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Influence of foam thickness, whipping time and drying temperature on production of guava powder during foam mat drying

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Abstract

The study was carried out for utilization of guava fruit for preparation of foam mat dried fruit pulp powder. The conversion of guava pulp into foam was optimized by whipping time pulp after addition of methyl cellulose as foaming stabilizer and egg albumin (0.8%) as a foaming agent and drying the foamed pulp in mechanical dryer at different temperature (55 °C, 60 °C and 65 °C) to constant moisture content. Drying of foamed guava pulp by using 0.8% egg albumin results in 10.68% yield and was found the most appropriate with respect to desired foaming properties, physico-chemical as well as sensory characteristics. With the increases in the whipping time, the foam density and foam stability decreases significantly however, the percentage of foam expansion was increased. The dried powder by using 0.8% egg albumin contained in range of 7.24-8.02 moisture content, 4.64-4.92 pH, 203.31 - 221.20 mg/100g ascorbic acid, 72.05 to 85.42% WSI, 351.99 to 365.36% WAI and 6.2 – 7.96 overall acceptability. The maximum value of overall acceptability was found to be 7.96 for foamed dried guava pulp powder for temperature of 60 °C with a whipping time of 10 min and 4 mm foam thickness of guava pulp.

Keywords: Guava pulp, egg albumin, foam properties, whipping, drying

Introduction

Guava (*Psidium Guajava* L.) is a seasonal fruit which is a native of tropical America where it occurs wild and grow well in tropical and subtropical regions up to 1500 meters above mean sea level of the world, has the second-highest vitamin C content in all fruits belonging to the myrtle family (De Aquino *et al.*, 2015).

Most of the guava produced around the world is consumed fresh, but a lot of processed product is also obtained and these include canned guava slices, guava concentrate, dehydrated guava products, jam, jelly, juice, nectar, pectin, puree, spread, syrup and yoghurt (Leite *et al.*, 2006). Although guava possesses enormous health benefits, the major drive in the research and development of guava as functional fruit is far behind the other exotic fruits. The fresh fruit is preferred for consumption but seasonal availability limits availability of fruit throughout the year. Guava is a perishable fruit and highly prone to bruising and mechanical injuries. Due to such perishability, control of fruit ripening is fundamental and this generates the necessity to search for new technologies to increase shelf life, reach distant markets and thus improve the marketing process (Mitra *et al.*, 2012).

Guava is a good source of fiber and a vitamin C with a moderate level of folic acid. It's low in calories with few essential nutrients such as lycopene, beta-carotene, protein, fat, carbohydrate, minerals, vitamin B₁, B₂ and B₃. Nutrient content varies across the guava cultivars. Because of its high level of pectin, guava is extensively used to make candies, preserves, jellies, jams and marmalades. To combat the scarcity researches have focused on the development of different formulations to maintain the nutraceutical properties of guava for fortification, for example, in milkshakes, curd, and other low-fat calorie products.

One of the most suitable preservation methods for fruits or fruit pulp is drying and converting them into powder form. Even though most of the drying methods are traditional and simple, there is an urging requirement to apply advanced techniques such as foam mat drying, with the objectives of increasing productivity and getting better control on the process to gain the product quality and to fulfill the demand of the market. The foam is spread as a porous sheet and exposed directly to the hot air. Due to the increase in the surface area of the food material by incorporating air is facilitated the quick and easy removal of moisture from the liquid (EKpong *et al.*, 2015). The foam mat drying technique can be successfully employed for drying of guava fruit pulps. Still, due to the higher drying rates, foam mat drying method is considered superior to non-foamed tray drying methods in terms of process feasibility, drying kinetics and energy efficiency.

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The success of foam-mat drying technique depends on the formation of stable foam which depends on the proper selection of suitable foaming stabilizers and foaming agents. This method is one of the most cost-effective and suitable technique for any heat sensitive, high sugar-containing sticky fruit pulp, which is difficult to be dried by convectional drying method (Kadam *et al.*, 2010) [5, 8, 12, 32]. Foam mat dried products are comparatively stable against microbiological, chemical and biochemical deterioration and have a high retention of color, flavor, vitamin and sensory characteristics compared to other drying methods. Although large volume of air present in the foamed mass because of enormous increases in liquid–gas interface.

Material and Methods

Selection of fruit and preparation of sample

The fresh guava fruits were procured from the local market of Udaipur, Rajasthan, India for use in experimentation for the pre preparation of foam mat dried guava pulp powder. For preparation of guava pulp fully ripened guava fruits were thoroughly washed under tap water to remove adhering impurities cut manually into a sliced by the help of sharp stainless steel knife and then, the cut slices were put in the food processor. Foamed guava pulp was prepared by adding of methyl cellulose as foaming stabilizer and egg albumin (0.8%) as a foaming agent. The sample of guava pulp were whipped by blender at speed of 1500 rpm for (5, 10 and 15 min) to generate foam by incorporating air in the pulp, thereby increasing the surface area.

Foaming properties

The foaming efficiency of guava pulp converted into a stable foam was optimized by determined various foaming properties as under:

Foam expansion

Foam expansion is the initial volume of guava pulp before whipping to the volume of guava pulp after whipping. The foam quality of foamed guava pulp in term of foam expansion was determined by using following equation (Thakur *et al.*, 2020) [14].

$$\text{Foam expansion (\%)} = \frac{V_1 - V_0}{V_0} \times 100$$

Where,

V_0 = Initial volume of guava pulp, cm^3

V_1 = Final volume of foam guava pulp, cm^3

Foam stability

Foam stability was determined by leaving 50 ml of the foamed guava pulp in a transparent graduated beaker kept at room temperature for 2 hours (Marinova *et al.*, 2009). The foam drainage in terms of volume reduction was measured as an index for the foam stability for every 30 min by using the following relationship.

$$\text{Foam stability (\%)} = \frac{V_0}{V_1} \times 100$$

Where,

V_0 = initial volume of the guava pulp before foaming (cm^3)

V_1 = final volume of the guava pulp after foaming (cm^3)

Foam density

The density of the foamed guava pulp was determined by dividing the mass of fresh pulp by the final volume of foam and expressed as g/cm^3 (Falade *et al.*, 2013) [10].

$$\text{Foam density } \left(\frac{\text{g}}{\text{cm}^3} \right) = \frac{\text{mass of foam pulp}}{\text{volume of the foam}} \times 100$$

Process of drying experiment

The drying experiment was carried out by using a mechanical tray dryer. Stable foamed guava pulp was subsequently spread as a 2, 4 and 6 mm thin mat and exposed to drying in a mechanical dryer at three different drying temperatures (55 °C, 60 °C and 65 °C) up to desired moisture content. Trays were arranged one above the other with the clearance between two successive trays to permit air circulation. The heater of the mechanical dryer was run for half an hour before the drying to reach the stable desired temperature inside the chamber, chosen as per experimental design. The tray was removed from the drying chamber and weighed regularly of every 10 minutes interval up to 1 hour and after 1 hour regular 15 minutes for determination of weight loss. The drying was continued until constant moisture content (db) of foamed guava pulp, which was assumed to be the stage of dynamic equilibrium.

Drying characteristics

Drying rate

The moisture loss data recorded during experiments were analyzed to determine the moisture lost by a sample of guava pulp at a particular time interval. The drying rate of the sample was calculated by following the mass balance equation (Brooker *et al.*, 1974),

$$R = \frac{\text{WML (g)}}{\text{Time interval (min)} \times \text{DM(g)}}$$

Where,

R = Drying rate at time θ

WML = Initial weight of sample – Weight of sample after time θ

Moisture ratio

The moisture content of guava pulp during foam mat drying was expressed in the form of moisture ratio (MR) and determined by the following equation (Mohsenin, 1980).

$$\text{MR} = \frac{M - M_\infty}{M_0 - M_\infty}$$

where, M , M_0 and M_∞ are moisture content at any time of drying, initial moisture content, and equilibrium moisture content, % (db), respectively.

Quality analysis

Quality analysis is important in food processing; control should be exercised at every stage from pre-processing to packaging, storing etc.

Ascorbic acid

Ascorbic acid was determined by the 2, 6 dichlorophenol-indophenols titrimetric method according to AOAC method

No. 967.21 (AOAC, 2000). The vitamin C content in dried guava pulp powder samples was evaluated. A total of 10 ± 0.1 g of triturated sample was weighed, filtered, and diluted to a volume of 50 mL. All measures were done in triplicate; the vitamin C content is expressed as mg AA/ 100 g dm (Miranda *et al.*, 2009).

Water absorption index (WAI) and Water solubility index (WSI)

WAI and WSI were determined by the method of Anderson (1982a). A 2.5 g sample was dispersed in 30 ml of a water in a 50 ml tarred centrifuge tube. Place the above tubes in water bath at 30 °C for 30 min. Then the sample was centrifuged at 2000 rpm for 15 min. The supernatant liquor was poured carefully into petridish and dried in a hot air oven. The remaining sediment weight was noted. WAI and WSI were calculated by the following equation:

$$\text{WAI} = \frac{\text{Weight of sediment}}{\text{Weight of dry solids}} \times 100$$

$$\text{WSI} = \frac{\text{Weight of dissolved solids in supernatant}}{\text{Weight of dry solids}} \times 100$$

Colour analysis

Colour analysis of all dried sample was performed by using Hunter Lab Colorimeter (Model ColorFlex). The 3-dimensional scale L*, a* and b* were used in a Hunter Lab Colorimeter. The L* is the lightness coefficient, ranging from

0 (black) to 100 (white) on a vertical axis. The a* is redness (positive a* value) and greenness (negative a* value) on a horizontal axis. A second horizontal axis is b*, that represent yellow (positive b* value) or blue (negative b* value) colour. Each value represented a mean value of triplicates determinations on different samples.

Statistical analysis

The randomized block and the 3×3×3 factorial experimental Box-Behnken design with three replications were adopted for statistical analysis of experimental data on the guava pulp and dried foamed guava pulp. Independent variables for foaming of guava pulp were whipping time (5, 10 and 15 min.), foam thickness (2, 4 and 6 mm) and drying temperature (55, 60 and 65 °C). The obtained data were subjected to analysis for the graphical representation, analysis of variance (ANOVA) and multiple regression by using the software of Design Expert Version 11. The significance of all the terms in the polynomial equation was judges statically by computing the F-value at a probability (p) value 0.001, 0.001 or 0.05.

Results and Discussion

Effect of foaming treatment

Experiments were performed by giving foaming treatment to the developed guava pulp by adding egg albumin (0.8%) and whipping time (5, 10, 15) minutes. Foaming properties i.e. foam expansion, foam stability and foam density were analyzed for each sample. Table 3.1 shows the complete experimental results for foamed guava pulp with egg albumin.

Table 1: Experimental data of foam properties of guava pulp

Treatment	Temperature (°C)	Thickness (mm)	Whipping time (min.)	Foam density (g/cm ³)	Foam expansion (%)	Foam stability (%)
12	60	6	15	0.88	13.21	96
3	55	6	10	0.92	11.70	97
6	65	4	5	0.95	10.46	98
16	60	4	10	0.91	12.1	98
14	60	4	10	0.92	12.02	97
4	65	6	10	0.91	12.1	97
8	65	4	15	0.89	13.46	95
7	55	4	15	0.89	13.4	96
15	60	4	10	0.91	12.29	97
9	60	2	5	0.96	10	98
2	65	2	10	0.93	11.6	98
5	55	4	5	0.94	10.89	99
1	55	2	10	0.92	11.39	97
10	60	6	5	0.95	10.4	98
11	60	2	15	0.9	12.8	96
13	60	4	10	0.91	12.38	98
17	60	4	10	0.92	12	98

Foam density

The foam density of the foamed guava pulp concentrates for the experiment of 17 run varied from 0.88 – 0.96 g/cm³ as shown in Table 3.1. The maximum foam density was obtained as 0.96 g/cm³ for treatment 9 of guava pulp at 60 °C drying temperature, 5 min whipping time and 2 mm foam thickness. Similarly, the minimum foam density was obtained as 0.88 g/cm³ for treatment 12 of guava pulp with egg albumin at temperature of 60 °C, 15 min whipping time and 6 mm of foam thickness. Foam density is lower due to more air absorption during whipping (Falade *et al.*, 2003) [10]. Foam density was frequently used to evaluate the whipping properties, and to exhibit a low value when more air was absorbed into the foam during whipping. The whipping ability increases due to more air presence in the foam. The foam density decreases with increases in whipping time.

Table 2: Analysis of foam properties of foamed guava pulp

Model	Foam density	Foam stability	Foam expansion
SS	0.0079	14.11	16.80
DF	9	9	9
Mean Square	0.0009	1.57	1.87
F- value	31.32	3.72	55.53
P-Value	<0.0001	0.0486	<0.0001
Mean	0.9182	97.24	11.91
C.V. (%)	0.5748	0.6676	1.54
R ²	0.9758	0.8271	0.9862

Table 3.2 show that the model F-value of 31.32 implies the model is significant. There is only a 0.01% chance that this F-value large could occur due to noise. For the model fitted, the coefficient of determination ($R^2 = 0.9758$), indicates that the mode was significant ($p < 0.05$).

From the response surface plot in Fig 3.1 it can be observed that the whipping time increases when the foam density decreases from 0.96 g/cm³ to 0.88 g/cm³. However, after a reduction in whipping time a little increase in foam density was found. When the whipping time increase foam density

slight increase was due to bubble collapse. During whipping air bubbles trapped in the foam and gave to lower foam density. Therefore, more air was absorbed in the foam as the whipping time increased which resulted in lower foam density.

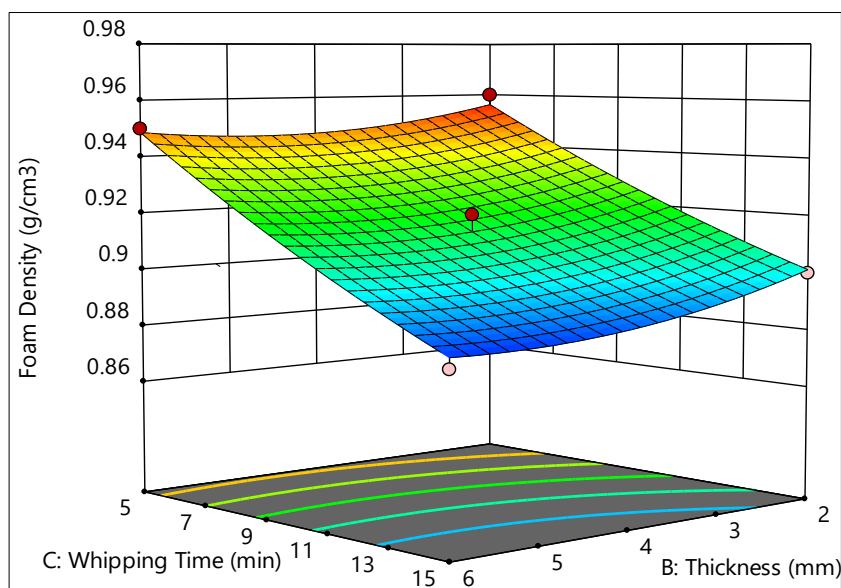


Fig 1: Response surface plot for foam density as a function of whipping time and foam thickness

Foam stability

The foam stability of guava pulp concentrates for the experiment was 95-99% as shown in Table 3.1. The maximum foam stability was obtained as 99% similarly the minimum foam stability was obtained as 95%. A higher percentile for foam stability implies a higher water holding capacity. It was noticed from Fig. 3.2 that at higher whipping

time, Foam stability was decreased due to breakage of foam bubbles and release of liquid phase intact in foam bubbles and foam stability was decreased at higher whipping time. Model F-value of 3.72 implies the model is significant. The R² value was determined by least square test and found to be 0.8271, indicates that the model was significant ($p < 0.05$). In this case whipping time is a significant ($p < 0.10$) model term.

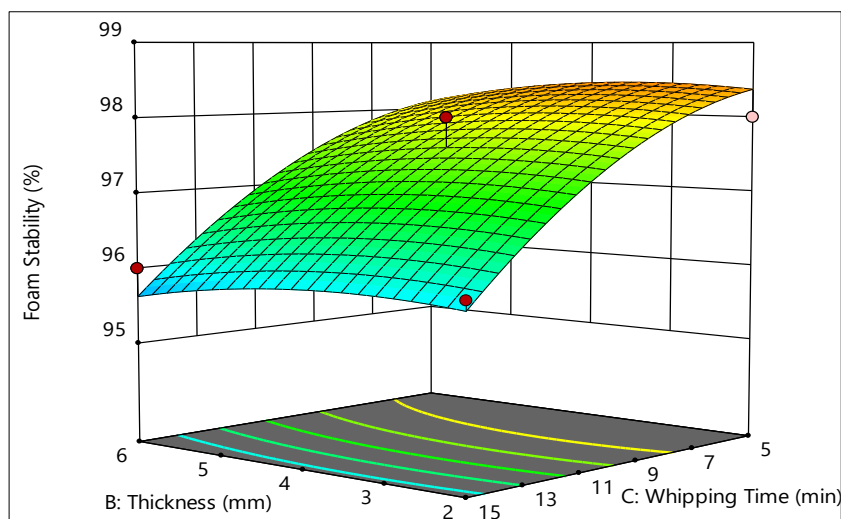


Fig 2: Response surface plot for foam stability as a function of whipping time and foam thickness

Foam expansion

The foam expansion of guava pulp was increased from 10-13.46% for whipping time 5-15 min as shown in Table 3.1. From Table 3.1 it was observed that the maximum foam expansion was found to be 13.46% for 15 min whipping time and similarly, the minimum foam expansion was found to be 10% for 5 min whipping time.

Model F-value of 49.67 implies the model is significant. The R² value was determine by least square technique and found to be 0.9862 good fit of the model to the data. P-values less than 0.0500 indicate model terms are significant. In this case foam thickness and whipping time are significant ($p < 0.10$) model terms.

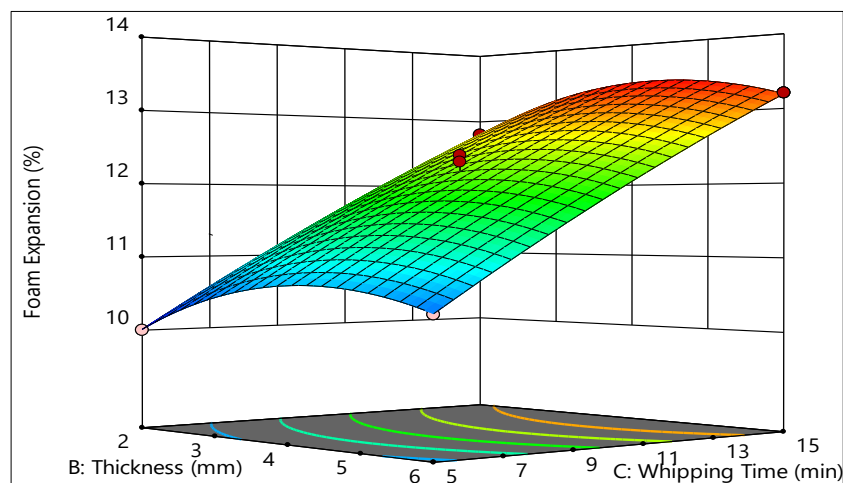


Fig 3: Response surface plot for foam expansion as a function of whipping time and foam thickness

Effect of drying time on drying rate

The typically curve from Fig. 3.4 to Fig. 3.6 shows that the variation in drying rate with drying time of foam mate drying of guava pulp for the experiment of 17 runs.

The drying rate was obtained maximum of 0.025297 g w/g dm-min for foam mate drying of guava pulp with Egg albumin for drying temperature of 65 °C, 2 mm foam thickness and 10 min whipping time. Similarly, the minimum initial drying rate obtained of 0.009 g w/g dm-min for 55 °C drying temperature, 10 min whipping time and 6 mm foam

thickness of guava pulp. It was observed that from Fig. 3.4 to Fig. 3.6 the rate of losses of moisture content increased with the drying temperature and whipping time and decreased with increase in the foam thickness for drying of guava pulp. It was found that during initial drying period the moisture removal rate was higher and after some hours of drying period the moisture content curve decreased up to horizontal line, it reveals that the moisture content decreases rapidly in initial drying period.

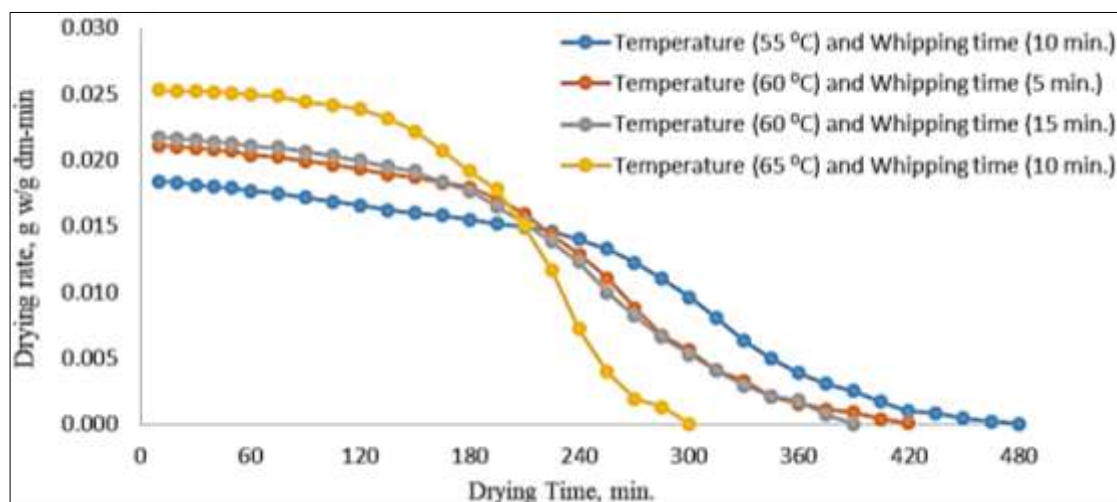


Fig 4: Effect of drying time on drying rate for 2 mm of foam thickness

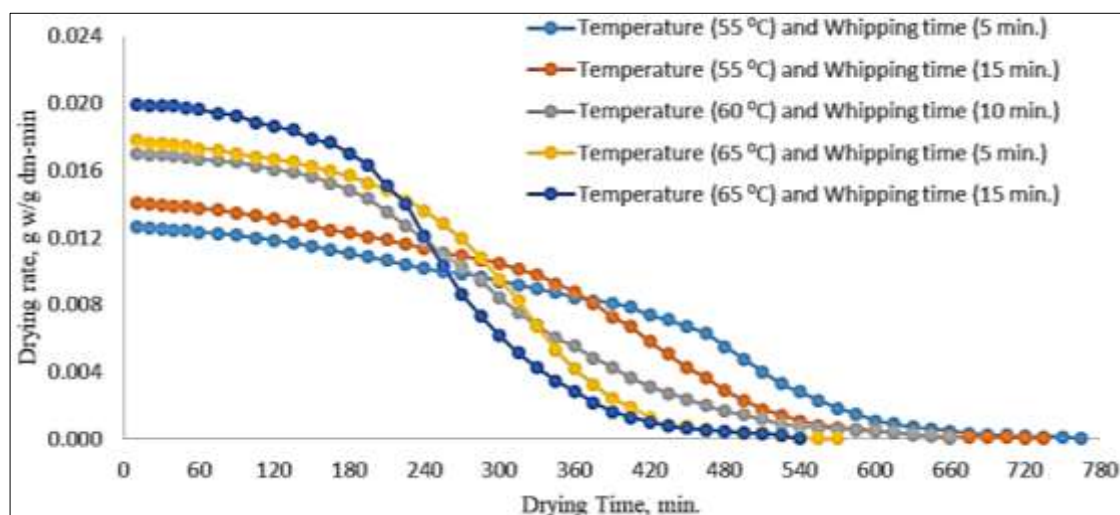
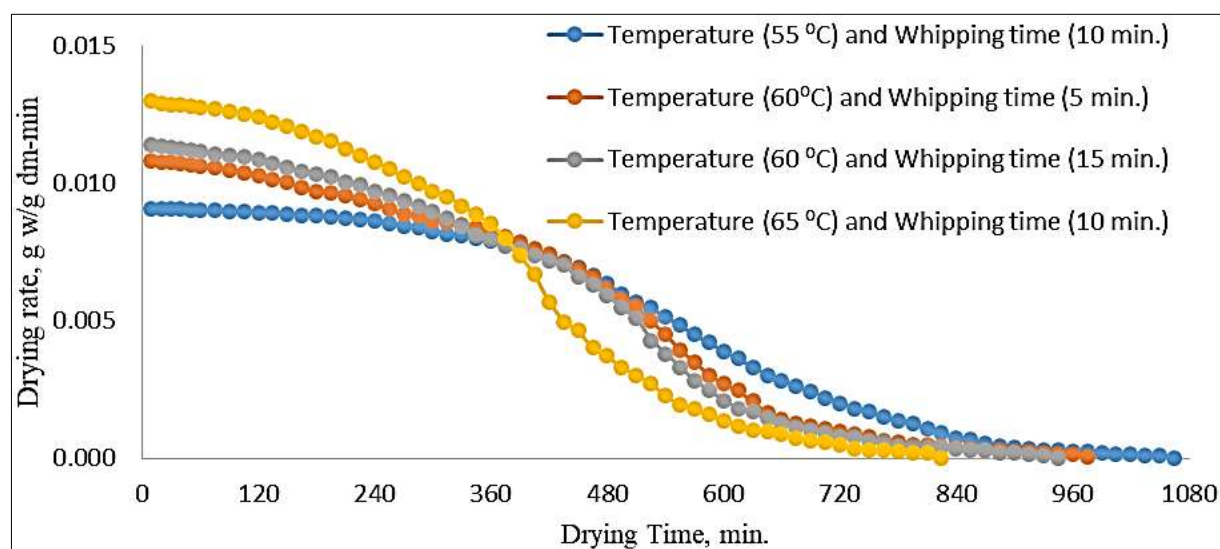


Fig 5: Effect of drying time on drying rate for 4 mm foam thickness

Table 3: Effect of independent variables on different quality parameter of foam mat dried guava pulp powder

Temperature (°C)	Thickness (mm)	Whipping time (min.)	Drying time (min)	Final moisture content (%)	pH	Ascorbic acid (mg/100g)	WAI (%)	WSI (%)	L*	a*	b*
60	6	15	945	7.71	4.70	214.21	358.37	78.43	62.02	13.99	31.11
55	6	10	1065	7.82	4.74	221.2	362.56	82.62	66.21	12.72	32.33
65	4	5	570	7.87	4.78	209.05	353.73	73.79	57.38	12.66	31.80
60	4	10	660	7.77	4.85	215.51	365.36	85.42	69.01	9.64	32.82
60	4	10	660	7.77	4.85	215.51	365.36	85.42	69.01	9.64	32.82
65	6	10	825	7.44	4.64	211.09	348.67	68.73	52.32	14.68	32.44
65	4	15	540	7.87	4.80	209.57	353.21	73.27	56.86	12.79	31.93
55	4	15	735	8.02	4.88	219.3	356.21	76.27	59.86	7.02	33.91
60	4	10	660	7.77	4.85	215.51	365.36	85.42	69.01	9.64	32.82
60	2	5	420	7.24	4.90	212.05	363.46	83.52	67.11	13.70	31.39
65	2	10	300	7.32	4.88	204.51	355.25	75.31	58.90	12.98	32.12
55	4	5	765	7.65	4.87	218.94	356.56	76.62	60.21	6.91	34.16
55	2	10	480	7.81	4.92	218.4	357.78	77.84	61.43	7.82	34.56
60	6	5	975	7.85	4.68	213.62	359.67	79.73	63.32	14.31	31.03
60	2	15	390	7.60	4.89	212.4	363.1	83.16	66.75	10.78	32.11
60	4	10	660	7.77	4.85	215.51	365.36	85.42	69.01	9.64	32.82
60	4	10	660	7.77	4.85	215.51	365.36	85.42	69.01	9.64	32.82

**Fig 6:** Effect of drying time on drying rate for 6 mm foam thickness

Effect of independent variables on drying time

The drying time of treatments of guava pulp with egg albumin was varies from 300 to 480 min, 540 to 765 min and 825 to 1065 min for a foam thickness of 2 mm, 4 mm and 6 mm, respectively, evaluated by using different whipping time and drying temperature. With increasing the drying temperature, the mean drying time was found to be decreased from 1065 min (55 °C temperature, 6 mm foam thickness and 10 min whipping time) to 300 min (55 °C temperature, 6 mm foam thickness and 10 min whipping time) as shown in Table 3.3. The reduction in drying time with increases in whipping time could be due to the increased porous area of the foamed sample allowing faster movement of dry air.

Product evaluation

The results of colour evaluation for foam mat dried powder are presented in the Table 3.3. For the dried guava pulp powder L*, a* and b* value were found to be in range of 52.32 to 69.01, 7.02 to 14.68 and 31.03 to 36.56, respectively. The dried guava powder was brighter (higher L value) at the drying temperature of 60 °C with a foam thickness of 4 mm and 10 min whipping time than other all treatment. Among different treatments of guava pulp, the pH of powder from foamed guava pulp foam mat dried guava pulp powder was found in the range of 4.64 to 5.85. Among with different temperature and foam thickness, it was found that with

increasing foam thickness, the pH with increases.

Ascorbic Acid

The ascorbic acid of the foamed dried guava pulp powder for the experiment of 17 run of guava pulp was varied from the range of 203.31 - 221.20 mg/100g. The maximum ascorbic acid was obtained as 221.20 mg/100g for foam mate dried guava pulp powder for drying temperature of 55 °C with a foam thickness of 6 mm and 10 min whipping time.

Model F-value of 31.18, produced from design expert statistical analysis for ascorbic acid show that the model is significant. There is only a 0.01% chance that this F-value large could occur due to noise. For the model fitted, the coefficient of determination ($R^2 = 0.9757$), indicates that the model was significant ($p < 0.05$). The response surface variation of ascorbic acid with drying temperature, foam thickness and whipping time (shown in Fig. 3.7 and Fig 3.8) indicates the increase in drying temperature decreases the ascorbic acid because it is a heat liable nutrient, whereas an increases in foam thickness and whipping time, also increases the ascorbic acid due to increasing the foam expansion.

The retention of vitamin C depends upon the water content, the foam thickness of the sample of guava pulp, amount of air circulation when sample was dried, the foam expansion of foamed guava pulp and the air temperature and time of exposure inside the dryer.

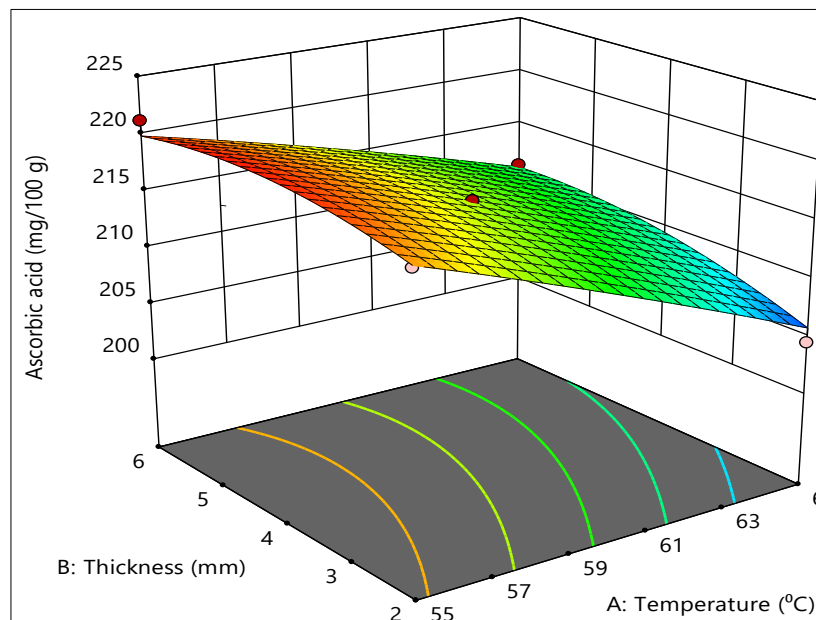


Fig 7: Response surface for the effect of drying temperature and foam thickness on ascorbic acid

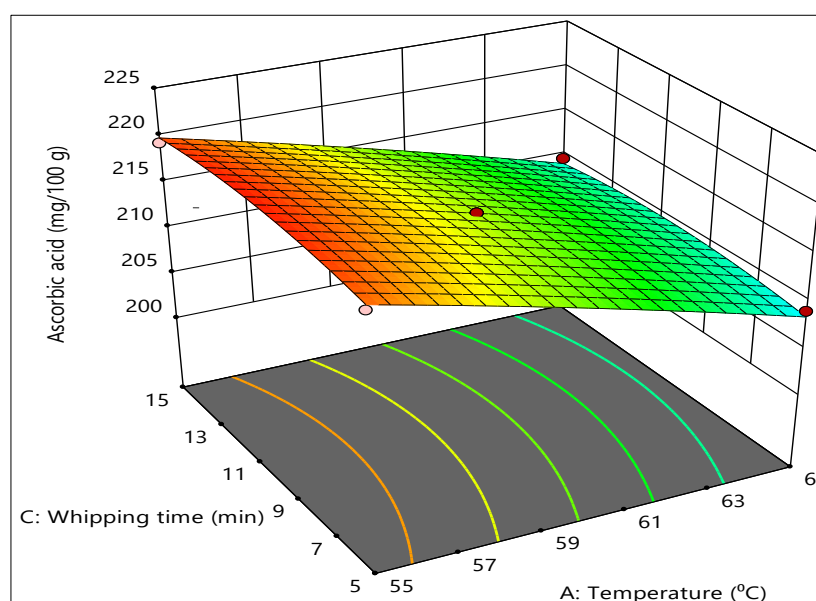


Fig 8: Response surface for the effect of drying temperature and whipping time on ascorbic acid

Water solubility index (WSI)

The water solubility index for the foamed dried guava pulp powder was varied from the range of 72.05 to 85.42% (shown in Table 4.22) and it was obtained maximum of 85.42% for the temperature of 60 °C, foam thickness 4 mm and 10 min of whipping time. Model F-value of 46.78, produced from design expert statistical analysis for WSI show that the model is significant. The coefficient of determination (R^2) was 0.9552 so was also found to be significant ($p < 0.05$). The results of foam mat dried guava pulp powder shows that water solubility index was best for temperature of 60 °C for all treatments of guava pulp powder.

Water absorption index (WAI)

To reconstitute the guava powder in a liquid, the WAI was an important parameter. For the foamed dried guava pulp powder for the experiment of 17 run for each foaming agent with guava pulp the WAI was varied from the range of 351.99 to 365.36% (shown in Table 3.3). Model F-value of 15.09, produced from design expert statistical analysis for WAI show that the model is significant. There is only a 0.08%

chance that this F-value large could occur due to noise. For the model fitted, the coefficient of determination ($R^2 = 0.9510$), indicates that the model was significant ($p < 0.05$).

Overall acceptability

The overall acceptability was conducted on the aspects of colour, taste, flavor, odour and appearance of foam mat dried guava pulp powder. The overall acceptability was found to be as in the range from 6.2 – 7.96. The maximum value of overall acceptability was found to be 7.96 for foamed dried guava pulp powder for temperature of 60 °C with a whipping time of 10 min and 4 mm foam thickness of guava pulp.

Conclusion

It is concluded, on the basis of all physico-chemical characteristics, effect of whipping time and foam thickness on foaming characteristics of papaya pulp and sensory evaluation of papaya powder, the use of 0.8% egg albumin followed by the foam mat drying of the resultant foam in mechanical dryer to a constant moisture content has been found the most appropriate and suitable for drying of guava pulp. Thus, the

technique can be used for commercial production of guava powder for further utilization in development of ready-to-serve beverage by reconstituting the powder.

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