Effect of drying treatments and storage stability on quality characteristics of bael powder

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Abstract Dehydration of bael pulp in to powder form is a challenging operation, mainly due to the sticky issue of bael pulp and caking of powder during handling and storage. To overcome on this problem maltodextrin MD (drying aid) and tricalcium phosphate, TCP (anti caking agent) were added to the bael pulp at four levels along with control and dried in a mechanical drier into thin layer at 58 ± 2 °C for 12 h, to obtain a moisture content of 4–5 % in dehydrated pulp. The dehydrated bael pulp was grounded in a laboratory powder mill and sieve with 30 mesh sieve. The powder was packed in 150gauge PP, 400gauge LDPE and 200gauge HDPE pouches and was stored at low temperature (7 °C) and ambient condition (18–35 °C) up to 6 months for storage study. The powder was evaluated for its quality characteristics in respect of acidity, sugars, antioxidant, phenol, ascorbic acid, non- enzymatic browning (NEB) before packaging and during storage. The amount of MD and TCP required to reduce powder stickiness and caking were optimized on the powder properties. The amount of MD (0.25 kg per kg dry bael solids) and TCP (0.15 kg per kg dry bael solids) with the values of degree of caking (19.24 %) and stickiness point temperature (45.4 °C) were found to be optimum for reducing the powder stickiness, caking and nutritional parameters. The adsorption isotherm of bael powder was found to be type-II sigmoid and 200 g HDPE as packaging material followed by storage at low temperature were selected as best process.

Keywords Bael powder · Tricalcium phosphate · Maltodextrin · Adsorption isotherms · Packaging material · Antioxidants · Storage temperature

Bael (*Aegle marmelos*) is one of the most useful medicinal fruits of India. It is highly nutritive and important from therapeutic point of view. The bael fruit has excellent flavour and contains many functional compounds such as carotenoids, phenolics, alkaloids, coumarins, flavonoids, terpenoids and has innumerable medicinal uses (Karunanayake et al. 1984; Nagaraju and Rao 1990).

Since bael is a seasonal fruit its availability is restricted throughout the year. Drying is one of the most economical methods for preservation of bael fruit pulp for longer time. But, drying of sugar-rich foods such as fruit pulp and juices are difficult, as they contain low molecular weight components like fructose, glucose, sucrose, citric acid, etc. Ingredients such as Maltodextrin and food-grade anti-caking agents like Tricalcium phosphate are generally added to prepare fruit powders (Jaya and Das 2004). Knowledge of water activity a_w and optimum concentration of anti caking agent is one of the useful measurements to decide the stability of foods, and selection of storage conditions for new products to improve drying process and equipments (Aroldo et al. 2006). Free flowing difficulty and caking problems in powders are generally occurs due to absorption of moisture by the food product from its surrounding atmosphere. These changes can be controlled only after providing adequate packaging and accurate information on equilibrium moisture contents of bael powder at various relative humidity and temperatures. The present paper deals with adsorption of bael powder, optimization of anticaking agent concentration and its packaging and storage requirement.

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Materials and methods

Raw material

Fresh bael (*Aegle marmelos*) fruits were purchased from local market, Azadpur New Delhi. Fully ripen bael fruits were washed, graded and their hard rind was broken manually. Pulp was scooped out along with seeds, gums and mixed with half amount of (w/w) water and then sugar and citric acid were added @ 40 % and 0.15 % respectively of the total weight of pulp. Mixture was heated up to the boiling point to mix the sugar and pulp properly and passed through a 30 mesh sieve to remove seeds and fibre. The pulp was packed in pre-sterilized glass bottles. Bottled pulp was pasteurized in boiling water for 15 min to inhibit microbial and enzymatic activity and stored at ambient condition for further studies.

Drying treatments

The extracted bael pulp was mixed with 1.5 % Tricalcium phosphate (TCP), 2.5 % Maltodextrin (MD), and combination of both along with one lot as control. Treated and control samples were loaded on an aluminium tray @ 2 kg/sq.m. and then dried in an electric cross flow of hot air at a flow rate of 1.20–1.80 m/s at a temperature of 58 ± 2 °C in a cabinet drier (Kilburn make, Model- 0248) for 12 h to a final moisture content of 4–5 % in the dehydrated material. During drying the samples were turned periodically for uniform drying.

Method of grinding

Since the dry product was found difficult to grind, it was kept in an environment condition for 30–45 min to equilibrium moisture and then ground in a laboratory powder mill (3375-E10 Model –4) and sieved with 30 mesh sieve.

Packaging and storage

The powder was packed in the packaging material of 150gauge polypropylene (PP), 400 gauge low density polyethylene (LDPE), and 200 gauge high density polyethylene (HDPE) pouches (8×6 cm size) of each packaging material as suggested by Ranganna (2002) and stored at room temperature (RT) (18–35 °C, 50–60 % RH), and low temperature (LT) (7 °C, 85 % RH). The product was withdrawn for analysis at 0, 2, 4 and 6 months interval during the storage study.

Chemical analysis

Moisture content was determined by drying a known weight of the sample in an oven at 60 ± 2 °C to a constant weight.

The results were expressed as percent moisture content. (Ranganna 2002). Reducing and total sugars were determined by using Shaffer–Somogyi micromethod (Ranganna 2002). Titratable acidity was estimated by titrating a known aliquot of the sample against the standard sodium hydroxide solution using phenolphthalein as an indicator (Ranganna 2002). Ascorbic acid was measured by titrating the samples against 2,6-dichlorophenolindophenol dye and non-enzymatic browning was measured in terms of optical density at 420 nm of an aliquot of 60 % alcoholic extract (Ranganna 2002). Total phenol were determined by Folin-Ciocalteu method (AOAC 1994). Total antioxidant power was determined by using FRAP method (Benzie and Stain 1996).

Sensory evaluation: Sensory evaluation of powder was done by Hedonic procedure as described by Amerine et al. (1965).

Degree of caking

Known weight (5 g powder) was placed in oven at 102 ± 2 °C for one hr. Then sample was removed, cooled at room temperature, weighed and transferred into a sieve of 500 µm size. The sieve was then shaken for 5 min in a shaking apparatus. The weight of the powder remaining on sieve was weighed. Degree of caking DC (%) was calculated by using the equation as

$$DC = c/d \times 100$$

Where, d(g) is amount of the powder used sieving and c(g) is amount of powder left on the sieve after sieving.

Sticky point temperature

Five g of powder having the known amount of moisture content was taken into a test tube of the apparatus developed by the present authors after slightly modification in the apparatus developed and designed by (Jaya and Das 2004) for the measurement of sticky point temperature Ts (°C).

Statistical analysis

Statistical analysis of variance technique of bael powder was done as suggested by Panse and Sukhatme (1989). Means and standards error were calculated and analysis of variance on the data were performed. The experiment was conducted two times with three replicated for each treatment.

Adsorption isotherms

The powder prepared by treating with combination of 1.5 % TP and 2.5 % MD was found to be the best and was used for adsorption isotherms. Procedure adopted by Iglesias and Chirife (1982) was followed for adsorption isotherms of

bael powder at 20, 30, and 40 °C. Approximately two grams bael powder was filled in sterilized glass weighing bottles and were placed in six separate vacuum desiccators containing saturated salt solutions (LiCl, MgCl₂, Mg(NO₃)₂, NaCl, KCl and KNO₃) for maintaining RH levels from 10 to 95 % (Greenspan 1977; Palipane and Driscoll 1992). The air inside of the desiccators was sucked partially to maintain a partial vacuum with the help of a vacuum pump. All six desiccators were kept in an incubator thermostatically controlled at 20 °C and the gain or loss in weights of all the samples in each desiccators were taken at 2 days interval until the sample attained Equilibrium moisture content (EMC). The attainment of EMC was ascertained when three consecutive weight measurements showed a constant weight. The same experiment was conducted for sorption process at 30 and 40 °C by changing the temperature of the incubator.

Results and discussion

The effect of concentration of tricalcium phosphate and maltodextrin on nutritional quality parameters is given in Table 1. The nutritional value of the powder in respect of acidity, reducing sugars, total sugar, total phenol and total antioxidants decreased significantly over the control with increased in 1.5 to 5.0 % of MD in the pulp. This might

be due to positive effect of MD on physical property of powder as it act as anti stickiness agent. However, non-enzymatic browning (NEB) of powder in above treatments was much lower as compared to control. This might be due to reduction in chemical reactions between sugars, acids, ascorbic acid, and phenol content with the interference of MD which might have reduced the oxygen and cause the low NEB in the powder.

The critical points for degree of caking (DC) decreased nearly 50 % along with relatively high values of sticky point temperature (Ts) of the bael powder prepared by mixing with MD and TCP as compared to control (Table 1). This might be due to positive effect of TCP and MD on the physical properties of the powder. As TCP acts as anti caking agent and MD as anti stickiness agent, therefore, both combination might have lead to above result (Jaya et al. 2006) However, a small decreasing trend for DC was observed with increasing the amount of MD in the powder prepared by treating with 1.5 % TCP + 5 % MD. This might be due to more amount of simple sugar, acids which contributed mainly caking of the powder substituted by MD. Similar observation have been reported by Hymavathi and Khader (2005) in beta- carotene rich mango powder, Jaya et al. (2006) in vacuum dried mango powder, Gabas et al. (2007) in vacuum dried pineapple powder.

Sensory score for colour of the powder was significantly higher in the powder treated with 1.5 % TP + 2.5 % MD followed by 1.5 % TP + 5 % MD as compared to control and

Table 1 Effect of concentration of tricalcium phosphate (TCP) and Maltodextrin (MD) on quality characteristics of bael powder

Parameters	Treatments					SE (±)	CD at 5 %
	Control	1.5 % TCP	1.5 % MD	1.5 % TCP + 2.5 % MD	1.5 % TCP + 5.0 %MD		
A: physico- chemical quality (<i>n</i> =3)							
Moisture (%)	3.7	3.7	3.9	3.6	3.6	0.08	0.18
Acidity (%)	1.2	1.02	1.1	1.2	1.1	0.03	0.06
R educing sugar (%)	5.7	4.2	4.3	4.4	4.3	0.08	0.18
Total sugar (%)	55.8	52.2	53.7	53.7	52.8	0.50	1.18
Ascorbic acid (mg/100 g)	28.5	27.4	26.5	27.8	26.5	0.18	0.40
Total phenol (mg/100 g)	24.9	19.5	23.7	23.7	21.2	0.43	0.98
Total antioxidant (mg/100 g)	101.1	77.8	79.04	97.6	69.4	0.42	0.99
NEB (at 420 nm)	0.08	0.06	0.06	0.05	0.03	0.04	0.09
Degree of caking (%)	32.09	28.9	21.1	19.2	20.6	0.07	0.15
Sticky point temperature Ts (°C)	39.3	40.8	42.7	45.4	45.05	0.06	0.13
B: sensory quality (<i>n</i> =5, panelists)							
Colour	5.5	7.5	6.5	8.7	8.5	0.1	0.3
Flavour	6.07	7.8	7.0	8.5	8.0	0.2	0.4
Texture	4.2	5.6	4.2	5.6	4.3	0.1	0.3
Overall	4.6	6.07	7.1	8.6	8.4	0.2	0.5

SE standard Error, CD Critical Difference, TCP Tricalcium phosphate, MD Maltodextrin

other treatments (Table 1). This may be due to an appropriately mutual compensated balance between sugars and NEB which might have contributed better appearance of the powder. Moreover, sensory score for flavour and overall acceptability was also significantly higher in the powder treated by above two treatments along with appropriate sensory score in texture as compared to control.

On the basis of values obtained in respect of degree of caking, sticky point temperature, antioxidant, phenol content, NEB, and sensory score, the amount of MD (0.25 kg per kg dry bael solids) and TCP (0.15 kg per kg dry bael solids) respectively were found optimal to improve the bael powder properties and drying condition.

The relationship between water activity (a_w) and equilibrium moisture content (EMC) of bael powder at 20, 30, and 40 °C is presented in Figure 1. It can be seen from the figure that the EMC of bael powder increased with an increase in a_w at all three temperatures, while it decreased with increase in temperature. The result may be explained that at higher temperatures the kinetic energy of the water molecules was high and water absorption at a given a_w was low (Demertzis et al. 1989; Mohamed et al. 2004). Similar results have been reported for the sorption isotherm (Sagar and Kumar 2006; Ghodake et al. 2007; Sinija and Mishra 2008). The moisture uptake was slow in the region of a_w : 0.0–0.45, followed by a linear and steady rise in the region of a_w : 0.45–0.85 and a subsequent accelerated rise in the region of a_w : 0.85–1.0. A reduction in moisture sorption and water binding capacity was observed as the temperature of sorption increased from 20 to 40 °C. Similar trend has been reported by previous researcher for sugar-rich fruit and dairy dried products (Kinsella and Fox 1987; Ayrançi et al. 1990; Tsami et al. 1990; Suresh Kumar and Sagar 2009).

The effect of packaging material on the quality and stability of bael powder in terms of changes in moisture, acidity, ascorbic acid, sugar, phenols, total antioxidants and

non- enzymatic browning is given in Table 2. It was observed that there was continuous pick up of moisture by the product in all the samples during storage and it was significantly affected by packaging materials. However, the gain of moisture was higher at ambient temperature as compared to LT. Similar trend was also described by Helkel et al. (1972) in dried mango sheets. With regard to packaging material the samples stored in higher gauge of polyethylene bags gained less moisture at both the conditions of storage as compared to lower gauge polyethylene. It may be due to lower permeability to water vapour in higher gauge of polyethylene. Similar trend has been reported by Sagar (2001) in osmotic dehydrated onion powder. The acidity decreased with increase in storage period at both the temperature. However, decrease in acidity was more in the samples store at ambient temperature as compared to LT. This may be due to the gain of more moisture content at ambient temperature as compared to LT. In respect of packaging material, the acidity was more in the samples packed in 200 gauge HDPE pouches compared to 400 gauge LDPE and 150 g PP pouches. This might be due to less permeability of the packaging material of 200 g HDPE which might have gain less moisture as compared to 400 g LDPE and 150 g PP pouches. But decrease in acidity due to packaging materials was found statistical significant. Ascorbic acid was higher in the bael powder packed in 200 gauge HDPE and stored at LT. This might be due to better protection by packages due to the better permeability of film as compared to other packaging material, but reduction in ascorbic acid due to packaging material and storage temperature was statistically significant. Similar trend has been reported by Sagar (2001) in onion powder. However, ascorbic acid content was higher in the samples stored at low temperature compared to room temperature. This might be due to rapid degradation of ascorbic acid at high temperature. Similar pattern has been reported by Chauhan et al. (1998). Reducing and total sugars increased with increase in storage period. The increases were higher in the samples stored at RT than LT. This may be due to faster rate of chemical reactions at higher temperature as compared to LT. However, the changes due to storage temperature in case of total sugars were found statistically significant. Reducing sugar was lower in the samples packed in higher gauge in comparison to lower gauge. This could be attributed due to the high level of acidity and greater protection caused by the higher gauge packages. In respect of packaging material, samples stored in 200 g HDPE pouches retain more reducing and total sugars. However, the changes with regard to packaging material were found statistically significant. Similar findings has been reported by Sagar (2001), in onion powder. Total phenols content of the bael powder decreased with increase in storage period and the

Fig. 1 Adsorption isotherms of bael powder at (a_w) different temperatures

level of decrease was slightly lesser in the powder stored at low temperature compared to room temperature. This might have degradation of some unstable phenolic compounds due to the oxidation of oxygen during storage. Similar pattern has been reported by Agrahari et al. (2004) in soy in rich apple bar (SEAB) during storage at ambient (22–31 °C) or low (4±1 °C) temperature. Total antioxidant

of bael powder decreased significantly with increase in storage period. This might have due to loss of ascorbic acid and total phenolics during storage which might be mainly responsible HAP contribution in the powder. The loss of total antioxidant was slightly lower in the samples stored at low temperature compared to room temperature. This might be due to pre treatment effect as well as effect

Table 2 Effect of packaging and storage on quality characteristics of bael powder during storage

Parameters	Storage period (months)	Storage temp CD at 5 %	Packaging and storage temp.						Packaging CD (5 %)
			150 g PP		400 g LDPE		200 g HDPE		
			RT	LT	RT	LT	RT	LT	
A: physico-chemical quality (<i>n</i> =3)									
Moisture (%)	2	NS	4.8	4.7	4.8	4.2	4.6	4.2	0.28
	4		4.9	4.8	4.8	4.8	4.6	4.3	
	6		5.9	5.6	6.7	5.6	5.5	5.3	
Acidity (%)	2	NS	1.2	1.2	1.2	1.2	1.2	1.3	0.02
	4		1.1	1.2	1.2	1.2	1.2	1.2	
	6		1.1	1.2	1.2	1.2	1.2	1.2	
Ascorbic acid (mg/100 g)	2	0.22	20.3	21.3	21.1	21.8	23.8	24.8	0.27
	4		18.4	19.8	20.1	19.7	21.2	22.6	
	6		16.3	17.2	18.2	17.8	18.6	20.8	
Reducing sugar (%)	2	NS	6.2	5.7	6.8	5.7	6.7	6.1	0.20
	4		6.7	6.6	6.9	6.4	6.9	6.6	
	6		6.8	6.6	6.9	6.7	7.5	6.6	
Total sugar (%)	2	0.11	54.6	53.7	55.7	53.8	54.8	55.7	0.13
	4		56.5	55.3	56.1	55.1	56.7	56.5	
	6		57.6	56.5	58.1	56.4	57.3	57.1	
Total phenol (mg/100 g)	2	0.10	43.3	45.4	46.3	47.2	46.3	48.1	0.12
	4		42.6	44.2	45.2	43.3	46.1	46.2	
	6		40.5	43.3	43.2	41.7	43.9	44.7	
Total antioxidant (mg/100 g)	2	0.04	17.4	18.2	18.3	17.6	18.7	18.2	0.05
	4		16.2	17.3	17.4	16.5	17.2	17.5	
	6		15.7	16.4	16.6	15.9	16.4	16.9	
NEB OD. (at 420 nm)	2	NS	0.44	0.42	0.42	0.44	0.41	0.41	0.01
	4		0.52	0.53	0.51	0.51	0.51	0.51	
	6		0.63	0.63	0.61	0.61	0.61	0.60	
B: sensory quality (<i>n</i> =5, panelists)									
Colour	2	NS	7.03	8.5	8.6	7.6	8.8	8.9	0.16
	4		6.4	8.1	8.03	7.07	8.6	8.5	
	6		6.4	7.1	8.1	6.5	8.1	8.2	
Flavour	2	NS	7.5	8.6	8.7	7.5	8.7	8.5	0.10
	4		7.2	8.4	8.5	7.5	8.5	8.4	
	6		6.5	8.2	8.4	7.0	8.4	8.2	
Texture	2	0.097	7.8	8.3	8.7	8.7	8.8	8.8	0.10
	4		6.6	8.2	8.5	8.6	8.6	8.5	
	6		6.2	8.1	8.4	8.1	8.2	8.3	
Overall	2	0.063	7.5	8.3	8.5	7.3	8.8	8.7	0.08
	4		8.7	8.3	8.3	7.1	8.6	8.5	
	6		6.2	7.9	8.2	7.2	8.2	8.3	

RT Room temperature, LT Low temperature, CD Critical Difference, NS Non significant, g gauge, PP Polypropylene, LDPE Low density polyethylene, HDPE High density polyethylene, NEB non- enzymatic browning

of other factors like mode of packaging, temperature and storage period on the powder which might have caused this change. The non- enzymatic browning was more in 150 g PP and 400 gauge LDPE pouches and least in 200 gauge HDPE pouches. This may be due to low moisture content in 200 gauge HDPE pouches, which helped to maintain the better colour of the product. However, the changes in NEB with regard to packaging material was found statistically significant.

With regard to sensory score of bael powder during storage, the samples packed in higher gauge of pouches and stored at low temperature retain better colour flavour and texture of the powder during storage. However, changes due to packaging materials after 6 months of storage were found statistical significant. The sensory score reduced with increase in storage period. This may be due to absorption of moisture from the atmosphere by the packages. The samples stored at LT received more sensory score and were better in colour, flavour and texture. This might be due to less moisture and less chemical reactions at LT compared to RT. Similar findings have been reported by Hymavathi and Khader (2004) in vacuum dehydrated ripe mango –mix powders, Evelin et al. (2007) in spray dried ripe banana powder, Sagar and Kumar (2009) in GOG powder.

Conclusions

Maltodextrin and tricalcium phosphate significantly increased the sticky point temperature and decrease the degree of caking of bael powder which is desirable for efficient handling and storage of fruit powder. The optimal amount of MD (0.25 kg per kg dry bael solids) and TCP (0.15 kg per kg dry bael solids) respectively were found to improve the bael powder properties and drying conditions. However, powder could be stored up to 6 months at LT and 4 months at RT after packaging it in 200 g HDPE or 400 g LDPE pouches with maximum nutritional quality in respect of reducing sugar, phenol, ascorbic acid, and total antioxidant during storage.

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