Effect of tray load on drying kinetics of mango, guava and aonla

P Suresh Kumar, V R Sagar* and Uadal Singh
Division of Post Harvest Technology, Indian Agricultural Research Institute, New Delhi 110 012

Received 09 August 2005; accepted 24 April 2006

A study was conducted to find out the optimum tray load and drier type for the drying of osmosed mango, guava slices and aonla segments. The osmosed slices and segments were dehydrated in a cabinet drier, low temperature drier and vacuum drier with the tray loads of 0.30, 0.35, 0.40 and 0.45 g/cm$^2$. On the basis of correlation and regression analyses performed by using dehydration time (h), drier and tray load as independent variables and moisture content as dependent variable, vacuum drier was found to be better in faster drying followed by cabinet drier. Tray load of 0.40 g/cm$^2$ was optimum quantity in drying of better quality osmo-dehydrated products by both vacuum and cabinet drier. $R^2$ value revealed that the model based on different tray loads and drier found to be appropriate to predict the drying under various drying conditions.

Keywords: Aonla, Dehydration, Drier, Drying rate, Guava, Mango, Osmosis, Tray load

IPC Code: A23N12/00

Introduction

India is second largest producer of fruits (45 million tons/year) next to China. Approx 20-30% of the total produce gets spoiled due to improper post harvest management factors like handling, packaging, transportation and processing. Besides, shelf life also gets affected due to unfavourable conditions and susceptibility to microbiological and physiological disorders. Mango is rich in important nutrients and vitamin A. Guava and aonla, rich in vitamin C and minerals, are commonly used for making processed products. Among major processing techniques employed on industrial scale to preserve fruits and vegetables such as canning, freezing etc., dehydration of perishables is best suited for developing countries. Osmotic dehydration, one of the recently developed novel drying methods, utilizes the principle of water diffusion from dilute solution to concentrated solution through semi-permeable membrane until concentration equilibrium is reached. The driving force is water activity gradient caused due to osmotic pressure. Cell membrane of fruits is semi-permeable and is more selective for water and acid than solute. Systematic approach was developed in the experimental drying kinetics of fruits, using several mathematical models to establish drying equation.

There is an urgent need to conduct basic studies to investigate the effects of process parameters on the drying rate, total drying time and quality of the product to set up the processing industry. This study presents osmo-dehydration behaviour of mango, guava and aonla fruits.

Materials and Methods

The ripe and firm in texture fruits of mango (var. Amrapali), guava (var. Allahabad safeda) and fully matured fruits of aonla (var. NA7) were procured from the Division of Fruits and Horticulture Technology, IARI, New Delhi. Fruits in good quality and uniform size were washed in running tap water to remove the adhering dirt and dust. In case of mango and guava, fruits were peeled and sliced into six uniform sizes of slices. Aonla fruits were blanched in lye solution (2% NaOH) for 7-10 min, washed thrice in tap water and then soaked in citric acid for 20 min to neutralize the traces of alkali, given to remove astringency. Then the segments were separated. A 60° Brix sugar syrup (0.05% KMS and 0.1% citric acid, temp 60°C) was used for all three kinds of fruits as osmotic dehydration solution for immersing the fruits for 6 h in 1:4 ratio (fruit slices: osmotic solution) without any agitation. At the end of immersion period, the samples were withdrawn from osmotic solution, washed and blotted with filter paper to remove the adhering water and then loaded in aluminum trays with different load capacity (0.30, 0.35, 0.40, 0.45 g/cm$^2$) in three different type of driers.
(cabinet drier, 58±2°C; low temperature drier, 45±2°C; vacuum drier, 38±2°C; atmospheric pressure, 640 mmHg). Drying was continued until the moisture content of the slices brought down to about 11-12 percent. The initial moisture content after osmosis was determined by drying a known weight of the sample in a hot air oven at 60±5°C to a constant weight\(^3\). Drying rate was calculated after taking observations on moisture at 30 min intervals and it was expressed as the rate of residual water to dry matter (kg of water/kg of dry matter). The moisture and T were calculated as:

\[
T = \frac{m}{100 - m}
\]

where, \(T = \text{kg of water/kg of dry matter, and m = percentage moisture on fresh weight basis.}

The calculation and regression analysis were performed to develop the relation among process variables like dehydration time (h), drier type, and tray load (g/cm\(^2\)) as independent variables and moisture content (%) as dependant variable\(^4\).

**Results and Discussion**

Moisture content of experimental fruits decreases with increase in drying time for a particular tray load, while increase in tray load at particular drier led to increase in corresponding drying time of the sample (Figs 1-3). Tray load and drier type had significant role in drying of mango slices (Fig. 1). The optimum tray load for drying the mango slices was found to be 0.40 g/cm\(^2\) under cabinet drier and vacuum drier and it was 0.35 g/cm\(^2\) for low temperature drier. Mango took 11, 9 and 13 h to dry the products under these driers respectively. Similar trend has been reported on drying of mango pulp in cabinet drier\(^5\). Besides, textural properties, the dried product was also superior in vacuum and cabinet drier when it compared to low temperature drier. This might have due to the faster removal of water owing to high vacuum created in vacuum drier and high temperature (58±2°C), low RH and constant airflow in cabinet drier.

For dehydration of guava slices (Fig. 2), vacuum drier was found to dry the product quickly as it took 5, 7, 8 and 10 h only for the same tray load. Increase in tray load increased drying time and decreased drying rate. It could be attributed to large amount of wet material per unit area\(^6,7\).

Cabinet drier took 5, 7, 9 and 11 h to dry the osmo-dried segments of the *aonla* with the tray load of 0.30, 0.35, 0.40, 0.45 g/cm\(^2\) while, in case of vacuum drier, it took 5, 6, 7 and 9 h only for the corresponding tray load (Fig. 3). It was clear that under particular drier, drying time was increased with an increase in tray load.

Among the three osmo-dried products, *aonla* took less time for drying irrespective of tray load with the particular drier. This would have due their fewer fibers and well arranged tissue structure, which led to faster removal of water from inner side of the produce. While mango had taken more time irrespective of tray load and drier due to their complex structural integrity.

Correlation and regression studies (Table 1) indicated that in all the products, drier and time was positively correlated. The strong positive correlation confirmed that type of driers positively influence drying time. The same trend was noticed between tray load and drying time. While, there was negative correlation between tray load X drier and moisture X drying time. It was clearly shown by “r” values that increase in tray load, irrespective of drier, negatively influenced the drying of the osmosed fruit slices. In the same line, negative correlation between moisture and drying time was also noticed; as with increase in time, moisture content of the slices significantly reduced. Regression coefficient values of the sample revealed the significant relation among the process variables.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Mango*</th>
<th>Guava*</th>
<th>Aonla*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drier X Time</td>
<td>0.074</td>
<td>0.075</td>
<td>0.072</td>
</tr>
<tr>
<td>Tray load X Time</td>
<td>0.26</td>
<td>0.26</td>
<td>0.28</td>
</tr>
<tr>
<td>Tray load X Drier</td>
<td>-0.023</td>
<td>-0.007</td>
<td>-0.027</td>
</tr>
<tr>
<td>Moisture X Time</td>
<td>-0.79</td>
<td>-0.78</td>
<td>-0.79</td>
</tr>
<tr>
<td>Moisture X Drier</td>
<td>-0.017</td>
<td>-0.014</td>
<td>-0.04</td>
</tr>
<tr>
<td>Moisture X Tray load</td>
<td>-0.004</td>
<td>-0.001</td>
<td>-0.013</td>
</tr>
<tr>
<td>Time</td>
<td>-0.09</td>
<td>-0.08</td>
<td>-0.12</td>
</tr>
<tr>
<td>Drier</td>
<td>0.003</td>
<td>0.002</td>
<td>0.005</td>
</tr>
<tr>
<td>Tray load</td>
<td>0.02</td>
<td>0.01</td>
<td>0.02</td>
</tr>
<tr>
<td>Multiple regression</td>
<td>0.84</td>
<td>0.80</td>
<td>0.82</td>
</tr>
<tr>
<td>Regression coefficient (R(^2))</td>
<td>0.72</td>
<td>0.75</td>
<td>0.74</td>
</tr>
</tbody>
</table>

*Significant level P=0.05
Fig. 1 — Effect of tray load on moisture content of mango slices in a) cabinet drier, b) low temperature drier, c) vacuum drier
Fig. 2 — Effect of tray load on moisture content of guava slices in a) cabinet drier, b) low temperature drier, c) vacuum drier
Fig. 3 — Effect of tray load on moisture content of aonla segments in a) cabinet drier, b) low temperature drier, c) vacuum drier
Conclusions

It would be economical to dry the osmosed slices with the tray load of 0.40 g/cm\(^2\) in cabinet and vacuum drier, though with less tray load faster drying was achieved. A tray load less than optimum might not be economically viable and more than this increases the drying time. However, under low temperature drier, since the osmosed slices tend to shrink due to more time for drying with high tray load, it was advisable to select optimum tray load of 0.35 g/cm\(^2\). Tray load and drier has the profound influence on the dehydration characteristics of fruit slices. Therefore, during setting up the drying industry on large scale, tray load, drying time and drier types are the process variables, which are to be monitored carefully so as to get good quality osmo-dehydrated products.

References