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Dehydration behaviour of plain and fortified mango pulps in the preparation of bars

(Penyahhidratan pulpa mangga yang kosong dan yang diperkuat untuk penghasilan kepingan)

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Key words: fortification, mango pulp, dehydration, drying time, sorption isotherm

Abstract

Mango and mango-roasted Bengal gram flour (mango-RBF) pulps were dehydrated in a cross flow cabinet tray drier and the dehydration behaviour was studied. The moisture loss data were used to calculate the drying rate and the moisture ratio. The results showed that the drying of mango and mango-RBF pulps takes place in the falling rate period and is governed by moisture diffusion. Mathematical relationships were established between moisture ratio and drying time for the mango and mango-RBF pulps. The incorporation of RBF in mango pulp reduces the drying rate and increases drying time comparatively. The sorption isotherm was also studied for the safe storage of bars. It was observed that the mango bars, so obtained should be stored under 43.9–64.8% relative humidity.

Abstrak

Pulpa mangga dan mangga yang dicampur dengan tepung kacang Bengal panggang (mangga-RBF) telah dinyahhidrat di dalam pengering dulang kabinet aliran silang. Corak tindakan penyahhidratan telah dikaji. Data kehilangan lembapan digunakan untuk mengira kadar pengeringan dan nisbah lembapan. Keputusan menunjukkan pengeringan mangga dan mangga-RBF berlaku semasa waktu kadar menurun dan dikawal oleh resapan lembapan. Pertalian matematik telah diwujudkan antara nisbah lembapan dengan masa pengeringan untuk pulpa mangga dan mangga-RBF. Penggunaan RBF di dalam pulpa mangga mengurangkan kadar pengeringan dan meningkatkan masa pengeringan. Isoterma sorpsi juga dikaji untuk keselamatan penyimpanan produk. Hasil kajian menunjukkan produk mangga perlu disimpan pada kelembapan relatif 43.9–64.8%.

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Introduction

The preservation of fruits and vegetables by dehydration offers a unique challenge and it may be considered as an alternate low cost preservation process (Uddin et al. 1990). Mango is a fruit crop of tropical countries and occupies vast area for production, but heavy post harvest losses are the major problem (Srinivas et al. 1997). Mango bar, a product of high significance is generally manufactured by drying ripe mango pulp into leathery sheets or bars. Absorption of moisture from external atmosphere and non-enzymatic browning during storage are the major problems. Therefore, adequate packaging and proper drying conditions are essential for maintaining their quality.

Roasted Bengal gram flour which is very rich in protein is readily and cheaply available source in India. The utilization of this flour, as a constituent in the value added product will make the product more nutritious and cost effective. But, the incorporation of this constituent requires a thorough understanding of its behaviour in the processing and the finished product quality.

Traditionally, sun-drying technique is employed for preparing mango bar from ripe fruit pulp (CFTRI 1990). But, the sun-dried product is dark brown and the process is unhygienic and lengthy due to coincidence of rainy season with the ripening of mango fruits (Rameshwar 1979). Heikal et al. (1972) and Mir and Nath (1995) optimized the cabinet drying process for the preparation of mango bars. Fortified mango pulp with roasted Bengal gram flour (RBF) for the preparation of bar may exhibit different dehydration characteristics than the plain mango pulp. Therefore, study was undertaken to explore the dehydration characteristics for plain mango and fortified mango pulps in the preparation of bars.

Materials and methods

Mango fruits *(Mangifera indica)* of Totapuri cultivar and roasted Bengal gram *(Cicer arietinum)* flour were obtained from reliable sources. Mango bars were prepared from pulp of soft ripe mangoes. The fruits were washed, peeled, pulped and heated at 85 °C for 2 min. Total soluble solids of pulp were raised to 30% using powdered cane sugar, and 0.6% citric acid and 1 000 ppm SO_2 were added.

Drying of the mango pulps

The data in the study represent the average of three individual trials. The pulp was dried as such (plain mango bar), or after adding 5% RBF (Mango-RBF bar). Initial trials showed that drying temperature greater than 70 °C caused darkening with de-traying problems and lesser temperature slowed down the drying rate. Therefore, drying temperature of 70 °C was optimized. For drying characteristics, pulp or blend was spread uniformly on stainless steel trays of 40 x 75 cm^2 (tray load 12.5 kg/m^2), and dried for 26 h in an electrically operated cross flow cabinet drier at 70 ± 1 °C to study dehydration kinetics. The changes in moisture content were found to be insignificant after 14 h and 16 h for plain and fortified mango pulp, respectively. Hence, these time intervals were selected for the preparation of plain and fortified mango bars and used for sorption isotherm study.

Sorption isotherms

Equilibrium relative humidity (ERH) was determined by Wink's Weight method using desiccators with different saturated salt solutions of relative humidity (RH) ranging from 11–93% (Ranganna 1986). Accurately weighed 5 g of the mango bars were taken in preweighed and dried petridishes and placed in these desiccators maintained at room temperature (25 ± 2 °C). The samples were allowed to equilibrate to constant weights. Physical conditions of the equilibrated samples were noted and their moisture contents at different RH on dry weight basis were determined by the vacuum oven method. Water activity (a_w) was calculated from the following equation:

$$a_w = \frac{ERH}{100}$$

Water activity data were plotted against the corresponding moisture contents of the samples. From sorption isotherms, first point of inflection (point A) which indicates the minimum moisture content to which the product should be dried and second point of inflection (point B) showing maximum safe moisture level (Gal 1987) were determined. These points divided the curves into three local isotherms (LI) – LI-I, LI-II and LI-III.

Mathematical modeling

The moisture ratio (MR) was calculated as

$$MR = \frac{M - M_e}{M_o - M_e} \qquad (1)$$

Where: M = Moisture content at time t
M_e = Equilibrium moisture content
M_o = Initial moisture content

The drying equation based on diffusion mechanism as reported by McCabe and Smith (1976) given as equation 2 was used to derive drying equations for plain and mango-RBF bars from experimental observations.

$$MR = \frac{M - M_e}{M_o - M_e} = Ae^{-kt} \qquad (2)$$

Where:
A = Shape factor
k = Drying constant
t = Drying time

$$\ln(MR) = \ln(A) - kt \qquad (3)$$

Analysis

Samples were analyzed for moisture by using vacuum oven method, acidity, reducing and total sugars by Lane and Eynon method, protein by micro-Kjeldahl method and total ash were determined by following the standard procedures (Ranganna 1986). Sensory evaluation of the samples was carried out at nine point hedonic scale (Amerine et al. 1965). Mathematical models and regression equations were obtained using Matlab v.3 software.

Results and discussion

Drying curve model

The pattern of moisture loss of mango pulp and the effect of incorporation of RBF during drying at 70 ± 1 °C is shown in *Figure 1*. The moisture loss was higher till the eight hours of drying time. Thereafter, less moisture loss was observed till 20 hours of drying time. After this hardly any moisture removal was noticed in the plain and mango-RBF pulps. The incorporation of RBF in the mango pulp had slowed down the moisture loss *(Figure 1)* in comparison to plain mango pulp. This may be due to the change in the compositional characteristics of the mango pulp.

Roasted Bengal gram flour is very popular as a traditional health drink after minor preparations with sugar or salt and spices in water base, in various parts of India. Being a pulse its flour is rich in protein (22.7%, wb). This is readily and cheaply available source. Therefore its utilization for the value addition is exploited to make the product more nutritious and cost effective. The utilization of RBF which is rich in protein (22.7%) and carbohydrate (59.5%) (by difference) with mango pulp will change the compositional characteristics thereby processing conditions viz. drying and moisture sorption characteristics.

The effect of incorporation of RBF on the drying rate of plain and mango-RBF pulp at 70 ± 1 °C is clearly evident from *Figure 2* that the entire drying took place in the falling rate period. The falling rate period was characterized by a product temperature above the wet bulb temperature. In this period free moisture is not available at the surface and the rate of drying is controlled by moisture diffusion towards the surface (Toledo 2000). A straight line was obtained when a semi-logarithmic plot of

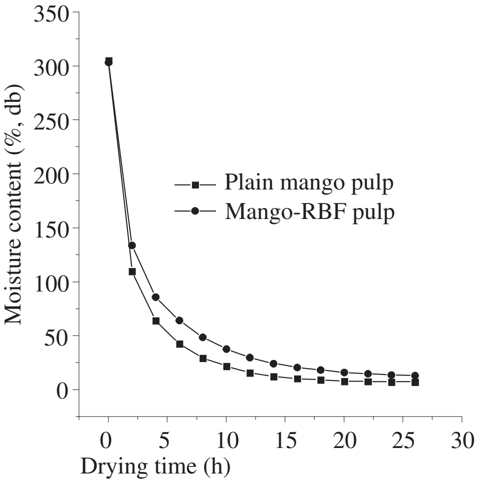

Figure 1. Effect of incorporation of RBF, in the mango pulps on moisture loss at 70 ± 1 °C

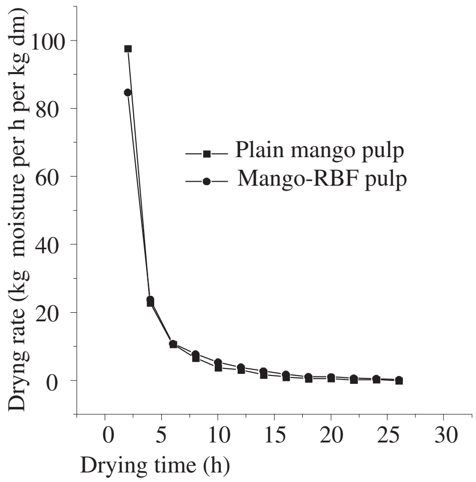

Figure 2. Effect of incorporation of RBF, in the mango pulps on drying rate at 70 ± 1 °C

MR vs drying time was plotted *(Figure 3)* revealing that the moisture transfer from both the types of pulps was governed by diffusion mechanism.

The drying equation based on the diffusion mechanisms was used to derive the equations for plain and mango-RBF pulps. The values of A and k were graphically regressed *(Equation 3)* and determined *(Figure 3)*. Shape factor (A) and drying constant (k) were found to be 1.017 & 0.997 and 0.318 & 0.255 for plain mango and

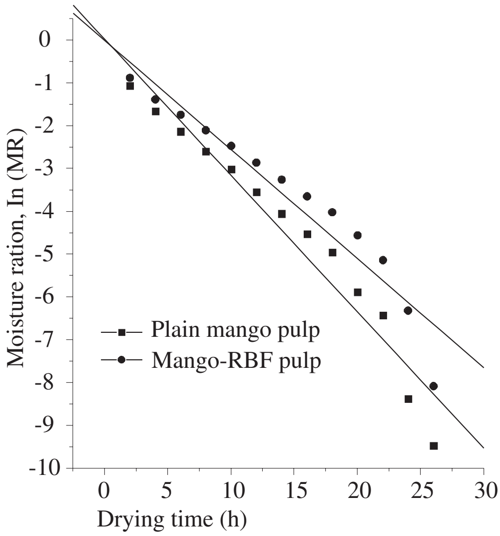

Figure 3. Drying time and moisture ration for mango pulps at 70 ± 1 °C

mango-RBF pulps respectively.The shape factors and drying constant were found to be highly significant with $p \leq 0.001$ having coefficient of multiple determination (R^2) = 0.957 and 0.942 for plain mango and mango-RBF pulps, respectively. Higher values of k signify rapid rate of moisture removal. This can be verified by the models obtained (Equation 4 & 5). This can also be substantiated from the *Figure 2*. These models can also be used for prediction of different desired variables directly.

For plain mango pulp:

$$MR = \frac{M - M_e}{M_o - M_e} = 1.017e^{-0.318t} \qquad (4)$$

For mango-RBF pulp:

$$MR = \frac{M - M_e}{M_o - M_e} = 0.997e^{-0.255t} \qquad (5)$$

Quality of dried products

Mango bars were then obtained after drying the plain mango and mango-RBF pulps for a period of 14 h and 16 h respectively. These drying times were followed due to better sensory characteristics. The sensory parameters indicated that the colour (7.10,

Table 1. Compositional characteristics for plain and fortified mango bars

Parameter	Plain mango bar	Mango-RBF bar
Moisture(%)	15.21[a]	19.33[a]
Acidity[b] (%)	1.23	1.27
Reducing sugar (%)	20.71	18.56
Total sugar (%)	65.94	59.46
Proteins (%)	2.00	3.44
Total ash (%)	2.00	2.08

[a]on dry weight basis
[b]as citric acid

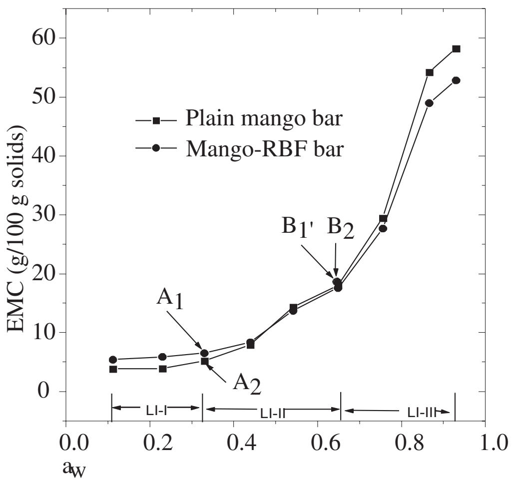

Figure 4. Sorption isotherms for mango bars showing local isotherms I and II at points of (A) first inflection, and (B) second inflection at 25 ± 2 °C

7.92), texture (7.80, 7.94), flavour (7.90, 8.14) and overall acceptability (7.60, 8.00) of the products were significantly superior ($p \leq 0.05$) after 14 and 16 h of drying time for plain and mango-RBF bars, respectively. Mango bars, containing moisture 15.21% and 19.33% (db), proteins 2.00% and 3.44%, total sugars 65.94% and 59.46% and total ash 2.00% and 2.08% *(Table 1)* for plain and mango-RBF bars respectively were subjected to sorption-isotherms study.

Sorption isotherm characteristics

The sorption study is significant for prediction and selection of shelf life and storage conditions. Mango bars, containing 59.46–65.94% total sugars had taken a long time to equilibrate at lower RH (≤64.8%) under ambient temperature. Most of the sugars were sucrose, which was reported to be in a less hygroscopic amorphous form and re-crystallization into crystalline form was known to take a long time under the prevailing storage conditions (Labuza 1968). The moisture absorption was faster in the higher RH range (>64.8%) for both types of bars. The results are in agreement with the findings of Nanjundaswamy et al. (1976) for plain mango bars. Sorption isotherms of plain mango and fortified mango bars were sigmoids *(Figure 4)*. The sorption isotherms of mango bars *(Figure 4)* exhibited short LI-I, intermediate LI-II and long LI-III, which is a characteristic feature of sugar rich products like dried fruits (Ayranci et al. 1990; Tsami et al. 1990). Water activities of plain mango bar and mango-RBF bar were 0.57 and 0.65, respectively *(Figure 4)* at their initial moisture contents of 15.20 and 19.34 (%, db). The mango bars retained their colour and texture best in the range of 43.9–64.8% RH.

Conclusion

The drying of mango and mango-RBF pulps takes place in the falling rate period and is governed by moisture diffusion. The incorporation of RBF in mango pulp reduces the drying rate and increases drying time. Moisture sorption study indicated that the mango bars, so obtained should be stored in the range of 43.9–64.8% RH for their longer shelf life. The data may be useful in the design and development of dryer and improvement in the processing techniques of these products.

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