EFFECTS OF MATURITY ON PHYSICOCHEMICAL PROPERTIES OF OSMOTICALLY DEHYDRATED MANGO CUBES


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ABSTRACT

Effect of different ripening stages on the physicochemical properties of osmotic dehydrated mango cubes (var. Chonsa) was investigated. Osmotic dehydration was performed at 50°C for 2 hours using 45, 55 and 65 °Brix osmotic solutions. Water Loss (WL), Solute Gain (SG) and Dehydration Efficiency Index (DEI) found to be dependent on the maturity stage. Partially-ripe mango cubes showed highest WL and SG but revealed low DEI. Shrinkage and Firmness revealed non-linear correlation with increasing maturity. Dehydrated mango cubes shrunk more and found harder at 55°Brix. Mango cubes dehydrated at 45 and 55°Brix showed significant variation in physicochemical properties.

Keywords: Osmotic Dehydration, Mango, Dehydration Efficiency Index, Firmness, Shrinkage.

INTRODUCTION

Mango (Mangifera indica L.) is an important tropical fruit of Pakistan produced 1.845 million metric tons in 2009-10 (FBS, 2011; Khan et al., 2008a). Pakistan ranked 5th largest producer of mango followed by India, China, Thailand and Indonesia (FAOSTAT, 2009; FBS, 2011). Mango preserved by traditional drying techniques found less marketable as a result of stale flavor, altered appearance, undesirable texture and loss of nutrients (Torres et al., 2006). Osmotic dehydration is a low energy minimal pretreatment performed prior to other drying techniques to produce intermediate moisture ready-to-eat products having superior organoleptic characteristics (Chiralt and Talens, 2005; Khan et al., 2008b; Madamba and Lopez, 2002). In this treatment, cellular foods are partially dehydrated by immersing in concentrated osmotic solution of low water activity made by dissolving sugars, salts, organic acids, humectanats, electrolytes and preservatives (Ponting et al., 1966; Raoult-Wack et al., 1991). The rate of mass transfer and resulting dehydration depends upon osmotic solution (composition, concentration, solubility, viscosity), process conditions (time, temperature, pressure, agitation), nature of food to be dehydrated (composition, maturity, porosity, dimensions, geometry), pre-treatment of food (blanching, coating, freeze-thaw, peeling), and ratio of food and osmotic solution (Chiralt and Talens, 2005; Tedjo et al., 2002).

Osmotic dehydration of mango has been researched to understand the process kinetics as a function of time and temperature (Torezan et al., 2004), sucrose concentration and temperature (Alakali et al., 2006; Sagar and Suresh Kumar, 2009), atmospheric pressure and vacuum (Giraldo et al., 2003), frozen storage (Rincon and Kerr, 2010) and process optimization (Madamba and Lopez, 2002). However, no attempts have been made to study the effects of mango maturity on the physicochemical properties of dehydrated product. Maturity is important as harvesting of fruits largely depends upon it which in turn affect postharvest life and quality. Mango is a climacteric fruit generally harvested at physiological maturity but consumed as a fresh fruit after attaining horticulture maturity (Jha et al., 2006). Hence harvesting maturity of mango depends upon intended use and could be different if proposed for osmotic dehydration.

The present work was conducted to study the influence of maturity on the physicochemical properties of osmotically dehydrated mango cubes. Efforts were aimed to determine optimum mango maturity most favorable for osmotic dehydration. The use of osmotic dehydration should hopefully facilitate mango.
digital re-fractometer (ATAGO DR-A1, Japan) was used to measure TSS (°Brix) of filtered mango juice (AOAC 932.14). TTA was determined by titration using standard alkali (0.1 M NaOH) to an endpoint of pH 8.2 (AOAC 942.15). Mangoes were classified and on the basis of firmness and Maturity Index (Mitcham and McDonald, 1992); mature-green (MI 37.72), partially-ripe (MI 72.85), firm-ripe (MI 131.39), soft-ripe (MI 157.61) and over-ripe (MI 165.38).

**Sample Preparation**

Each day, 20 mangoes were taken and thoroughly washed with tap water, dried and peeled off by hand-peeler. Mangoes were cut into two longitudinal halves close to the fruit stone and then sliced into 5 mm thick cubes of 2.5 cm length and width (Torezan et al., 2004). Mango cubes were distributed on absorbent paper to remove surface juice and used immediately for OD.

**Physicochemical Properties**

Total solids (%) of mango cubes were determined by oven-drying at 70°C (AOAC 920.151) to calculate Solute Gain (Torezan et al., 2004). Water loss was also calculated per gram of initial dry matter and expressed as percentage to avoid moisture variation due to increasing maturity (Matuska et al., 2006). Shrinkage was quantified by taking ratio of apparent volumes of mango cubes before and after dehydration while apparent volumes were determined by displacement technique using toluene as a solvent (Yan et al., 2008)

\[
SG (\%) = \frac{W_s f (\%)}{W_s i (\%)} - 1
\]

\[
WL (\%) = \frac{[m_o (1 - s_o) - m_k (1 - s_k)]}{m_o (1 - s_o)}
\]

\[
\text{Shrinkage (\%) = } \frac{V_o}{V_o} \times 100
\]

\[
\text{Apparent Volume (V) = } V_f - M_{sf} / \rho_s
\]

\[
\text{DEI = WL/ SG}
\]

Where;

- \( W_s i \) Total solids before OD
- \( W_s f \) Total solids after OD
- \( m_o \) Weight of mango before OD
- \( s_o \) Weight of initial solids in mango before OD
- \( m_k \) Weight of mango after OD
- \( s_k \) Weight of final solids in mango after OD
- \( V_o \) Apparent volume of mango before OD
- \( V_d \) Apparent volume of mango after OD
- \( V_f \) Volume of volumetric flask
- \( M_{sf} \) Weight of solvent added to fill volumetric flask
- \( \rho_s \) Density of solvent

Mango firmness was determined by simple compression test using Universal Testing Machine (Zwick GmbH & Co, Ulm, Germany). Mango cubes were compressed by stainless steel probe of 10 mm diameter at the test speed of 150 mm/minute to achieve 3 % strain. Pre-load was 0.2 N (10 mm/minute) to minimize the effect of uneven surface of mango cubes.

**Statistical Analysis**

All tests were performed in triplicate and results were reported as mean with standard deviation. The data was subjected to analysis of variance (ANOVA) followed by Duncan’s test using SPSS 17.0. Pearson's correlation coefficients were also determined. All statistical tests were carried out at significance level of \( p \leq 0.05 \).

**Abbreviation**

- OD Osmotic Dehydration
- OS Osmotic Solution
RESULTS AND DISCUSSION

Maturity Index and firmness of fresh mango cubes with increasing maturity are presented in figure 1 and 2 respectively. As expected, MI increased while firmness decreased with increasing maturity.

WL revealed 2nd order polynomial association with increasing maturity at 45 (R²= 0.99), 55 (R²= 0.97) and 65˚Brix (R²= 0.85) (Table 1). WL increased considerably in partially-ripe and firm-ripe mango cubes compared with mature-green followed by decline in soft-ripe and over-ripe mango cubes. Partially-ripe mango cubes dehydrated at 55˚Brix revealed maximum WL while unripe mango cubes at 45˚Brix had minimum. No significant difference in WL was observed between soft-ripe and over-ripe mangoes at 45 and 55 ˚Brix. WL also showed dependence on the concentration of OS (Table 1). For example, increase in concentration gradient (45, 55 and 65˚Brix) augmented WL significantly in mature-green mango cubes (48.04 %, 60.49 %, and 51.88 %) at 0.05. Mango tissues experienced a greater driving force by increasing concentration of osmotic solution as evident by increase in WL. However, a proportional increase in WL was not seen at 65˚Brix as resistance caused by case hardening of surface tissues diminished the driving force created by concentration gradient (Giraldo et al., 2003). WL of firm-ripe mangoes showed insignificant variation with increasing concentration of OS.

SG showed polynomial trends with increasing maturity at 45 (R² = 0.99), 55 (R² = 0.60) and 65 °Brix (R² = 0.99) (Table 1). SG depends upon the characteristics of the plant tissues (Giraldo et al., 2003) while increasing maturity also changed membrane permeability (Prasanna et al., 2007). It was revealed that partially-ripe mango cubes gained more solutes compared with soft-ripe. Mango is a climacteric fruit, ripe with dramatic change in chemical composition. TSS of mango increased abruptly (16.67 to 19.67°Brix) due to enzymatic hydrolysis of storage polysaccharides (starch) and subsequently increased neutral sugars particularly sucrose (Prasanna et al., 2007; Rincon and Kerr, 2010). Hence, increased cellular concentration reduced concentration gradient (driving force) between mango tissues and OS. Conversely, SG found higher for partially-ripe mangoes (Alakali et al., 2006; Rincon and Kerr, 2010). SG also varied with the concentration of OS (Table 1). Mature-green, partially-ripe, firm-ripe and soft-ripe mango cubes dehydrated at 55˚Brix gained more solutes at 95 % confidence level compared with 45˚Brix. Mango tissues are comparatively porous; hence uptake of osmotic solution by Hydrodynamic mechanisms was substantial (Rincon and Kerr, 2010). Hydrodynamic gain was limited at 45˚Brix due to low viscosity as evident by less SG (Giraldo et al., 2003). Further increase in concentration (65 ˚Brix) did not increase SG to considerable level. SG increased quickly at 55 and 65˚Brix due to capillary diffusion and surface retention of OS but as OD continued, fruit pores immersed at 65 ˚Brix expelled OS as surface cells started to lose water and intercellular spaces squeezed (Giraldo et al., 2003). Over-ripe mangoes showed statistically similar SG with increasing concentration of OS. In general, maximum SG (46.67 %) was recorded for partially-ripe mangoes dehydrated at 55˚Brix while mature-green mangoes had gained minimum solutes (19.13 % at 45˚Brix).

The DEI of dehydrated mango cubes changed with maturity (Table 1). Partially-ripe mango cubes had low DEI similar to over-ripe but their SG was different. Partially-ripe mango cubes revealed considerably high SG while over-ripe had low (Figure 3). Partially-ripe mango cubes had high WL but it was accompanied by high SG leading to unsuitable choice for OD as revealed by low DEI. Mature-green mango cubes showed high DEI than soft-ripe due to less SG at 45˚Brix. On the other hand at 55˚Brix, DEI of mature-green mango cubes found similar to soft-ripe due to same amount of SG. Increasing maturity showed no significant variation in DEI at 65˚Brix despite of considerable variation in WL and SG. DEI of mature-green and partially-ripe mango cubes modified with increasing concentration of OS while firm-ripe, soft-ripe and over-ripe varied insignificantly (Table 1). DEI found higher for mango cubes dehydrated at 45 and 65˚Brix revealing mass transfer more favorable for WL. At 55˚Brix, mangoes dehydrated maximally but they also gained considerable solutes as revealed by low DEI. DEI of soft-ripe and over-ripe mango cubes varied insignificantly with increasing concentration. Overall, partially-ripe mango cubes dehydrated at 55˚Brix showed lowest DEI while mature-green (45˚Brix) and firm-ripe (55˚Brix) showed highest.

<table>
<thead>
<tr>
<th>WL</th>
<th>Water Loss (%)</th>
<th>SG</th>
<th>Solute Gain (%)</th>
<th>DEI</th>
<th>Dehydration Efficiency Index</th>
<th>MI</th>
<th>Maturity Index</th>
<th>TSS</th>
<th>Total Soluble Solids</th>
<th>TTA</th>
<th>Total Titratable Acidity</th>
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Table 1. Physicochemical Properties of Osmotic Dehydrated Mango Cubes.

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<tbody>
<tr>
<td>Water Loss (WL %)</td>
<td>45˚Brix</td>
<td>48.04 ± 0.44 a,1</td>
<td>65.92 ± 1.2 a,3</td>
<td>65.22 ± 1.72 a,3</td>
<td>52.11 ± 0.31 a,2</td>
<td>54.15 ± 0.58 a,2</td>
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<td></td>
<td>55˚Brix</td>
<td>60.49 ± 0.08 b,2</td>
<td>68.35 ± 0.2 b,4</td>
<td>64.16 ± 0.45 a,3</td>
<td>56.88 ± 1.42 b,1</td>
<td>56.43 ± 0.1 b,1</td>
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<td></td>
<td>65˚Brix</td>
<td>51.88 ± 0.56 b,1</td>
<td>63.92 ± 0.15 a,3</td>
<td>65.94 ± 0.87 a,4</td>
<td>51.61 ± 1.56 a,1</td>
<td>56.81 ± 1.05 b,2</td>
</tr>
<tr>
<td>Solute Gain (SG %)</td>
<td>45˚Brix</td>
<td>19.13 ± 1.18 b,1</td>
<td>38.05 ± 0.43 a,4</td>
<td>31.25 ± 0.35 a,3</td>
<td>23.37 ± 1.51 a,2</td>
<td>31.09 ± 1.35 a,3</td>
</tr>
<tr>
<td></td>
<td>55˚Brix</td>
<td>31.55 ± 0.0 b,1</td>
<td>46.67 ± 0.5 b,3</td>
<td>38.59 ± 0.39 b,2</td>
<td>31.3 ± 1.67 b,1</td>
<td>33.85 ± 1.11 a,1</td>
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<tr>
<td></td>
<td>65˚Brix</td>
<td>30.5 ± 1.850 b,1</td>
<td>37.39 ± 0.43 a,2</td>
<td>34.0 ± 0.37 b,12</td>
<td>28.96 ± 0.58 h,1</td>
<td>32.2 ± 1.20 a,12</td>
</tr>
<tr>
<td>DEI</td>
<td>45˚Brix</td>
<td>2.51 ± 0.17 b,3</td>
<td>1.80 ± 0.13 b,1</td>
<td>2.09 ± 0.19 b,2</td>
<td>2.23 ± 0.12 a,2</td>
<td>1.74 ± 0.04 a,1</td>
</tr>
<tr>
<td></td>
<td>55˚Brix</td>
<td>1.91 ± 0.01 a,3</td>
<td>1.46 ± 0.0 a,1</td>
<td>1.66 ± 0.12 a,2</td>
<td>1.81 ± 0.05 a,23</td>
<td>1.66 ± 0.05 a,2</td>
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<tr>
<td></td>
<td>65˚Brix</td>
<td>1.70 ± 0.08 a,1</td>
<td>1.70 ± 0.01 b,1</td>
<td>1.94 ± 0.03 h,1</td>
<td>1.78 ± 0.03 a,1</td>
<td>1.76 ± 0.09 a,1</td>
</tr>
<tr>
<td>Shrinkage (%)</td>
<td>45˚Brix</td>
<td>49.95 ± 0.37 a,3</td>
<td>48.10 ± 0.89 a,3</td>
<td>43.16 ± 0.5 b,1</td>
<td>51.23 ± 0.51 a,4</td>
<td>44.99 ± 0.48 a,2</td>
</tr>
<tr>
<td></td>
<td>55˚Brix</td>
<td>52.13 ± 0.81 b,4</td>
<td>48.90 ± 0.51 a,3</td>
<td>41.55 ± 0.61 a,1</td>
<td>51.34 ± 0.51 a,4</td>
<td>44.65 ± 0.1 a,2</td>
</tr>
<tr>
<td></td>
<td>65˚Brix</td>
<td>52.05 ± 0.84 b,4</td>
<td>48.30 ± 0.82 a,3</td>
<td>41.70 ± 0.51 a,1</td>
<td>56.09 ± 1.54 b,5</td>
<td>44.91 ± 0.49 a,2</td>
</tr>
<tr>
<td>Firmness (N)</td>
<td>45˚Brix</td>
<td>64.38 ± 0.15 a,1</td>
<td>68.69 ± 0.52 a,2</td>
<td>128.1 ± 0.74 a,2</td>
<td>118.1 ± 0.51 a,2</td>
<td>66.28 ± 0.95 a,1</td>
</tr>
<tr>
<td></td>
<td>55˚Brix</td>
<td>120.86 ± 1.6 b,1</td>
<td>153.7 ± 1.26 b,3</td>
<td>152.2 ± 1.33 c,3</td>
<td>134.11 ± 1.9 b,2</td>
<td>112.29 ± 2.2 b,1</td>
</tr>
<tr>
<td></td>
<td>65˚Brix</td>
<td>76.62 ± 2.15 b,1</td>
<td>142.3± 2.18 b,3</td>
<td>139.2 ± 1.12 b,3</td>
<td>106.30 ± 2.6 a,2</td>
<td>66.40 ± 1.8 a,1</td>
</tr>
</tbody>
</table>

Different letters and numbers in a column and row respectively specify significant difference at p ≤ 0.05

Shrinkage in dehydrated mango cubes fluctuated with increasing maturity (Table 1). The cell walls of parenchyma cells (mango pulp) are developed by biopolymers of diverse chemical nature (Pectins, Cellulose, Hemi-cellulose and Lignin). Fruit ripening degraded these biopolymers by respective enzymes and their structural-functional characteristics are modified as evident by change in shrinkage at different maturity stages (Prassana, 2007). Increase in maturity (mature-green, partially-ripe and firm-ripe) showed a linear decrease in shrinkage at 45, 55 and 65˚Brix followed by abrupt increase in line with optimum maturity (soft-ripe). Increase in maturity brought changes in cell wall (thickness, hydration) thus creating more intercellular spaces and weaken structural organization leading to high shrinkage (Prasanna et al., 2007). Shrinkage reduced considerably in over-ripe mangoes. Mangoes dehydrated at 55˚Brix shrank more than 45˚Brix. Gas phase filled the intercellular spaces within porous mango tissues and developed an internal pressure. The osmotic pressure gradient altered the internal pressure which affect Hydrodynamic mechanisms. Mango tissues experienced more pressure gradient at 55˚Brix and accelerated the
hydrodynamic mechanisms leading to higher impregnation of osmotic solution. Cells dehydrated and deformed to a greater extent due to high concentration gradient contributing higher shrinkage at 55˚Brix (Giraldo, 2003). A proportional increase in shrinkage was not observed at 65˚Brix due to case hardening and expulsion of osmotic solution leaving more intercellular space for gas phase and regain in tissue volume (Fito, 2002; Chiralt 2005).

Moreover, OD increased tissue porosity and created more intercellular spaces occupied by dense liquid phase (55˚Brix) which substantially decrease cell volume (Giraldo et al., 2003). This effect was not seen at 45˚Brix as gas phase was more dominant due to low viscosity of liquid phase. No effect on shrinkage was observed in partially-ripe and over-ripe mangoes at 45, 55 and 65˚Brix.

Firmness of dehydrated mango cubes changed with the maturity. Partially-ripe, firm-ripe and soft-ripe mango cubes revealed hard texture than mature-green at 45, 55 and 65˚Brix while over-ripe showed decreased firmness. Mangoes dehydrated at 55˚Brix were significantly firmed than 45˚Brix. OD increased the porosity in mango tissues and this effect was more pronounced at 55˚Brix (Barat et al., 1998; Fito et al., 2002). High concentration gradient at 55˚Brix deformed cells to a greater extent due to high WL followed by cell wall relaxation leading to suction of osmotic solution. High pressure gradient at 55˚Brix proportionally increased this Hydrodynamic effect and regain of turgor pressure was evident by increased firmness. Mangoes dehydrated at 65˚Brix were less hard than 55˚Brix as Hydrodynamic mechanism was limited due to high viscosity leading to less SG. However, rigidity of surface cells dehydrated at 65˚Brix caused more firmness than at 45˚Brix due to case hardening (Giraldo et al., 2003).
Conclusion

1. Appropriate maturity stage is of paramount importance as it significantly affects physico-chemical properties of osmotically dehydrated mango cubes.
2. Increasing concentration of OS modified physico-chemical properties of dehydrated mango cubes.
3. WL, SG, Shrinkage and firmness of dehydrated mango cubes were found to be highest at 55°Brix OS.
4. DEI was found to be associated with mango maturity. WL and SG both increased simultaneously in dehydrated mango cubes but their relative proportion depended upon the maturity stage of mango.
5. Partially-ripe mango cubes revealed highest WL and SG but corresponded to low DEI while firm-ripe had high WL and SG but their DEI found higher similar to soft-ripe mango cubes.
6. DEI remained unchanged with increasing maturity at 65°Brix.

REFERENCES

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