o \) = mass of fruit after time ‘t’
- \( X_{wo} \) = water content as a fraction of the mass of fruit at time ‘t’

Estimation of solid gain (sugar gain): Solid gain or dry matter gain or sugar gain (SG) was the net gain in total solid by the fruit on initial mass basis (Pokharkar and Prasad, 1998). It was calculated using the following relationship:

\[ SG = \frac{W_i (1-X_{wi}) - W_o (1-X_{wo})}{W_i \times X_{wi}} \times 100 \]

Where,
- \( W_i \) = initial mass of fruit, gms
- \( X_{wi} \) = water content as a fraction of the initial mass of fruit.
- \( W_o \) = mass of fruit after time ‘t’
- \( X_{wo} \) = water content as a fraction of the fruit at time ‘t’

Rehydration: The rehydration ratio was calculated as follows:

Rehydrated ratio (RR) =

\[ \frac{\text{Mass of reconstituted dehydrated sweet potato}}{\text{Mass of dehydrated sample before rehydrated}} \]

Color measurement: The color of fresh, pre-treated and dried sample was measured by using Miniscan XE plus Hunter Lab Colorimeter. The dried sample was placed below the viewing area so that the instrument measured the reflected light from the sample. The output of the Hunter Lab includes ‘L’, ‘a’ and ‘b’ values. The ‘L’ value is a measure of psychometric lightness and varies from 100 for perfect white to zero for black. The dimension ‘a’ and ‘b’ give the colour. The ‘a’ value measures redness when positive and grey when zero and green when minus. The ‘b’ value measures yellowness when plus, grey when zero and blueness when minus. From these the overall change in colour (\( \Delta E \)), relative change in hue and chroma of different samples with respect to that of fresh were calculated to estimate variation in sample colour.

Total color difference was obtained using the formula:

\[ \Delta E = \sqrt{\Delta L^2 + \Delta a^2 + \Delta b^2} \]

\[ \text{Hue} = \tan^{-1} \left( \frac{b}{a} \right) \]

\[ \text{Chroma} = \sqrt{(a^2 + b^2)} \]

Shrinkage ratio: It was measured using the following relationship:

\[ \text{Shrinkage Ratio} = \frac{\text{Vol. of dried sample after tray drying}}{\text{Vol. of fresh sample}} \]

RESULTS AND DISCUSSION

Drying characteristics of sweet potato: The drying rate decreased with increase in drying time and thereafter it became almost constant after 10 hours irrespective of drying temperature or concentration of sugar solution (Fig 1). This may be due to removal of bound moisture from within the sample which is also evident from the high hardness values of the product dried at different temperatures. With increase in drying time for all the sugar concentrations, the moisture content of the samples decreased. The moisture content of sweet potato sample dipped at 70\(^{0}\) Bx concentration sugar syrup was found as (30.56\%), when dried at 55\(^{0}\) C drying temperature in 16 hour, whereas, at 65\(^{0}\) C and 75\(^{0}\) C temperature nearly the same moisture content was attained in 6 and 4 hours respectively. Similar trend was observed for samples dipped in sugar solution of concentration 60 and 50\(^{0}\) Bx. This indicates that it takes longer (19 hours) to dry the sample at 55\(^{0}\) C as compared to the sample dried at 65\(^{0}\) C (16.5 hours) and 75\(^{0}\) C (14.5 hours) temperatures. For sugar concentration of 50\(^{0}\) Bx also the desired moisture content is attained fastest at drying temperature of 75\(^{0}\) C i.e. 14.5 hours and slowest at 55\(^{0}\) C temperature i.e. 18 hours. Hence it
FIG 1: Variation of drying rate with drying time for different sugar concentrations (a) 50, (b) 60 and (c) 70°Bx of sweet potato.
can be concluded that drying time goes on decreasing as the temperature of drying increases.

**Effect of drying temperature and sugar concentration on quality parameters**

**Bulk density:** The bulk density of the sweet potato samples as influenced by the different drying temperatures and sugar solution concentrations have been presented in Fig. 2. The bulk density of the sample varied between 38.86 kg/m$^3$ and 46.52 kg/m$^3$. The maximum value of bulk density was obtained for the sample dipped in sugar solution concentration of 60°Bx and dried at 65°C whereas, the minimum value of bulk density was observed for the sample dipped at 70°Bx and dried at 65°C temperature.

**Water activity:** The water activities of the sweet potato sample varied between 0.392 and 0.530 as shown in Fig 3. The maximum value of water activity was observed as 0.530 for the sample dipped in 50°Bx sugar solution and dried at a temperature of 55°C and the minimum value was observed as 0.392 for the sample dipped in sugar solution of 60°Bx sugar concentration and dried at 75°C temperature. Almost similar trend was observed for the other drying temperatures i.e. 55 and 65°C.

**Sugar gain and water loss of sweet potato sample:** The sugar gain for sweet potato samples after osmosis and drying have been shown in Fig 4 (a & b) respectively. It was observed that sugar gain increased with the increase in sugar concentration and drying temperature. Maximum sugar gain of 36.56% was observed at 70°Bx sugar concentration for 75°C drying temperature.

![FIG 2: Variation in bulk density for osmo-convectivly dehydrated sweet potato samples](image)

![FIG 3. Variation of water activity for osmo-convectivly dehydrated sweet potato](image)

![FIG 4: Effect of different sugar concentration and temperature on sugar gain (a) after osmosis (b) after drying](image)

The maximum water loss of 0.65% was observed for the sample dipped at 70°Bx sugar concentration and minimum water loss of 0.23% for the sample dipped at 50°Bx sugar concentration when dried at 65°C temperature; however the maximum water loss of 0.83% was observed for the sample dipped at of 70°Bx sugar concentration and minimum water loss of 0.62% for the sample dipped at 50°Bx sugar concentration when dried at 75°C temperature as (Fig. 5 a & b).

**Hardness:** The maximum hardness was observed as 532.68 kgf for the sample dipped in 50°Bx sugar solution and dried at 55°C; whereas minimum hardness was observed as 43.04 kgf for the sample dipped in 70°Bx sugar solution and dried at 75°C (Fig 6).

**Colour:** The L value was least i.e. 49.6 in dehydrated sweet potato having 70°Bx sugar concentration and 75°C drying temperature, whereas maximum value of 60.2 was observed for dehydrated samples of 70° Bx and temperature of 55°C. Change in colour (ΔE) was least i.e. 4.14 for sample having sugar concentration of 60° Bx at 75°C temperature and its maximum value was 14.79 for sample having sugar concentration of 60° Bx at 65°C (Table 1).

**Shrinkage ratio:** Maximum shrinkage of 0.706 was observed for the sample having 70° Bx sugar solution and drying temperature of 75°C, whereas, minimum shrinkage was observed as 0.578 for the sample having 50° Bx and dried at 55°C as shown in Fig 7.
FIG 5: Effect of different sugar concentration and temperature on water loss (a) after osmosis (b) after drying

FIG 6: Variation in hardness of sweet potato samples after osmosis

FIG 7: Effect of different sugar concentration on shrinkage ratio

TABLE 1: Variation in color of sweet potato samples

<table>
<thead>
<tr>
<th>Temperature</th>
<th>50° Bx</th>
<th>60° Bx</th>
<th>70° Bx</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>L</td>
<td>a</td>
<td>b</td>
</tr>
<tr>
<td>55°C</td>
<td>56.6</td>
<td>-0.2</td>
<td>9.2</td>
</tr>
<tr>
<td>65°C</td>
<td>54.7</td>
<td>1.6</td>
<td>12.4</td>
</tr>
<tr>
<td>75°C</td>
<td>51.9</td>
<td>2.7</td>
<td>13.2</td>
</tr>
</tbody>
</table>

CONCLUSION

Sweet potato was osmotically dehydrated in sugar syrup concentrations of 50, 60 and 70° Bx for 48 hours and thereafter samples were dried using tray drier at temperatures of 55, 65 and 75°C. It was found that drying time increased with decrease in temperature of drying. Water loss was observed to be maximum for the sample of 50° Bx sugar concentration. Bulk density was maximum for sugar solution concentration of 50° Bx at 65° C and the minimum value of bulk density was obtained for sugar solution concentration of 60° Bx and drying temperature of 75° C. The maximum water activity was found for sample having sugar concentration of 50° Bx and drying temperature of 55° C and the minimum value of water activity was attained for sliced sample at a drying temperature of 75° C and sugar concentrations of 60° Bx. It was observed that the sugar gain was highest in samples dipped in sugar solutions of concentration 70° Bx and lowest in the samples of sugar solution concentration of 50° Bx.

REFERENCES


