Effect of microwave power on foam-mat drying of tomato pulp

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Abstract: The experiments were conducted to study the effect of microwave power on drying characteristics vis-à-vis on quality attributes of foamed tomato pulp-egg albumin mixture in a microwave assisted foam-mat drying system. Samples were prepared using tomato pulp by incorporating 10% egg albumin as foaming agent and whipping for 5 min. 10 mm thick layer of foamed tomato pulp was spread on a tray and dried in the dryer at different microwave power levels (0, 480 W, 640 W and 800 W) at an inlet air temperature of 45°C. The increase of microwave power accelerated the dehydration of the foam and it was observed that the drying time reduced about 15-16 times in case of microwave assisted foam-mat drying as compared to simple foam-mat drying. There was no adverse effect on colour, titrable acidity and pH of the product, and the retention of ascorbic acid, in samples dried in microwave assisted foam-mat drying, was also better as compared to that in samples dried in air convection foam-mat dried system.

Keywords: foam-mat drying, tomato, microwave drying, tomato powder

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1 Introduction

Tomato is one of the widely grown and consumed vegetables throughout the world. It is an important source of minerals, iron, phosphorus, organic acid, essential amino acids, dietary fibers, beta-carotene pigments, antioxidants such as lycopene, phenolics, and vitamins (A and C) and has been linked with reduced risk of prostate cancer and heart diseases (Abushita *et al*., 1997; Clinton, 1998; Rao and Agarwal, 2000). India is the second largest producer of tomato only after China and this is also the second largest vegetable crop produced in India (Kumar, 2011). Tomato is produced in surplus amount during the harvesting season but its high moisture content (90-94%) makes it prone to spoilage and difficult to transport. Due to the lack of efficient post-harvest handling techniques in developing countries there is a huge loss of food as well as economy (Verma and Joshi, 2000). In order to prevent the spoilage of tomato it is processed into different products like tomato ketchup, tomato puree, tomato powder, etc. Preservation of tomato by drying is a common practice and the dried tomato products include tomato halves, slices and powders. Drying is a complex operation involving transient transfer of heat and mass along with several rate processes, such as physical or chemical transformations, which, in turn, may cause changes in product quality as well as the mechanisms of heat and mass transfer (Mujumdar and Devahastin, 2006). Foam-mat drying is a process in which a liquid or semi liquid material is converted into stable foam by incorporating substantial volume of air or other inert gas in the presence of a foaming agent, which works as a foam inducer and stabilizer. Foam-mat drying has received attention because of its ability to process hard-to dry materials and high volatiles preservation (Muthukumran *et al*., 2008). Foam-mat drying offers the advantages of air drying, cheapness and accessibility (Kadam *et al*., 2012).

The shortcoming of foam-mat drying method, however, is the poor heat transfer of air entrapped in the foamed materials. Microwave heating has the property of volumetric heat generation throughout the product which

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may eliminate this problem (Ratti and Kudra, 2006). The unique characteristics of the heat generation by microwave energy have been successfully employed in the processing of various food products (Gunasekaran, 1999; Shivhare, 1992). In foam-mat drying, the poor thermal conductivity of the product is not a limiting factor when heat is generated by the microwave energy.

In this study, the effect of microwave power on drying time and quality indices (ascorbic acid, acidity & pH and colour difference) of the dried tomato pulp were studied. Objective of the present study was to compare the results of microwave assisted foam-mat drying with the simple foam-mat drying of tomato pulp.

2 Materials and methods

Fresh and ripe tomatoes were procured from the local market of Aligarh and were used in the study. Eggs were also procured from the local market weighing between 47.2 g and 50.7 g. Fresh egg albumin was separated manually by gently breaking the shell and pouring content in to a bowl followed by removing yolk by a spatula. About 26.7 g to 28.5 g of egg albumin was obtained from each egg.

2.1 Experimental procedure

Tomatoes were washed under tap water to remove the dirt and other extraneous matter. After washing the tomatoes were hot water peeled by dipping them in boiling water for 1-2 min followed by dipping in cold water which loosened their skin and then the skin was removed. After peeling the tomatoes were pulped to obtain tomato pulp free from seeds and any remaining portions of skin adhering to the tomato pieces. The obtained pulp was pasteurized by heating at 65°C for 30 min (Mahapatra and Lan, 1999), packed in polyethylene bags and then kept in frozen storage at minus 16°C.

Before each experiment, the frozen tomato pulp was thawed by dipping the bags in warm potable water. The egg albumin was homogenized and incorporated as foaming agent at 10% (v/v) as per the available literature (Kadam and Balasubramanian, 2011). Whipping was done for five min using hand blender (Orpat OHM 207, India) which was operated at 1,400 rpm for foam generation by incorporating air, to increase surface area of tomato pulp (Kadam and Balasubramanian, 2011).

A shallow, flat-bottom, microwavable plastic pan with diameter 18 cm was used for the drying of the tomato pulp. A layer of 10 mm of foamed tomato pulp was spread over the pan evenly. The thickness of the foam-mat was measured accurately by placing the pan over a horizontal platform and dipping a graduated dip-stick in it at different places. The pan was placed in a domestic microwave oven (Kenstar, KE-20 CMGJ-MGK) modified to include hot air convection system. The temperature of drying air was 45˚C and flow rate was 1.3 m/s. Different microwave power levels (0, 480 W, 640 W & 800 W) were selected after preliminary trials. The weighing of the pan before and after loading of tomato pulp foam was done over an electronic balance (BL-220H, Shumadzu® Corporation, Japan) of 220 g capacity and least count of 0.001 g. The weight of the pan was quickly recorded at every one minute interval while drying with microwave power and at every 5 min interval while drying with only hot air, by opening the door of the oven and gently taking the pan out of the cavity followed by placing of the pan over weighing balance quickly, transferring again on the turn-table and pressing the start button. The tomato pulp foam was dried to a final moisture content of about 6% d.b, which was approximately equal to the predetermined weight of sample. The predetermined final weight was calculated by applying mass balance to the initial moisture content of the foam which was estimated by hot-air oven method. After the completion of drying, the dried tomato pulp was immediately scrapped off from the pan and was kept in a dessicator and allowed to cool down. Then the dried flaky product was ground into powder and was packed in the combination films and kept for further analyses.

2.2 Physical and chemical analysis

Different physical and chemical properties of fresh tomato pulp, tomato pulp egg albumin foam and reconstituted tomato powder were determined. The dried tomato powder was reconstituted at a ratio of 1:19 (tomato powder: water) to obtain its original moisture content (i.e., 14.52 g H_2O/g d.m or 93.56%).

2.2.1 Drainage volume of foam

A volume of 500 mL of the foam was gently transferred

into a beaker and left undisturbed for 30 min and the drainage volume was measured by gently tilting beaker and pouring the liquid collected in the bottom into a measuring cylinder of 10 mL capacity. The time for drainage was limited to only 30 min because from the preliminary trials of microwave assisted foam-mat drying of tomato pulp, it was observed that the maximum time required for drying was within this period. Similar method of measuring drainage volume has been reported by many authors (Karim and Wai, 1999; Muthukumaran *et al*., 2008; Raharitsifa *et al*., 2006).

2.2.2 Foam density

Foam density was determined using a method described by Labelle (1966) and also reported by Karim and Wai (1999). The density of unfoamed tomato pulp-egg albumin mixture was determined by weighing 100 mL of the mixture in a 100 mL measuring cylinder. For the foam, 200 mL of the foam was transferred into a 250 mL measuring cylinder and weighed. The foam transferring was carried out very carefully to avoid destruction of foam structure or trapping of air voids while filling the cylinder. The determinations were done in triplicate for each batch of preparation and the average values have been reported.

2.2.3 Volume expansion

The expansion of volume during foaming of tomato pulp egg albumin solution was determined by foaming 100 mL of the mixture and gently transferring the foam into a 250 mL measuring cylinder. Foam expansion (%) was calculated by the following equation as described by Durian (1995):

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

Since it is not possible to foam the whole mixture taken then

$$V_0 = V_i - V_u$$

where, V_1 is the final volume of foamed mixture, cm^3; V_i is the initial volume of mixture, cm^3 and V_u is volume of mixture remained unfoamed.

2.2.4 Moisture content

Moisture contents of the tomato pulp egg albumin mixture and that of the foam during drying were recorded and calculated for determining the drying kinetics. Moisture contents of tomato pulp, mixture of tomato pulp and egg albumin and foamed tomato pulp were determined in triplicates. In each case, 10 g of sample was poured in one or more pre-weighed clean petridish(es). The uncovered dish with its lid open was placed in a well-ventilated hot air oven at 70°C till the variation in consecutive weighing made at 2 h intervals was less than 0.05 g. Moisture content of samples was determined using following formula.

$$\text{M.C(\%, d.b)} = \frac{\text{Loss in wt of sample}}{\text{Final (bone dry) wt of sample}} \times 100$$

2.2.5 Drying-rate calculation

Drying rate was calculated using following equation.

$$DR = \frac{W_t - W_{t+dt}}{dt \times W_d}$$

where, DR = drying rate, g H_2O/g dry matter/ min; W_t = weight of sample at time t, g; W_{t+dt} = weight of sample at any time $t+dt$, g; dt = time interval, min; W_d = weight of bone dry material in sample, g.

2.2.6 Ascorbic acid

Ascorbic acid was estimated using 2,6-dichlorophenol-indophenol visual titration method as given in Rangana (1986) and reported by Kadam *et al.* (2012). An aliquot of the sample was diluted to a fixed volume with 3% HPO_3 and then titrated with 2,6-dichlorophenolindophenol. A standard ascorbic acid solution of 5 mL was added to 5 mL of 3% HPO_3 and titrated with dye solution to a pink color, which persisted for 15 s. The dye factor, i.e., mg of ascorbic acid per ml of the dye, was determined using the formula:

$$\text{Dye factor} = \frac{0.5}{\text{titre}}$$

Ascorbic acid (mg/100 mL) of reconstituted juice was calculated using the formula:

$$\text{Ascorbic acid}\left(\frac{\text{mg}}{100\text{ mL}}\right) = \frac{T \times DF \times V_1}{V_2 \times V_3}$$

where, T = titre; DF = Dye factor; V_1 = volume made up; V_2 = aliquot of extract taken for estimation and V_3 = volume of sample taken for estimation

2.2.7 Titrable acidity and pH

Titrable acidity was estimated by diluting the aliquot of the sample with water to a fixed volume and then titrating it with 0.1 N NaOH using phenolphthalein as an indicator (Rangana, 1986). The percent acidity as

percent anhydrous citric acid was calculated using following the formula:

$$\text{Total acid (\%)} = \frac{T \times N \times V_1 \times E \times 100}{V_2 \times V_3 \times 1000}$$

where, T = titre; N = normality of alkali; V_1 = volume made up; E = equivalent weight of acid; V_2 = volume of sample taken for estimation and V_3 = volume of sample taken for titration.

A digital pH meter (Cyberscan pH-1500, Ectech Instruments, Singapore) was used to measure the pH of the samples.

2.2.8 Colour difference

The measurement of 'L', 'a' and 'b' values was done by placing Hunter Colour Lab (Mini Scan XE Plus, USA) over the reconstituted MAFMD tomato powder and the L, a, b values were recorded. These values were used for calculating the colour difference to describe the effect of microwave on colour of reconstituted tomato powder with reference to original colour (L^*, a^*, b^*) of fresh tomato pulp as has been used by many researchers in their studies (Kadam, and Balasubramanian, 2011; Rzepecka *et al*., 1976). The following formula was used for the calculation of colour difference.

3 Results and discussion

The initial moisture content of tomato pulp-egg albumin foam was 14.52 g H_2O/g d.m. Titrable acidity, ascorbic acid content and pH of fresh tomato pulp were 0.422%, 15.476 mg/100 mL and 4.15 respectively which changed to 0.358%, 13.095 mg/100 mL and 4.39 respectively when 10% egg albumin was added as foaming agent to the tomato pulp, as shown in Table 1. This change in acidity and pH was because of the difference in the acidities and pH of tomato pulp and egg albumin, also reported by Kadam and Balasubramanian (2011). The ascorbic acid content of fresh tomato pulp reduced when 10% egg albumin as foaming agent was added to it. This decrease in ascorbic acid content was due to the absence of ascorbic acid in egg albumin.

The density of the tomato foam ranged between 0.32-0.38 g/cm^3 which was well within the range of 0.2-0.6 g/cm^3 reported by Hart *et al*., (1963), as the optimum range of bulk density of material for foam-mat drying. A volume expansion of 135.86% was observed on whipping of tomato pulp for 5 min when incorporated with 10% egg albumin (Table 1).

Table 1 Properties of Tomato Pulp and Tomato Pulp with 10% Egg Albumin

Properties	Tomato pulp	Tomato pulp with 10% egg albumin
Acidity (%)	0.422	0.358
pH	4.15	4.39
Ascorbic acid (mg/100 mL)	15.476	13.095

3.1 Effect of microwave power on drying time

Microwave power had a pronounced effect on the drying time. From the Figure 1, it can be clearly observed that moisture content of the sample decreased as the drying time progressed till a constant value of 0.06 g H_2O/g d.m. was attained. Initial moisture content of the foam i.e., 14.52 g H_2O/g d.m. reduced faster during initial stage of drying, however, at the end, the slope of curves became flatter indicating the slower drying rate. Similar results were also reported in the microwave foam-mat drying of tomato paste (Rzepecka *et al*., 1976). An increase in microwave power from 0 to 800 W caused a drastic reduction in the drying time. The time taken to attain a moisture content of about 0.06 g H_2O/g d.m. for foam of thickness 10 mm at inlet air temperature 45°C and 0 W microwave power was 110 min while the drying time for the foam of same thickness and inlet air temperature but at 480 W microwave power was 15 min. The drying time further decreased to 12 min and 10 min when the microwave power level was increased to 640 W and 800 W, respectively with other conditions remaining the same. This enormous decrease in drying time of the foam-mat is attributed to the ability of the microwave to

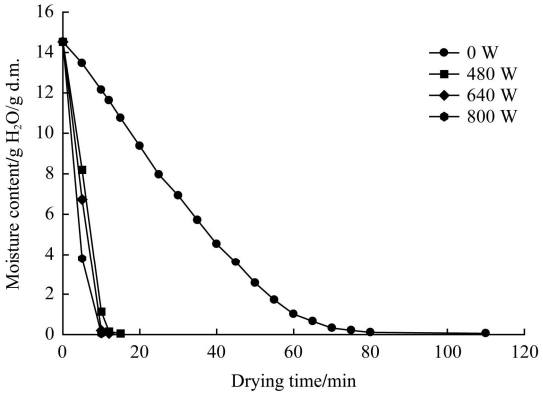

Figure 1 Effect of microwave power on drying time

cause rapid heating of foam to a greater depth which increased the mass transfer rate and hence the faster drying. Similar results have been reported in the microwave drying of tomato paste by Rzepecka *et al.* (1976), kiwifruits by Maskan (2001), garlic by Sharma and Prasad (2001), and spinach by Ozkan and Akbudak (2007).

3.2 Effect of microwave power on drying rate

Drying rate was calculated in terms of gram of water lost per minute per gram of dry matter and henceforth the unit used for drying rate is denoted as g H_2O/g d.m./min. The drying rate increased sharply at the beginning when microwave power was used while there was a gradual increase in the drying rate of the foam-mat dried at 0 W microwave power, as can be seen in the Figure 2. The increase in the drying rate at the beginning shows the presence of a heat up period which reduced with the increase in microwave power. The drying rate had a maximum value at microwave power 800 W but after reaching the peak value, it dropped sharply, whereas, at microwave power 640 W and 480 W the drying rate after attaining the peak value remained almost constant for some time and then decreased. At microwave power 0 W, the heat up period was slow and the constant rate period persisted for longer duration. The reason for this is volumetric heat generation by microwave energy which resulted in instantaneous heating up and continuous heat generation in the foam until the moisture content decreased. Also, as the microwave power increased from 480 W to 800 W there was more heat generation because of greater penetration and higher energy of the microwaves, whereas, at 0 W microwave power the mode of heat transfer to the foam was convection, and within the foam principally was conduction that resulted in slower heat transfer as compared to that occurred when microwave energy was used. In all the cases, 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, 2002). The drying rate at microwave power 800 W reached a peak value of 2.55 g H_2O/g d.m./min while at 640 W and 480 W the peak drying rates were 1.77 g H_2O/g d.m./min and 1.54 g H_2O/g d.m/min, respectively. In comparison to these, the peak drying rate at 0 W microwave power was much lower (0.28 g H_2O/g d.m./min). Karim and Wai (1999), Thuwapanichhayanan *et al*., (2008), Phinthida and Thanakorn (2011), have also reported the heat up periods and falling rate periods during drying of star fruit foam, banana foam and mango foam, respectively.

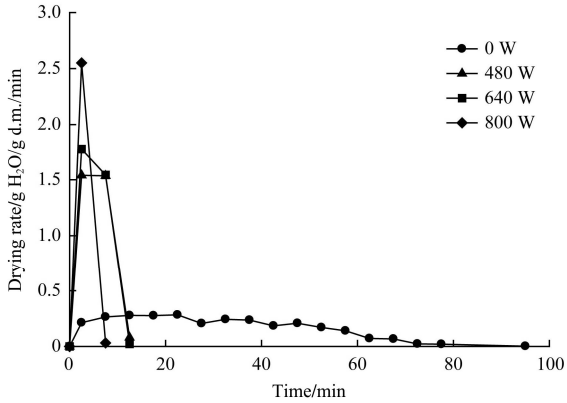

Figure 2 Effect of microwave power on drying rate

3.3 Effect of microwave power on physical & chemical properties

3.3.1 Ascorbic acid

The average experimental values of the ascorbic acid of the reconstituted tomato powder ranged between 4.284 mg/100 mL and 6.845 mg/100 mL (Table 2). The ascorbic acid content reduced during the foam-mat drying, evidently due to its heat labile nature. The ascorbic acid content of the sample increased with an increase in microwave power in the selected range (0 to 800 W), exhibiting a positive correlation with microwave power. This supports the concept that nutrients are more sensitive to time than to temperature, which implies that a greater reduction in time at the cost of slighter increase in temperature results in better retention of nutrients (Teixeira, 2012). Similar decline in ascorbic acid content was noticed in other studies with tomato by Kadam *et al*., (2012), potato by Marwaha and Pandey (2006), pulses by Mehta *et al*., (2007), muskmelon by Fernandez *et al*., (2007), cauliflower by Kadam *et al*., (2005), and onion by Kadam *et al*., (2009), following heat treatment.

Table 2 Effect of microwave power on physical and chemical properties of reconstituted tomato pulp

Microwave power, W	Ascorbic acid, mg/100 mL	Acidity, %	pH
0	4.284	0.317	4.28
480	5.952	0.304	4.28
640	6.786	0.326	4.30
800	6.845	0.336	4.31

3.3.2 Titrable acidity & pH

Citric acid is the main acid present in tomato and pH is an important measure of the active acidity which influences the flavour or palatibility of a product. The average experimental values of the titrable acidity of the reconstituted tomato powder ranged between 0.304% and 0.336% and the pH of the samples varied between 4.28 and 4.31 as given in Table 2. It was observed that the titrable acidity and the pH of reconstituted tomato powder varied randomly but the values were very close with those of the fresh tomato pulp egg albumin mixture. This suggests that the drying process did not have a marked effect on organic acids of the tomato powder responsible for the titrable acidity and pH.

3.3.3 Colour difference

Colour difference (ΔE) is a measure of qualitative change in processed sample with respect to raw sample indicating effect of processing on colour. The average value of colour difference for the dried samples varied between 7.914 (microwave power 0 W) and 12.738 (microwave power 800 W). A slight increase was observed in colour difference (ΔE) when microwave power increased from 0 W to 640 W, but at 800 W the increase was substantially high as shown in Table 3. An increase in temperature of foam-mat due to the increase in microwave power resulted in whiter tint to the foam-mats owing to increased cauglation of egg albumin which resulted in the increase in *L* value (brightness). The colour parameters of the microwave dehydrated tomato pulp foam-mat samples were very close to the parameters of the untreated samples, so no adverse effects on the colour quality were observed. Similar results were reported by Rzepecka *et al.,*(1976).

Table 3 Effect of microwave power on *L, a, b* and colour difference (ΔE)

Microwave power, W	*L*	*a*	*b*	Colour difference (ΔE)
0	21.5	19.58	24.69	7.914
480	23.18	19.83	24.25	8.216
640	26.14	17.94	22.35	8.5
800	27.24	18.25	27.29	12.738

4 Conclusion

There was an enormous decrease in drying time of tomato pulp-egg albumin foam in microwave assisted foam-mat drying as compared to air convection foam-mat drying. Colour, titrable acidity and pH of the product were not adversely affected. The retention of ascorbic acid in samples was also better as compared to that in samples dried in air convection foam-mat drying system. The study has indicted that microwave assisted foam-mat drying is a promising alternative to existing convention-drying methods applied to liquid foods in dehydration industry.

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