BIOSCIENCES BIOTECHNOLOGY RESEARCH ASIA, December 2016. Vol. **13**(4), 2255-2261

Influence of Pretreatments and Drying methods on Water Activity, Dehydration and Rehydration ratio of Dried Tomato

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http://dx.doi.org/10.13005/bbra/2391

(Received: 25 July 2016; accepted: 20 September 2016)

The study was carried out to investigate the effect of different chemical pretreatments (2% ethyl oleate + 1% potassium carbonate, 1% ascorbic acid+1% citric acid and 2% sodium metabisulfite, 1% calcium chloride + 0.25% sodium chloride and 1% sodium chloride at different drying methods (sun drying, solar tunnel drying and cabinet drying at 45°C, 55°C and 65°C) on Water activity, Dehydration and Rehydration ratio of dried tomato slices. The effects of drying methods and pretreatments and their interactions were found statistically significant ($p<0.05$). Maximum water activity 0.64 was recorded in open sun dried samples in variety Shalimar I (T_0) while as minimum water activity 0.38 was recorded in samples which were cabinet dried at 65°C using T_4 as pre-treatment solution in Punjab Chuhra. Minimum Dehydration and Rehydration ratio 20.00 and 1.33 was recorded in open sun dried samples in variety Punjab Chuhra (T_0) respectively while as maximum Dehydration ratio 33.33 was recorded in samples which were cabinet dried at 55°C (T_2) in Shalimar I and maximum Rehydration ratio 2.98 was recorded in samples which were cabinet dried at 55°C (T_2) in Punjab Chuhra.

Key words: Cabinet dried, Dehydration ratio, Pretreatments, Punjab Chuhra, Rehydration ratio, Shalimar I, Water activity.

Tomato (*Lycopersicon esculantum* L.*)* is one of the most widely consumed fresh vegetables in the world. Tomatoes are rich source of polyphenols (10-50 mg kg-1), lycopene (60-90 mg kg^{-1}) and small quantities of vitamin E (5-20 mg kg^{-1}) and also a nutritionally recognized vegetable for their vitamin C content, with an average tomato supplying about 40% of the adult United States Recommended Daily Allowances (RDA) of 60 mg[6].

Dehydration offers a unique challenge to preserve the fruits and vegetables for a longer time. The removal of moisture being one of the important factor which will be accomplished in a manner that will be least detrimental to the product quality due to the structural configuration of the fruit and vegetable. Tomato (*Lycopersicum esculantum* L.) is highly perishable with a limited shelf life at ambient conditions thus creating glut during production season and becomes scanty during off-season. Thus, there exists a need to develop suitable technology for processing and preservation of this valuable product which will not only check losses but can also generate additional revenue for the country[3].The quality of the tomato depends on many parameters like tomato variety, total soluble solid content of the fresh product, size of the tomato segments and air temperature, thus there exists a need to use specific drying methods to dry tomatoes while retaining maximum quality parameters. Spray drying and

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convection drying using solar or mechanical systems has been used for many years for drying of tomatoes[14, 2, 8, 9, 4, 16]. Traditional sun-drying is a slow process compared with other drying methods and quality losses may result from high moisture content, colour degradation by browning, microbial growth[11].

Presently, there are few published studies comparing the single or mixed effects of calcium chloride and sodium metabisulfite dipping treatments on quality parameters of cabinet-dried tomatoes. Hence, the objective of this study was to evaluate the effects of different pre-treatments and drying methods on the water activity, dehydration and rehydration ratio.

MATERIALS AND METHODS

Two varieties of fresh tomato (Shalimar I and Punjab Chuhra) were selected for the present study. Fruits were sorted and washed with water to remove dirt and soil and finally they were cut into slices of 15mm thickness. Following pre-treatment methods were applied to tomatoes before drying:

T_1 : Whole tomatoes were dipped in 2% ethyl oleate + 4% potassium carbonate solution for one minute and the 1% ascorbic acid +1% citric acid dipping solution was applied to sliced tomato samples for 2 minutes.

T_2: Whole tomatoes were dipped in 2% ethyl oleate + 4% potassium carbonate solution for one minute and then 2% sodium metabisulfite dipping solution was applied to sliced tomato slices for 2 minutes.

T_3: Tomato slices were treated with 1% calcium chloride + 0.25% sodium chloride solution for 2 minutes.

T_4: Tomato slices were treated with 1% sodium chloride solution for 2 minutes.

T_0 Control: Non- pretreated samples were used as control samples.

The pretreated samples were dried by following drying methods namely:

Sun drying (SD)

Perforated sample trays were used in sun drying experiments. During the sun drying of tomato slices, the air temperature and relative humidity were determined by using thermometer and hygrometer. The air temperature and relative humidity was recorded as 26-32°C and 33- 44%, respectively. Open sun drying experiments were done between 10:00 and 05:00.

Solar tunnel drying (ST)

Solar tunnel drier (Fig.1) was constructed using high density polyethene (HDPE). Sample was placed on trays specially designed for the solar tunnel drier. During solar tunnel drying, the air temperature and relative humidity was recorded as 30-37°C and 39-45%, respectively using thermometer and hygrometer respectively.

Cabinet drying (C)

Cabinet drying was carried out in cabinet drier which was designed and constructed in Ludhiana, India with model no NSW -154. Three different drying temperatures, 45°C (D_1), 55°C (D_2) and 65°C (D_3) were used to dry the product.

Dehydration Ratio

Known weight of samples was dried and the weight of dried sample was recorded[15]. Dehydration ratio was calculated using equation:

$$\text{Dehydration ratio} = \frac{\text{Weight of prepared material}}{\text{Weight of dried material}}$$

Rehydration Ratio

Dried sample weighing 5 g was placed in 500ml beaker containing 150 ml boiled distilled water. Beaker was covered with watch glass and continued to boil for 20 minutes. Then sample was transferred into a glass funnel covered with coarsely porous Whatman No. 4 filter paper. After filtration, sample was removed from funnel and weighed immediately[15]. Rehydration ratio was calculated using equation:

$$\text{Rehydration ratio} = \frac{\text{Weight of rehydrated sample}}{\text{Weight of sample taken for rehydration}}$$

Water Activity

Water activity of fresh and dried samples was determined by using water activity meter (PRE AQUA LAB, Water activity analyzer, SN: PRE000197).

Statistical analysis

Experimental data was subjected to the statistical analysis following analytical procedures as described by[5]. The data collected was subjected to statistical analysis using statistical software "STATISTICA-AG" from Stat Soft (USA) licensed to FOA, SKUAST-Kashmir, Wadura campus.

RESULTS AND DISCUSSION

Water activity (a_w)

The effect of pre-treatments and drying methods on water activity of dried sample is depicted in Table 1. At the completion of drying process, the water activity of open sun dried samples was significantly higher than solar tunnel dried and cabinet dried samples in all treatments. The water activity recorded in open sun dried samples without any pre-treatment was maximum 0.64 in variety Shalimar I followed by Punjab Chuhra

Table 1. Effect of pre-treatments and drying methods on the water activity (a_w) of the dried tomato slices

Treatments/ drying	Variety I (Shalimar I)	Variety II (Punjab Chuhra)	Sub Mean (treatment × drying)
T_0SD	0.64	0.63	0.64
T_1SD	0.60	0.60	0.59
T_2SD	0.59	0.57	0.51
T_3SD	0.57	0.54	0.49
T_4SD	0.54	0.51	0.46
SUB MEAN	0.59	0.57	0.54
T_0ST	0.60	0.58	0.60
T_1ST	0.57	0.54	0.56
T_2ST	0.54	0.51	0.48
T_3ST	0.51	0.48	0.47
T_4ST	0.50	0.46	0.44
SUB MEAN	0.54	0.52	0.51
T_0D_1	0.51	0.50	0.58
T_1D_1	0.48	0.48	0.53
T_2D_1	0.46	0.46	0.46
T_3D_1	0.44	0.44	0.44
T_4D_1	0.41	0.41	0.42
SUB MEAN	0.46	0.46	0.48
T_0D_2	0.49	0.49	0.56
T_1D_2	0.47	0.46	0.50
T_2D_2	0.44	0.43	0.44
T_3D_2	0.42	0.41	0.42
T_4D_2	0.40	0.40	0.40
SUB MEAN	0.43	0.44	0.46
T_0D_3	0.45	0.47	0.55
T_1D_3	0.43	0.45	0.51
T_2D_3	0.42	0.41	0.43
T_3D_3	0.40	0.40	0.42
T_4D_3	0.39	0.38	0.41
SUB MEAN	0.42	0.42	0.49

CD ($p \leq 0.05$)
T: 0.035 D: 0.035 T×D: 0.079 V: NS
T×V: 0.050 D×V: 0.050 T×D×V: 0.011
Where T_0= Control, T_1= 2% ethyl oleate + 4% potassium carbonate (1 min) + 1% ascorbic acid + 1% citric acid (2 min), T_2= 2% ethyl oleate + 4% potassium carbonate (1 min) + 2% sodium metabisulfite (2 min), T_3=1% calcium chloride + 0.25% sodium chloride (2min) & T_4= 1% sodium chloride (2 min)
SD= Sun Drying, ST= Tunnel Drying, D_1= 45°C, D_2=55°C & D_3= 65°C.

Factor Means

Treatments	0.54	0.51	0.48	0.46	0.46
Drying	0.54	0.51	0.48	0.46	0.49
Variety	0.48	0.48			

with a water activity of 0.63, whereas, the water activity of pre-treated samples varied from 0.38 to 0.60. Minimum water activity (0.38) was recorded in samples which were cabinet dried at 65°C using T_4 as pre-treatment solution in Punjab Chuhra followed by 0.39 in samples pretreated with same T_4 solution in Shalimar I at same temperature. Irrespective of drying methods and varieties the untreated samples possessed over all mean water activity (0.54) compared to lower values (0.46 to

Table 2. Effect of pre-treatments and drying methods on the dehydration ratio of the dried tomato slices

Treatments/ drying	Variety I (Shalimar I)	Variety II (Punjab Chuhra)	Sub Mean (treatment × drying)
T_0SD	22.51	20.00	17.86
T_1SD	25.54	22.70	22.30
T_2SD	25.00	20.80	22.30
T_3SD	25.41	23.80	18.62
T_4SD	25.57	22.72	19.00
SUB MEAN	24.80	22.00	20.01
T_0ST	18.18	20.00	20.00
T_1ST	19.60	23.80	22.76
T_2ST	20.80	23.80	22.30
T_3ST	20.00	21.73	20.46
T_4ST	18.80	23.80	21.90
SUB MEAN	19.47	22.62	21.48
T_0D_1	12.50	19.51	18.62
T_1D_1	17.24	25.31	21.77
T_2D_1	17.80	21.73	19.76
T_3D_1	20.00	17.24	19.25
T_4D_1	17.24	20.00	16.25
SUB MEAN	16.95	21.31	19.13
T_0D_2	21.73	17.24	24.28
T_1D_2	33.33	25.00	24.17
T_2D_2	26.31	23.80	22.90
T_3D_2	21.73	17.54	25.05
T_4D_2	25.00	19.20	20.61
SUB MEAN	25.62	20.55	23.40
T_0D_3	19.20	21.00	20.86
T_1D_3	21.73	25.60	29.16
T_2D_3	20.80	26.31	24.02
T_3D_3	20.00	21.13	24.02
T_4D_3	20.00	24.00	25.00
SUB MEAN	20.34	23.60	24.61

CD ($p \leq 0.05$)
T: 0.013 D: 0.013 T×D: 0.029 V: 0.082
T×V: 0.018 D×V: 0.018 T×D×V: 0.041
Where T_0= Control, T_1= 2% ethyl oleate + 4% potassium carbonate (1 min) + 1% ascorbic acid + 1% citric acid (2 min), T_2= 2% ethyl oleate + 4% potassium carbonate (1 min) + 2% sodium metabisulfite (2 min), T_3=1% calcium chloride + 0.25% sodium chloride (2min) & T_4= 1% sodium chloride (2 min)
SD= Sun Drying, ST= Tunnel Drying, D_1= 45°C, D_2=55°C & D_3= 65°C.

Factor Means

Treatments	20.32	24.03	22.25	21.48	20.55
Drying	20.01	21.48	19.13	23.40	24.61
Variety	21.43	22.01			

0.51) in treated samples. Minimum water activity 0.46 was recorded in samples pre-treated with T_4 and T_3 solution respectively. Irrespective of pre-treatments and drying methods the variety Shalimar I and Punjab Chuhra recorded over all mean water activity 0.48 and 0.48 respectively. Irrespective of pre-treatments and varieties the open sun dried sample possessed over all mean water activity of 0.54 compared to lower value 0.46 in cabinet drying at 55°C.

In this study, it was observed that due to various drying methods and pretreatments, the

Table 3. Effect of pre-treatments and drying methods on the rehydration ratio of the dried tomato slices

Treatments/ drying	Variety I (Shalimar I)	Variety II (Punjab Chuhra)	Sub Mean (treatment × drying)
T_0SD	1.83	1.33	1.59
T_1SD	2.31	1.56	2.02
T_2SD	2.39	2.94	1.87
T_3SD	2.04	1.84	1.86
T_4SD	2.60	1.91	1.93
SUB MEAN	2.23	1.91	1.85
T_0ST	1.35	1.37	1.23
T_1ST	1.35	1.80	1.31
T_2ST	1.41	1.89	1.51
T_3ST	1.47	1.91	1.46
T_4ST	1.56	1.97	1.46
SUB MEAN	1.42	1.78	1.39
T_0D_1	1.67	1.74	1.71
T_1D_1	1.69	1.77	1.73
T_2D_1	1.90	1.75	1.82
T_3D_1	1.63	1.80	1.71
T_4D_1	1.68	1.80	1.74
SUB MEAN	1.71	1.77	1.74
T_0D_2	1.81	2.31	2.62
T_1D_2	2.24	2.85	1.69
T_2D_2	1.85	2.98	1.86
T_3D_2	1.82	2.67	1.94
T_4D_2	1.89	2.34	2.25
SUB MEAN	1.92	2.63	2.07
T_0D_3	2.43	1.11	2.55
T_1D_3	2.97	1.28	2.58
T_2D_3	2.86	1.61	2.91
T_3D_3	2.77	1.46	2.55
T_4D_3	2.81	1.36	2.89
SUB MEAN	2.76	1.36	2.69

T: 0.016 D: 0.016 T×D: 0.036 V: 0.010
T×V: 0.022 D×V: 0.022 T×D×V: 0.051
Where T_0= Control, T_1= 2% ethyl oleate + 4% potassium carbonate (1 min) + 1% ascorbic acid + 1% citric acid (2 min), T_2= 2% ethyl oleate + 4% potassium carbonate (1 min) + 2% sodium metabisulfite (2 min), T_3=1% calcium chloride + 0.25% sodium chloride (2min) & T_4= 1% sodium chloride (2 min)
SD= Sun Drying, ST= Tunnel Drying, D_1= 45°C, D_2=55°C & D_3= 65°C.

Factor Means

Treatments	1.86	1.90	1.99	2.05	1.94
Drying	1.85	1.39	1.74	2.07	2.69
Variety	2.00	1.89			

value of water activity decreased from initial of 0.64 to final of 0.38. Lowest water activity in cabinet dried samples could be due to the efficient and quick removal of water from tomato slices because of uniform heat transfer compared to sun drying. Similar results were reported by[10] in green leafy and yellow succulent vegetables upon drying and subsequent ambient storage.

Dehydration ratio

The effect of pre-treatments and drying methods on water activity of dried sample is depicted in Table 2. The dehydration ratio recorded in open sun dried samples without any pre-treatment was minimum 20.00 in variety Punjab Chuhra followed by Shalimar I with the dehydration ratio of 22.51, whereas, the dehydration ratio of pre-treated samples varied from 17.24 to 26.31. Maximum dehydration ratio (33.33) was recorded in samples which were cabinet dried at 55°C using T_1 as pre-treatment solution in Shalimar I followed by 26.31 in samples pretreated with T_2 solution in Punjab Chuhra at drying temperature (65°C). Irrespective of drying methods and varieties the untreated samples possessed over all mean dehydration ratio (20.32) compared to higher values (20.55 to 24.03) in treated samples. Minimum dehydration ratio (20.55 and 21.48) was recorded in samples pre-treated with T_4 and T_3 solution respectively. Irrespective of pre-treatments and drying methods the variety Shalimar I and Punjab Chuhra recorded over all mean dehydration ratio 21.43 and 22.01 respectively. Irrespective of pre-treatments and varieties the open sun dried sample possessed over all mean dehydration ratio of 20.01 compared to higher value 24.61 in cabinet drying at 65°C.

In this study, it was observed that higher dehydration ratio in cabinet dried samples could be attributed to efficient removal of water more quickly. The results are in conformity with the observations of [7,13].

Fig. 1. Solar Tunnel Drier

The dehydration ratio was found to be lowest in NaCl treated samples as NaCl being a osmotic agent, leached the juice into the medium. Further Sodium metabisulfite and calcium appears to maintain the structural integrity of the cell walls. Similar observations were recorded by [1].

Rehydration ratio

The effect of pre-treatments and drying methods on water activity of dried sample is depicted in Table 3. The rehydration ratio recorded in open sun dried samples without any pre-treatment was minimum 1.33 in variety Punjab Chuhra followed by Shalimar I with the rehydration ratio of 1.83, whereas, the rehydration ratio of pre-treated samples varied from 1.11 to 2.98. Maximum rehydration ratio (2.98) was recorded in samples which were cabinet dried at 55°C using T_2 as pre-treatment solution in Punjab Chuhra followed by 2.97 in samples pretreated with T_1 solution in Shalimar I at drying temperature (65°C). Irrespective of drying methods and varieties the untreated samples possessed over all mean rehydration ratio (1.86) compared to higher values (1.90 to 2.05) in treated samples. Minimum dehydration ratio (1.90 and 1.99) was recorded in samples pre-treated with T_1 and T_2 solution respectively. Irrespective of pre-treatments and drying methods the variety Shalimar I and Punjab Chuhra recorded over all mean rehydration ratio 2.00 and 1.89 respectively. Irrespective of pre-treatments and varieties the open sun dried sample possessed over all mean rehydration ratio of 1.85 compared to higher value 2.69 in cabinet drying at 65°C.

In this study, it was observed that maximum rehydration ratio in cabinet dried samples has been attributed to uniform and efficient heat transfer and quick removal of water which leads to less textural changes during dehydration which subsequently offered higher rehydration ratio of final product[12].

Further results revealed that the effectiveness of sodium metabisulfite on the textural qualities of tomato resulted in the best rehydration properties and showed a higher value. Similar results were observed by[11].

Conflict of interest

There is no conflict of interest.

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