Induction heating assisted foam mat drying of papaya pulp: drying kinetics, drying modeling, and effects on quality attributes

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Abstract: The study was focused on investigating the drying kinetics, drying modeling and quality parameters of induction heating assisted foam mat dried papaya pulp powder.   Variable parameters in induction drying were induction voltage (150, 175 and 200 V) at 100ºC and foam-mat thickness (4, 6 and 8 mm).   Both the independent variables had a pronounced effect on drying characteristics of papaya pulp foam.   For comparison, 6 mm thick foam was dried at 100ºC air temperature.   Seven drying models were fitted to obtain the models that fit best.   The selection of the model was done on the basis of certain statistical parameters.   Midilli-Kucuk model was found to be the best in all cases except at thickness 6 mm and 200 V where Wang and Sing model exhibited the best results.   Effect of drying parameters on properties of reconstituted papaya pulp powder was studied by applying face-centered design of response surface methodology.   Modified quadratic models were significant at $p \leq 0.05$ for pH, Vitamin C, total sugar, reducing sugar and total soluble solids, but not for color change.   The optimum values of input voltage and foam-mat thickness were 150 V and 8 mm, respectively which would yield dried papaya powder of pH 4.6, reducing sugar 3.55%, ascorbic acid 124.4 mg/100 g; color change 11.92 with desirability 0.889.

Keywords: foam mat drying, induction heating, papaya pulp powder, quality attributes

1   Introduction

Papaya (*Carica papaya*), a tropical fruit has economic importance because of its potential nutritive and medicinal value. Papaya proffers not only the delightful taste but is wonderful sources of antioxidants such as vitamin C, carotenes and flavonoids; the B vitamins, pantothenic acid, and folate; and the minerals, potassium, magnesium and iron; and fiber. Fibers, sugars, and starches constitute about 10% of carbohydrates in papaya. It is also a rich source of common minerals and vitamins (Krishana et al., 2008). Previous studies revealed that papaya fruit exhibits laxative effect (Widyastuti and Srianta, 2011). About 60 countries are producing papaya,

with the major production taking place in developing nations. The production share of papayas by region is Asia, constituting 49% of the world production between 1994 and 2016, chased by America (37.7%), Africa (13.2%), and Oceania (0.2%) (FAOSTAT, 2016).   The developing countries have post-harvest losses of papaya ranging from 40%-100% (Silva et al., 2007). The total postharvest loss of papaya works out to 25.49% (Gajanana et al., 2010). These massive losses of papaya fruit are due to high moisture content and with the result, it cannot be preserved for a longer period of time. In order to increase the shelf stability and prevent these massive losses, removal of moisture from the product is imperative. The dehydrated papaya by-products can be used for the preparation of a range of food product formulations such as ready to eat fruited cereals, ice cream flavors, nectar, instant soup cubes, etc., thus new processed food products from papaya are highly desirable (Kandasamy et al., 2012). Papaya can also be transformed

into jam, jelly, nectar, dried into slabs, canned in the form of slice and the fruit powder (Kandasamy et al., 2012). The complex operation of drying involves the transient transfer of heat and mass including several rate processes, such as physical or chemical transformations, which in turn, may lead to changes in product quality as well as the mechanisms of heat and mass transfer (Mujumdar and Devahastin, 2000; Hawalder et al., 2006). Freeze drying is known to be the most expensive method of drying. Conventional drying methods have limitations such as long drying time, inferior product quality and high degradation. The capability to process hard-to-dry materials, to get products of desired properties with desirable rehydration, controlled density, and high volatile preservation is the reason that foam mat drying has received attention (Muthukumuran et al., 2008; Azizpour et al., 2013; Qadri and Srivastava, 2014). Because of a prodigious increase in the liquid-gas interface, in spite of the fact that the heat transfer is impeded by a large volume of gas that exists in the foamed mass, the drying rate in this process is very high (Martin et al., 1992). One of the recognized methods to shorten drying time is foaming. Foam-mat drying is a process of conversion of liquid or semi-liquid material into stable foam by incorporating ample volume of air or other inert gas in the presence of a foaming agent, which functions as a foam inducer and stabilizer. Foam-mat proffers the benefits of air drying, cheapness, and accessibility. Characteristic advantages in drying, spreading, surface removal, crumpling and rehydration of product are offered by foam structure. The dilemma of thickness control is avoided by foaming (Kadam et al., 2012). A layer of foam dries much more rapidly, reducing the drying time to one-third than the same amount of un-foamed liquid under the similar external condition (Tayeb, 1994). This method is appropriate for any heat susceptible, sticky and viscous materials which cannot be dried by spray drying (Hart et al., 1963; Berry et al., 1965). Foam mat drying yields powders with better reconstitution properties and superior quality compared to that produced by drum and spray drying (Morgan et al., 1961; Chandak and Chivate, 1974). There is no data available on induction heating assisted foam mat drying (IHFMD) of papaya pulp. This is an emerging method of

heating foods. In this method of heating, the movement of moisture and transfer of heat is in the same direction i.e. from bottom layers to top whereas in an air convection drying (except fluidized bed drying), the heat moves from top to bottom while the movement of moisture is in the reverse direction which offers resistance to heat transfer. Due to this reason, the rate of drying in this drying method is expected to be faster as compared to air convection drying method of foods. Therefore, a study was conducted to investigate the feasibility of drying papaya pulp in a laboratory set-up of induction heating assisted foam mat drying system.

2   Materials and methods

2.1   Selection of fruit and preparation of foam

Fresh and superior quality papaya fruits used for this study were obtained from local market of Aligarh, India. The fruits were washed with tap water to remove the dirt and other extraneous matter. Only sound and fully ripened fruits were peeled manually using a stainless steel knife. The flesh was cut into small pieces and then these pieces were pulped with the help of a blender. The pulp obtained was then packed in metalized polyethylene pouches and stored in a deep freezer at −16°C for further study. For the foaming study, the stored papaya pulp was taken out of the freezer and thawed under tap water till it attains room temperature. As papaya pulp is very thick and viscous, it is difficult to foam it without the addition of water. Water was added in proper proportions so that it foams well and spreads desirably on the pan. Fresh eggs containing about 26.7-28.5 g of egg albumin were broken and the content of egg was gently poured into a beaker. The egg yolk was carefully taken out of egg albumin with the help of a spoon. The egg albumin volume and water content were measured with the help of measuring cylinder and methylcellulose was measured on weighing balance. The packets were cut and precisely measured 100 mL of papaya was transferred into a 500 mL beaker; then accurately measured water, egg albumin, and methylcellulose was added to the papaya pulp with continuous stirring. The mixture was whipped using a hand mixer (Orpat Model: OHM 207, Ajanta Limited, Morbi, India) provided with counter-rotating twin beater attachment. The whipping was done for a constant time of

5 minutes at 1400 r.p.m to develop stable foam. Based on preliminary trials, the concentrations of foaming agents and water content were selected.

2.2   Drying of foam

For the drying experiments, the foaming of papaya pulp was done by selecting optimum levels of egg albumin, methylcellulose, and water content. Drying was carried out on an experimental setup consisting of a chamber, domestic type induction cooker power rating 800 W (Model Popular, Bajaj Electronics Ltd., Veer Nariman Road Mumbai, India), voltage transformer (variac), pan, and motorized blower (Model OEH-1220, Ajanta Ltd., Morabi-163641, India). The induction cooker was kept inside the drying chamber and the pan containing foam was placed on the induction cooker. Foamed papaya pulp was spread uniformly over the Teflon coated pan (diameter 7 inches). Desirable thickness (4, 6 and 8 mm) of foamed pulp was evenly spread over a flat-bottomed shallow pan with a diameter of 18 cm. The thickness of the foam-mat was measured accurately by placing the pan over a horizontal platform and dipping a calibrated dip nail in it at different places. The electronic weighing balance of 600 g capacity was used for weighing of the pan before and after loading of papaya pulp foam. During the drying process, the weight of the pan was recorded after every three-minute interval. The range of operational parameters was selected by conducting preliminary experiments. At 100°C temperature option in induction cooker (at the standard voltage of 220 V) selected input voltages were 150, 175, and 200 V. The drying process was continued to the point where weight difference between two consecutive observations was less than the least count of the balance. On completion of the drying process, promptly the dried papaya pulp was scraped off from the pan using a wooden spatula and kept in a desiccator to cool down. The scraped pulp was ground and packed in metalized polyethylene pouches for further analyses.

2.3   Model fitting

Semi-theoretical models which are usually applied to fruits and vegetable drying were taken from literature (Gunhan et al., 2005; Saeed et al., 2008). To pick out a satisfactory fitting model to explain the foam mat drying process of papaya pulp, drying curves were fitted with thin layer drying equations. The evaluated moisture ratio models are given in Table 1. Nonlinear regression modeling was carried out using "user defined model" option of Σ-Plot.10 software. The coefficient of determination R^2 and the goodness of fit of drying models to experimental data were evaluated on the basis of statistical parameters; namely, Chi-square (χ^2) and root mean square error (RMSE). These three parameters describe the comparative adequacy of a model among the chosen ones. For best fit, the R^2 value should be higher and χ^2 and *RMSE* values should be lower (Goyal et al, 2007; Erentruk and Erenturk, 2004)

Table 1   Drying models and their equations

Models	Model equations
Lewis	$MR = \exp(-k*t)$
Henderson & Pabis	$MR = a*\exp(-k*t)$
Page	$MR = \exp(-k*t^n)$
Wang & Singh	$MR = 1+a*t+b*t^2$
Two term exponential	$MR = a*\exp(-k*t)+(1-a)*\exp(-k*a*t)$
Logarithmic	$MR = c+a*\exp(-k*t)$
Midilli-Kucuk	$MR = a*\exp(-k*t^n)+b*t$

Note: a, b, c, k, n are model constants and t is time (min).

2.4   Analysis of fresh pulp and reconstituted papaya pulp powder

In order to determine the effect of drying parameters on the quality of papaya pulp, the papaya powder was reconstituted to the juice of almost original moisture. The reconstitution of dried samples was done at a ratio of 1:11 (papaya pulp: water) to obtain its original moisture content (87.6%)

2.4.1   Initial moisture content

The method used for moisture content determination is the same as used by Qadri and Srivastava (2014).

2.4.2   Titrable acidity

The titrable acidity of fresh and reconstituted papaya pulp was estimated by the method used by Rangana (1986). Results were expressed as a percentage with respect to citric acid.

2.4.3   pH value

The samples were diluted with distilled water in 1:10 ratio and then filtered and pH of the extracts was measured by dipping the electrode of the standardized pH meter (Cyberscan pH-1500, Ectech Instruments, Singapore) in the extract and waiting for the readings to stabilize.

2.4.4   Ascorbic acid

Estimation of ascorbic acid in the samples was done by the same visual titration method as given by Rangana (1986) and reported by Kadam et al. (2012).

2.4.5   Total sugar (Lane and Eynon method)

Total sugar of fresh and dried powder was estimated using the method described by (Ranganna, 1986).

2.4.6   Total soluble solids (TSS)

Papaya pulp was squeezed through a muslin cloth to obtain juice extract. Bench refractometer (Metz 1408, Metzer Optical Instruments, India) was used to measure TSS and values are expressed as °Brix.

2.4.7   Color analyses

The 'L', 'a' and 'b' values were determined by placing Hunter Colour Lab (Mini Scan XE Plus, USA) over the reconstituted IHFMD papaya powder and these values were recorded. These values were used for calculating the color difference to describe the effect of IHFMD on the color of reconstituted papaya powder with reference to the original color of fresh papaya pulp. This method has been used by many researchers in their studies like Rzepecka et al. (1976), and Kadam and Balasubramanian (2011).

2.5   Statistical analyses

The response surface methodology was applied using Face Centered-Central Composite Design to study the effect of independent variables (i.e., factors) on relevant dependent parameters (i.e., responses). Response surface methodology was applied to various responses like moisture, pH, TSS, acidity, ascorbic acid, total sugar, reducing sugar and color difference of the IHFMD experiments. Regression analysis and analysis of variance (ANOVA) were conducted for fitting the model to the experimental data and to examine the statically significance of the model terms.

3   Results and discussion

3.1   Drying characteristics of papaya pulp foam

The optimum foam developed was followed by the drying process. The initial moisture content of papaya pulp was 87.6%. The drying characteristics of papaya pulp foam are discussed in the following sections.

3.1.1   Effect of induction voltage and foam-mat thickness on moisture content

The rate of drying was faster during the initial stage of drying, however, at the end, the slope of curve became flattered indicating slow drying rate. Induction voltage has a pronounced effect on drying time. From Figure 1, it can be interpreted that an increase in induction voltage from 150 to 200 V caused a reduction in drying time. Equilibrium moisture content was attained by a combination of foam thickness 4 mm in 42 min (Figure 1a) at induction voltage 150, while the same thickness took 33 minutes at 200 V (Figure 1c). The reduction in drying time by an increase in induction voltage is simply due to the generation of more heat leading to faster drying.

Foam-mat thickness has an obvious effect on drying time and a prominent increase in drying time was recorded when the foam-mat thickness increased as can be observed from the Figure 1. At induction voltage of 150 V, foam-mat of thickness 4 mm took 42 min, whereas, the foam-mat of thickness 8 mm took 78 min under same conditions of temperature and voltage. The increase in drying time with the increase in foam-mat thickness was obviously due to the fact that the surface area of foam-mat for mass transfer in all the cases remained same while the depth of the foam-mat increased in thicker foams that resulted in more resistance to both heat and moisture transfer.

The comparison drying experiment was also conducted for a thickness of 6 mm without induction heating at a drying temperature of 100°C and the time taken was 63 min. In comparison, FMD at 6 mm thickness and 150 V (Lowest voltage) took only 51 minutes. This shows that induction heating drying is much powerful than air drying.

3.1.2   Effect of induction voltage and foam mat thickness on drying rate

Drying rate during IHFMD was calculated in terms of gram of water lost per minute per gram of dry matter and thus, the unit is termed as g H_2O/g.d. m. /min. The graphs indicate that in all the cases the drying rate first increased to a maximum level and then decreased. The increase in the drying rate was rapid but the decrease was gradual.

Both the induction voltage and foam mat thicknesses had pronounced effect on drying rate. It was observed that the peak drying rate was the maximum for foam mat of minimum thickness (4 mm) which decreased with an increase in foam mat thickness and it was minimum for the foam mat of 8 mm thickness. A decrease in the peak value of drying rate with an increase in foam-mat thickness was due to a slower rise in temperature as a greater mass of sample had a higher thermal capacity and also offers more resistance to moisture migration. A greater time lag in achieving peak drying rate with an increase in mat thickness was also due to the same reasons.

There was a pronounced effect of induction voltage on the drying rate. The peak value of drying rate at a certain thickness increased with increase in voltage. The reason for this was higher heat generation due to higher voltages and thus, a higher drying rate. The exception here is at 4 mm thickness where the peak value of drying

rate followed the same trend from 150 to 175 V but it deviated from 175 to 200 V. The reason may be the less mat thickness.

The increase in the drying rate at the beginning shows the presence of a heat up period which reduced with the increase in voltage and decrease in foam-mat thickness. In foam mat of thickness 4 mm this heat up period was immediately followed by the falling rate period while in case of foam mat-mat thickness of 6 and 8 mm the drying rate stabilized for some time as can be observed from the Figure 2 which was probably because the surface area for mass transfer remained almost the same in all cases while as the depth increased, a greater mass of available water maintained fairly constant drying rate for quite some time. After the surface of the foam dried out, the rate of water movement from the interior to the surface of the foam fell below the rate at which water evaporated to the surrounding air and hence resulting in falling rate period (Fellows, 2009).
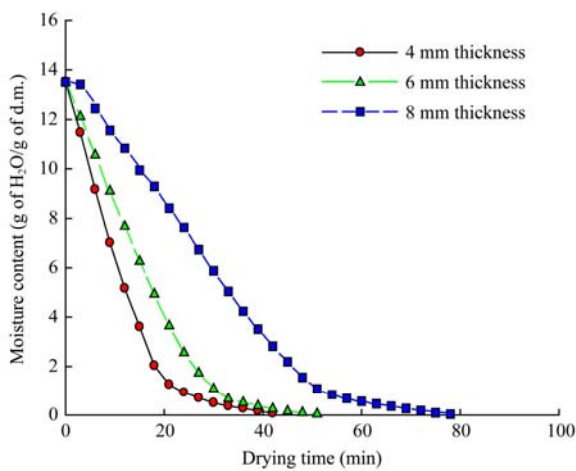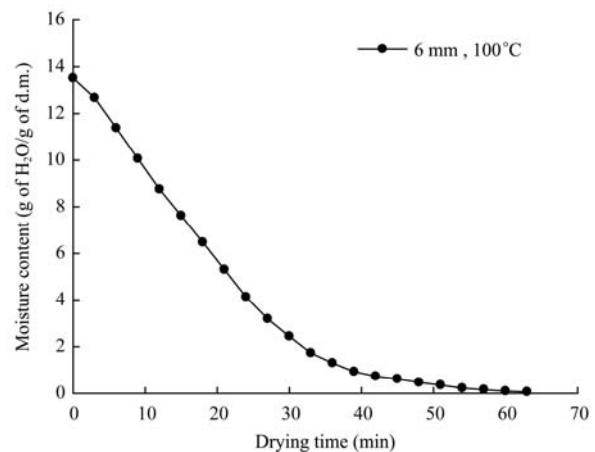

a. Drying at 150 V
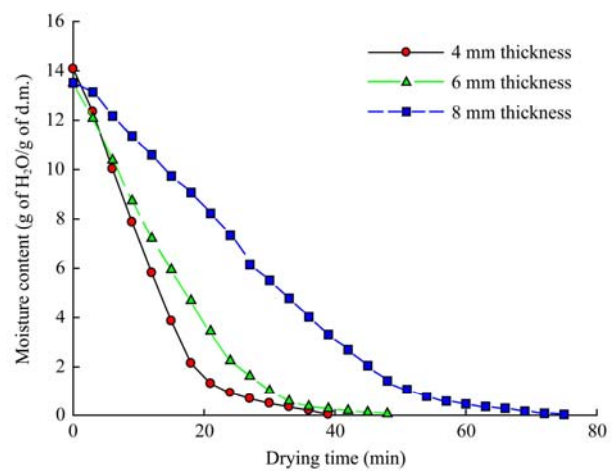
b. Drying at 175 V
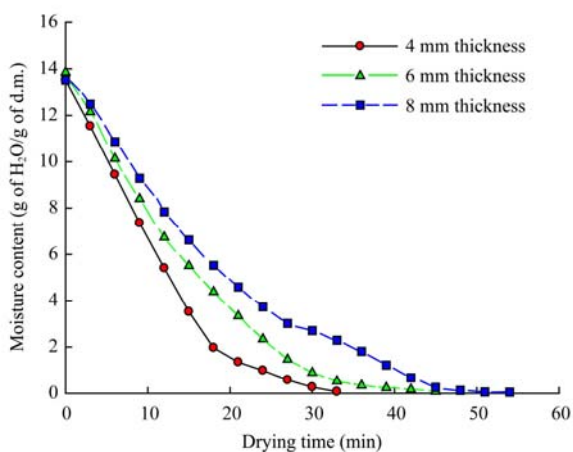
c. Drying at 200 V

d. Hot air drying at 100°C

Figure 1   Effect of foam- mat thickness on drying time of papaya pulp foam during induction assisted foam mat drying

a. Drying at 150 V

b. Drying at 175 V

c. Drying at 200 V
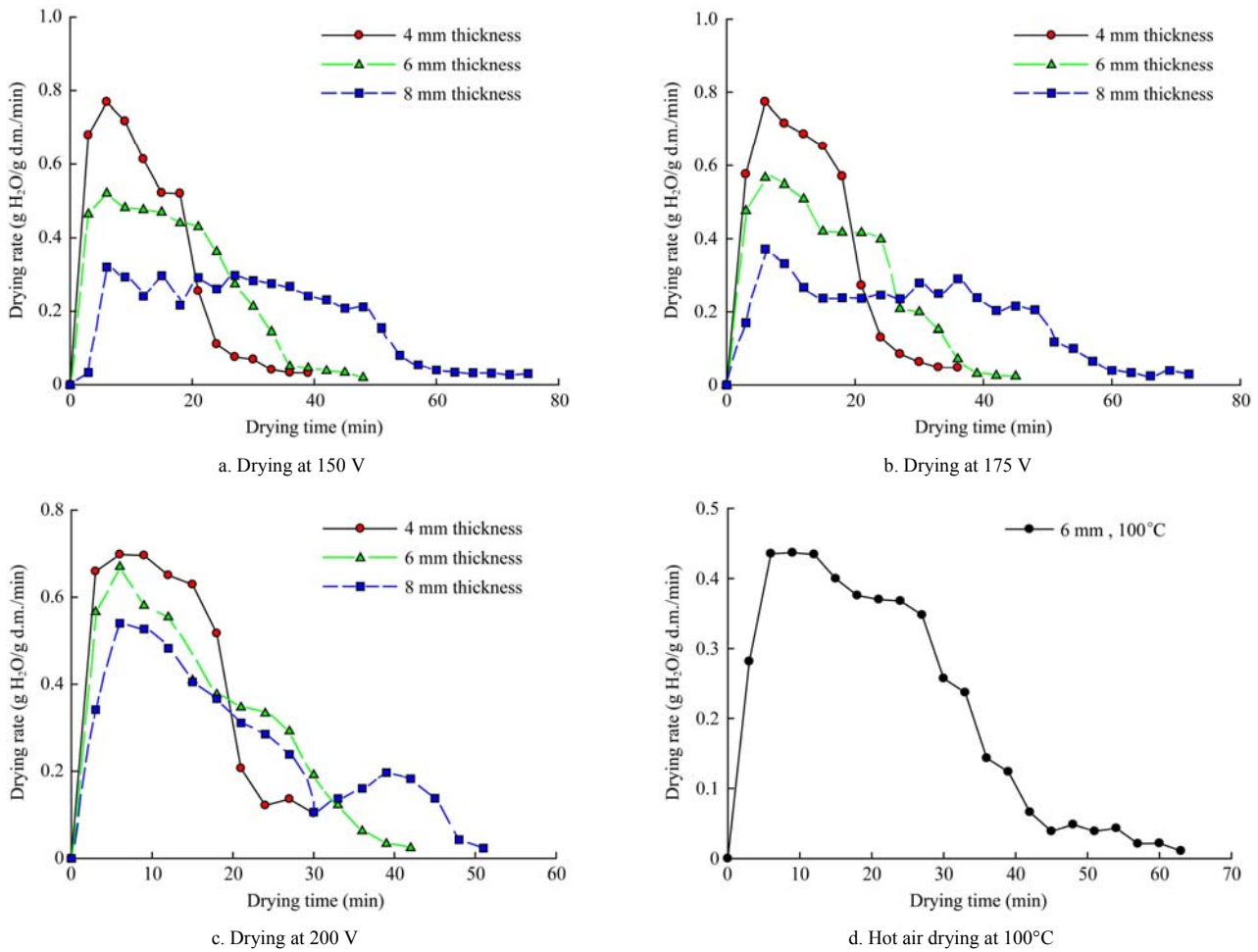
d. Hot air drying at 100°C

Figure 2 Effect of foam mat thickness on drying rate of papaya pulp foam during induction assisted foam mat drying

3.2 Model fitting

Moisture ratio data obtained from foam mat drying studies of papaya pulp at different voltages and thicknesses were fitted into thin layer drying models. The fitness of drying models was tested in terms of R^2, χ^2 and RMSE. A higher value of the coefficient of determination (R^2) and lower values of χ^2, as well as RMSE for a model, indicate that the model fits better to the given set of experimental data. The highest R^2 value of 0.9994 was obtained for Wang and Singh's model fitted to drying condition: 6 mm foam-mat thickness and 200 V induction voltage. The same model also exhibited lowest χ^2 and RMSE values 0.00008 and 0.00814, respectively for this drying condition. However, in all other cases of IHFMD, Midilli-Kucuk model exhibited the highest value of R^2 and lowest values for χ^2 and RMSE. The lowest R^2 value of 0.9308 was obtained for Two Term model fitted to drying conditions: 8 mm foam-mat thickness and 150 V induction voltage. It was observed that all models fitted gave R^2 well above 0.90 in all conditions.

3.3 Quality characteristics

3.3.1 pH

The pH of fresh papaya pulp was 4.40. The average experimental values of pH of dried samples were found in the range of 4.56 to 5.06. The quadratic model was found to be significant for pH at $p \leq 0.05$. The linear terms and interaction term (AB) of induction voltage and foam-mat thickness were also found to be significant at $p \leq 0.05$. The coefficient of determination (R^2) was 0.9089 and lack of fit was not significant. The following regression equation, describing the effect of process variables on pH, was obtained, where A represents Induction Voltage and B represents foam mat thickness

$$pH = +4.71296 - 1.77778E{-}003*A - 0.17500*B + 1.33333E{-}003*A*B$$

According to the model equation, both input voltage and foam-mat thickness had a negative correlation with the response, although the former was dominant as it is evident from corresponding regression coefficients and F values. The negative effects of both input voltage and

foam-mat thickness suggest a lower pH at lower levels of these factors. This is also evident from the 3D plot below Figure 3. The pH increased with increase in voltage and thickness. This may be due to the destruction of acids by more heat generation and greater time required for drying of higher thickness.
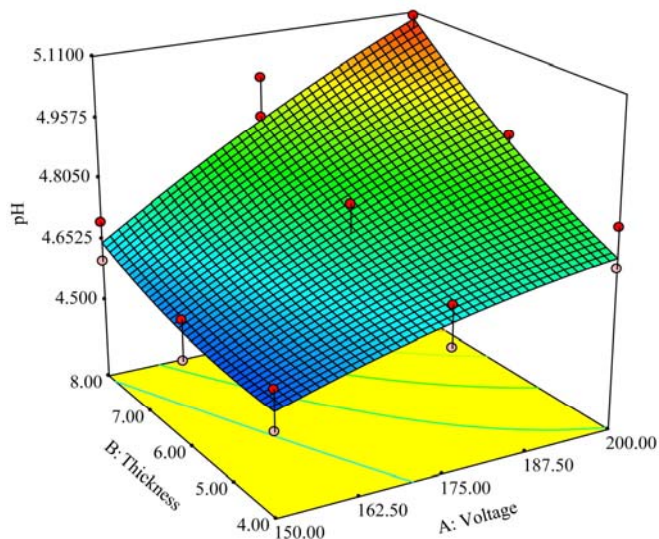

Figure 3   3D response surface plot showing variation in pH during IHFMD of papaya pulp

3.3.2 Ascorbic acid

The ascorbic content of the foamed papaya pulp was 149 mg 100 mL^{-1}. The average experimental values of the ascorbic acid of reconstituted papaya powder ranged between 100.2 and 133.3 mg 100 mL^{-1} the quadratic model was found to be significant at $p \leq 0.05$. The linear terms of induction voltage and foam thickness and the quadratic term of induction voltage (A^2) were found to be significant at $p \leq 0.05$. The following regression equation, representing the effect of the process variables ascorbic acid content, was obtained

Ascorbic acid (mg 100 mL^{-1}) = + 448.45000–
3.20156*A–1.79167*B +7.65333E–003*A^2

The above equation depicts that both input voltage (A) and foam-mat thickness (B) had a negative effect on the response. The effect of the input voltage is dominant as is evident from corresponding coefficients and F values. The negative effects of both input voltage and foam thickness suggest a lower loss of ascorbic acid content at lower levels of these factors. This is also clear from 3D plot below Figure 4. The ascorbic acid content in foam-mat dried powder was found to be less as compared to fresh fruit, and it may be due to the destructive effect

of the thermal treatment causing oxidation of the ascorbic acid. The ascorbic acid content decreased with increase in voltage due to higher heat generation at high voltages. Foam mat thickness also has an effect on ascorbic acid content with higher thickness retaining fewer nutrients due to the long time required for drying. A similar decline in ascorbic acid content was noticed in papaya pulp by Kandasamy et al. (2012).
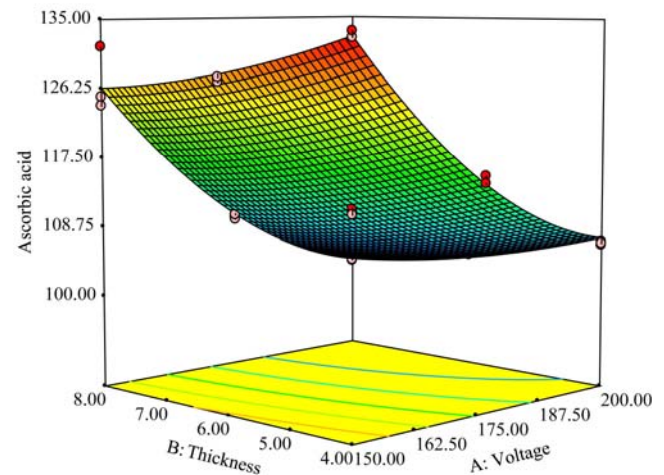

Figure 4   3D response surface plot showing the effect of IHFMD on ascorbic acid of papaya pulp

3.3.3 TSS

TSS of the fresh sample was found to be 13 Brix. The average value of TSS for the IHFMD dried samples varied between 10.5 and 12.5 Brix. The quadratic model was found to be significant for TSS at $p \leq 0.05$. The linear terms of induction voltage and foam thickness were also found to be significant. The R^2 was 0.9178 and lack of fitness was not significant. The following regression equation, presenting the effect of process variables on TSS, was obtained

TSS= +27.50000–0.15778*A+0.055556*B+
3.55556E–004*A^2

According to the above model equation, the input voltage (A) had a negative correlation with the response and foam mat thickness (B) had a positive correlation with the response. The regression coefficients and F values showed that the input voltage has a much greater correlation with TSS as compared to the foam thickness. The variation is shown by 3D plot below Figure 5. TSS declined with increase voltage although the decline is less. TSS was observed to decline by some researchers (Rajkumar et al., 2007), because of the heat sensitive nature of some compounds. Also, the variation in the TSS

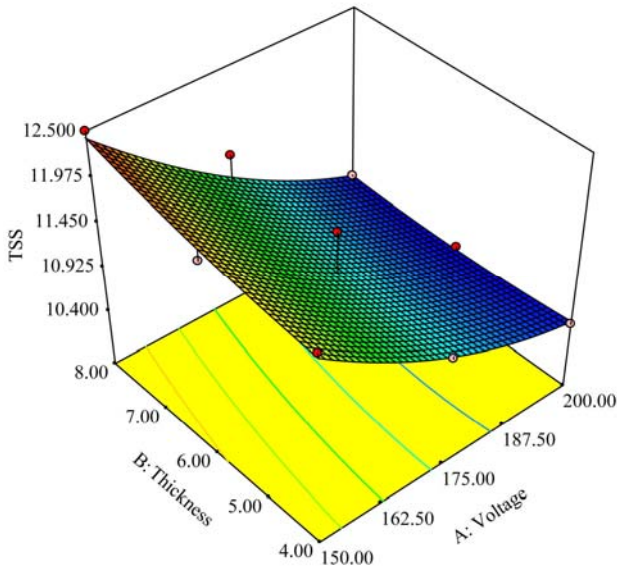is due to the difference in final moisture content of the samples.

Figure 5　3D response surface plot showing the effect of IHFMD on TSS of papaya pulp

3.3.4　Total sugar

The total sugar content of fresh papaya pulp was about 3.875%. The sugar content of IHFMD papaya powder was found in the range of 3.60% to 3.69%. The quadratic model was found to be significant at $p \leq 0.05$. The linear terms of induction voltage and foam thickness were found to be significant at $p \leq 0.05$. The value of R^2 was 0.8451 and lack of fit was not significant indicating that the model was adequately fitting to the experimental data. The effect of processes variables is represented by the following regression equation.

$$\text{Total sugar} = +3.89022 - 1.21778E{-}003*A - 6.16667E{-}003*B$$

The above equation depicts that both A and B had a negative effect on the response, although the former was dominant as it is evident from corresponding regression coefficients and F values. The negative effects of both input voltage and foam mat thickness suggest a lower loss of total sugar at lower levels of these factors. It can be clearly inferred from the 3D plot Figure 6 and Table 2 that the level of sugar content decreased as there is an increase in the thickness of foam and voltage. The loss may be due to high heat generation by voltage and the higher time taken by the thicker foam mat. Similar results were also obtained in foam mat dried papaya pulp powder by Kandasamy et al., (2014).
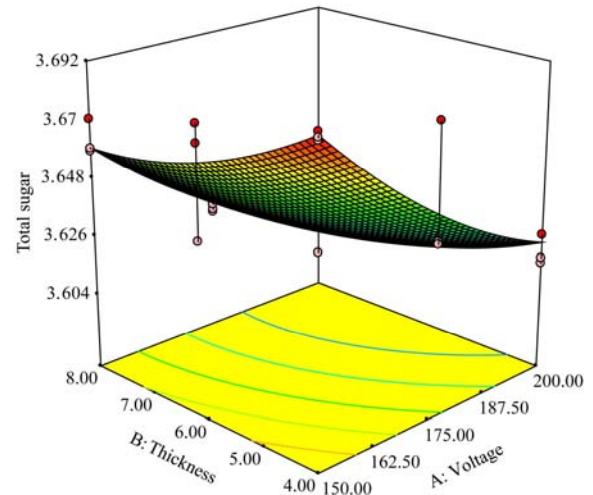

Figure 6　3D response surface plot showing the effect of IHFMD on the total sugar content of papaya pulp

3.3.5　Reducing sugar

The reducing sugar of fresh papaya pulp was about 3.734%. The reducing sugar content of IHFMD papaya powder was found to be in the range of 3.451% to 3.598%. The quadratic model was found to be significant at $p \leq 0.05$. The value of R^2 was 0.9919. The following regression equation, representing the effect of process variables on reducing sugar, was obtained.

$$\text{Reducing sugar} = +4.00688 - 2.46333E{-}003*A - 0.019986*B + 6.16667E{-}004 *A*B$$

The above equation depicts that both A and B had a negative effect on the response, although the former was dominant as it is evident from corresponding regression coefficients and F values. The negative effects of both input voltage and foam mat thickness suggest a lower loss of reducing sugar at lower levels of these factors. This is evident in the 3D plot shown in Figure 7. The decrease in the sugar content noticed in samples may be attributed to Maillard reaction due to high temperature during drying. A similar decline in sugar content was also reported during the preparation of dehydrated chips (Marwaha and Pandey, 2006).

3.3.6　Color change

There was no particular trend followed by color change (ΔE) as can be inferred from the 3D plot in Figure 8. The quadratic model for color change was not significant. Hence it could not predict the color change. The average value of color change for the IHFMD dried sample varied between 9.67and 20.76. This suggested that there was very less difference in color between different IHFMD samples.
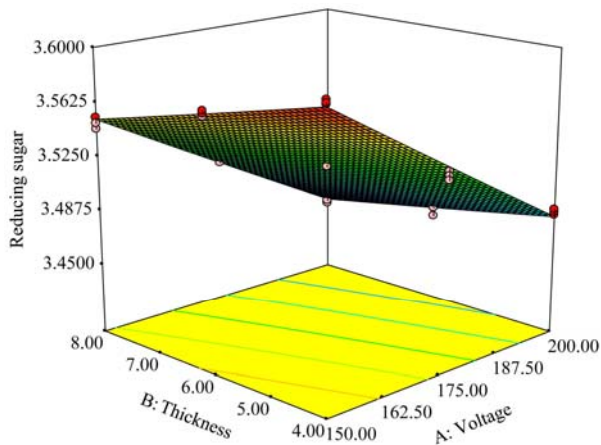
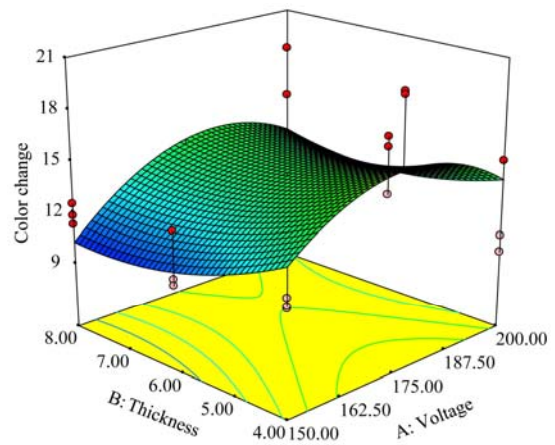Figure 7   3D response surface plot showing the effect of IHFMD on reducing the sugar content of papaya pulp

Figure 8   3D response surface plot showing the effect of IHFMD on the color of papaya pulp

Table 2   Mean values of the physicochemical composition of reconstituted papaya powders obtained from induction heating assisted foam-mat drying and hot air drying

Induction voltage (V)	Foam thickness (mm)	pH value	TSS Brix (°B)	Ascorbic acid (mg/100 g)	Total sugar (%)	Reducing sugar (%)	Colour change (ΔE)
150	4	4.56±0.57	12±0.0	133.3±0.40	3.690±0.001	3.598±0.052	11.42±0.31
	6	4.56±0.56	12±0.0	128.2±0.30	3.680±0.022	3.573±0.002	11.17±1.71
	8	4.63±0.57	12.5±0.0	124.4±1.99	3.663±0.006	3.549±0.004	11.92±0.61
175	4	4.63±0.55	11±0.0	116.4±0.51	3.639±0.025	3.533±0.003	20.68±0.10
	6	4.73±0.54	11.5±0.05	110.7±0.45	3.631±0.001	3.521±0.002	13.37±0.05
	8	4.93±0.57	11.5±0.05	108.2±0.30	3.622±0.001	3.507±0.005	11.34±0.22
200	4	4.73±0.54	10.5±0.02	106.7±0.20	3.617±0.005	3.487±0.002	11.81±2.90
	6	4.9±0.55	10.5±0.5	103.6±0.55	3.611±0.001	3.468±0.005	13.27±1.52
	8	5.06±0.57	10.5±0.5	100.2±0.1	3.60±0.001	3.451±0.001	14.95±2.17
Hot air drying (100°C)	6	5.02±0.56	9±0.28	96±0.43	3.59± 0.024	3.412±0.053	17.54±1.70

3.3.7   Quality comparison of hot air dried powder and IHFMD powder

The papaya foam prepared was dried by two drying methods viz. hot air and induction drying. By drying mat thickness of 6 mm by both methods at the same temperature, it was observed that the quality of the powder produced by induction method was much better than the powder produced by hot air method. From the data available in Table 2, it can be seen that the powder produced by induction method is superior in quality in terms of pH, vitamin C, reducing sugar, TSS and even the color change in induction dried powder was less than that of hot air dried powder. Furthermore, from the drying curves in Figure 1, it is clear that the drying time in hot air drying method was higher compared to that with induction method. This may be the reason for higher nutrient destruction in hot air method, as the nutrients are more sensitive to heating time than intensity.

4   Conclusion

It can be deduced from the above study that IHFMD is indeed a superior choice and potential method for the preservation of papaya pulp in the form of dried powder. It is clear from the experimental study that there is a considerable decrease in drying time as compared to simple hot air drying. Hence, induction heating is a promising method of drying. The feasibility of induction heating in combination with foam mat is depicted by the above study. The product was not adversely affected in any of the combinations of voltage and thickness in induction heating. The color and pH of the product was not adversely affected. The retention of ascorbic acid and sugar in samples was also better as compared to samples dried in a hot air dryer. So, IHFMD seems to have good potential to be adsorbed if a commercial scale dryer is developed based on this method of drying.

Acknowledgment

Appreciation is extended to the Department of Post Harvest Engineering and Technology, Aligarh Muslim University, Aligarh, India.

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