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Assessment of physicochemical and sensory characteristics of foam-mat dried papaya fruit powder

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Abstract

Foam-mat drying is an alternative for the preservation of papaya in the form of powder. The aim of the present work was to evaluate the physicochemical characteristics of foam-mat dried papaya powder. Papaya pulp with 9ºBrix concentration was foamed using methyl cellulose, glycerol monostearate and egg albumin. The foam slurries were dried at 60, 65 and 70°C with foam thicknesses of 2, 4, 6 and 8 mm and then powdered. The physicochemical characteristics such as bulk density and water solubility index decreased with increasing foam thickness and increased with increasing temperature. Moisture content and water absorption index decreased with increasing temperature and increased with increasing foam thickness. Vitamin C, β-carotene, total sugars and TSS showed significant reduction at higher temperature and foam thickness. However, there were no changes in acidity and pH. Egg albumin treated papaya pulp dried at 60ºC with 2 and 4 mm foam thicknesses showed better physicochemical quality whereas glycerol monostearate treated papaya powder had better sensory ratings on colour, flavour, taste, and overall acceptability.

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Introduction

Papaya (*Carica papaya* L.) is a climacteric fruit, which grows in tropical and subtropical regions around the world. After harvest, ripe papaya fruits normally have a storage life of three to five days under ambient tropical conditions (Ergun *et al*., 2006) thus marketing of fresh papaya fruits is a great problem which leads to significant postharvest losses. Therefore, the development of value-added products is the only way to prevent these postharvest losses. Different value-added products such as jam, jelly, nectar, candy, pickle, fruit leather, toffees, chunks, slices and papaya wine can be prepared from papaya (Devaki *et al*., 2015). Conversion of the papaya fruit into powder is also a good alternative for minimising the post-harvest losses. The dehydrated papaya products can be used for preparation of many food product formulations such as ready-to-eat fruit cereals, nectar, ice cream flavours, custard powder, weaning mixture and instant soup cubes (Johari and Kawatra, 2016).

Foam-mat drying is more suitable for drying of liquid and semi-liquid food materials and also drying of high sugar content, viscous, stickiness and heat-sensitive food materials. In this method, a liquid or semi liquid food concentrate is whipped along with a suitable foaming agent to form stable foam and subjected to dehydration in the form of a mat of foam at relatively low temperature, 50 to 70ºC (Raharitsifa *et al*., 2006; Rajkumar *et al*., 2007a). The stable foam can then be dried by hot air (the most common method), vacuum, microwave and freeze drying (Zheng *et al*., 2011). The rate of drying is increased in this process since great volume of gas is present in the foamed mass, enormous gas-liquid interface, porous foam structure and superior rate of heat transfer through the foam. Moreover, drying occurs in more than one constant rate period because of the periodic bursting of successive layers of foam

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bubbles (Kandasamy *et al*., 2014). Foam-mat drying is cost-effective, does not require a large capital outlay, and the dried product is reduced to light and porous form which when packaged in polyethylene material allows for good stability, porous structure of foam which provides better reconstitution properties, higher nutritional and organoleptic quality and lowered browning rates (Kudra and Ratti, 2006).

Foam-mat drying technology has been applied on many fruits and vegetables in recent years. Karim and Wai (1999) prepared star fruit purée foam using methocel as foaming agent and dried at 70 and 90ºC. The colour and flavour changes were observed in the product dried at 90ºC. Falade *et al*. (2003) produced the stable cowpea foam using egg albumin and glycerol monostearate foaming agents, and dried at 60ºC. They found that no significant difference in sensory quality attributes of reconstituted glycerol monostearate stabilised cowpea powder. Sankat and Castaigne (2004) used soy protein as foaming agent to prepare banana foam and the foam was dried at temperatures from 45 to 90ºC and found that the foam layer thickness greatly influenced over the drying time; resulting products were brittle solid and had porous structure. Rajkumar *et al*. (2007b) obtained mango pulp foam using 0.5% methyl cellulose and 10% egg albumin and dried at 60ºC, which retained the nutritional quality characteristics. Kadam *et al*. (2010) showed better biochemical properties of mango powder obtained under the foaming condition of 10% milk as foaming agent and dried at 65°C. Kadam *et al*. (2012) showed decreasing trend in the total sugars, ascorbic acid, lycopene and total acid of foam-mat dried tomato powder; however, pH slightly increased as compared to that of fresh tomato juice. Abbasi and Azizpour (2016) reported a decreasing trend in the total anthocyanin content, acidity, and browning index of foam-mat dried sour cherry powder with increasing egg white levels and drying temperatures; however, pH exhibited an increasing trend and the powder had maximum solubility at 65ºC.

Since papaya fruit contains high sugar content, stickiness and viscosity, the foam-mat drying technology was employed in the preparation of papaya fruit powder. The objective of the present work was to evaluate the effect of different foaming agents, drying temperatures and foam layer thicknesses on the physicochemical and sensory characteristics of foam-mat dried papaya fruit powder.

Materials and methods

Preparation of raw materials

Ripened papaya fruits were procured from a local farmer's field, washed under running water to remove dirt, and kept in the laboratory at atmospheric condition till the desired peel colour (more than 80%) was attained. Papaya flavour is at its peak when the skin is 80% coloured (Morton, 1987). The fruits were peeled manually using stainless steel knife, and the seeds were removed. The flesh portions were homogenised using a mixer grinder (Icon Superb 1000W, Morphy Richards, Mumbai, India), and the pulp was packed in sterilised stainless steel container and heated in boiling water for 15 to 20 min, cooled to room temperature (30ºC) and treated with potassium metabisulphite at 0.05% (w/w) to inhibit microbial and enzymatic activity. Foaming agents such as methyl cellulose (MC), glycerol monostearate (GMS) and egg albumin (EA) were used because these food emulsifiers have an excellent foaming characteristic as well as stabilise the foam for longer time (Phillips *et al*., 1987; Karim and Wai, 1999; Lomakina and Mikova, 2006; Rajkumar *et al*., 2007b). The MC and GMS powders were purchased from a local distributer (Parry Enterprises India Limited, Chennai, India) and fresh eggs from local market. The albumin was separated using yolk separator (Rrimin, Chennai, India) and homogenised.

Preparation of papaya fruit powder

To prepare papaya powder, four levels of MC (0.25, 0.50, 0.75 and 1.00%), four levels of GMS (1, 2, 3 and 4%) and four levels of EA (5, 10, 15 and 20%) were selected and incorporated into homogenised papaya pulp on w/w basis. This mixture was whipped for 10 to 15 min at a speed of 1,440 rpm using a foaming device to obtain maximum reliable foam. Foam was not formed with initial pulp concentration (13ºBrix) which could be due to its sticky and viscous nature. Hence, calculated amount of distilled water was added to dilute the concentration of pulp using Pearson square method (Lal *et al*., 1998) upon which foam rapidly formed. The levels of foaming agents were optimised based on foam expansion and stability. In our previous study, foaming and drying parameters of papaya pulp was optimised (Kandasamy *et al*., 2014). MC 0.75%, GMS 3% and EA 15% produced highest foam expansion of 72, 90 and 125%, respectively with papaya pulp concentration of 9ºBrix. These foam slurries were uniformly spread at 2, 4, 6 and 8 mm thicknesses in the non-stick food-grade Teflon coated stainless steel trays. The foam layer thickness was determined by dividing the known volume of foam by drying area. The foams were dried at 60, 65 and 70ºC with an air flow rate of 2.25 m3/min using batch type cabinet drier (Model: 024E, Kilburn Engineering Ltd, Kolkata, India). The drying temperatures used by previous studies ranged between 50 and 80ºC for foam-mat drying of various food materials (Sangamithra *et al*., 2015). The dried products were scrapped after cooling the trays to room temperature, ground to a fineness of 250 µm using food processor (Icon Superb 1000W, Morphy Richards, Mumbai, India), packed immediately in 75 µm thick polyethylene bags and sealed to prevent caking. The powder samples were stored at room temperature (30ºC) for evaluation of physicochemical characteristics.

Determination of physical properties

Moisture content

During drying, the moisture content of the sample was determined at regular interval using a digital electronic balance (Citizen Instruments, Pune, India) on initial and final weight basis. The drying was ceased when two consecutive readings appeared similar. The moisture content was calculated using Eq. 1:

$$\text{Moisture content (\%)} = \frac{W_m}{W_d} \times 100 \qquad \text{(Eq. 1)}$$

where, W_m = weight of moisture in the sample (g); W_d = weight of dry matter of the sample (g).

Bulk density

The bulk density (g/cm3) of the foam-mat dried papaya powder was determined as described by Chegini and Ghobadian (2005). Briefly, 5 g of powder sample was placed in a 25 mL graduated measuring cylinder, the cylinder was gently tapped 10 to 15 times onto a rubber mat from a height of 15 cm to settle down the powder and the final volume of the powder was measured using Eq. 2:

$$\rho_b = \frac{M_p}{V_p} \qquad \text{(Eq. 2)}$$

where, M_p = mass of the powder sample (g); and V_p = volume of powder sample (cm^3)

Water solubility index and water absorption index

Solubility is one of the important physical parameters of the powder that indicates the rate of dispersing or rehydration ability in a liquid medium. Water absorption index is the weight of water absorbed per gram of dry powder sample. Water solubility index and water absorption index of the foam-mat dried papaya powder were determined as described by Grabowski *et al*. (2006). Briefly, 5 g of powder sample was dissolved in 100 mL of distilled water in a beaker at room temperature (30ºC) and stirred for 20 min. The juice concentrate was centrifuged at 12,000 rpm for 10 min using a digital centrifuge machine (T-10M, Laby Instruments Industry, Ambala Cantt, India). The supernatant solution was carefully transferred into a Petri dish and dried in a hot air oven at 130ºC. The solids in dried supernatant was weighed and used to determine the water solubility index (%) using Eq. 3. The water absorption index was calculated by the ratio of weight of wet solids remaining in the centrifuge tube to the dry weight of initial powder sample using Eq. 4:

$$WSI = \frac{W_{ds}}{W_p} \times 100 \qquad \text{(Eq. 3)}$$

$$WAI = \frac{W_{ws}}{W_p} \qquad \text{(Eq. 4)}$$

where, W_{ds} = weight of dry solids in dried supernatant (g); Wws = weight of wet solids remaining after centrifugation (g); and W_p = weight of initial dried powder sample (g).

Rehydration ratio

The rehydration ratio was determined as described by Rajkumar *et al*. (2007a). Briefly, 5 g of foam-mat dried papaya powder sample was thoroughly dissolved in 100 mL of distilled water at room temperature (30ºC). The resulted filtrate was weighed and used as weight of rehydrated sample. The rehydration ratio was calculated using Eq. 5:

$$RR = \frac{W_r}{W_d} \qquad \text{(Eq. 5)}$$

where, W_r = weight of rehydrated sample (g); and W_d = weight of dehydrated sample (g).

Determination of chemical characteristics

The quality of resulting products plays an important role in the success of a preservation method. Therefore, the chemical quality of foam-mat dried papaya fruit powder was evaluated for vitamin C, β-carotene, total sugars, titratable acidity, total soluble solids (TSS) and pH. In order to distinguish any relative changes in chemical quality characteristics of the dried product during foam-mat drying, the freshly harvested ripe papaya fruit was also analysed for quality attributes, and served as control.

The vitamin C content was estimated by the 2, 6-dichlorophenol-indophenol visual titration method (Ranganna, 1986). The β-carotene content was estimated as described by Ranganna (1986). The total sugars were determined by the phenol sulphuric acid method (Sadasivam, 1996). The titratable acidity was estimated as described by Ranganna (1986). The TSS and pH were determined according to AOAC (1995). For the determination of TSS and pH level, juice concentrate was prepared by reconstituting the foam-mat dried papaya powder in distilled water in the ratio of 1:20 (powder:water). The juice concentrate was centrifuged at a speed of 12,000 rpm for 10 min using a digital centrifuge machine (T-10M, Laby Instruments Industry, Ambala Cantt, India). The supernatant was collected, and a drop of supernatant was placed on the prism of the handheld refractometer (Master-53a, Atago, Japan) and TSS level was measured in ºBrix. The supernatant was also used for the determination of pH using a digital pH meter (Type-335, Systronics India Ltd, Ahmedabad, India).

Sensory evaluation

The sensory evaluation of foam-mat dried papaya fruit powder was carried out as described by Ranganna (1986). Papaya juice concentrate was prepared in the concentration of 12.5ºBrix from each sample of foam-mat dried papaya powder by dissolving the powder in distilled water in the ratio of 1:20. Fresh papaya fruit juice (12.5ºBrix) was also prepared for comparison. The acceptability of the product (colour, flavour, taste, overall acceptability) was evaluated by a panel of 10 judges using 9-point hedonic scale rating (where, 9 = extremely like, and 1 = extremely dislike). The panel members included male and female staff members (age between 25 and 60 years) of the Department of Food and Agricultural Processing Engineering, Tamil Nadu Agricultural University, India. Each member assessed the product quality according to their individual perception.

Statistical analysis

Each experimental analysis of physicochemical characteristics was carried out in triplicate (n = 3) and the average values of each experiment with standard deviations were reported. Completely randomised block design was adopted in the present work. The obtained data were analysed statistically using the SPSS software (version 16.0.0 software, SPSS Inc., Chicago, USA). To test the difference between the average values, the Least Significant Difference (LSD) method was adopted, and the significance was defined at the level of 5%. Sensory evaluation was tested with 10 replications (n = 10) and significance was defined at 1% level.

Results and discussion

Moisture content

The moisture content of the foam-mat dried papaya fruit powder varied between 4.56% (db) and 8.34% (db) depending on the foam layer thickness and drying temperature (Table 1). The foam layer thickness and temperature had a significant ($p \leq 0.05$) effect on moisture content. The moisture content showed an increasing trend with increasing foam layer thicknesses. On the other hand, the moisture content was significantly decreased with increasing drying temperatures. The drying time of 2, 4, 6 and 8 mm foam layer thicknesses was 2.0, 3.5, 4.5 and 6.0 h, respectively at 60ºC and 1.0, 2.5, 3.5 and 5.0 h, respectively at 65ºC. and 1.0, 1.5, 3.0 and 5.0 h, respectively at 70ºC. These results agree with that reported by Falade *et al*. (2003) for drying of cowpea foams that the moisture content decreased with decreasing foam layer thicknesses. Salahi *et al*. (2015) also reported that the moisture reduction rate of cantaloupe foams was low with increasing foam layer thicknesses.

Bulk density

Bulk density is one of the important physical characteristics for predicting the functional properties of powder. Bulk density is directly affected by moisture content, particle size, pore space and compaction profile. Powder with higher bulk density can be stored in smaller packages and provides perception to product appearance, rehydration, packaging and transportation. Bulk density decreases at higher moisture as the tendency of particles to adhere to each other which creates more pores within them thereby resulting in the increase in bulk volume of powder (Chegini and Ghobadian, 2005). In the present work, the bulk density of foam-mat dried papaya powder varied between 0.463 and 0.498 g/cm3, and showed a decreasing trend with increasing foam layer thicknesses (Table 1). The reduction in bulk density may be due to higher moisture content in the powder obtained from higher foam layer thickness. However, statistically, the foam layer thicknesses were not significantly different ($p \geq 0.05$). Similar results were reported by Oguntunde and Adeojo (1992) for foam-mat dried whole milk powder, and Falade and Omojola (2010) for dehydration of okra foams.

Table 1. Effect of drying temperatures, foaming agents and foam layer thicknesses on physical characteristics of foam-mat dried papaya fruit powder.

Drying temperature (ºC)	Foaming agent	FLT (mm)	Moisture content (%), dry basis	Bulk density (kg/cm^3)	Water solubility index (%)	Water absorption index	Rehydration ratio
60	MC	2	5.26 ± 0.04^a	0.49 ± 0.02^a	62.54 ± 0.63^d	4.16 ± 0.26^c	3.15 ± 0.10^a
		4	6.57 ± 0.06^b	0.48 ± 0.02^a	61.62 ± 0.88^e	4.32 ± 0.18^d	3.17 ± 0.07^a
		6	7.73 ± 0.08^c	0.47 ± 0.01^a	60.76 ± 0.77^f	4.50 ± 0.32^d	3.20 ± 0.12^a
		8	8.34 ± 0.13^d	0.46 ± 0.02^a	60.14 ± 0.84^f	4.62 ± 0.29^d	3.25 ± 0.17^a
	GMS	2	5.31 ± 0.05^a	0.48 ± 0.03^a	62.58 ± 0.67^d	4.18 ± 0.25^c	3.15 ± 0.13^a
		4	6.49 ± 0.07^b	0.48 ± 0.03^a	61.67 ± 0.81^e	4.36 ± 0.17^d	3.21 ± 0.08^a
		6	7.65 ± 0.06^c	0.47 ± 0.02^a	60.79 ± 0.73^f	4.57 ± 0.32^d	3.24 ± 0.11^a
		8	8.28 ± 0.15^d	0.47 ± 0.01^a	60.24 ± 0.82^f	4.61 ± 0.28^d	3.28 ± 0.18^a
	EA	2	5.28 ± 0.05^a	0.45 ± 0.02^a	62.52 ± 0.63^d	4.19 ± 0.24^c	3.17 ± 0.11^a
		4	6.53 ± 0.06^b	0.49 ± 0.02^a	61.60 ± 0.82^e	4.37 ± 0.16^d	3.21 ± 0.05^a
		6	7.69 ± 0.10^c	0.48 ± 0.01^a	60.74 ± 0.75^f	4.55 ± 0.30^d	3.23 ± 0.17^a
		8	8.31 ± 0.14^d	0.46 ± 0.02^a	60.19 ± 0.82^f	4.66 ± 0.29^d	3.28 ± 0.14^a
65	MC	2	4.94 ± 0.09^a	0.50 ± 0.01^a	63.82 ± 0.94^c	4.02 ± 0.10^b	3.16 ± 0.08^a
		4	6.14 ± 0.07^b	0.49 ± 0.01^a	63.13 ± 1.08^c	4.08 ± 0.14^b	3.26 ± 0.04^a
		6	7.05 ± 0.10^c	0.48 ± 0.00^a	62.71 ± 1.33^d	4.12 ± 0.21^b	3.31 ± 0.08^a
		8	7.91 ± 0.06^d	0.47 ± 0.02^a	62.05 ± 0.61^d	4.15 ± 0.15^c	3.38 ± 0.16^a
	GMS	2	4.92 ± 0.10^a	0.49 ± 0.01^a	63.83 ± 0.91^c	4.06 ± 0.12^b	3.18 ± 0.06^a
		4	6.26 ± 0.09^b	0.48 ± 0.01^a	63.15 ± 1.05^c	4.10 ± 0.14^b	3.25 ± 0.08^a
		6	7.10 ± 0.13^c	0.48 ± 0.00^a	62.76 ± 1.31^d	4.15 ± 0.18^b	3.28 ± 0.05^a
		8	7.87 ± 0.08^d	0.47 ± 0.02^a	62.09 ± 0.57^d	4.17 ± 0.18^c	3.34 ± 0.16^a
	EA	2	4.97 ± 0.09^a	0.52 ± 0.02^a	63.84 ± 0.91^c	4.04 ± 0.11^b	3.14 ± 0.05^a
		4	6.27 ± 0.07^b	0.51 ± 0.01^a	63.18 ± 1.08^c	4.06 ± 0.15^b	3.23 ± 0.04^a
		6	7.27 ± 0.10^c	0.49 ± 0.01^a	62.75 ± 1.30^d	4.15 ± 0.15^b	3.28 ± 0.03^a
		8	7.85 ± 0.06^d	0.47 ± 0.03^a	62.09 ± 0.63^d	4.14 ± 0.17^c	3.34 ± 0.12^a
70	MC	2	4.57 ± 0.08^a	0.49 ± 0.00^a	65.68 ± 0.67^a	3.92 ± 0.03^a	3.15 ± 0.09^a
		4	5.98 ± 0.09^a	0.49 ± 0.01^a	65.13 ± 0.51^a	3.94 ± 0.08^a	3.17 ± 0.16^a
		6	6.45 ± 0.11^b	0.48 ± 0.00^a	64.86 ± 1.87^b	4.06 ± 0.14^b	3.25 ± 0.16^a
		8	6.94 ± 0.10^c	0.48 ± 0.01^a	64.17 ± 0.64^b	4.10 ± 0.15^c	3.34 ± 0.13^a
	GMS	2	4.58 ± 0.08^a	0.49 ± 0.00^a	65.65 ± 0.67^a	3.95 ± 0.03^a	3.16 ± 0.10^a
		4	5.87 ± 0.09^a	0.49 ± 0.01^a	65.16 ± 0.51^a	3.96 ± 0.08^a	3.21 ± 0.16^a
		6	6.42 ± 0.11^b	0.48 ± 0.00^a	64.81 ± 1.77^b	4.08 ± 0.14^b	3.28 ± 0.15^a
		8	6.87 ± 0.10^c	0.47 ± 0.01^a	64.21 ± 0.64^b	4.13 ± 0.15^c	3.38 ± 0.16^a
	EA	2	4.56 ± 0.08^a	0.49 ± 0.00^a	65.61 ± 0.67^a	3.97 ± 0.03^a	3.18 ± 0.10^a
		4	5.78 ± 0.10^a	0.48 ± 0.01^a	65.22 ± 0.51^a	3.91 ± 0.08^a	3.26 ± 0.14^a
		6	6.38 ± 0.11^b	0.48 ± 0.00^a	64.76 ± 1.73^b	4.11 ± 0.14^b	3.31 ± 0.15^a
		8	6.82 ± 0.11^c	0.46 ± 0.01^a	64.26 ± 0.60^b	4.18 ± 0.16^c	3.36 ± 0.15^a

Data are means ± SD of three replicates (n = 3). Mean values with different superscript in each column showed significant difference ($p \leq 0.05$). FLT foam layer thickness, MC methyl cellulose, GMS glycerol monostearate, EA egg albumin.

Water Solubility Index (WSI)

An ideal powder is characterised by its rapid wettability, sink instead of floating, and ability to dissolve in water without formation of lumps and cake (Hogekamp and Schubert, 2003). WSI measures the ability of solids to absorb water and amount of soluble solids released from the powder. Drying conditions mainly affects the water absorption, distribution and dispersion ability in powder (Azizpour *et al*., 2016). In the present work, the WSI of foam-mat dried papaya powder ranged between 60.14 and 62.54%, 62.05 and 63.82%, 64.17 and 65.68% at 60, 65 and 70ºC respectively. The WSI significantly increased ($p \leq 0.05$) with increasing drying temperatures from 60 to 70ºC. A decreasing trend was however observed in the WSI as the foam layer thickness increased from

2 to 8 mm (Table 1). This may be due to the fact that higher foam layer thickness takes longer time to complete the drying process which leads to greater protein denaturation, thus reduced WSI (Franco *et al*., 2016). Particle size distribution is when fine particles have the ability to completely dissolve in water as compared to the course particles (Akintoye and Oguntunde, 1991). Similar trends in WSI were observed by Wilson *et al*. (2014) for foam-mat dried mango powder, and Azizpour *et al*. (2016) for foam-mat dried shrimp powder.

Water Absorption Index (WAI)

The WAI of the foam-mat dried papaya powder was found to increase with increasing foam layer thicknesses. On the other hand, the WAI decreased with increasing drying temperatures. The drying temperature had a significant influence ($p \leq 0.05$) on the reduction in WAI (Table 1). The changes in WAI were in the ranges of 4.16 to 4.62, 4.02 to 4.15, and 3.92 to 4.10 at 60, 65 and 70ºC, respectively. The reduction in the WAI at higher drying temperatures may be due to denaturation of proteins (Franco *et al*., 2016). Similar trends in WAI were observed by Wilson *et al*. (2014) for foam-mat dried mango powder, and Azizpour *et al*. (2016) for foam-mat dried shrimp powder. Powders with high WAI can be used as food additives owing to their high water absorption even at low temperature.

Rehydration ratio

The potential of powder to rehydrate in water can be measured by the rehydration ratio. Rehydration is a multi-stage process in which water absorption transfers to the porous network, distribution within the solid matrix, swelling of solid matrix and dissolving the solids into the aqueous medium (Bhandari *et al*., 2013). In the present work, the rehydration ratio of foam-mat dried papaya powder was found between 3.15 and 3.38 (Table 1). The powder of lower bulk density showed a higher rehydration ratio. The rehydration of dried food products is mainly affected by the physical characteristics such as particle size distribution, bulk density, porosity and internal molecular structure. Rehydration occurs when free hydroxyl group in foaming agents sticks to water molecules from surrounding medium (Franco *et al*., 2015).

Vitamin C

The vitamin C content of freshly harvested ripe papaya fruit was determined as 156.18 mg/100 g fresh pulp (Table 2) whereas it was ranged between 76.03 and 152.10 mg/100 g sample in the foam-mat dried papaya powder (Table 3). The results showed that the vitamin C content of the dried powder was significantly reduced as compared to the freshly harvested ripe papaya fruit. This may be due to the destructive effect of the thermal treatment causing degradation of the vitamin C. The drying temperature, foaming agents and foam layer thickness had a significant effect ($p \leq 0.05$) on vitamin C reduction. It was observed that the vitamin C decreased as the drying temperature increased. For instance, at 60ºC, the vitamin C content ranged between 101.06 and 152.10 mg/100 g sample whereas at 65 and 70ºC, it was 90.02 to 139.09 mg/100 g sample and 76.03 to 125.06 mg/100 g sample, respectively depending on the foaming agents and foam layer thicknesses (Table 3). The losses in vitamin C increased with increasing foam layer thicknesses because the higher foam layer thicknesses (6 and 8 mm) were exposed in hot air for longer time to dry up than lower foam layer thicknesses (2 and 4 mm). Therefore, the degradation of vitamin C was more at higher foam layer thickness. EA treated papaya powder retained higher vitamin C content (112.06 to 152.10 mg/100 g sample) followed by MC treated (76.09 to 125.04 mg/100 g sample) and GMS treated (76.02 to 104.09 mg/100 g sample) depending on drying temperatures and foam layer thicknesses. The stability of EA treated foamed papaya pulp during drying may be the cause of the retained vitamin C content. Statistical analysis showed that the EA treated foamed pulp dried at 60ºC with 2 and 4 mm foam layer thicknesses was found to be the best. Similar decline in vitamin C content at increasing drying temperature was noticed in other foam-mat drying studies with mango (Rajkumar *et al*., 2007b) and tomato (Kadam *et al*., 2012).

Table 2. Chemical characteristics of freshly harvested ripe papaya fruit.

Chemical characteristic	Value
TSS (°Brix)	13.02 ± 0.03
pH	5.23 ± 0.02
Titratable acidity (%)	0.34 ± 0.01
Total sugars (g/100 g sample)	37.83 ± 0.01
Vitamin C (mg/100 g sample)	156.18 ± 0.02
β–carotene (mg/100 g sample)	5.13 ± 0.02
Moisture content (%), wet basis	85.24 ± 0.03

Data are means ± SD of three replicates ($n = 3$).

β-carotene content

The β-carotene content of the freshly harvested ripe papaya fruit was 5.13 mg/100 g fresh pulp (Table 2) whereas it was ranged between 4.73 and 5.09 mg/100 g sample in the foam-mat dried papaya fruit powder (Table 3). The results showed that the β-carotene content decreased significantly during the drying process. This decline in β-carotene may be due to its heat sensitive nature. The drying temperature, foaming agents and foam layer thickness had a significant effect ($p \leq 0.05$) on β-carotene content. The β-carotene content of the dried papaya powder showed a decreasing trend with increasing drying temperatures and foam layer thicknesses. At 60ºC, the β-carotene ranged between 4.84 and 5.14 mg/100 g sample whereas at 65 and 70ºC, it was 4.83 to 5.03 mg/100 g sample and 4.74 to 4.97 mg/100 g sample, respectively depending on the foaming agents and foam layer thicknesses (Table 3). The β-carotene level decreased with increasing foam layer thicknesses. This could be due to prolonged exposure to heat treatment thereby resulting in the destruction of β-carotene. Among the foaming agents used, EA treated papaya powder retained higher β-carotene content (4.92 to 5.09 mg/100 g sample) as compared to MC and GMS treated papaya fruit powder (4.73 to 4.92 mg/100 g sample). This may be due to stability of EA foam that reduced the drying time thereby leading to small loss in β-carotene. The statistical analysis showed that the treatment combination of EA treated foamed papaya pulp dried at 60ºC with 2 and 4 mm foam layer thicknesses were found best among the treatments. Rajkumar *et al*. (2007b) and Kadam *et al*. (2010) also reported similar decline in β-carotene content of foam-mat dried mango powder with increasing drying temperatures and foam thicknesses.

Total sugars

The total sugars level in freshly harvested ripe papaya fruit was 37.83 g/100 g sample (Table 2) whereas in foam-mat dried papaya fruit powder, it was 35.02 and 36.84 g/100 g sample (Table 3). Foaming agents, drying temperatures and foam layer thicknesses had a significant influence ($p \leq 0.05$) over total sugars level of papaya fruit powder. The total sugars level in papaya fruit powder showed a decreasing trend with increasing drying temperatures. The total sugars level at 60, 65 and 70ºC were 36.84 to 36.19, 36.47 to 35.42 and 35.91 to 35.02 g/100 g sample, respectively depending on the foaming agents and foam layer thicknesses. The reduction trend in total sugars was also observed with increasing foam layer thickness (Table 3). This could be due to the fact that higher foam layer thickness took longer time to complete the drying process than lower foam layer thickness. Thus, there may a loss of sugars due to prolonged exposure to heat treatment. GMS treated papaya fruit powder showed significantly higher total sugars than MC and EA treated papaya powder. Overall, GMS treated foamed papaya pulp dried at 60ºC with 2 and 4 mm foam layer thicknesses retained significantly higher total sugars as compared to other treatments. Similar trends in total sugars were reported for foam-mat dried mango powder (Rajkumar *et al*., 2007b; Kadam *et al*., 2010), and tomato powder (Kadam *et al*., 2012).

Titratable acidity

The level of titratable acidity in the freshly harvested ripe papaya fruit was 0.33% (Table 2), and in the foam-mat dried papaya fruit powder was 0.40 and 1.56% (Table 3). The increase in titratable acidity may be due to the influence of foaming agents. Statistical analysis showed that the drying temperatures and foam layer thicknesses had no significant effect ($p \geq 0.05$) on titratable acidity whereas the foaming agents had a significant effect (Table 3). However, EA treated papaya powder had a significantly higher titratable acidity (1.50 to 1.54%) as compared to MC treated (0.40 to 0.42%) and GMS treated (0.75 to 0.77%). Similar observations were reported on titratable acidity of foam-mat dried mango powder (Rajkumar *et al*., 2007b; Kadam *et al*., 2010), and banana powder (Falade and Okocha, 2012).

Total Soluble Solids (TSS)

The TSS of freshly harvested ripe papaya fruit was 13.02ºBrix (Table 2) and in the foam-mat dried papaya fruit powder was 12.35 and 12.63ºBrix (Table 3). The drying temperatures and foam layer thicknesses had a significant effect ($p \leq 0.05$) on the reduction in TSS level of the papaya fruit powder. This reduction in TSS content could be due to the heat sensitive nature when exposed to higher drying temperature. Moreover, this reduction was slightly higher at elevated drying temperature (65 and 70ºC) as compared to 60ºC. It was also observed that its reduction was slightly higher when increasing foam layer thickness. This may be due to the fact that higher foam thicknesses took longer drying time to dry up than the lower foam layer thickness. On the other hand, the foaming agents had no significant effect ($p \geq 0.05$) on TSS content. Overall, the foam-mat drying condition had not much effect on TSS. These results agree with that reported for foam-mat dried mango powder (Rajkumar *et al*., 2007b; Kadam *et al*., 2010).

pH

In general, fruits are acidic in nature with pH value ranges between 2.0 and 6.8 (USFDA, 2007) and a low range of pH is recommended for safety point of view. The average pH content of the freshly harvested

Table 3. Effect of drying temperatures, foaming agents and foam layer thicknesses on chemical characteristics of foam-mat dried papaya fruit powder.

Drying temperature (ºC)	Foaming agent	FLT (mm)	Vitamin C (mg/100 g sample)	β-carotene (mg/100 g sample)	Total sugar (g/100 g sample)	Titratable acidity (%)	Total soluble solid (ºBrix)	pH
60	MC	2	125.02 ± 0.06^{e}	4.92 ± 0.06^{b}	36.47 ± 0.09^{a}	0.42 ± 0.02^{a}	12.52 ± 0.05^{a}	4.91 ± 0.05^{a}
		4	124.34 ± 0.07^{e}	4.91 ± 0.06^{b}	36.31 ± 0.04^{a}	0.42 ± 0.01^{a}	12.60 ± 0.05^{a}	4.92 ± 0.04^{a}
		6	118.05 ± 0.08^{g}	4.94 ± 0.04^{b}	36.21 ± 0.06^{a}	0.41 ± 0.02^{a}	12.45 ± 0.05^{a}	4.98 ± 0.05^{b}
		8	118.07 ± 0.05^{g}	4.93 ± 0.06^{b}	36.19 ± 0.07^{b}	0.41 ± 0.03^{a}	12.46 ± 0.06^{a}	4.93 ± 0.03^{a}
	GMS	2	104.09 ± 0.04^{i}	4.91 ± 0.03^{b}	36.84 ± 0.04^{a}	0.76 ± 0.02^{b}	12.51 ± 0.05^{a}	4.89 ± 0.04^{a}
		4	104.06 ± 0.06^{i}	4.92 ± 0.04^{b}	36.78 ± 0.04^{a}	0.75 ± 0.03^{b}	12.45 ± 0.05^{a}	4.86 ± 0.03^{a}
		6	102.08 ± 0.02^{j}	4.84 ± 0.03^{c}	36.53 ± 0.05^{a}	0.75 ± 0.02^{b}	12.47 ± 0.06^{a}	4.87 ± 0.03^{a}
		8	101.76 ± 0.07^{j}	4.84 ± 0.02^{c}	36.31 ± 0.06^{a}	0.76 ± 0.04^{b}	12.42 ± 0.08^{a}	4.83 ± 0.04^{a}
	EA	2	152.10 ± 0.02^{a}	5.14 ± 0.03^{a}	36.81 ± 0.02^{a}	1.52 ± 0.03^{c}	12.63 ± 0.05^{a}	5.08 ± 0.07^{b}
		4	151.38 ± 0.05^{a}	5.12 ± 0.03^{a}	36.76 ± 0.03^{a}	1.52 ± 0.02^{c}	12.50 ± 0.05^{a}	5.10 ± 0.03^{b}
		6	146.08 ± 0.04^{b}	5.09 ± 0.05^{a}	36.68 ± 0.03^{a}	1.51 ± 0.01^{c}	12.42 ± 0.07^{a}	5.03 ± 0.03^{b}
		8	142.08 ± 0.03^{c}	5.04 ± 0.04^{a}	36.52 ± 0.03^{a}	1.51 ± 0.02^{c}	12.42 ± 0.07^{a}	5.07 ± 0.04^{b}
65	MC	2	97.06 ± 0.04^{k}	4.92 ± 0.05^{b}	36.28 ± 0.06^{a}	0.42 ± 0.02^{a}	12.53 ± 0.06^{a}	4.94 ± 0.03^{a}
		4	97.04 ± 0.06^{k}	4.90 ± 0.06^{b}	36.18 ± 0.06^{b}	0.41 ± 0.02^{a}	12.44 ± 0.07^{a}	5.03 ± 0.06^{b}
		6	92.08 ± 0.05^{l}	4.85 ± 0.04^{c}	36.12 ± 0.04^{b}	0.42 ± 0.02^{a}	12.37 ± 0.07^{b}	4.92 ± 0.03^{a}
		8	90.11 ± 0.07^{m}	4.83 ± 0.03^{c}	36.05 ± 0.03^{b}	0.40 ± 0.02^{a}	12.30 ± 0.08^{b}	4.94 ± 0.04^{a}
	GMS	2	97.02 ± 0.05^{k}	4.92 ± 0.03^{b}	36.47 ± 0.08^{a}	0.76 ± 0.03^{b}	12.43 ± 0.03^{a}	4.88 ± 0.07^{a}
		4	96.45 ± 0.05^{k}	4.89 ± 0.03^{b}	36.35 ± 0.07^{a}	0.76 ± 0.01^{b}	12.35 ± 0.05^{b}	4.84 ± 0.04^{a}
		6	90.07 ± 0.09^{m}	4.83 ± 0.04^{c}	36.27 ± 0.06^{a}	0.77 ± 0.02^{b}	12.42 ± 0.08^{a}	5.03 ± 0.03^{b}
		8	85.07 ± 0.07^{o}	4.81 ± 0.03^{c}	36.15 ± 0.03^{b}	0.76 ± 0.04^{b}	12.40 ± 0.01^{b}	4.97 ± 0.06^{b}
	EA	2	139.09 ± 0.02^{d}	5.03 ± 0.03^{a}	35.82 ± 0.04^{c}	1.53 ± 0.03^{c}	12.52 ± 0.05^{a}	5.09 ± 0.05^{b}
		4	139.06 ± 0.06^{d}	5.01 ± 0.03^{a}	35.68 ± 0.07^{c}	1.53 ± 0.02^{c}	12.42 ± 0.06^{a}	4.99 ± 0.07^{b}
		6	139.08 ± 0.06^{d}	4.96 ± 0.05^{b}	35.51 ± 0.02^{c}	1.53 ± 0.03^{c}	12.42 ± 0.07^{a}	5.02 ± 0.06^{b}
		8	125.09 ± 0.07^{e}	4.93 ± 0.03^{b}	35.42 ± 0.03^{c}	1.54 ± 0.03^{c}	12.40 ± 0.06^{b}	4.96 ± 0.09^{b}
70	MC	2	90.10 ± 0.09^{m}	4.83 ± 0.03^{c}	35.81 ± 0.05^{c}	0.41 ± 0.02^{a}	12.42 ± 0.05^{a}	4.91 ± 0.03^{a}
		4	87.06 ± 0.05^{n}	4.81 ± 0.04^{c}	35.67 ± 0.02^{c}	0.41 ± 0.02^{a}	12.35 ± 0.06^{b}	4.89 ± 0.04^{a}
		6	83.04 ± 0.07^{p}	4.77 ± 0.05^{d}	35.52 ± 0.02^{c}	0.40 ± 0.01^{a}	12.40 ± 0.05^{b}	4.88 ± 0.06^{a}
		8	76.09 ± 0.05^{s}	4.74 ± 0.03^{d}	35.47 ± 0.04^{c}	0.42 ± 0.02^{a}	12.37 ± 0.05^{b}	4.81 ± 0.05^{a}
	GMS	2	83.06 ± 0.07^{p}	4.94 ± 0.03^{b}	35.91 ± 0.03^{c}	0.76 ± 0.01^{b}	12.37 ± 0.05^{b}	4.99 ± 0.07^{b}
		4	81.08 ± 0.03^{q}	4.87 ± 0.03^{b}	35.85 ± 0.02^{c}	0.77 ± 0.02^{b}	12.35 ± 0.05^{b}	4.99 ± 0.04^{b}
		6	78.02 ± 0.08^{r}	4.83 ± 0.04^{c}	35.76 ± 0.04^{c}	0.77 ± 0.02^{b}	12.40 ± 0.06^{b}	4.93 ± 0.06^{a}
		8	76.03 ± 0.05^{s}	4.82 ± 0.03^{c}	35.54 ± 0.04^{c}	0.76 ± 0.03^{b}	12.43 ± 0.06^{b}	4.86 ± 0.06^{a}
	EA	2	125.06 ± 0.05^{e}	4.97 ± 0.04^{b}	35.21 ± 0.05^{d}	1.50 ± 0.02^{c}	12.50 ± 0.05^{a}	4.98 ± 0.08^{b}
		4	121.04 ± 0.08^{f}	4.95 ± 0.03^{b}	35.16 ± 0.05^{d}	1.51 ± 0.02^{c}	12.50 ± 0.08^{a}	4.97 ± 0.06^{b}
		6	118.03 ± 0.09^{g}	4.87 ± 0.04^{c}	35.10 ± 0.04^{d}	1.50 ± 0.02^{c}	12.37 ± 0.05^{b}	5.03 ± 0.07^{b}
		8	112.06 ± 0.10^{h}	4.85 ± 0.02^{c}	35.02 ± 0.02^{d}	1.51 ± 0.02^{c}	12.40 ± 0.07^{b}	5.06 ± 0.08^{b}

Data are means ± SD of three replicates (n = 3). Mean values with different superscript in each column showed significant difference ($p \leq 0.05$). FLT foam layer thickness, MC methyl cellulose, GMS glycerol monostearate, EA egg albumin.

ripe papaya fruit was 5.20 (Table 2) whereas the pH value in the foam-mat dried papaya fruit powder juice ranged between 4.80 and 5.10 (Table 3). It was found that drying temperatures and foam layer thicknesses had no significant effect ($p \geq 0.05$) on the pH content. Among the treatments, EA treatment showed significantly higher pH as compared to the other treatments. The pH value of EA treated papaya powder was approximately equal to the pH of freshly harvested fruit. The alkaline nature of egg albumin could have increased thes pH level of EA treated papaya powder samples. The pH level of hen's egg

Table 4. Sensory characteristics of reconstituted foam-mat dried papaya fruit powder under different conditions.

Drying temperature (ºC)	Foaming agent	Sensory characteristic			
		Colour	Flavour	Taste	Overall acceptability
Control	Fresh juice	6.32 ± 0.03[a]	6.74 ± 0.02[a]	6.85 ± 0.04[a]	6.69 ± 0.03[a]
60	GMS	6.26 ± 0.02[a]	6.71 ± 0.05[a]	6.83 ± 0.07[a]	6.65 ± 0.03[a]
	MC	6.15 ± 0.03[a]	6.62 ± 0.04[a]	6.71 ± 0.04[a]	6.57 ± 0.05[a]
	EA	5.84 ± 0.06[b]	6.55 ± 0.02[a]	6.07 ± 0.06[b]	6.23 ± 0.06[b]
65	GMS	6.21 ± 0.02[a]	6.48 ± 0.04[b]	6.54 ± 0.05[a]	6.32 ± 0.03[b]
	MC	6.08 ± 0.03[b]	6.42 ± 0.04[b]	6.46 ± 0.06[a]	6.21 ± 0.04[b]
	EA	5.82 ± 0.03[b]	6.27 ± 0.08[c]	6.04 ± 0.09[b]	6.07 ± 0.07[c]
70	GMS	5.78 ± 0.05[c]	6.38 ± 0.06[b]	6.48 ± 0.07[a]	5.96 ± 0.06[c]
	MC	5.73 ± 0.04[c]	6.38 ± 0.06[b]	6.27 ± 0.09[a]	5.93 ± 0.07[c]
	EA	5.73 ± 0.06[c]	6.26 ± 0.08[c]	6.05 ± 0.08[b]	5.91 ± 0.09[c]

Data are means ± SD of ten replicates (n = 10). Mean values with different superscript in each column showed significant difference ($p \leq 0.01$). MC methyl cellulose, GMS glycerol monostearate, EA egg albumin.

albumin ranges from 7.6 to 9.7 (Brown, 2010). These results agree with the findings for foam-mat dried mango powder (Rajkumar *et al*., 2007b; Kadam *et al*., 2010), tomato powder (Kadam *et al*., 2012), and banana powder (Falade and Okocha, 2012).

Sensory attributes

Powder obtained from 2 and 4 mm foam layer thicknesses showed better physicochemical characteristics as compared to 6 and 8 mm at all drying conditions. Since, the powder obtained from 2 and 4 mm showed similar quality characteristics, powder of 4 mm foam layer thickness was selected for sensory evolution. Juice was prepared from this powder and was compared with fresh papaya fruit juice. The influence of different foaming agents and drying temperatures on sensory characteristics (colour, flavour, taste and overall acceptability) of reconstituted papaya fruit powder is presented in Table 4. At 60ºC, the sensory scores of 5.84 to 6.26, 6.55 to 6.71, 6.07 to 6.83 and 6.23 to 6.65 were recorded on colour, flavour, taste, and overall acceptability, respectively. At 65ºC, the sensory scores of 5.82 to 6.21, 6.27 to 6.48, 6.04 to 6.54 and 6.07 to 6.32 were recorded on colour, flavour, taste, and overall acceptability, respectively. Similarly, the sensory scores of 5.73 to 5.78, 6.26 to 6.38, 6.05 to 6.48 and 5.91 to 5.96 were recorded on colour, flavour, taste, and overall acceptability, respectively at 70ºC. The fresh fruit juice received significantly higher sensory scores of 6.32, 6.74, 6.85 and 6.64 on colour, flavour, taste, and overall acceptability, respectively as compared to foam-mat dried papaya powder juice. It was also found that the sensory scores on colour, flavour, taste, and overall acceptability decreased significantly ($p \leq 0.01$) with increasing drying temperatures. The decreasing trend in sensory quality may be due to the loss of organoleptic properties at higher drying temperature. It was obvious that the heating temperature at 60ºC at different foaming agents gave higher overall acceptance than 65 and 70ºC ($p \leq 0.01$). Similar trends were reported for sensory quality of foam-mat dried tamarind powders (Vernon-Carter *et al*., 2001), banana paste (Falade and Okocha, 2012), and sea buckthorn (*Hippophae salicifolia*) leather (Kaushal *et al*., 2013).

Conclusion

In the present work, papaya fruit powder was prepared by foam-mat drying method and some physicochemical quality characteristics of powder were tested for its suitability in preservation of papaya in the form of powder. Higher foam layer thickness with lower drying temperature took longer time to dry up. The moisture content of powder varied between 4.56 and 8.34% on dry basis. The bulk density decreased at higher foam layer thickness and the rehydration ratio increased in the powder of lower bulk density. The water solubility increased at higher drying temperature whereas decreased at higher foam layer thickness. The water absorption index decreased at higher drying temperature and increased at higher foam layer thickness. Vitamin-C, β-carotene, total sugars and TSS significantly decreased at higher drying temperature and foam layer thickness. No significant changes in titratable acidity and Ph were observed. Egg albumin treated foamed papaya pulp dried at 60ºC with 2 and 4 mm foam layer thicknesses retained significantly higher physicochemical quality characteristics whereas glycerol monostearate treated papaya powder had better sensory ratings on colour, flavour, taste, and overall acceptability. It is thus concluded that the papaya fruit powder can be preserved using foam-mat drying without losing much of its nutritive values. The results obtained in the present work demonstrated that foam-mat drying has the potential to be used in papaya preservation.

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