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EFFECT OF SIZE/SHAPE ON PHYSICO-CHEMICAL QUALITIES OF TOMATOES DRIED USING SOLAR TUNNEL DRYER

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Abstract—*The dehydration process is influenced by many factors like size, shape, thickness, atmospheric conditions in which the product is dehydrated. In this experiment fresh tomatoes were prepared for dehydration by cutting into different size/shapes (S_1 - 0.5 cm slices, S_2 -1 cm slices and S_3 - Longitudinal quarters) and dehydrated in solar tunnel dryer. The dehydrated tomatoes were analyzed for different physico-chemical qualities like time taken for dehydration(hr), recovery(%), rehydration ratio, lycopene(mg/100g), titratable acidity(%), sensory evaluation, moisture(%), water activity, and instrumental color values. The shape S_3 (Longitudinal quarters) recorded significantly maximum recovery (5.01%), titratable acidity (0.80%) and lycopene content (3.23 mg/100 g) followed by S_2 (1cm).*

Introduction

Tomato (*Lycopersicon esculentum* Mill.), is one of the most important vegetables which occupied an important place in almost all Indian as well as western cuisines. India is the 2nd largest producer of tomato (11.5%) after China (30.7%) followed by USA (8.1%) with a production of 197 lakh tonnes from an area of 18.1 lakh ha. In India, Andhra Pradesh is leading in area and production, whereas, productivity is higher in Karnataka (Anon., 2016). In Karnataka, Kolar, Bangalore, Belgaum, Bellary, Dharwad are the major tomato growing centres. The commonly grown varieties are Arka Rakshak, Arka Abha, Arka Sourabh, Pusa Gourav, Pant Bahar, Rathna, Rupali, Abhilash, Ryna *etc.* (Anon, 2016). Consumers demand is increasing rapidly both in domestic and international markets with major portion of it being used for preparation of convenience food (Davoodi, *et al.* 2007). Tomato is used to a great extent in the fresh state but being highly perishable with a limited shelf life at ambient conditions creates glut during production season and becomes scanty during off-season. Hence, there is a need to develop suitable processing and preservation technologies which will not only check losses but can also generate additional returns for farmers (Purseglove, *et al.* 2001).

Among the numerous methods of preservation, drying is one of the oldest and most important methods of food preservation (Lima, *et al.* 2002) practiced by humans. The main moto of drying is to remove moisture from the food matrix to prevent detrimental loss of nutritional and organoleptic properties which occur after harvest (Araya- Farias and Ratti, 2009). The removal of moisture prevents the growth and reproduction of microorganisms which cause decay and minimize many of the moisture-mediated deteriorative reactions. It brings about substantial reduction in weight and volume, minimizing packing, storage and transportation costs and enables storability of the product under ambient temperatures (Majumbar, 1995) and makes the product available throughout the year.

The easiest and cheapest method of drying any commodity is sun drying but it is always associated with some disadvantages like infestation by insects, rodents, direct exposure to rain, storm, windborne dirt, dust, and brings some undesirable changes in product like shrinkage, loss of volatiles and nutrients, case hardening, and reduces capacity of rehydration.

Mechanical drying is one of the alternatives to sun drying but it is an energy consuming method. So the best alternative is solar dryer for dehydration as solar energy is considered as an important alternative renewable source of energy, it is abundant, inexhaustible and non-pollutant in nature (Basunia and Abe, 2001). Solar tunnel helps to reduce crop losses, improve the quality of dried product significantly and is economically beneficial compared to traditional and mechanical drying methods by drying the products rapidly, uniformly, hygienically. Therefore, solar tunnel dryer may become a more convenient alternative for rural sector and in other areas where electricity is scarce and irregular in supply. Hence present experiment was conducted with an objective to know the effect of different size/shape on quality of dehydrated tomatoes dried using solar tunnel dryer. There by adding value to the tomatoes during excess in production which otherwise go as waste. The demand for dried tomato products are increasing as they are main ingredient for salads, pizza, burger and other fast foods.

MATERIAL AND METHODS

An experiment entitled “Effect of size/shape on physico-chemical qualities of tomatoes dried using solar tunnel dryer” was carried out in the Department of Post-Harvest Technology, College of Horticulture, Bagalkot, Karnataka during the year 2017-18. The details of the experimental material used and techniques adopted are presented below.

Geographical location and climate

Bagalkot is located in northern dry zone (Zone-3) of Karnataka. The center is located at 75˚ 42˚ East longitude and 16˚ 10˚ North latitude with an altitude of 542 m above mean sea level (MSL).

Raw material

Fully ripe, complete red colored locally grown tomato (variety Raina) fruits were purchased from farmers field and used in the present investigation. The damaged, bruised and diseased tomatoes were removed and sound ones were washed with tap water to remove adhered dirt. Then fruits were cut into different size/shapes (S_1 - 0.5 cm slices, S_2 -1 cm slices and S_3 - Longitudinal quarters) for dehydration.

Solar tunnel dryer

A natural convection type solar tunnel dryer useful for bulk drying of agricultural and industrial products at moderate air temperature was employed in the experimentation. The structure consisted of a cylindrical metallic frame of size 30x15x10 feet covered with UV stabilized transparent polythene sheet of 200 micron thickness. The structure is positioned in N-S direction, with a door on south wall. The two exhaust fans located on front and back side of the tunnel assist to remove the moist air from the structure with a chimney on the top. The product intended for drying was uniformly spread on stainless steel trays (80x60x5 cm) which were kept on the metallic mesh stand inside the tunnel. The dehydrated tomatoes after attaining safe moisture level were removed and subjected for various physico-chemical analysis.

Dehydrated tomato recovery (%)

The weight before drying and the weight at the end of drying were noted and recovery(%) was calculated using the formula:

$$\text{Recovery (\%)} = \frac{W2}{W1} \times 100$$

Where,

W_2: Weight of dried tomato

W_1: Weight of fresh tomato

Drying Time (Hours)

The time required for drying to the safe moisture level of 15-20 per cent was obtained by recording the time at which samples were kept into solar tunnel for drying and the time at which they were taken out. For eg: If time taken was 50 hours and 18 minutes it was indicated as 50.30 hours (1 hour = 60 min and 0.3 hour = 18 min).

Moisture (%)

The moisture content of dehydrated tomatoes was estimated using Radwag moisture analyzer (Model: MAC 50, Make Poland). Two grams of dried sample was placed in the sample dish. The moisture analyzer indicated the end point of measurement by a beep sound and the resultant constant value for moisture was recorded.

Water activity (a_w)

Water activity of dried tomato was determined by water activity meter (Labswift-a_w Novasina). Small pieces of sample was filled into sample holder up to the mark indicated and then placed inside the water activity meter so that the sample wouldn’t touch the sensor present in the lid. The end point was indicated by three beep sound and the instrument gives constant value for water activity.

Color (L^*, a^* and b^*)

Colour of the samples was measured using Colour Flex EZ colorimeter (Model: CFEZ 1919, Hunter associates laboratory. Inc., Reston) fitted with 45 mm diameter aperture. Calibration of the instrument was carried out using black and white tiles provided. Colour was measured and expressed as L^* (lightness/darkness), a^* (redness/greenness) and b^* (yellowness/blueness) values.

Rehydration ratio

Five grams of the dehydrated tomatoes were placed in a beaker and 50 ml distilled water was added to the beaker at room temperature. Weight of rehydrating sample was measured at 0.5, 1, 2, 3, 4 and 5 hours until sample attained a constant weight. Then, rehydrated material was drained,

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blotted with filter paper and weighed. If the weight of the rehydrated sample was **'a'** and dehydrated sample was **'b'** then rehydration ratio was calculated as below.

$$\text{Rehydration ratio} = \frac{a}{b}$$

Titratable acidity (%)

The titratable acidity of dried tomatoes was calculated by titration method. A known quantity of sample (5g) was crushed in 10 ml of distilled water, juice was extracted and volume was made up to 25 ml. Five ml of this extract was titrated against 0.1 N NaOH with phenolphthalein as an indicator. The end point of titration was determined by color change from colorless to pink. The value was expressed in terms of citric acid as per cent titratable acidity (Anon, 1984).

Lycopene (mg /100 g)

Five gram of sample was crushed repeatedly in acetone in a pestle and mortar until the residue was colorless. The acetone extract was transferred to a separating funnel containing 10 to 15 ml of petroleum ether. Then it was gently mixed to take up the pigments into the petroleum ether phase. The lower (acetone) phase was transferred to a 100 ml volumetric flask and extracted repeatedly with petroleum ether until colorless. The volume of extract was made up to 100 ml with petroleum ether and measured the O.D. of the solution at 503 nm using petroleum ether as blank (Srivastava and Sanjeevkumar, 1998).

$$\text{Lycopene (mg/100g)} = \frac{3.1206 \times \text{OD value} \times \text{Vol. made up} \times \text{Dilution} \times 100}{1 \times \text{weight t. of sample} \times 100}$$

Sensory evaluation

Sensory evaluation of dehydrated tomato was carried out by a semi trained panel consisting of teachers and post-Graduate students of College of Horticulture, Bagalkot with the help of nine point hedonic rating scale (1 = dislike extremely, 2=like only slightly, 3 = dislike moderately, 4 = dislike slightly, 5 = neither like nor dislike, 6=like slightly, 7 = like moderately, 8 = like very much and 9 = like extremely) for colour and appearance, texture, taste, flavour and overall acceptability (Swaminathan, 1974).

Statistical analysis

The data of this experiment are analyzed by completely randomized design (CRD) at 5% (P = 0.05) level of significance. Statistical analysis was performed using Web Agri Stat Package (WASP) Version 2 (Jangam and Thali, 2010). The Critical difference values were calculated whenever F- test was found significant.

Results and discussion

Recovery (%)

The Longitudinal Quarters (S_3-5.04%) recorded significantly higher mean recovery per cent followed successively by 1cm (S_2-4.55) and 0.5 cm (S_1-4.17) (Table 1). In comparison to slices, the tomatoes of S_3 are less subjected to structural changes and therefore restrict the loss of solids. Greater the weight of soluble solids greater will be the dried weight. Additionally, these differences could also be due to difference in moisture content due to shape/size. Tomatoes of S_3 being larger in volume must have contained higher moisture content even after drying was completed as the distance needed for travel by moisture from interior to surface for evaporation was more and more moisture may still be trapped unlike the other two treatments.

Drying time (Hours)

Significantly minimum and maximum mean drying time was recorded in 0.5 cm (S_1-43.58) and Longitudinal quarters (S_3-121.20) respectively. This may be attributed to the fact that drying time increases significantly by increasing the thickness which causes increase in resistance to the removal of moisture (Naeimi, *et al.* 2016). Joshi, *et al.* (2006) reported that the tomato halves required significantly maximum drying time than quarters, slices and wedges. The results of present study are in accordance with the results of Fernando, *et al.* (2011) in tomato.

Moisture (%)

This study witnessed a significant reduction in moisture content from that of fresh tomatoes with moisture level of 92.32 per cent. Decrease in moisture content was found to be influenced by different size/shape. Among different size/shapes, significantly minimum mean moisture content was recorded in S_1 (0.5 cm-17.77%). Drying of food samples is influenced by physical structure, chemical composition and extent of water bound within the food (Potter and Hotchkiss, 1996). In case of quarters, moisture from the interior had to traverse a great distance before it was evaporated at the surface. On the other hand, slicing (S_1 and S_2) has exposed more porous surface to drying air facilitating drying and the distance to be travelled by water was greatly reduced. Therefore, the ease with which water removed was more in S_1 and S_2 than in S_3. This may be substantiated by minimum time taken for drying in S_1 (43.58 hours.) and S_2 (50.55 hours.) than in S_3 (121.20 hours) (Table 1).

Water Activity (a_w)

Water activity is an intrinsic product characteristic and it is free moisture content in the product (Phisut, *et al.* 2013). Water activity is more closely related to the physical, chemical and biological properties of foods and other natural products than its total moisture content (Rockland and Nishi, 1980). It

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plays an important role in determining physical properties such as texture and shelf life of foods. Water activity of dehydrated tomato samples due to size/shape s showed non-significant differences. However the water activity values were in the range of 0.32 to 0.38 (Table 1) and are well below the a_w level required for microbial growth. As the water activity values of the dried tomato slices were lower than 0.60, they are considered to be safer and shelf-stable with respect to microbial growth (Perumal, *et al.* 2007). Similar findings were also recorded by Akanbi, *et al.* (2006) in tomato and Wang and Brennen (1991) in potato.

Instrumental Color (*L, *a** and *b**) values**

The L^* and b^* value of fresh tomato was 44.81 and 30.14, whereas L^* and b^* value after dehydration were in the range of 25.86 to 29.27 and 9.71 to13.08. This decrease in L^* and b^* values might be due to thermal degradation of carotenoids responsible for color and also due to non-enzymatic reactions like Maillard reaction and caramelization of sugars at higher temperature (Priyanka, *et al.* 2017). As a result, the tomato product turns to brick red in color from bright red color resulting in decreased lightness and blueness. Perumal, *et al.* (2007) observed darkness (a decrease in the L^* value) in all the dried tomato slices when compared to fresh tomato. The decrease in b^* value was also reported in tomatoes by Hameed, *et al.* (2016).

Instrumental a^* value of fresh tomato was 33.30 and it decreased upon dehydration. In dehydrated tomatoes, it was in the range of 11.81 to 17.30. This might be attributed to oxidative break down of lycopene responsible for red color during dehydration. Among different size/shapes, significantly maximum mean a^* value was recorded in Longitudinal quarters (S_3-17.07) followed by S_2-15.63 and S_1-12.52. (Table 3). This may owe to the presence of more tomato skin intact with S_3. Skin and outer pericarp tissue of tomato contains more than 80-90 per cent of total lycopene present in tomatoes (Shi and Maguer, 2000). but the a^* values decreased with the decrease in size/thickness of tomato samples. This could be due to greater oxidative degradation of coloring pigment (lycopene) in view of greater surface area exposed in S_1 followed S_2 than in S_3.

Rehydration Ratio

Rehydration is an important parameter signifying effective dehydration. Effect of different size/shape was found to be statistically significant. Among different size/shapes, significantly maximum mean rehydration ratio value was recorded in S_1 (4.97) (Table 2) due to short diffusion water path during rehydration. Lower values of rehydration observed for S_3 can be partly attributed to high initial moisture content in those dehydrated tomatoes. Joshi, *et al.* (2006) reported significantly maximum rehydration ratio in tomato slices (21.54) than in quarters (18.39). Similar results were also reported by Sacilik, *et al.* (2006) in open sun dried tomatoes. However, Perumal, *et al.* (2007) attributed variation in rehydration ratio of tomatoes dried by different methods to less structural changes occurring during dehydration which helps in absorption of more water during rehydration by several structural polysaccharides.

Titratable acidity (%)

The titratable acidity of dehydrated tomatoes was found to increase many fold as compared to its level in fresh tomatoes (0.15%). This significant increase in titratable acidity might be due to concentration of organic acids upon dehydration. Hameed, *et al.* (2016) observed an increase in acidity from 0.16 per cent (fresh) to 0.66 per cent (dehydrated) in Shalimar variety of tomato. Among different size/shapes, significantly higher titratable acidity was found in S_3 (0.80%) (Table 2). Organic acids are sensitive to heat and oxygen. Larger surface area exposed by slices (S_1 and S_3) might have caused greater decline in acidity during dehydration than longitudinal quarters (S_3). It is also opined by Pavani, *et al.* (2017) that partial fermentation of sugars might have partly contributed to higher acidity levels seen in longitudinal quarters (S_3) of tomato.

Lycopene (mg/100g)

Exposure of tomato samples to processing conditions such as high temperature, light and oxygen may bring degradation of lycopene affecting the attractive color and appearance (Shi, *et al.* 1999 and Shi, 2000). In this study, lycopene content of fresh tomato fruit (2.01 mg/100 g) was found to increase in the samples after dehydration. This significant increase in lycopene content, might be due to concentration of pigment upon dehydration. Though pigments appear to concentrate, comparing the quantum of moisture removed during processing, actual degradation of pigment is more than its getting concentrated. The main causes of tomato lycopene degradation during processing are isomerization and oxidation (Shi and Maguer, 2000).

Among different shapes significantly higher lycopene was recorded in S_3 (3.23) (Table 2) samples than others. This may be largely because of the presence of more intact skin. The epidermal area of tomatoes (skin and outer pericarp tissue) contains more than 80 to 90 per cent of total lycopene present in tomatoes (Shi and Maguer, 2000). In other two shapes (S_1 and S_2), loss of lycopene due to degradation was more pronounced than in S_3. This could obviously be reasoned to difference in surface area of shapes in relation to degradation.

Sensory evaluation

Sensory evaluation of a product is an important tool for deciding the consumer acceptability. Sensory characteristics of quality include appearance in terms of color, texture, taste, flavor, nutritive value and wholesomeness. In the present study, score for overall acceptability (OA) is higher for S_2-7.69 followed by S_1-7.42. The dark red appearance and hard texture leading to difficulty in chewing resulted in less sensory score for S_3-7.28 (Table 4).

Summary and Conclusion

The shape S_3 (Longitudinal quarters) recorded significantly maximum recovery (5.01%), titratable acidity (0.80%) and lycopene content (3.23 mg/100 g) followed by S_2 (1cm). Lycopene in fresh tomato fruits is essentially present in the all-*trans* configuration. Heat induces isomerisation of the all-*trans* form to *cis* forms. Bioavailability of *cis*-isomers is higher than that of all-*trans* isomers. Lycopene bioavailability in processed tomato products is higher than in unprocessed fresh tomatoes. The *cis*-isomers increase with temperature and processing time (Shi and Maguer, 2000). Thus, in the current investigation, dehydrated tomatoes of S_3 may theoretically have higher *cis*-form of lycopene owing to longer duration of time taken during their dehydration. Hence, though no significant differences were seen in dehydrated tomato samples, those of S_3 may be thought to be nutritionally better than other shapes tried in this study on account of enhanced *cis*-isomers of lycopene. So among the shapes the longitudinal quarters (S_3) were found best as they have good effect on physico-chemical properties and their preparation and drying in large scale was also easier compare to other two shapes.

Table 1: Effect of different size/shape on recovery (%), drying time (hours), moisture (%) and water activity (a_w) of dehydrated tomatoes

Size/ Shape	Recovery (%)	Drying time (Hours)	Moisture (%)	Water Activity (a_w)
S_1	4.19^c	42.21^c	17.71^b	0.32^a
S_2	4.72^b	50.79^b	21.28^a	0.32^a
S_3	5.24^a	121.00^a	21.99^a	0.33^a
CD 5%	0.158	1.36	1.64	NS

Note: Values in the same superscripts are not significantly different by critical difference at *P*=0.05

S_1: 0.5 cm slices

S_2: 1 cm slices

S_3: Longitudinal quarters

Table 2: Effect of different size/shape on titratable acidity (%), rehydration ratio and lycopene content (mg/100g) of dehydrated tomatoes

Size/ Shape	Titratable acidity (%)	Rehydration ratio	Lycopene (mg/100g)
S_1	0.22c	5.10^b	2.74^b
S_2	0.52b	4.75^c	3.08^{ab}
S_3	0.81a	5.38^a	3.49^a
CD 5%	0.05	0.51	0.44

Note: Values in the same superscripts are not significantly different by critical difference at *P*=0.05

S_1: 0.5 cm slices
S_2: 1 cm slices
S_3: Longitudinal quarters

Table 3. Effect of different size/shape on instrumental color (*L, *a** and *b**) values of dehydrated tomatoes**

Size/Shape	*L**	*a**	*b**
S_1	29.27^a	12.52^c	11.56^a
S_2	26.01^b	15.63^b	12.93^a
S_3	25.86^b	17.07^a	9.64^b
CD 5%	2.29	1.73	1.87

Note: Values in the same superscripts are not significantly different by critical difference at *P*=0.05

S_1: 0.5 cm slices
S_2: 1 cm slices
S_3: Longitudinal quarters

Table 4. Effect of different size/shape on sensory scores of dehydrated tomatoes

Size/ Shape	Colour	Flavour	Taste	Texture	O A
S_1	7.29^c	7.29^b	7.54^{ab}	8.47^a	7.42^b
S_2	7.98^a	7.54^a	7.64^a	7.96^b	7.69^a
S_3	7.51^b	7.50^a	7.41^b	7.13^c	7.28^c
CD 5%	0.13	0.12	0.17	0.26	0.14

Note: Values in the same superscripts are not significantly different by critical difference at *P*=0.05

S_1: 0.5 cm slices
S_2: 1 cm slices
S_3: Longitudinal quarters

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