As. J. Food Ag-Ind. **2012**, 5(05), 374-387

OPEN ACCESS

Asian Journal of Food and Agro-Industry

ISSN 1906-3040
Available online at www.ajofai.info

Research Article

Production of papaya powder under foam-mat drying using methyl cellulose as foaming agent

P. Kandasamy[1]*, N. Varadharaju[2], S. Kalemullah[3] and Ranabir Moitra[1]

[1]Agricultural Engineering Section, Institute of Agriculture, Visva-Bharati (Central University), Santiniketan - 731235, West Bengal, India.

[2]Department of Food and Agricultural Process Engineering, Agricultural Engineering College and Research Institute, Tamil Nadu Agricultural University, Coimbatore – 641003, India.

[3]Department of Agricultural Engineering, S. V. Agricultural College, Tirupati - 517502, India.

*Email: pkandasamy1973@gmail.com

Abstract

Experiments were carried out to optimize the process parameters for production of papaya powder under foam-mat drying. Papaya pulp was foamed by incorporating methyl cellulose as foaming agent at different concentrations of 0.25, 0.50, 0.75 and 1.00% on w/w basis. The maximum stable foam formation was 83% at 0.75% methyl cellulose with 9°Brix pulp and whipping time of 15 min. The foam expansion was significantly influenced by pulp concentration and levels of the methyl cellulose at 1% level. The foamed pulp was dried at air temperature of 60, 65 and 70°C with foam thickness of 2, 4, 6 and 8 mm in a batch type cabinet dryer. The drying time required for foamed papaya pulp was lower than non-foamed pulp at all selected temperatures. Biochemical analysis results showed a significant reduction in ascorbic acid, β-carotene and total sugars in the foamed papaya dried product at higher foam thickness (6 and 8 mm) and temperature (65 and 70°C) due to destruction at higher drying temperature and increasing time. There was no significant change in other biochemical constituents such as pH and acidity. The sensory evaluation of the quality attributes of papaya powder juice showed significant reduction in colour, taste, flavour and overall acceptability at 65 and 70°C. The papaya powder obtained from the pulp of 9°Brix added with 0.75% methyl cellulose, whipped for 15 min and dried with a foam thickness of 4 mm at a temperature of 60°C was found to be optimum condition for production of papaya powder.

Keywords: fruit juice, cabinet drying, biochemical analysis, moisture content, sensory, India.

Introduction

Foam-mat drying is one of the simple methods of drying in which a liquid food concentrate along with a suitable foaming agent is whipped to form a stable foam and is subjected to dehydration in the form of a mat of foam at relatively low temperature [1, 2]. Rate of drying in this process is comparatively very high because of an enormous increase in the liquid-gas interface, in spite of the fact that the heat transfer is impeded by a large volume of gas present in the foamed mass [3]. Drying occurs in multiple constant rate periods due to periodic bursting of successive layers of foam bubbles, thus exposing new surfaces for heat and mass transfer as the drying progresses [4, 5]. This method is suitable for any heat sensitive, sticky and viscous materials which cannot be dried by spray drying. The foam-mat dried products have better reconstitution properties because of their honeycomb structure and are superior to drum and spray dried products [6]. Renewed interest in foam-mat drying could be due to its simplicity, cost-effectiveness, rapid drying rate and enhanced product quality. Foaming of liquids and semi liquid materials has long been recognized as one of the methods to shorten drying time. Unlike other drying methods, foam-mat drying does not involve a large capital outlay. The product is also reduced to a light and porous form which, when packaged in polyethylene material, allows for good stability. The drawback of this method is the throughput of the dryer as the moisture is removed from the thin layer of the foam hence the material spread per unit surface of drying area is very small [7].

Papaya (*Carica papaya L.*) is an important fruit of tropical and subtropical regions in the world. The fruit is rich in β-carotene, vitamin-A and C, iron, calcium, protein, carbohydrates, phosphorous and is a good source of energy [8]. Papaya can be made into jam, jelly, glace, nectar, dried into slabs, canned in the form of slices, etc. Papaya in the form of powder is also used for preparation of nectar, ice cream flavouring, ready to eat fruited cereals, etc. Over the last two decades global production of papaya reached almost 10.5 million tonnes. India is the leading producer of papaya and its share in the world production is about 37% [9, 10]. Most fruit including papaya have high moisture content and are highly perishable, cannot be preserved for longer periods of time, resulting in massive losses. The total postharvest losses of papaya are estimated to be 25.49% [11]. The climacteric nature, high tendency to deteriorate in ambient storage conditions and inadequate preservation techniques are some of the reasons for losses. When the moisture is removed, they can be preserved over a longer period of time with minimal deterioration. Among the methods of preservation, air drying is one of the common methods for preservation of foodstuffs, offering dehydrated products that have extended shelf life. However, the quality of conventionally dried products is often lower compared to the original material, particularly the colour, rehydration ratio, texture, and other characteristics. This could be due to the long exposure of food to heat during drying [12]. Thus, the dehydration time needs to be minimized to avoid loss of nutritional and sensory qualities.

Over the years, foam-mat drying has been applied to many fruit and other food materials including mango, banana, guava, apple [13], coffee extract [6], mango [14], egg melonge [15], soymilk [16], pineapple [17], starfruit [18], cowpea [19], banana [20, 21, 22], mango [23, 24], tomato juice [25, 26], mandarin powder [27], bael fruit [28]. Since there is no report showing its application to papaya, this investigation has been carried out with the specific objectives (a) to optimize the concentration of methyl cellulose and papaya pulp (b) to study the drying characteristics of foamed papaya concentrate and (c) to analyse the nutritional qualities of foam mat dried papaya powder**.**

Materials and Methods

The major steps involved in the processing of papaya by foam-mat drying are: selection of fruit, peeling, pulping, pretreatment, incorporation of foaming agent, whipping, spreading the foam in the form of thin mat, drying under selected temperature, scraping, grinding, sieving, packing and sealing. Papaya fruit used for this study were procured from a local orchard and the fruit were washed in running water and kept at atmospheric condition until the desired peel colour was attained. Fully ripened fruit were peeled manually using a stainless steel knife and the flesh portions were pulped using a mixer grinder (Sumeet, India). Biochemical analyses of fresh papaya pulp such as acidity, pH, total soluble solids (TSS), total sugars, ascorbic acid and β-carotene contents were carried out to evaluate their relative loss during foam mat drying as per the method described by Ranganna [29]. The fruit pulp was placed in a sterilized glass bottle which was heated in boiling water for 20 min and cooled to room temperature and was then treated with potassium metabisulphite at 0.05% (w/w) to inhibit microbial and enzymatic activity [13, 28]. Methyl cellulose was used as a foaming agent within the limits stipulated in the Prevention of Food Adulteration Act [30].

Preparation of papaya pulp foam

A laboratory scale foaming device consisting of 153 mm diameter and 280 mm height cylindrical stainless steel container with a graduated scale inside was connected to a nozzle at the bottom. A rubber tube at one end was connected to the nozzle and other end with an air compressor. A regulating valve was installed for monitoring compressed airflow rate. The whipping mechanism of 17 mm diameter shaft was fixed with 8 stainless steel propeller blades having height and diameter of 150 and 100 mm respectively and was used to agitate the material in the foaming container. The shaft of the mechanism was fitted an electric motor having 0.25 horsepower mounted on the top lid (Figure 1). The speed of the rotation of the propeller was 1440 rpm.

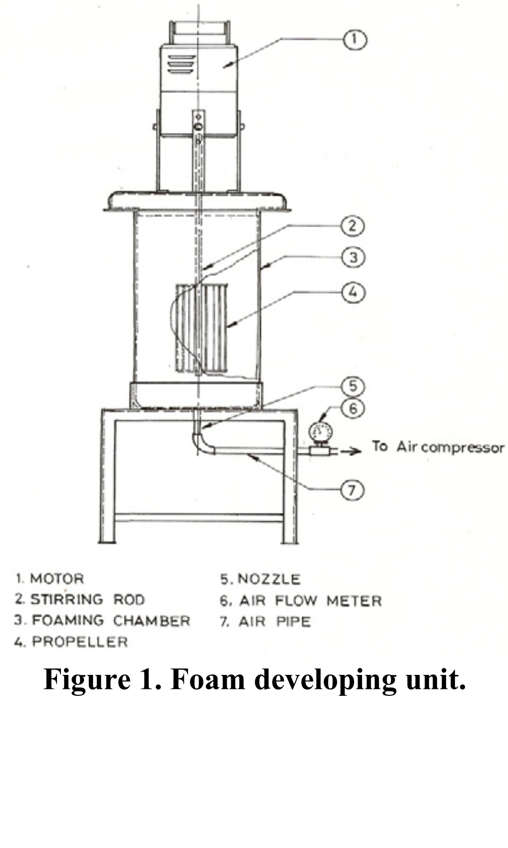

Figure 1. Foam developing unit.

About 200 ml of papaya pulp was placed in the foaming container along with selected levels of methyl cellulose (0.25, 0.50, 0.75 and 1.00%, w/w). The whipper was allowed to rotate and air was introduced to the chamber slowly at the rate 0.03 m^3/min, however, there was no foam formation in the pulp. This may be due to its high consistency and viscosity. When the pulp was adjusted to a lower concentration, foam developed rapidly. Hence, it was adjusted to different concentrations (12, 11, 10, 9, 8 and 7°Brix) from its initial concentration (13°Brix) by using Pearson square method [31]. The desired pulp concentration (°Brix) was prepared by mixing calculated amount of distilled water. The TSS was checked with hand refractometer (ERMA, Tokyo, Japan). The pre-determined papaya pulp concentrate and required quantity of methyl cellulose was placed in the foaming chamber on w/w basis. The foaming device was operated at 1440 rpm at room temperature until maximum foam formation. Compressed airflow at the rate 0.03 m^3/min was maintained. The foamed slurry was directly discharged from the foaming device by removing the top lid along with the electric motor. During the foaming study, all the experiments were replicated three times and the mean values were recorded. The influence of concentrated papaya pulp and methyl cellulose on foam expansion was statistically analyzed ($P \leq 0.01$) by factorial completely randomized design [32].

Determination of foaming properties

The foaming process was optimized in terms of maximum foam expansion (i.e., minimum foam density) and maximum foam stability (i.e., minimum drainage volume). Based on these foaming properties, the optimum levels were identified. The foam expansion was measured (Eqn.1) as described by Akiokato, *et al* [33]:

$$FE = \frac{V_1 - V_0}{V_0} \times 100 \text{ --------- (1)}$$

Where FE is the foam expansion (%), V_1 is the final volume of foamed papaya pulp (cm^3) and V_0 is the initial volume of papaya pulp (cm^3). Foam stability with minimum drainage volume of papaya foam was determined as per the method described by Akiokato, *et al* [33]. The foam obtained from 9°Brix pulp concentration was filled into a transparent graduated cylinder and kept at room temperature for 3 hours. The amount of liquid juice which separated from the foam as a result of drainage and the reduction in foam volume were measured as an index for the foam stability for every 30 minutes by using the following relationship (Eqn.2):

$$\text{Foam stability} = V_0 \frac{\Delta t}{\Delta V} \text{ --------- (2)}$$

Where V_0 is the volume of foam at zero time and ΔV is the change in foam volume during the time interval Δt.

Drying experiments

A batch type cabinet drier (Kilburn, India) having a heating unit, blower, drying chamber, air outlet openings and thermostat was used for drying studies. The drier was run intermittently in order to stabilize the desired temperature inside the chamber. The homogeneous foamed papaya pulp was evenly spread on food grade non-sticky stainless steel plates of 16.5 cm diameter at foam thickness of 2, 4, 6 and 8 mm. These plates were kept in an aluminium tray size of 90 x 40 x 2.5 cm having 5 mm diameter holes. The foam thickness was arrived at by multiplying the foam of known density (mass/volume) with drying area to attain 'g/mm'. Similarly, non-foamed papaya pulp thickness was also calculated. The trays were then placed on the tray stand in position for drying. The temperature inside the drying chamber was measured by using a thermometer. The foamed and non-foamed papaya pulps were dried at different temperatures viz., 60, 65 and 70°C with an air flow rate of 2.25m^3/min. The drying temperatures and thickness of foam were selected based on the data available in the previous literature. The trays were taken out of the drying chamber at one hour intervals for determination of weight loss. Moisture content was recorded every hour using a digital electronic balance having least count of 0.01 mg (Citizen Instruments, Pune, India) on initial and final weight basis. Drying was stopped when the weight of the samples recorded constant values. Experiments were conducted in triplicate. The moisture content (%) on dry basis was calculated (Eqn.3) as described by Chakraverty [34]:

$$MC, \%(db) = \frac{W_m}{W_d} \times 100 \quad \text{------------- (3)}$$

Where MC is the moisture content, % (dry basis), W_m is the weight of moisture in the sample, g and W_d is the weight of dry matter of the sample, g.

Quality analysis of dried product

The dried foam was scraped after cooling the trays to room temperature and the product was ground to a fineness of 250 micron and packed immediately in high density polythene bags having 300 gauges to prevent diffusion of moist air and caking. The samples were stored at ambient conditions for periodical evaluation. To distinguish the relative changes in nutrients, papaya powder samples were analysed for different biochemical properties viz., pH, TSS, acidity, ascorbic acid, total sugars and β-carotene after reconstituting the powder to its original moisture content by following standard procedures [29]. The biochemical contents of the reconstituted foam mat dried papaya powder with three replications were statistically analysed as completely randomized block design using AGRES statistical package ($P \leq 0.05$). Sensory evaluation for acceptability of papaya powder samples were evaluated by 9-point Hedonic scale (where 9 = like extremely, 1 = dislike extremely) with a panel of 10 untrained judges for colour, flavour, taste and overall acceptability by using unknown codes [29] and the results obtained were analysed statistically by completely randomized block design using AGRES statistical package ($P \leq 0 .01$).

Results and Discussion

Various biochemical contents of fresh papaya pulps were determined as ascorbic acid (145 mg/100g), β–carotene (4.056 mg/100g), total sugar (36.8 g/100g), acidity (1.4%), pH (5.2) and total soluble solids (13°Brix). The results obtained on biochemical properties are in comparison with the results reported by other researchers [35, 36, 37].

Effect of concentration of methyl cellulose and papaya pulp on foam expansion

Effect of concentration of papaya pulp and levels of methyl cellulose on foam expansion is shown in Figure 2. From the figure, it is seen that all the levels of methyl cellulose have no influence over the foam formation at higher concentration of the pulp (13 and 12^{o}Brix). This may be due to its high viscosity and consistency. As the concentration of pulp decreased, the foam volume increased with amount of foaming agent increased and whipping time up to 15 min. The effect may be explained in terms of shear force applied on the system. Foam expansion was increased with decrease in total soluble solids content of pulp from 13 to 9°Brix. The lowering of the concentration of papaya pulp below 9°Brix did not yield much change in the foam expansion. Similar results were witnessed on foaming of bael (*Aegle marmelos* L) fruit pulp [28]. As the concentration of methyl cellulose in the pulp increased, the foam expansion increased significantly (P≤0.01). Higher foam expansion indicates that more air was trapped in the foam. Apparently, at lower concentration of methyl cellulose, the air bubbles were not stable because the critical thickness required for interfacial film could not be formed [38]. At 9°Brix, the foam expansion was 24 and 53% at 0.25 and 0.5% methyl cellulose respectively. When the concentration of methyl cellulose was 0.75% the volume increase in the papaya foam was as high as 83%. Beyond this level, addition of the foaming agent did not produce appreciable changes in the foam expansion. The foam expansion at 1% methyl cellulose was 88%. Similar observations were reported on the foam expansion of star fruit [18, 38], mango pulp [39] and bael fruit pulp [28].

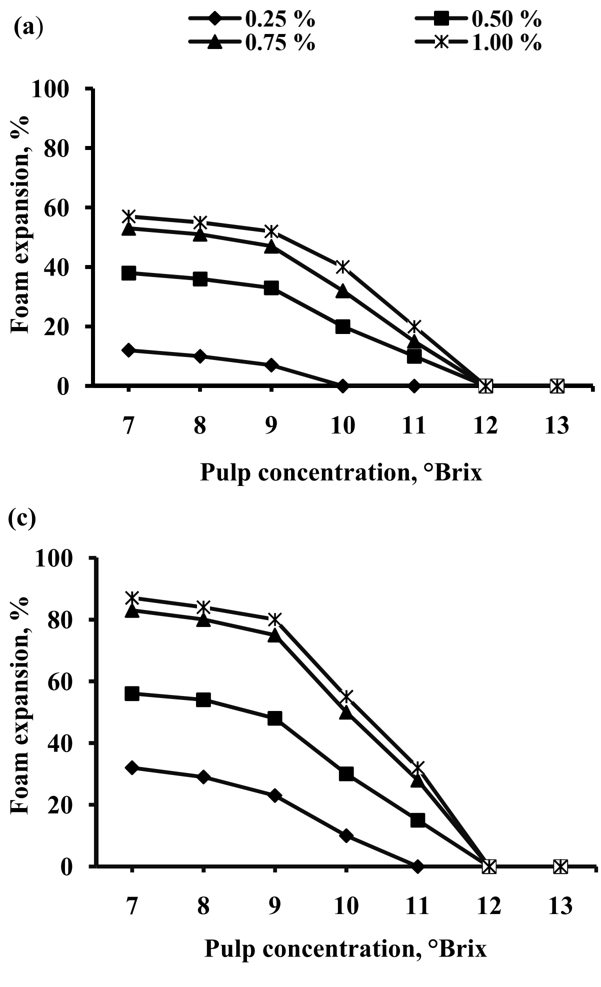

Figure 2. Effect of concentration of methyl cellulose and papaya pulp on foam expansion (a), (b), (c) and (d) are 5, 10, 15 and 20 min whipping time respectively.

Each observation is the mean of three replicates, significant at 1%, CV=3.61.

The whipping time also influenced the foam expansion. It is observed from Figure 2 that the foam expansion increased with increase in whipping time. The methyl cellulose stabilized foams exhibited their maximum up to 15 min of whipping and thereafter no appreciable increase in foam expansion occurred. The expansion of foams increased with whipping time up to the maximum and decreased thereafter probably because excessive whipping (overbeating) could cause foam to collapse [40]. Similar trends were reported for banana [20] and bael fruit pulp [28]. Hence, the pulp concentration of 9°Brix was optimized as the maximum foam expansion of 83% at 0.75% methyl cellulose with whipping time of 15 min. The optimized foamed pulps were taken for drying studies.

Effect of concentration of methyl cellulose on foam stability

The concentration of foaming agent is one of the major factors in foam stability. Figure 3 shows the effect of methyl cellulose concentration on foam stability. From the figure, it is seen that the foam with higher concentration of methyl cellulose exhibited more stability as compared to lower concentration of methyl cellulose. However, decrease in pulp concentration caused decrease in stability of foam and increase in drainage volume. Increase in methyl cellulose concentration caused stability of foam or decrease of drainage volume. The foam stability value was 95.4% and 97.2% at the concentration of 0.75% and 1% methyl cellulose respectively at 180th min and it was less in lower concentration of methyl cellulose (0.25 and 0.5%). Similar results were reported for cowpea [19] and egg white [41].

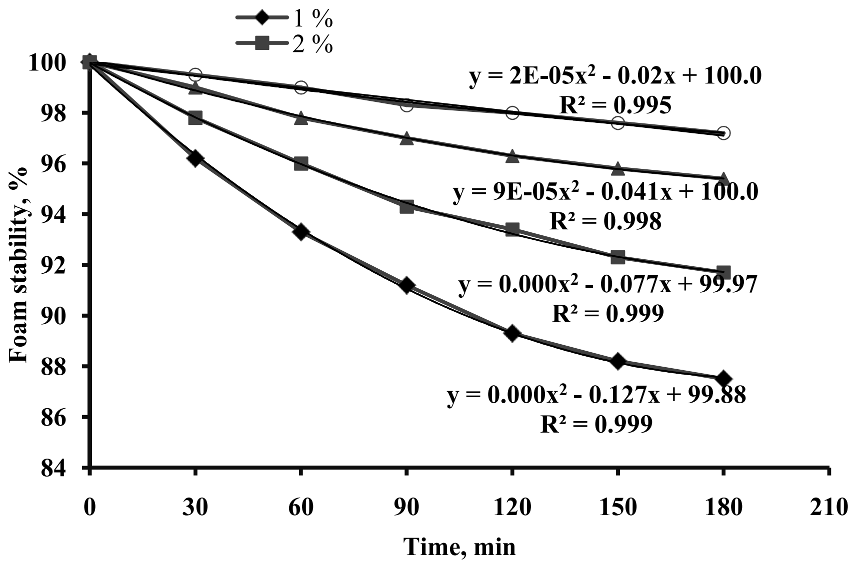

Figure 3. Effect of concentration of methyl cellulose on foam stability.

Foam stability reflects the water holding capacity of the foam and one way to determine the rate at which the liquid drains from it [42]. The liquid in foams is distributed between thin films and plateau borders. Because of the radius of curvature of a plateau border, the pressure inside is less than that in thin films by capillary pressure. This difference, known as plateau border suction, leads to drainage of liquid from thin films to the neighbouring plateau border. Finally, all liquid in the plateau border of foams are subject to drain of the liquid from between the bubbles caused by the action of gravity [43]. The stable foam structure is desirable for rapid drying and ease of removing the dried material from the tray. If foams break or drains excessively, drying time is increased, reducing product quality.

Effect of thickness on drying characteristics of foamed and non-foamed papaya pulp

The drying of methyl cellulose foamed papaya pulps was carried out with four foam thicknesses viz., 2, 4, 6 and 8 mm and three drying temperatures viz., 60, 65 and 70°C (Figure 4). At 60°C, time taken for drying of foamed papaya pulp from 843.57 to 4.5 ± 0.3% moisture content on dry basis was 3, 4, 7 and 9 h for 2, 4, 6 and 8 mm foam thicknesses. While time taken for drying of non-foamed papaya pulp was 6, 8, 10 and 12 for 2, 4, 6 and 8 mm thickness respectively to reach the moisture content 18 ± 3% on dry basis.

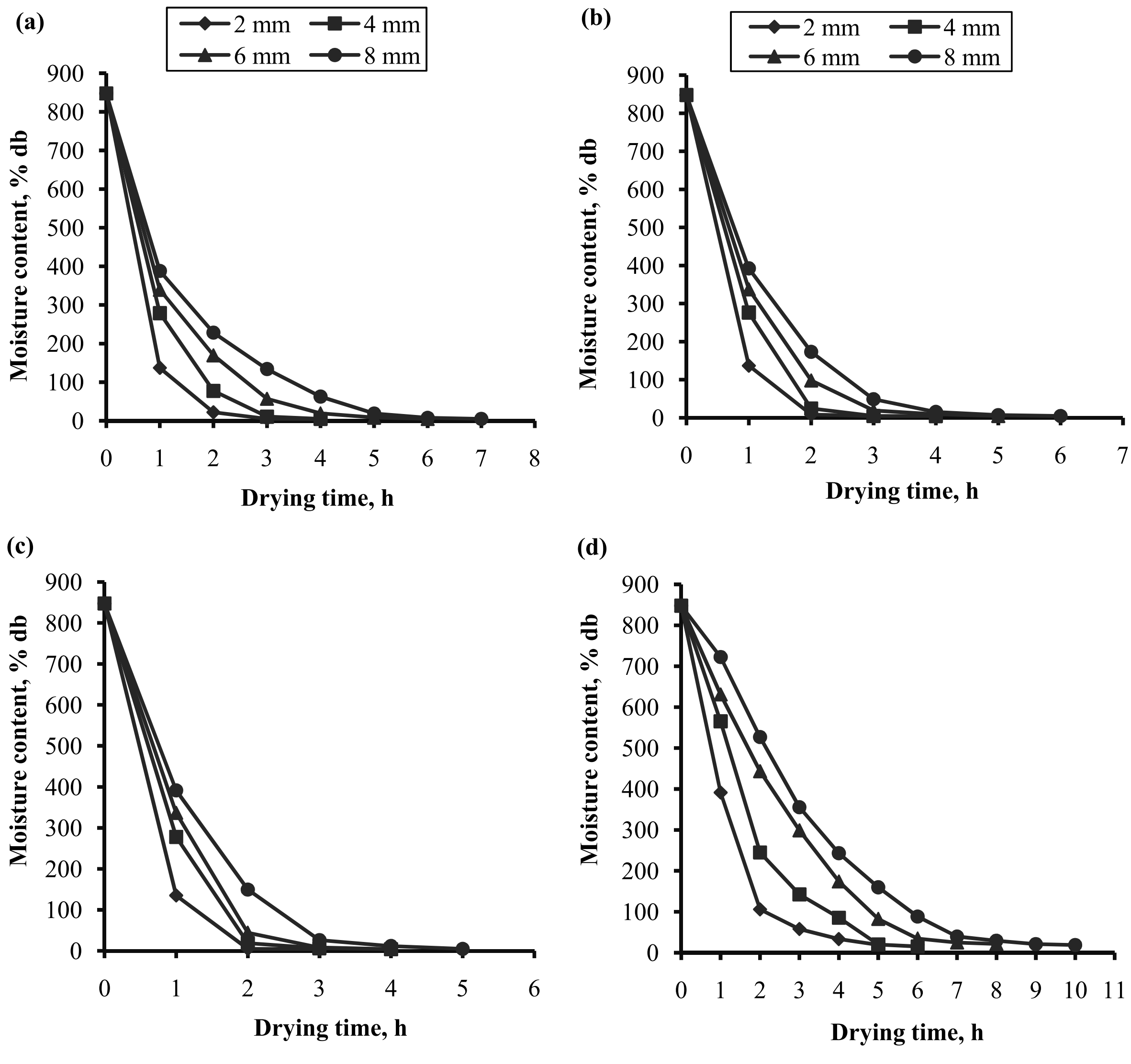

Figure 4. Effect of foam thickness on drying of foamed and non-foamed papaya pulp.
(a), (b) and (c) are drying 60, 65 and 70°C respectively (d) non-foamed pulp at 60°C.

At 65°C, the drying time of 1, 3, 5 and 7 h for 2, 4, 6 and 8 mm foam thickness respectively was taken to bring the final moisture content 4.5 ± 0.3% on dry basis, whereas it took 4, 5, 7 and 9 h for 2, 4, 6 and 8 mm pulp thickness of non-foamed papaya pulp to bring the moisture content 18 ± 3% on dry basis. At 75°C, the drying time for 2, 4, 6 and 8 mm foam thickness were 1, 3, 4 and 5 h respectively to bring the final moisture content 4.5 ± 0.3% on dry basis. The equilibrium weight could be obtained in 4, 5, 6 and 8 h for 2, 4, 6 and 8 mm pulp thickness of non-foamed papaya pulp respectively with moisture content of 18 ± 3% on dry basis. From Figure 4, it is also observed that the drying of foamed and non-foamed papaya pulp occurred in the falling rate period. The drying time increased as the foam thickness increased and decreased with temperature. This may be due to the fact that moisture migration is higher in less foam thickness than high foam thickness. The rate of moisture removal in the foamed papaya pulp was very high as compared to non-foamed pulp due to fact that the water present in the foamed pulp was in the form of thin films making for easier vaporization. These drying results are in conformity with the drying results for soymilk [16], banana [21], mango [24] and apple [44].

Effect of drying temperature on quality of foam-mat dried papaya powder

The nutritional qualities of dried product play an important role in selecting the drying parameters and were compared with fresh pulp. The dried foam was scraped after cooling the trays to room temperature and the product was ground to a fineness of 250 micron and packed immediately in high density polythene bags. However, it was not possible to scrape non-foamed dried samples of thickness 2 and 4 mm from the plates because they were fully adhered to the plate, whereas 6 and 8 mm thick dried products became leathery and it was not possible to grind them. The biochemical results of the foamed papaya pulp dried at 60, 65 and 70°C are shown in Table 1.

Table 1. Biochemical composition of foam-mat dried papaya powder.

Drying temperature (°C)	Foam thickness (mm)	Biochemical composition				
		pH	Acidity (%)	Ascorbic acid (mg/100g)	Beta carotene (mg/100)	Total sugars (g/100g)
60	2	5.0	0.42	125.0	4.02	36.5
	4	5.0	0.42	125.0	4.02	36.4
	6	4.9	0.41	118.3	3.93	35.6
	8	4.9	0.41	118.6	3.91	35.0
65	2	5.0	0.42	110.8	3.85	35.5
	4	5.0	0.41	110.5	3.83	35.1
	6	4.9	0.40	104.3	3.74	34.7
	8	4.9	0.40	99.6	3.70	34.7
70	2	5.0	0.41	95.2	3.64	34.8
	4	4.9	0.41	90.0	3.60	34.8
	6	4.9	0.40	84.4	3.50	34.5
	8	4.9	0.40	80.0	3.45	34.5
	CD (5%)	0.18	0.04	1.86	0.19	1.81
		NS	NS	**	**	**

Each observation is the mean three replicates, NS = Not significant
** Significantly different at ($P \leq 0.05$)

The biochemical changes were comparatively higher in 6 and 8 mm thick foam dried at 65°C and 70°C than in 2 and 4 mm thick foam dried at 60°C. It was found that there was a significant reduction in ascorbic acid (125 to 80 mg/100g). This may be due to the destructive effect of the prolonged thermal treatment, which caused oxidation of the ascorbic acid [45]. It was also found that there was a significant reduction in β-carotene (4.02 to 3.45 mg/100g). Total sugars (36.5 to 34.5 g/100g) also changed significantly. Changes to other biochemical contents such as pH (5.1 to 4.9) and acidity (0.42 to 0.40%) were not significant. Similar biochemical changes were reported for pineapple [17], bananas [21], papaya [36], mango [39], apple [44] and mango [46]. Based on the biochemical analysis, it was found that the papaya powder treated with methyl cellulose dried at

60°C and foam thickness of 2 and 4 mm retained significantly higher amount of nutritional qualities than other treatments such dried at 65°C and 70°C and 6 and 8 mm foam thickness. For selecting the foam thickness, yield of the powder was considered as nutritional values are same in 2 and 4 mm thick foamed powder. The yield obtained from 2 and 4 mm thick foamed papaya powder is presented in Table 2. It is clear from Table 2 that 4 mm thick dried foamed pulp yielded nearly 100% more than that of 2 mm thickness for all the temperatures and foaming agents studied.

Table 2. Yield of foam-mat dried papaya powder.

Foam thickness (mm)	Yield (kg/m^2)		
	60°C	65°C	70°C
2	0.0787	0.0784	0.0789
4	0.1539	0.1572	0.1563
6	0.2365	0.2384	0.2375
8	0.3168	0.3174	0.3173
10	0.3896	0.3976	0.3946

Each value is the mean of three replicates

Sensory evaluation of foam-mat dried papaya powder

Juice was prepared from the papaya powder obtained from 4 mm thick foam and was compared with fresh papaya fruit juice. Table 3 shows the effect of drying temperature on sensory attributes of reconstituted papaya powder for different characteristics such as colour, flavour, taste and overall acceptability.

Table 3. Effect of drying temperature on sensory attributes of reconstituted papaya powder.

Characteristics	Fresh sample	Dried sample			CD (1%)	
		60°C	65°C	70°C		
Colour	6.7	6.2	6.0	5.7	1.278	**
Flavour	7.3	6.8	6.4	6.3	1.46	NS
Taste	7.2	6.6	6.2	5.9	1.438	NS
Overall acceptability	6.75	6.5	6.4	5.9	1.35	NS

Each observation is the mean of ten replicates, NS = Not significant
** Significantly different at $P \leq 0.01$,

From the Table 3, it is clearly seen that the samples dried at 60°C recorded higher ratings on colour, flavour, taste and overall acceptability compared to the samples dried at 65°C and 70°C. The various treatments adopted had no significant effect on flavour, taste and overall acceptability, but significant effect on colour (Table 3). Moreover, the fresh sample also received higher ratings for all attributes. However, the flavour and taste of the reconstituted sample at 65°C and 70°C received a lower rating. This could be due to the loss of volatiles at higher drying temperature. Similar trends were reported for foam-mat dried pineapple powder juice [17] and foam-mat dried reconstituted banana paste [22].

Conclusions

The optimum level of methyl cellulose was found to be 0.75% with papaya pulp concentration of 9°Brix and whipping time of 15 min for foam-mat drying of papaya pulp. The stability of foam (95.4%) also was found to be longer at higher concentration of methyl cellulose (0.75%) compared to lower concentration of methyl cellulose. Based on the nutritional qualities, it was concluded that 2 and 4 mm thick foamed papaya powder at 60°C retained significantly higher amount of nutritional qualities than the other treatments. Yield of the papaya powder was considered for selecting the foam thickness as nutritional values are the same in 2 and 4 mm thick foamed powder. Therefore, 4 mm foam thickness was optimum for foam-mat drying of papaya pulp. It was concluded that the time taken for drying of 4 mm thick foamed papaya pulp was 4, 3 and 3 h at 60, 65 and 70°C respectively to obtain dried papaya powder of 4.5 ± 0.3% moisture content on dry basis. Based on the overall study, it was concluded that the papaya pulp of 9°Brix added with 0.75% methyl cellulose whipped for 15 min and dried with a foam thickness of 4 mm at a temperature of 60°C was found to be optimum to produce the foam-mat dried papaya powder.

References

1. Morgan, A.I., R.P. Graham, L.F. Ginnette and G. Williams (1961). Recent developments in foam-mat drying. ***Food Technology,*** 15: 37–39.

2. Berry, R.E., O.W. Bissett and J.C. Lastinger (1965). Method for evaluating foams from citrus concentrates. ***Food Technology,*** 19(7): 144-147.

3. Chandak, A.J and M.R. Chivate (1972). Recent development in foam-mat drying. ***Indian Food Packer***, 26(6): 26-32.

4. Hart, M.R., R.P. Graham L.F. Ginnette and A.I. Morgan (1963). Foams for foam-mat drying. ***Food Technology,*** 17: 1302–1304.

5. Martin, R.O., G. Narasimhan, R.K. Singh and A.C. Weitnaner (1992). Food dehydration. In: D.R. Heldman and D.B. Lund (Ed.) Handbook of Food Engineering, Academic press, London. pp. 530-531.

6. Chandak, A.J and M.R. Chivate (1974). Studies in foam-mat drying of coffee extract. ***Indian Food Packer,*** 28(2): 17-27.

7. Kudra, T and C. Ratti (2006). Foam-Mat drying: Energy and cost analysis. ***Canadian Biosystems Engineering,*** 48: 3.27-3.32.

8. Gopalan, C., B.V. Ramasastri and S.C. Balasubramanian (1972). Nutritive value of Indian Foods. Published by National Institute of Nutrition, Hyderabad, India. pp. 35-50.

9. National Horticultural Board (2009). Government of India.

10. OECD (2010). Consensus document on compositional considerations for new varieties of papaya (*Carica papaya* L): Key food and feed nutrients and anti-nutrients, toxicants and allergens. Series on the safety of novel foods and feeds No. 21, OECD Environment Directorate, Paris.

11. Gajanana, T.M., M. Sudha, A.K. Saxena and V. Dakshinamoorthy (2010). Post harvest handling, marketing and assessment of losses in papaya. ***Acta Horticulture (ISHS),*** 851: 519-526.
12. Ratti, C (2001). Hot air and freeze drying of high value food: a review. ***Journal of Food Engineering,*** 49: 311–319.

13. Jayaraman, K.S., T. Goverdhanan, R. Sankaran, B.S. Bhatia and H. Nath (1974). Compressed ready to eat fruited cereals. ***Journal of Food Science and Technology,*** 11(3): 181-185.
14. Baldry, G.R.J., J.C. Breag, R.D. Caygill, C.E.M. Cooke and K. Lalitha (1976) Alternative methods of processing of mangoes. ***Indian Food Packer***, 30(5): 56-62.

15. Rao, T.S.S., H.S. Murali and K.R.G. Rao (1987). Preparation of foam-mat dried and freeze dried whole egg powder (Hen's). ***Journal of Food Science and Technology,*** 24(1): 23-26.

16. Akintoye, O.A and A.O. Oguntunde (1991). Preliminary investigation on the effect of foam stabilizers on the physical characteristics and reconstitution properties of foam-mat dried soymilk. ***Drying Technology,*** 9(1): 245-262.

17. Hassan, M and J. Ahmed (1998). Sensory quality of foam-mat dried pineapple juice powder. ***Indian Food Packer,*** 52(7): 31-33.

18. Karim, A.A and C.C. Wai (1999a). Foam mat drying of star fruit puree, stability and air drying characteristics. ***Food Chemistry,*** 64(3): 337-343.

19. Falade, K.O., K.I. Adeyanju and P.I. Uzo-Peters (2003). Foam-mat drying of cowpea (Vigna unguiculata) using glyceryl monostearate and egg albumin as foaming agents. ***European Food Research and Technology,*** 217(6): 486–491.

20. Sankat, C.K and F.F. Castaigne (2004). Foaming and drying behaviour of ripe bananas. ***Lebensmittel Wissenshaft und Technolgie,*** 37: 517-525.

21. Thuwapanichayanan, R., S. Prachayawarakorn and Soponronnarit, S. (2008). Drying characteristics and quality of banana foam mat. ***Journal of Food Engineering,*** 86(4): 573-583.

22. Falade, K.O and J.O. Okocha (2010). Foam-mat drying of plantain and cooking banana (*Musa spp.*). ***Journal of Food and Bioprocess Technology,*** doi: 10.1007/s11947-010-0354-0.

23. Kadam, D.M., R.A. Wilson and S. Kaur (2010). Determination of biochemical properties of foam mat dried mango powder. ***International Journal of Food Science and Technology,*** 45(8): 626-1632.

24. Rajkumar, P., R. Kailappan, R. Viswanathan and G.S.V. Raghavan (2007). Drying characteristics of foamed alphonso mango pulp in a continuous type foam mat dryer. ***Journal of Food Engineering,*** 79: 1452–1459.

25. Kadam, D.M and S. Balasubramanian (2011). Foam mat drying of tomato juice. ***Journal of Food Processing and Preservation,*** 35(4): 488-495.

26. Kadam, D.M., R.A. Wilson and S. Kaur (2011a). Influence of foam-mat drying on quality of tomato powder. ***International Journal of Food Properties,*** doi: 10.1080/10942911003763701.

27. Kadam, D.M., D.R. Rai, R.T. Patil, R.A. Wilson, S. Kaur and R. Kumar (2011b). Quality of fresh and stored foam mat dried mandarin powder. ***International Journal of Food Science and Technology,*** 46(4): 793-799.

28. Bag, S.K., P.P. Srivastav and H.N. Mishra (2011). Optimization of process parameters for foaming of bael (Aegle marmelos L.) fruit pulp. ***Food and Bioprocess Technology,*** 4: 1450–1458.

29. Ranganna, S (2000). Handbook of analysis and quality control for fruit and vegetable products. Sixth edition, Tata McGraw-Hill Publishing Co. Ltd. New Delhi.

30. The Prevention of Food Adulteration Act (1955). Act 37 of 1954, Government of India.

31. Siddappa, G.S., Girdharilal and G.L. Tandon (1998). Syrups and brines for canning. In: Preservation of fruits and vegetables. Published by Indian Council of Agricultural Research, New Delhi. pp. 43-52.

32. Cochran, W.G and G.M. Cox (1957). Completely randomized designs. In: Experimental designs. 2nd Edn. John Killey and Sons Inc., Canada, New York. pp. 95-102.

33. Akiokato, A.T., N. Matsudomi, K. Kobayashi (1983). Determination of foaming properties of egg white by conductivity measurements. ***Journal Food Science and Technology,*** 48(1): 62-65.

34. Chakraverty, A (1997). Post harvest technology of cereals, pulses and oilseeds, 3rd edn. Oxford & IBH Publishing Co. Pvt. Ltd, New Delhi. pp. 26.

35. Pandey, P.H (1997). Technology of Processing Papaya. Post Harvest Technology of fruits and vegetables (principle and practices). Saroj Prakasham Publishing Company, Allahabad, India. pp. 111-117.

36. Aruna, K., K. Dhanalakshmi and V. Vimala (1998). Development and storage stability of cereal-based papaya (*Carica papaya* L.) powder. ***Journal of Food Science and Technology,*** 35(3): 250-254.

37. Workneh, T.S., M. Azene and K. Woldetsadik (2011). Effect of packaging materials and storage environment on post harvest quality of papaya fruit. ***Journal of Food Science and Technology,*** doi: 10.1007/s13197-011-0607-6.

38. Karim, A.A and C.C. Wai (1999b). Characteristics of foam prepared from starfruit (Averrhoa carambola L.) puree by using methyl cellulose. ***Food Hydrocolloids,*** 13(3): 203–210.

39. Rajkumar, P., R. Kailappan, R. Vishwanathan, K. Parvathi and G.S. Raghavan (2007b). Thin layer drying study on foamed mango pulp. ***International Commission of Agriculture and Biosystem Engineering (CIGR) Journal,*** IX: 224-238.

40. Raharitsifa, N., D.B. Genovese and C. Ratti (2006). Characterization of apple juice foams for foam-mat drying prepared with egg white protein and methylcellulose. ***Journal of Food Science,*** 71(3): 142–151.

41. Pernell, C.W., E.A. Foegeding, P.J. Luck and J.P. Davis (2002). Properties of whey and egg white protein foams. ***Colloids and Surfaces: Physicochemical and Engineering Aspects,*** 204: 9-21.

42. Kampf, N., M.C. Gonzalez, M.G. Corradini and M. Peleg (2003). Effect of two gums on the development, rheological properties and stability of egg albumen foams. ***Rheological Acta,*** 42(3): 259–268.

43. Narsimhan, G (1991). A model for unsteady state drainage of a static foam. ***Journal of Food Engineering,*** 14(1): 139–165.

44. Mishra, H.N., J.K. Jacob, and N. Srinivasan (2002). Preparation of apple powder and evaluation of its shelf life. ***Beverage and Food World,*** 29(1): 49–52.

45. Levi, A., S. Gagel and B. Juven (1983). Intermediate moisture tropical fruit products for developing countries 1. Technological data on papaya. ***Journal of Food Technology,*** 18(6): 667-685.

46. Srivastava, J.S (1998). Mango processing industries-A scenario. ***Indian Food Packer,*** 52(6): 43-49.