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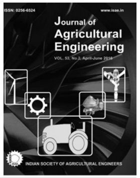

Drying Characteristics of Plum Tomato under Different Physical Treatments for Producing Powder

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ABSTRACT

Plum tomatoes were dried under hot air convection for producing powder. Different physical treatments were performed to achieve faster drying and milling. Initial moisture of tomato was 93.97 % with TSS of 4.6 %, which was dried to around 5 % moisture. Among the treatments, longitudinally cut in 16 pieces and cross-section slice segments took less time to dry and gave higher (6.4 %) drying yield. The effectiveness of treatments on drying characteristics and quality of tomato powder were examined. Mathematical models were employed by non-linear regression analysis to appropriately describe the drying behaviours. The physico-chemical quality characteristics of fresh and powder tomato were evaluated in terms of size and shape, peel pulp seed ratio, TSS, ascorbic acid, acidity, lycopene and solubility. The overall sensory perception revealed that all treatment samples of tomato powder reconstituted well in the form of soup-mix and achieved nearly equal scores on different quality attributes.

Tomato is one of the most acceptable vegetable crops in the world after potato. Tomato is rich in nutrition, and it also adds sensation to taste and flavour to food preparations. The average area and production of tomato in India during the year 2016-17 was about 0.50 Mha and 20.7 MMt, respectively (Anon., 2018). Out of the estimated 41 Mt of tomato processed globally in 2015, only 0.13 MMt were processed in India and was 0.3 % of the global tomato processing market. India could potentially process much more because of world's second largest tomato producer (Subramanian, 2016).

Plum tomato is a hybrid cultivar of tomato specially developed for processing. They are generally oval or cylindrical in shape, with significantly fewer seed compartments than common variety of round tomatoes. Plum tomato generally consists of higher solid content that makes it more appropriate for processing.

Tomatoes are generally processed for the production of sauce, ketchup, puree and paste. Tomato puree is used as a substitute to fresh tomato during cooking. Tomato powder can conveniently be used in many food preparations, particularly readymade foods like soups, noodles, etc. Preparation of dried tomato powder is performed at cottage industries. Fresh tomatoes can be dried in different shapes such as halves, slices and quarters for making powders and used as a component for pizza and various vegetable and spicy dishes (Khazaei *et al.,* 2008a)

The purpose of dehydrating fruits and vegetables is to reduce the moisture content to an extent that allows the fruits and vegetables to be stored safely for an extended period. Drying is an important process for preserving food as it considerably decreases the water activity and minimizes physical and chemical changes during its storage (Doymaz and Ozdemir, 2014). Drying also brings about substantial reduction in mass and volume, minimizing packaging, storage and transportation costs (Subukola *et al.,* 2007). The growing market opportunities have necessitated that tomatoes be accessible in a more convenient form, and led to the development of technologies for the preservation and sale of the product especially in a dry form (Purkayastha *et al.,* 2013). Dried form of tomato is used as a component for pizza and various vegetable dishes. It was suggested by Doymaz (2007) that to improve the quality of dried tomato products, mechanical drying methods such as hot air and solar drying are preferred over sun drying techniques which are mostly prevalent in Mediterranean countries. However, the most popular method of drying tomato is hot air drying in convective dryer due to its simple operation and relatively inexpensive technology (Akanbi *et al.,* 2006).

In tomato drying, the colour and flavour are considered as the most important quality attributes affecting the degree of acceptability of the products by consumers (Cernisev, 2010). Among many factors affecting the quality attributes during drying, the important ones are moisture content and temperature. Consumers always prefer that processed tomato products should have many of its original nutritional characteristics. According to Chang *et al.* (2006), maintaining the colour, nutrition and level of antioxidant compounds is more important in producing tomato products. These include vitamins A, C, E and carotenoids such as beta-carotene and lycopene. It is highly desirable by the consumers that the oxidative damage to tomato should be least during drying process and storage of the dried tomato (Albano *et al.,* 2011). The drying air temperature is one of the responsible factors for oxidation damage during tomato drying.

Optimization of tomato drying can be accomplished by maximizing drying rate and minimizing oxidative heat damage, and can be achieved by reducing the tomato thickness and drying of small pieces in the form of slices, quarters and cubes (Giovanelli *et al.,* 2002). Such smaller geometries of tomato involve shorter drying time to achieve the same level of moisture removal.

Tomato powder is one of the most convenient dried products and that can be used in many food preparations. Manufacturing of tomato powder at industrial level is being done by spray drying method that needs high investment. The simple method to produce high quality powder is to dry the tomato in slices or pieces to moisture content of around 6 %, and the dried slices is milled and sieved in a desired particle size.

The present investigation was conducted to study the drying behaviour of 'Plum' tomato for producing powder with different physical treatments primarily for conversion of whole tomato in simple geometries.

MATERIALS AND METHODS

Experimental Material

Poly-house cultivated fresh and uniformly ripe plum tomato (EC-596742) was harvested during the month of February from the vegetable research farm of the ICAR-RCER Research Centre, Ranchi. The variety was a F1 hybrid exotic collection introduced from AVRDC, Taiwan (Fig.1). About 10 kg of harvested tomato was

Fig. 1: Fresh plum tomato, slice and piece of tomato (T1 to T4), dried piece, dried slice and tomato powder

properly washed and wiped to remove dust and dirt prior to experimentation. The criteria for selection of tomato was uniformity in shape and size with similar ripeness level and firmness.

Physical Treatment of Tomato

The physical treatments (Fig.1) given to the Plum tomato included (a) longitudinal cut into 16 pieces of average thickness 4.5 mm (T1),(b) longitudinal cut into 8 pieces (T2) of average thickness of 9.0 mm, (c) cross-sectional cut slices of 5.0 mm thickness (T3), and (d) longitudinal cut slices of 5.0 mm thickness (T4).

The cut pieces of tomato were made by cutting the tomato along the centre to the surface. This increased the surface area to be exposed to drying air temperature.

A stainless-steel kitchen knife was used to accomplish the desired size reduction of tomato by visual observation.

Blanching

All physically treated samples were subjected to blanching. Blanching was performed in a microwave oven for 4.0 min with a sample size of 0.5 kg and at a power level of 800 W. The time of blanching was decided on the basis of preliminary trials conducted to achieve the desired heating of slices/pieces without any visual deformation or change in shape of slice or piece.

Drying

Each blanched sample was subjected to convective hot air drying at 55^{o}C in an air circulatory electric tray dryer with loading capacity of 6.0 kg.m^{-2}. The air temperature of 55^{o}C was selected for least non-enzymatic browning to maintain good quality of the dried sample.Tomato samples were spread in a single layer on stainless steel trays inside the drying chamber. The hot air circulation dryer was equipped with thermostat controlled heating elements (5.0 kW) and axial flow fans to create sufficient heated air circulation inside the drying chamber. A circular opening was provided at the bottom of the backside panel for exhaust of the moist air. The dryer was thermostatically controlled by PID controller to maintain a constant pre-set air temperature 55^{o}C. The dryer was continuously operated until the sample was dried to desired moisture content (5-6 % w.b.), which upon cooling provided brittleness to some extent. The moisture content of samples before and after drying was determined by static oven drying at 110^{o}C till the sample attained a constant weight. Observations on moisture losses were recorded at every one-hour interval. At the time of observation, approximately 20-25 g of sample was taken out in a moisture box, weighed immediately and again put into the dryer. The entire process of opening the door, withdrawing and weighing the sample and closing the door took not more than one minute.

Milling

The milling of dried pieces/slices of tomato was carried out in a high-speed rotary grinder (750 W) with blade speed of 2000 rpm for approximately 30 seconds. The ground samples were further sieved to obtain a fine powder of particle size less than 0.425 mm (Fig.1). The powder obtained from each sample was kept separately in polypropylene (PP) bags and sealed with impulse heat sealer.

Packaging and Storage

Milled sample of dried tomato powder (about 25 g) of particle size less than 0.425 mm were packaged in polypropylene pouches with the help of heat-sealing device (Sepack, 200DV2). The packets containing the dried powder were stored under laboratory condition (18-38^{o}C, 30-80 % RH) for 6 months. Moisture content, TSS, acidity and ascorbic acidof stored powder tomato were determined at an interval of 60 days.

Properties of Powder Tomato

Moisture content of sample was measured directly without dilution under oven drying method.

The powder was diluted in distilled water (1:10) to make syrup for measurement of TSS, acidity and ascorbic acid. Solubility was determined by homogenization (homogenizer with serrated pestle, GW123, HIMEDIA), centrifugation (Laboratory centrifuge REMI C-852, 35000 rpm) and determination of the insoluble residue from the dissolution of one gram of powdered juice in 10 ml distilled water at 25^{o}C according to the methodology of IAL (1977) as reported by Abadio *et al*. (2004).

Properties of Tomato Slice/piece

Physical properties

Plum tomato was evaluated to determine its physico-chemical characteristics. Digital electronic balance (Mettler Toledo, LC: 0.01g) was used to determine the average weight of tomato (n=10). Linear dimension of tomato (n=10) was measured with the help of a digital vernier caliper (Mitutoyo Japan, LC: 0.01 mm).

Geometrical mean diameter in cm (Dp) was determined using Eq. 1 as suggested by Koochaki *et al*. (2007):

$$D_p = (LWT)^{1/3} \quad \ldots(1)$$

Sphericity (ø) and surface area in cm^2 (S) of plum tomato was evaluated by using Eq. 2 and 3 as suggested by Khazaei *et al*. (2008b) and Jafri *et al*. (2011), respectively:

$$ø = [(L.W.T)^{1/3}]/L \quad \ldots(2)$$

Where,
L = Length, cm,
W = Width, cm,
T = Thickness, cm, and
S = $(\pi Dp^3)/6$. …(3)

Bulk density and true density of plum tomato was measured. Determination of bulk density was carried out by observing the weight of sample occupying half cubic meter volume.

True density of tomato was measured by toluene displacement method.

The measurement of total soluble solids (TSS, °B) of fresh tomato juice (n=10) and of dried powder (with 10 times dilution) were carried out using a digital hand held refractometer (PAL-1, 0-53°B, LC: 0.2°B).

Acidity

To determine the acidity of fresh tomato juice and dried powder, 0.1N NaOH was used for titration. Two to three drops of phenolphthalein indicator were added to 5 ml juice of fresh tomato and of juice from dried powder (with 10 times dilution), and the resultant juice was titrated against 0.1 N NaOH till the appearance of pink colour of juice.

Acidity was determined as:

Acidity (%) = (Titer x acid factor) x 100/5 ml juice (either of fresh tomato or diluted powder) …(4)

Acid factor for tomato (mainly citric acid) was considered as 0.0064.

Ascorbic acid

Ascorbic acid (Vitamin C) was determined by 2, 6-dichlorophenol indophenols visual titration method (Rangana, 2000). Ten g of sample was blended with metaphosphoric acid (3 %), made to 100 ml, and filtered. Ten ml of filtrate was titrated rapidly against 2, 6-dichlorophenol indophenols to end point with pink colour that persisted at least for 15 seconds.

Ascorbic acid content ($mg.100g^{-1}$ pulp weight) was calculated Eq. 5:

$$Ascorbicacid\left(\frac{mg}{100g}\right) = \frac{\text{Titre x dye factor x volume made up}}{\text{Aliquot of extract x volume of sample for estimation}} \text{x } 100 \quad \ldots(5)$$

The value of dye factor was considered as 6.25.

Lycopene

Lycopene of fresh tomato and dried powder was analysed according to the method described by Albano *et al.* (2011). The observance of the extracted samples was measured at 503 nm on a spectrophotometer (ECI Ltd., UV5704M) with petroleum ether as blank.

Lycopene was calculated as:

$$L = (31.206 \text{ x } Abs)/Wt \quad \ldots(6)$$

Where,
L = Lycopene content, $mg.100g^{-1}$,
Abs = Observance, and
Wt = Weight of sample, g.

Sensory Evaluation

Sensory evaluation of tomato powder was evaluated by making soup-mix using standard ingredients (Tomato powder-36 %, Roasted wheat fine flour-30 %, Milk solids-18 %, Corn starch-9 %, Coarsely ground dry cabbage-2 %, Coarsely ground dry carrot- 2 %, Onion powder-2 % and Garlic powder-1 %). The soup-mix was reconstituted and served to a semi-trained panel of 10 judges for organoleptic evaluation in terms of colour and appearance, texture and consistency, taste and flavour, and overall acceptability.

A 5-point balanced Hedonic scale ranging from extreme approval (excellent) to extreme disapproval (poor) was followed (Laxmi and Vimla, 2000; Thakur and Jain, 2006). The sensory score assigned by the judges for each attribute were statistically analysed by 2-factor analysis of variance at 5 % level of significance (Levine, 2012).

Mathematical Modelling for Drying

Drying curves obtained for the tomato samples of different treatments were fitted with four mathematical models based on moisture ratio (Table 1). The final moisture contents attained by the samples on completion of drying were approximated as equilibrium moisture content (M_e) after completion of moisture diffusion process for calculation of moisture ratio; and further applying to drying models (Thakur and Jain, 2006; Thakur *et al.* 2010). The hourly observation of moisture content (M, % d.b.) during the drying period of physically treated tomato slice/piece were converted into moisture ratios expressions as:

$$MR = (M-M_e)/(M_o-M_e) \qquad \ldots (7)$$

Where, M_o and M_e are initial and final moisture content (% d.b.).

The suitability of mathematical models was judged on the basis of values obtained for coefficient of determination (r^2), root mean square error and sum of residual mean square (s^2). The Marquardt-Levenberg nonlinear optimization technique of statistical package for social sciences (SPSS 10.0) was applied to evaluate the coefficients of each equations and to choose the best mathematical model for illustrating the observed drying curves (Thakur *et al.,* 2010). The instantaneous drying rate (g of moisture.100g^{-1} drying solid), and average moisture contents were computed for the samples under study.

RESULTS AND DISCUSSION

Physico-chemical Properties of Plum Tomato

Plum tomato is considered to be of superior quality among several varieties of tomato. The physico-chemical attributes of fresh Plum tomato are presented in Table 2.

Table 1. Mathematical models applied to the drying curves

Sl. No.	Model name	Model equation	Reference
1.	Newton	$MR = \exp(-kt)$	Brooker *et al.* (1974), Lui and Bakker-Arkema (1997)
2.	Henderson and Pebis	$MR = a \exp(-kt)$	Chhinman (1984)
3.	Page	$MR = \exp(-kt^n)$	Brooker *et al.* (1974)
4.	Midilli-Kucuk	$MR = a \exp(-kt^n) + bt$	Midilli and Kucuk (2005)

Note: a, b & n are model coefficients; k is the drying rate constant (h^{-1})

Observed dimensions of tomato suggested it to be oblong shaped because spherecity was near to 0.7. Single tomato fruit weight varied from 57 - 98 g depending on their size. The width and thickness of fruit were almost same, and thus cross-sectional view looked like nearly a circle with geometrical mean diameter equivalent to 53.5 mm.

Bulk density of tomato was found to be 45.9 % less than its true density. plum tomatoes firm at full maturity with red colour, and the pulp has less juicy characteristics (Brooks *et al.,* 2008). TSS value was in the range of 4.57 - 4.72° B. The variation in TSS

Table 2. Physico-chemical attributes of plum tomato

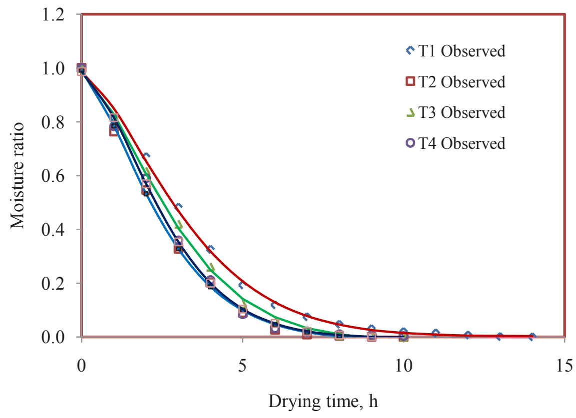
Sl. No.	Parameter	Value (mean±SD)
1.	Peel thickness, mm (n=10)	0.17±0.035
2.	No. of seeds (n=10)	9.4±4
3.	Seed thickness, mm (n=10)	0.232±0.032
4.	Pulp: peel: seed, % (n=10)	95.1±4.2 : 4.01±0.74 : 0.99±0.12
5.	Single fruit weight, g (n=10)	77.27±20.37
6.	Length (L), mm (n=10)	80.6±0.57
7.	Width (W), mm (n=10)	43.8±0.36
8.	Thickness (T), mm (n=10)	43.5±0.35
9.	Geometrical mean dia. (D_p), cm	5.35±0.37
10.	Sphericity, $ø = [(L.W.T)^{1/3}]/L$	0.66±0.03
11.	Surface area, cm^2	60.21±9.49
12.	Bulk density, kg.m^{-3}	540
13.	True density, kg.m^{-3}	998
14.	Moisture content, % wb	93.97±1.28
15.	Water activity of fresh tomato	0.946
16.	Total soluble solid (TSS), °B	4.62±0.05
17.	Acidity, g of citric acid.100g^{-1}	0.28±0.022
18.	Ascorbic acid, mg.100g^{-1}	23.54±2.32
19.	Lycopene content, mg.100g^{-1}	8.94

was due to the variations in ripening level of tomato. The average acidity and ascorbic acid values of fresh tomato were 0.28 g.100g^{-1} and 23.54 mg.100g^{-1}, respectively. Lycopene content of fresh tomato pulp was 8.94 mg.100g^{-1}.Purkayastha and Mahanta (2011) had analysed the physico-chemical characteristics of five different cultivars of tomato fruits of Meghalaya region, India and they found average TSS, acidity and ascorbic acid for oval shaped selection variety as 4.4 °B, 0.35 g.100g^{-1} and 18.58 mg/100g respectively, where tomato weight average was 64.0 g. Sahin *et al.* (2011) observed that the lycopene content of fresh tomato was 7.41 mg.100 g^{-1}, which significantly increased after drying.

Drying Behaviour

During the convective drying process of tomato slice/piece, it was observed that the moisture content continuously decreased with drying time. However, the relationship between moisture content and drying time was non-linear for most of the drying period (Fig. 2). In the initial period of drying of approximately 20 min, mostly free moisture was released. The non-linear relationship between moisture and drying time was due to the initiation of diffusion process, and then exclusion of moisture from the samples. Tomato slice (8 pieces, T2) took maximum time (14 h) to dry with minimum drying rate (134.2 % moisture.h^{-1}), and this was because of less exposed pulp area with higher peel surface area. The waxy cuticle peel surface created impediment in evaporation of moisture from the pulp. The other physically treated samples (T1, T3, T4) took almost similar time (10 - 11h) to dry with an average overall drying rate of 183 % moisture.h^{-1}. The horizontally (T3) and longitudinally (T4) cut slices took 11h, and required at least one time turning in the middle of the drying period to avoid tendency to glue with the tray surface. This might be due to liberation of juice between the tomato slices and tray. Whereas, longitudinal cut pieces either in 8 pieces (T1) or 16 pieces (T2) did not require any turning during the entire period of drying.

Brooks *et al.* (2008) studied the effects of tomato geometries and air temperature on the drying behaviour of plum tomato, and concluded that exposed surface area have a significant effect on moisture removal in comparison to only the cut surface area. They suggested that cutting the tomato into smaller pieces and drying at lower temperature is effective to reduce the drying time and maintain quality. In this study, it was noted that hot air convective drying of tomato pulp was a diffusion-controlled process (Fig. 2), and therefore, physical treatment of tomatoes to have maximum exposed area is essential to overcome the slow rate of drying. It was observed that the sample T1 (longitudinal cut into 16 pieces) resulted in higher rate (231.7 g of water per 100g of dry solid) of overall drying, followed by sample T3 (cross sectional slices) 224.3 g of water per 100g of dry solid, T2 (longitudinally cut in 8 pieces) 213.6 g of water per 100 g of dry solid and T4 (longitudinal slices) 181.4 g of water per 100 g of dry solid. The instantaneous drying rate curve vs. average moisture content (Fig. 3) also showed the similar trend as in the case of overall drying rate. Decreasing trend of moisture removal during the drying process of tomato was due to diffusion action of bound moisture that express the



(T1: Longitudinally cut into 16 pieces, T2: Longitudinally cut into 8 pieces, T3: Cross-sectional cut slice, T4: Longitudinal cut slice; Solid line are predicted values for T1, T2, T3, T4)

Fig. 2: Effect of physical treatment on moisture ratio of plum tomato as described by Midilli-Kucuk model

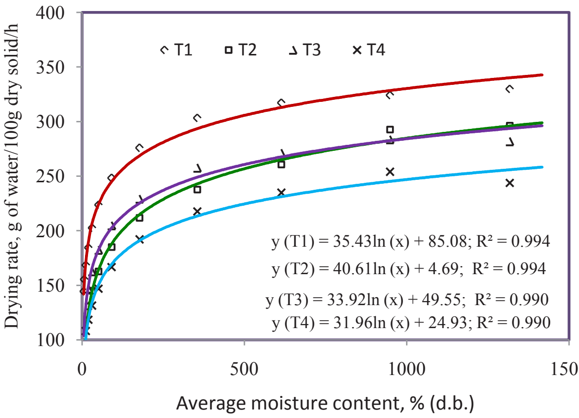


Fig. 3: Instantaneous drying rate as influenced by average moisture present in tomato slice/piece during drying

complex relationship of moisture-solid content of pulpy tomato, asit also contains soluble sugars apart from various bio-chemicals (Albano *et al.* 2011).

Mathematical Modelling of Drying

The MR values were fitted statistically to generally use mathematical models (Table 1) that have been typically applied for illustration of drying curves for many biological materials (Midilli and Kucuk (2005) for pistachio; Thakur and Jain (2006) for cauliflower; Doymaz (2010) for banana slices; Thakur *et al*. 2010 for grape). The values of the coefficients and constants of the equations for different treatment are presented in Table 3. The fitting of moisture ratio values to the model equations is considered acceptable if the value of coefficient of determination (r^2) is near to 1 and residual mean square error (s^2) is close to zero. Midilli and Kucuk (2005) equation suitably described the observed drying curves for plum tomato slice/piece (Table 3). The highest value for coefficient of determination (0.998 - 0.999) and lowest value of residual mean square error (0.0002 - 0.0004) indicated a good fit of the above equation with experimental drying data. The Page's model equation was equally good because coefficient of determination ranged from 0.997 to 0.998 and residual mean square error from 0.0002 to 0.0003. However, Midilli and Kucuk model was more appropriate to represent the drying behaviour of plum tomato in slice or pieces.

Quality Characteristics of Tomato Powder

The moisture content of fresh plum tomato was 93.97 % (w.b.) that upon drying and powder formation reduced to ~ 4.7 % (w.b.). Davoodi *et al*. (2007) found that moisture content of various pre-treated and hot air-dried tomato slice varied between 4.5 % to 5.1 % (w.b.). Dried powder was free flowing as visually observed after six months of storage in packaged condition. The effects of drying on qualities of tomato powder from different treatment slices/pieces during different storage periods are shown in Table 4. No appreciable change in moisture content was observed during the periods of storage, and this showed that the processing and packaging condition was reliable.

The variations in quality parameters as moisture content, TSS, and acidity were non-significant ($p>0.05$) among the treatments as well during the period of storage (Table 5). The acidity of fresh tomato was 0.28, and that of powder from different treatments varied between 0.25 to 0.28 after 180 days of storage. The variation in ascorbic acid of tomato powder during the period of storage was significant ($p<0.05$), while within treatments it was non-significant ($p>0.05$). There was appreciable change (approximately 35 % loss) in ascorbic acid content of tomato powder from all treatments after 180 days of storage. However, the colour of powder was almost similar to fresh one.

Table 3. Parameters specific to each model equation for drying of plum tomato at 55°C

Sl.No.	Model	Treatment	k	n	A	b	r^2	s^2
1.	Newton	T1	0.291	-	-	-	0.976	0.00262
		T2	0.386	-	-	-	0.976	0.00293
		T3	0.336	-	-	-	0.967	0.00417
		T4	0.367	-	-	-	0.970	0.00363
2.	Henderson and Pebis	T1	0.309	-	1.069	-	0.981	0.00227
		T2	0.404	-	1.057	-	0.980	0.00277
		T3	0.356	-	1.068	-	0.973	0.00391
		T4	0.388	-	1.068	-	0.975	0.00337
3.	Page	T1	0.160	1.420	-	-	0.998	0.00019
		T2	0.236	1.421	-	-	0.998	0.00023
		T3	0.179	1.489	-	-	0.997	0.00038
		T4	0.199	1.508	-	-	0.998	0.00028
4.	Midilli-Kucuk	T1	0.150	1.457	0.986	0.00015	0.999	0.00020
		T2	0.233	1.409	0.992	(-)0.00121	0.999	0.00023
		T3	0.172	1.486	0.987	(-)0.00160	0.998	0.00037
		T4	0.190	1.532	0.987	(-)0.00028	0.998	0.00033

Note: a, b and n are model coefficient, k is the drying rate constant (h^{-1})

Table 4. Effect of physical treatment on quality of plum tomato powder during storage

Sl. No.	Parameter	Treatment	Storage duration, days		
			60	120	180
1.	Moisture content, % (w.b.)	T1	4.8	4.6	4.7
		T2	4.6	4.8	4.7
		T3	4.6	4.7	4.9
		T4	4.7	4.9	5.0
2.	Total soluble solid (TSS), ^{o}B	T1	6.5	6.3	6.2
		T2	6.7	6.6	6.6
		T3	6.4	6.6	6.7
		T4	6.5	6.4	6.7
3.	Acidity, g citric acid.100g^{-1}	T1	0.25	0.27	0.28
		T2	0.24	0.23	0.27
		T3	0.25	0.24	0.26
		T4	0.26	0.24	0.25
4.	Ascorbic acid, mg.100g^{-1}	T1	18.5	16.4	15.0
		T2	18.6	16.6	15.5
		T3	18.8	16.5	15.7
		T4	18.7	16.4	15.2
5.	Lycopene content, mg.100g^{-1}	T1	65.3	58.3	52.5
		T2	67.7	57.6	51.2
		T3	71.4	58.4	52.0
		T4	70.2	56.7	51.2

Note: TSS: Total soluble solids, T1: longitudinally cut into 16 pieces, T2: longitudinally cut into 8 pieces, T3: cross-sectional cut slices, T4: longitudinal cut slices

Table 5. ANOVA (2-way classification) effect of physical treatment on quality of plum tomato powder during storage

Sl. No.	Parameter	Source of variation	SS	df	MS	F	p-value	F crit
1.	Moisture content	Treatment	0.043	2	0.022	1.857	0.35	19.0
		Storage duration	0.007	1	0.007	0.571	0.53	18.5
		Error	0.023	2	0.012			
		Total	0.073	5				
2.	TSS	Treatment	0.010	2	0.005	0.429	0.70	19.0
		Storage duration	0.027	1	0.027	2.286	0.27	18.5
		Error	0.023	2	0.012			
		Total	0.060	5				
3.	Acidity	Treatment	3.33E-05	2	1.67E-05	0.143	0.875	19.0
		Storage duration	0.000817	1	0.000817	7.0	0.118	18.5
		Error	0.000233	2	0.000117			
		Total	0.001083	5				
4.	Ascorbic acid	Treatment	0.229	3	0.076	3.313	0.098715	4.757
		Storage duration*	22.515	2	11.257	488.277	2.28E-07	5.143
		Error	0.138	6	0.023			
		Total	22.883	11				
5.	Lycopene	Treatment	1.603	2	0.802	5.938	0.144	19.0
		Storage duration*	55.815	1	55.815	413.444	0.002	18.5
		Error	0.27	2	0.135			
		Total	57.688	5				

** Significant at $p<0.05$*

To compare the effect of hot air drying and physical treatments on lycopene content, the lycopene of tomato powder from different treatments were compared with that of fresh tomato. The lycopene level of fresh tomato was 8.9 mg.100g^{-1}, which significantly increased ($p<0.05$) after 60 days of storage to 65.3, 67.7, 71.3 and 70.2 mg.100g^{-1} for dried powder from treatments T1, T2, T3,T4, respectively. Thereafter, significant ($p<0.05$) loss in lycopene content was observed at the end of 180-day storage (Table 5). Takeoka *et al*. (2001) reported that the values of lycopene content after hot air drying of physically treated tomatopaste was relatively lower than 82.9 mg.100g^{-1}.

Solubility is one of the important parameters to determine the quality of processing food items particularly in powder form. Higher value of solubility represents comparatively better quality of powder food material. The solubility values (%) were obtained as 18.3, 20.4, 22.2 and 22.6 for the powder samples of Plum tomato of treatments T1 to T4 respectively at the end of 180 days of storage. Alexandre *et al*. (2008) reported that the value for the solubility was from 17.7 to 26.7 percent for tomato powder obtained by spray drying method.

Sensory Evaluation

The sensory assessment of soup-mix prepared using tomato powder was carried out after 180 days of storage. At that time the moisture content of tomato powder was 6 % (w.b.). The differences in sensory score (Table 6) among treatments (soup-mix using powders from T1 to T4) were determined by examining F-value (Table 7).

Table 6. Mean score of sensory assessment of soup-mix prepared using Plum tomato powder

Sl. No.	Quality attribute	Treatment			
		T1	T2	T3	T4
1.	Colour and appearance	4.5	4.7	4.7	4.6
2.	Texture and consistency	4.2	4.4	4.5	4.5
3.	Taste and flavour	4.5	4.6	4.8	4.5
4.	Overall acceptability	4.2	4.4	4.5	4.5

Score level: 5 – Excellent, 4 – Good, 3 – Average, 2 – Fair, 1 – Poor

All quality parameters of soup-mix from different treatments showed non-significant difference ($p<0.05$). Judges also reported non-significant difference in their mean scores for the quality parameters. However, soup prepared from all treatment powders was at par in terms of overall quality. The overall acceptability score for soup-mix prepared from treatment T1 to T4 varied from 4.2 to 4.5 out of a maximum score of five.

CONCLUSIONS

Plum tomato after size reduction convection dried at 55°C air temperature was suitable to maintain product quality at reasonably less drying time. Tomato slices (≈5.0 mm thick) cut either in horizontally or vertically was best suitable for speedy drying. Microwave blanching of tomato piece/slice gave good results in dried powder with quality retention during the period of storage without preservatives or additives. Midilli and Kucuk mathematical model was appropriate for illustrating the convective drying behaviour of Plum tomato. Powder obtained after milling could be safely stored for 6 months in an airtight packaging with no significant change in its quality. At the end of the storage period tomato powder could be reconstituted and recognized as good powder product. The 'Plum' tomato powder can be successfully used in preparation of variety of soups and other kinds of food formulations.

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Table 7. ANOVA (2-way classification) of organoleptic score for qualityattributes and treatments

Sl. No.	Source of Variation	SS	df	MS	F	p-value	F crit.
1.	Treatments	0.056	2	0.028	3.57	0.129	6.94
2.	Quality attribute	0.029	2	0.014	1.86	0.269	6.94
3.	Error	0.031	4	0.008			
4.	Total	0.116	8				

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