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P Geetha
Associate Professor, Department of Food Science and Nutrition, Centre for Post Harvest Technology, Agricultural Engineering College and Research Institute, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

P Preetha
Teaching Assistant (FPE), Department of Food Process Engineering, Agricultural Engineering College and Research Institute, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

Corresponding Author:
P Geetha
Associate Professor, Department of Food Science and Nutrition, Centre for Post Harvest Technology, Agricultural Engineering College and Research Institute, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

Effect of pre-treatment on the drying characteristics of solar dried tomato (*Lycopersicon esculentum* Mill.) slices

P Geetha and P Preetha

Abstract
Tomatoes are most common consumable vegetable in the world and major sources of carotenoid in human diet. Due to highly perishable nature, tomatoes are wasted in large quantity during peak harvesting season. The most effective way to reduce the post-harvest loss of tomatoes is converting them in to value added products. The 1 cm slices were pre-treated with 2% of salt, sugar and sodium benzoate solution and dried in solar drier and analysed for its nutrition value. The moisture content was reduced from 93.92 ±1% (w.b.) to 7.0 ± 0.5% (w.b.) in a solar dryer for 28h, whereas 36h was required in sun drying. The maximum temperature of 52˚C and 36% of relative humidity was observed in the solar cabinet dryer. Among the different pre-treatments, the 2% sugar treated slices recorded lesser effect on the quality characteristics such as maximum retention of total sugars (91%), ascorbic acid (80%), lycopene (90%) and acidity (67%). Sensory attributes of soup prepared using 2% sugar treated solar dried slices have on par with fresh samples.

Keywords: Sun drying, solar drying, drying characteristics, pre-treatment, tomato slices

Introduction
Tomato (*Lycopersicon esculentum* Mill.) is the widely used and cultivated crop in the world (Celma *et al.*, 2008; Khama *et al.*, 2016) [8, 16]. It is a most common consumable vegetable in the world and major sources of carotenoid in human diet (Pokharkar *et al.*, 2017) [25]. Tomatoes are rich in lycopene content which has higher amount of fibres, total phenolic compounds, and vitamins (EL-Safy *et al.*, 2016) and it is useful in preventing heart diseases and cancers (Choksi and Joshi, 2007) [9]. Due to highly perishable nature, tomatoes are wasted in large quantity during peak harvesting season (Purkayastha *et al.*, 2013) [27]. The major post harvest loss of about 35% was recorded during the peak season (Djebli *et al.*, 2020) [12]. It is generally consumed as raw and only 10% were processed (Pokharkar *et al.*, 2017) [25]. The most effective way to reduce the post-harvest loss of tomatoes is converting them in to value added products.
Drying is the most common method of preservation to extend the shelf life of minimally processed fruits and vegetables (Tan *et al.*, 2020). Drying also helps in reducing the transport and storage cost (Abouo *et al.*, 2016; Benkhelfellah *et al.*, 2005) [1, 7]. The demand for dried tomatoes has been increased because of its regular use in the ready to eat foods (EL-Safy *et al.*, 2016), toppings in pizza, snacks, soups and in savoury dishes (Movagharnejad and Nikzad, 2007) [20].
Traditional sun drying methodis useful in reducing the post-harvest losses. Sun drying method is limited due to its longer drying time of about 4-8 days (Oberoi *et al.*, 2005) [23], depends on Weather condition and attack of insects, dust and microbes are more (Okoroigwe *et al.*, 2013) [24]. Mechanical driers are most commonly used in food industries, however the use of more electricity consumption leads to higher cost of production (Delfiya *et al.*, 2018) [11]. The major disadvantage in mechanical driers is loss of nutritional composition (Hasturk *et al.*, 2010) [14].
Solar drying can be best alternative method since it is green and clean method. It is the expansion of sun drying. This method of drying utilizes the incident radiation and natural wind. Hence it utilizes high air temperature and low RH which increases the drying rate (Murali *et al.* 2019) [21]. Earlier work reported for solar drying of various agricultural produce such as potato slices (Chouicha *et al.*, 2013) [10], red pepper (Elkhadraoui *et al.*, 2015) [13], Chilli pepper (Rabha *et al.*, 2017) [28], melon slices (Aktas *et al.*, 2016) [3], cherry tomatoes (Nabnean *et al.*, 2016) [22], and banana slices (Lingayat *et al.*, 2017) [19].
Solar drying improves the overall nutritional quality of the product (Bala *et al.*, 2001) [5]. In this context, to prevent the nutritional degradation and enhance the drying rate, the pre-treatment can be adopted. Pre-treatment can preserve the quality of the products by reducing the drying time (Karaasian *et al.*, 2019).

Based on our knowledge, there is a scarcity of information regarding pre-treatments followed by solar drying of tomato slices. Hence, a study was undertaken to standardize the methodology for solar drying of tomato slices and evaluate the effect of different pre-treatments on quality of solar dried tomato slices.

Materials and Methods

Sample preparation

Avinashi varieties of tomatoes were purchased from the local market, Coimbatore, India. Tomatoes are graded using in-house developed rotary drum tomato grader (Preetha *et al.*, 2016) [26]. Graded tomatoes were washed to eliminate dirt, soil and other particles. Tomatoes were sliced using a sharp stainless steel knife of approximate thickness of 1 cm. The sliced tomatoes were treated at 30±2˚C for 30 min with different pre-treatments such as a) 2% sodium benzoate (b) 2% sugar solution and (c) 2% salt solution. The concentration and treatment time was selected based on the preliminary studies. d) untreated tomato slices were considered as control sample. After pre-treatment, the water is drained and the slices were spread on aluminium trays for solar drying.

Solar drying of tomato slices

The solar dryer consists of a single semi-cylindrical drying chamber made of mild steel (width 25 mm and height 725 mm). The dimension of the drying chamber is 100 × 66 cm^2 for drying of sliced tomatoes. A coating of red oxide was provided over the dryer as a rust proof and then it was painted in black. The dryer with metallic frame structure was enclosed with 250 micron polythene sheet (UV stabilized semi-transparent). The door was provided at front side of the dryer with an area of 66×40 cm^2 for loading and unloading the produce. The sides of the door were provided with Velcro so that it can be opened at any time. Natural ventilation to the dryer was provided at the top of two sides of the dryer, having an area of 100 mm × 80 mm. The provision for ventilation in solar dryer helped efficient removal of moisture from the produce and allowing fresh air inside. The lab model solar dyer was kept at the terrace of the Post-Harvest Technology Centre (PHTC), TNAU, Coimbatore which lies at 11˚ North Latitude and 77˚ East longitude, located at an altitude of 426.72 m above mean sea level. The dryer was kept at East-West direction since the light transmittance was high in this direction and maximum exposure of solar radiation is possible. The temperature and relative humidity are recorded during the experiment using the "Data logger" (Make: Nomad-Omega)

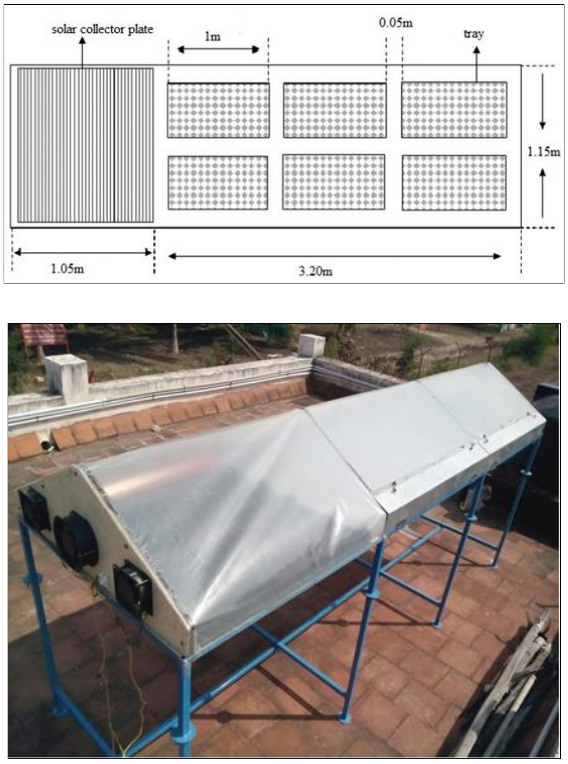

Fig 1: Schematic diagram of Solar dryer

Drying of tomato slices

The trays containing pre-treated tomato slices were kept inside the solar dryer as shown in the Figure 1 and drying was carried from 8 am to 6 pm (IST) and simultaneously open sun drying was carried on the other side. The trays were kept inside the solar tunnel dryer and a data logger was placed inside the dryer to record the temperature for every 1h time interval. During the experiment the weight loss was recorded by taking 1000g of sample and keeping in a weigh balance. After 10 hours of drying, the tomato slices were collected since there was no sunshine available after 6 pm. The dried tomato samples were packed in low density poly ethylene (LDPE) bags and then sealed packets stored in ambient condition. Solar dried and sun dried samples were packed separately and used for analysis of physico-chemical properties.

Drying characteristics of dehydrated tomato

Determination of moisture content

Moisture content was determined using hot air oven by following the standard procedure of AOAC (2005).

$$\text{Moisture content on wet basis, \%} = \frac{\text{weight of water removed in g}}{\text{weight of sample taken in g}} X\ 100 \ldots\ldots\ldots\ldots (1)$$

Determination of rate of drying

The drying rate (DR) represents the amount of moisture evaporated over a period of time. It was found by using the following equation (Delfiya *et al.*, 2018) [11].

$$\text{DR (kg of water / kg of dry matter/h)} = \frac{M_t - M_{t+\Delta t}}{\Delta t} \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where, Mt– moisture content at time t, Δt – time difference in hour, $M_{t+\Delta t}$ – moisture content at time = t+Δt (kg of water/kg of dry matter).

Determination of rehydration ratio

Five gram dried samples were taken and soaked in water at the ratio of 1:50 (w/v) for 3 hours. After that the rehydrates samples were taken out of the water and wiped with tissue paper to remove surface water and the weight was recorded (Lewicki, 1998) [18].

$$\text{Rehydration Ratio (RR)} = \frac{W_r(\text{final weight of the sample after immersing in water and drained})}{w_d(\text{weight of dry sample})} \quad (3)$$

Data analysis
SPSS version 20 statistical tool was used for analysing the data obtained from the study. One-way analysis was carried out and Turkey's test were used to compare the means at $P<$ 0.05 level of significance.

Results and Discussion
Drying characteristics of tomato slices
Comparison between sun and solar drying on the moisture content
The initial moisture present in the fresh tomato was 93.92% ± 1 (w.b). The moisture was reduced to 7.0 ± 0.5% (w.b) (Figure 2).The moisture content had a significant (P≤0.05)effect on drying time. The moisture content decreases with increase in drying time. During solar drying of tomato slices, moisture loss was high during the initial period and slower rate (or falling rate) was found during the remaining drying period. The total time required for drying the samples was 28h in solar dryer, whereas 36h in sun drying. Bala *et al.*, (2003) [6] noted that solar dried pineapple slices had final moisture of 14.13% (d.b) in 3 days whereas the sun dried samples had 21.52 (d.b) after 3 days. Similar trend of results were reported by Wankhade *et al.*, (2012) [31] for okra slices. The drying was continued until no change in the weight. The maximum temperature of 52˚C with a relative humidity of 36% was recorded in the solar cabinet dryer. The drying rate in solar dryer was higher than sun drying. This may be due to the more absorption of solar energy since the dryer is covered with polythene sheet which is UV stabilized semi-transparent has a transitivity of 90%. During day time, the short wave radiations are entrapped through the UV stabilized sheet. This phenomenon increased the temperature inside the dryer.

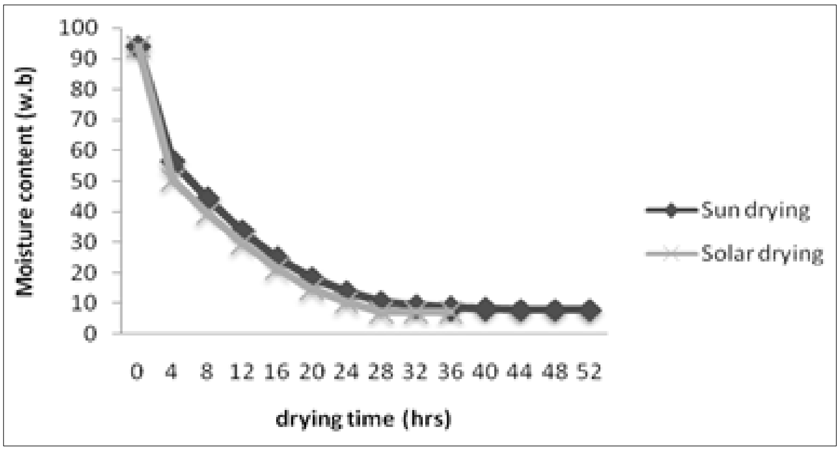

Fig 2: Comparison between sun drying and solar drying – moisture content

Comparison between sun and solar drying on drying rate
The drying rate for sun and solar tunnel drying was found to be 1.62 and 1.66 g/g h which is shown in the Fig 3. The rate of moisture removal in the solar drying is faster than the sun drying. This probably due to the energy received in solar drier is from both collector and incident solar radiation whereas only the incident radiation was received in the sun drying and also loss of energy to the environment (Bala *et al.*, 2001) [5]. The moisture removal was higher at the initial stage which leads to higher drying rate. The rate of moisture removal is greatly affected by the weather parameters. Wankhade *et al.*, (2012) [31] also reported that the weather parameters influenced the drying rate of okra slices by solar cabinet drier. Drying rate was higher at the initial period; this might be due to the removal of moisture from the surface of the product and decreased over a period of time due to the low penetration of heat in to dried layer.

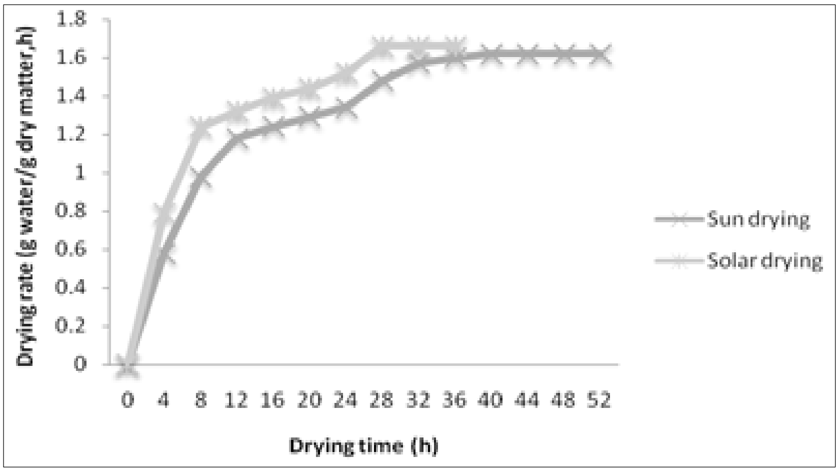

Fig 3: Drying rate of sun drying and solar drying

Effect of pre-treatment on moisture content

The effect of pre-treatment on the moisture content is shown in the Fig. 4. The different pre-treated tomato slices such as 2% sugar, salt and sodium benzoate samples was able to reach the final moisture content (7.0 ± 0.5%) quickly. The samples initially reduced to the moisture content of 48.60 ± 0.52 (w.b) from 93. 9 ± 1.0 (w.b) after the pre-treatments. The pre-treated samples were finally reduced to the moisture content of 7.0 ± 0.5% within 28 hours in solar tunnel drier. The drying time does not get varied due to the pretreatment in the solar dryer.

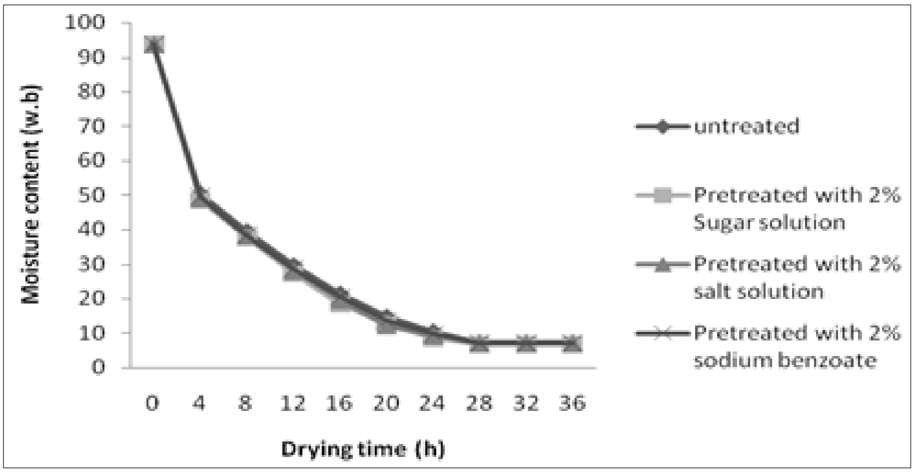

Fig 4: Moisture content of different pre-treated solar dried tomatoes

Effect of pre-treatment on drying rate

The effect of pre-treatment on the drying rate is shown in the Fig 5.The higher drying rate was observed more at initial drying period. The maximum drying rates of pre-treated 2% sugar solution, 2% salt solution and 2% sodium benzoate are, 1.72, 1.70 and 1.69 g/g.h, respectively. The pre-treatment does not show any variation in the drying rate. Similar results were reported by Hemaprabha *et al.* (2007). The drying rate period was not constant in all the pre-treated samples; it was observed to be falling rate since the dried tomato slices was shirked. The major drying period was falling rate. The moisture removal is mainly assumed due to the diffusion (Kulanthaisami *et al.*, 2010) [17]. The drying rate of carrot slices does not had a significant change with pre-treatment (Sra *et al.*, 2011) [30].

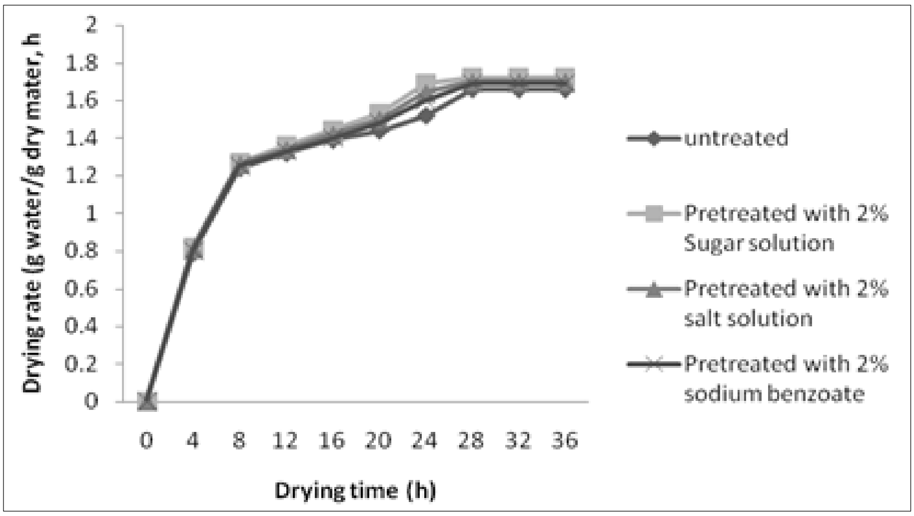

Fig 5: Drying rate of different pre-treated solar dried tomatoes

Rehydration ratio of dried tomato slices

The rehydration ratio of the dried tomato slices are given in the Table 1. The pre-treated tomato slices dried using solar dryer are shrinked due to the moisture removal. The lower RR was recorded for sun dried sample of about 2.64 ± 0.05%. The increase in temperature increases the RR which was given by Akhijahani, *et al.*, (2017) [4] for plum fruits. Among the pre-treated samples, 2% sugar treated tomato slices showed higher retention of rehydration of 4.51 ± 0.03%. The size and shape of the dried slices will be considerably dissimilar from the fresh one due to the moisture removal (Samimi-Akhijahani & Arabhosseini, 2018) [29]. The water absorption in the samples is very rapid due to the damages that occur in the material structures leads to shrinkage of the product which reduces the intercellular space available for filling water (Krkioda & Marinos-Kouris, 2003) [15]. Abrol *et al.*, (2014) [2] also stated that solar dried papaya had higher RR of about 4.9% and lesser in solar dried banana of 3.14 which is due to the water absorption capacity of the dried sample.

Table 1: Rehydration ratio of the dried tomato slices

S.no	Parameter	Sun dried samples	Treatment		
			2% sugar	2% salt	2% sodium benzoate
1.	Rehydration Ratio	2.64±0.05	4.51±0.01	4.0±0.02	4.35±0.03

Conclusion

A small solar dryer was used to dry 10 kg of tomatoes per day. The trays of dimension 1m x 0.5 m was fabricated and kept inside the drying chamber with a clearance of 0.05 m. The length of the drying chamber was kept as 3.20 m and breadth 1.15 m. The front portion of the dryer was kept with solar collector and a black corrugated GI plate was fitted with an area of 1.22 m^2 which is 25 per cent of the total area of the dryer and the remaining 75 per cent was used for drying chamber. Tomatoes were cut into 1 cm thickness, pre-treated with 2% sugar solution and solar dried for 28 h was sufficient to obtain a product with good properties. The chemical characteristics slightly changed during storage period. It was observed that high quality, electricity free, low cost dried tomatoes can be produced from solar drying. The higher drying rate observed in solar drying facilitates a superior quantity of products in a fairly short space and time.

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