Intl. J. Food. Ferment. Technol. 6(2): 421-432, December, 2016

DOI: 10.5958/2277-9396.2016.00068.4

RESEARCH PAPER

Effect of Drying Methods and Pre-treatments on Phytonutrients of Tomato Slices

Poonam Aggarwal, Payal Goyal and Swati Kapoor*

Department of Food Science and Technology, Punjab Agricultural University, Ludhiana, India

*Corresponding author: swatikapoor74@yahoo.com

Paper No.: 154 Received: 12 June 2016 Accepted: 10 Dec. 2016

ABSTRACT

Tomato slices pre-treated with 4% potassium metabisulphite (KMS) and dried by hot air drying at 58°C and freeze drying at 0.008 m Bar vacuum were assessed for phytonutrient quality. Freeze drying was found to retain better antioxidant activity and phytonutrients in tomato slices compared to the hot air dried tomato slices. Sulphur dioxide exerted beneficial effect (antioxidative) on retention of phytonutrients during hot air drying but had negligible effect during freeze drying. Total carotenoids in pretreated hot air dried tomato slices were 17.49% higher than control samples whereas in case of freeze drying, carotenoids were 3.01% higher in control samples than pretreated samples Rehydration ratio was the highest in pretreated freeze dried tomato slices (6.69) compared to pretreated hot air dried tomato slices (5.77). Maximum nutrients were retained by KMS treated slices during storage.

Keywords: Tomato slices, Freeze drying, Hot air drying, Phytonutrients, Storage

Tomato (*Lycopersicon esculentum*) is the world's most commercially produced vegetable and has an excellent nutritional profile, owing largely to its balanced mixture of vitamins such as A, B1, B2, K, biotin, folic acid, nicotinic and pantothenic acids, vitamin C (160-240 mg/kg), vitamin E (5-20 mg/kg), minerals like potassium, phosphorous, calcium, iron and zinc, lycopene (60-90 mg/kg) and phenolic acids (ferulic acid, chlorogenic acid and caffeic acid 10-50 mg/kg) (Kaur *et al*., 2004). Lycopene is the most prominent dietary carotenoid in tomato followed by beta-carotene, gamma-carotene and phytoene as well as several minor carotenoids. The antioxidant activity of lycopene as well as several other carotenoids along with phenolic compounds present in tomatoes make it and its products rich sources of antioxidant activity (Beecher, 1998). Antioxidant function of lycopene is associated with immune-stimulatory properties, lowering DNA damage, malignant transformation and reducing biological oxidative damage of proteins, lipids and other cell components. High intake of vitamin C and beta-carotene may prevent atherosclerosis, diabetes, colon cancer, and asthma (Krajcovicova-Kudlackova and Dusinska, 2004; Harik-Khan *et al*., 2004).

Tomatoes are used in almost every vegetable preparation all over the world. Drying of tomatoes offers advantages such as long storage life and reduction of bulk volume for easy transportation commonly by hot air tray drying. However, conventional hot air drying decreases lycopene retention in tomato samples due to the influence of heat and oxygen. Hot air drying of tomatoes

also leads to an increase in the 5-hydroxymethyl-2-furfural (HMF) content, which results in undesirable color and appearance changes of dried tomatoes (Shi *et al*., 1999; Jalili and Ansari, 2015). Correia *et al.* (2015) studied the effect of temperature, time and material thickness on dehydration process of tomato and recorded optimal conditions at 52-67°C for 35-44 hr for tomato slice thickness between 15-27mm for drying of tomato slices. Use of chemical pre-treatments however, plays an important role to prevent degradation of phytochemicals as reported by Ghavidel and Davoodi (2010) who studied the application of solar drier and continuous tunnel drier to dry tomato paste and slices using different pre-treatments such as calcium chloride, potassium metabisulphite, combination of calcium chloride and potassium metabisulphite and sodium chloride to produce good quality tomato powder. However, there is scanty information available regarding the use of freeze drying and hot air drying method in combination with chemical pre-treatments and their effect on bioactive components of tomato. Thus, the objective of the present study was to pre-treat tomato slices with blanching and potassium metabisulphite and to investigate the effect of hot air drying and freeze drying on retention of phytonutrients in treated and untreated dried tomato slices.

MATERIALS AND METHODS

Raw materials

For carrying out experiments, fully ripened tomatoes were procured during the month of May from the local market of the Punjab Agricultural University, Ludhiana.

Preparation and pre-treatment of sample

Tomatoes were weighed, washed thoroughly under running tap water and surface water was dried. They were cut into thin slices with a stainless steel knife. The slices were kept in a stainless steel sieve placed over a pan containing boiling water and steam blanched for 130 sec. Blanched tomato slices were then treated with 4% potassium metabisulphite (KMS) for 10 min. Tomato slices without any blanching and KMS treatment were taken as control samples. Both blanched and sulphur dioxide treated and untreated (control) tomato slices were subjected to hot air drying and freeze drying, subsequently.

Conventional hot air drying of tomato slices

Untreated control (T1) and blanched and KMS pre-treated tomato slices (T2) were spread evenly in a single layer on trays of hot air cabinet drier (Frederick Herbert-Design 20, Bombay, India) and placed inside the cabinet maintained at 58±2°C. The position of trays was interchanged periodically and the tomatoes were dried till constant weight was attained.

Freeze drying of tomato slices

Tomato slices without any pre-treatment (control, T3) were spread in a single layer on the first stoppering tray of the freeze drier (-25°C) (Freezone freeze dry systems, Labconco, Kansas, USA). Blanched and potassium metabisulphite (KMS) treated tomato slices (T4) were spread in a single layer on the second and third stoppering tray of the freeze drier (-25°C). Freeze dryer was operated at -85 °C condensation temperature and 0.008 mBar vacuum for 52 hrs to dry the tomato slices till the low moisture content was obtained.

Chemical analysis

Dried tomato slices were ground in a mixer to obtain fine homogenous powder for further chemical analysis. Fresh hot air dried (T1 and T2) and freeze dried tomato slices (T3 and T4) were analyzed for total solids and titratable acidity (Ranganna, 1997). Sulphur dioxide was estimated in pre-treated samples by titration with 0.1 N NaOH using bromophenol blue as indicator (Ruck 1969). Rehydration ratio for freeze dried samples was determined as per Rai and Jain (1970) and for hot air dried samples by Sra *et al* (2011).

Phytonutrient composition

Ascorbic acid was determined using 2, 6-dichlorophenol indophenol dye titrimetric method

and expressed as mg/100g (Ranganna, 1997). Estimation of total carotenoids was based on the measurement of absorption of the petroleum ether extract of the carotenoids at 452nm. Beta-carotene was measured by passing the petroleum ether extract of total carotenoids through activated aluminium oxide column (20 cm length and 1 cm diameter). The color intensity of the eluted β-carotene extract was measured at 452nm (Spectronic 20, Bausch & Lomb, USA). The results were expressed as mg/100g by taking beta-carotene as a reference material. Lycopene estimation was done as per Ranganna (1997) method by measuring the absorption of petroleum ether extract containing lycopene at 503 nm (Spectronic 20, Bausch & Lomb, USA). Total phenolic content was determined by Folin Ciocalteu method (Swain and Hillis, 1959). The results were expressed as mg GAE/100g by taking gallic acid as a reference material.

Antioxidant activity

Free radical scavenging activity was determined with the di -phenyl picryl hydrazyl (DPPH) method (Brand-Williams *et al*., 1995) with some modifications. Methanolic extract of 5 g sample was taken for antioxidant activity analysis and calculated according to the following formula. The assay contained 2 ml of sample aliquot, 2 ml of tris HCl buffer (pH 7.4) and 4 ml of 0.1mM DPPH. The contents were mixed immediately and the degree of reduction of absorbance was recorded continuously for 30 min. at 517 nm (Spectronic 20, Bausch & Lomb, USA). The antioxidant activity was calculated according to the following formula:

$$\text{Radical scavenging activity \%} = \frac{\text{Control OD (0 min)} - \text{Sample OD (30 min)} \times 100}{\text{Control OD (0 min)}}$$

Butylated hydroxy toluene (BHT) was used as the standard at a fixed concentration of 5mg mL^{-1}.

Packaging and storage studies

Hot air and freeze dried tomato slices were packed in high density polythene (HDPE) bags and stored under ambient conditions for 6 months. The effect of storage on phytonutrients and antioxidant activity of these products was studied at fixed interval of one month.

Statistical analysis

The experiment was designed in a completely randomized design. The results were expressed as mean (n=3). The data was subjected to ANOVA followed by Duncan's multiple range tests with $p \leq 0.05$ significance level on SPSS 18.0 statistical software (SPSS Inc.). If interactions were present, they were used to explain the results (Gomez and Gomez, 2010).

RESULTS AND DISCUSSION

Effect of drying methods on physico-chemical properties of tomato slices

Total solids and titratable acidity

Drying methods and pre-treatments are one of the most important factors that affect the quality of the final dried product. Physico-chemical compounds of tomato were significantly ($p \leq 0.05$) affected by the treatment (Table 1). Highest total solids were found in control hot air dried tomato slices (T1) (93.87%) followed by 4% KMS treated hot air dried sample (T2), its value being 93.32%. Control freeze dried tomato slices (T3) contained 92.50% of total solids followed by 4% KMS freeze dried tomato slices (T4) containing 91.47% of total solids. Sra *et al.* (2011) also found the highest total solids in untreated samples and lowest in KMS treated samples. Significantly, more titratable acidity was recorded for the T3 slices (3.19%) followed by T4, T1 and T2 tomato slices (Table 1). These results corroborates with the findings of Prajapati *et al.* (2011) where the authors reported low acidity in blanched and SO_2 treated aonla shreds as compared to unblanched shreds. According to Woodroof and Luh (1975), sulphite solutions are known to leach the natural acids of fruits and vegetables that might be the reason for slightly lower acidity of KMS treated samples as compared to control in both the drying methods.

Table 1: Effect of drying methods on physico-chemical properties, phytonutrients and antioxidant activity of dried tomato slices

Treatment	Total solids (g/100g)	Acidity (%)	Ascorbic acid (mg/100g)	Total carotenoids (mg/100g)	β- carotene (mg/100g)	Lycopene (mg/100g)	Total phenols (mg GAE /100g)	Antioxidant activity (%)	Rehydration ratio	SO_2 retention (ppm)
T1	93.87	3.06	51.36	120.30	74.28	44.52	692.38	32.28	5.62	ND
T2	93.32	2.90	56.09	141.35	89.48	51.06	512.18	42.64	5.77	1127.24
T3	92.50	3.19	64.25	138.61	87.10	50.59	470.44	40.64	6.45	ND
T4	91.74	3.14	60.97	134.55	84.79	49.86	431.23	39.01	6.82	518.88
CD	0.08*	0.06*	0.05*	0.11*	2.17*	0.05*	2.23*	0.22*	0.05*	2.26*

* Significant at p≤0.05, ND- not detected

T1- Control hot air dried tomato

T2- 4% KMS hot air dried tomato

T3- Control freeze dried tomato

T4- 4% KMS freeze dried tomato

Also, Pant *et al.* (2004) reported heavy leaching losses of acids during blanching of aonla fruit slices. Thus, combination of blanching and sulphating resulted in lower acidity of the T2 and T4 samples as compared to their respective control samples.

Rehydration ratio and sulphur dioxide

Freeze dried tomato slices were found to have more rehydration ratio as compared to hot air dried tomato slices. Rehydration ratio was 15.94% higher in T4 sample than T2 slices (Table 1). Lowest value was recorded in T1 slices (5.62). Rehydration ratio of freeze dried foods is in general 4-6 times higher than air-dried foods, making freeze dried products excellent for ready- to- eat instant meals (Ratti, 2001) because at lower temperatures less cellular destruction occurs, thus the material is capable of absorbing more water (Nour, 2011). Tomato samples treated with sulphite (T2 and T4) were observed to have more rehydration ratio (5.77 and 6.82, respectively) as compared to the control counterparts (T1 and T3). Latapi and Barrett (2006) observed an increment in rehydration ratio of dried tomato halves when sulphite treatment was given prior to drying, supporting the outcome of the present study. Potassium metabisulphite has been reported to have a positive effect on the textural quality of dried tomato slices resulting in better rehydration (Ghavidel and Davoodi, 2010).

Also, pre-treated tomato slices had less shrinkage after drying as compared to the raw tomatoes causing increase in rehydration ratio (Davoodi *et al*., 2007). Thus, pre-treatment with sulphur dioxide resulted in improvement of rehydration ratio of tomato slices. Higher retention of SO_2 was found in T2 sample (1127.24 ppm) compared to T4 sample (518.88 ppm) (Table 1).

According to Paulus (2005) vacuum is one of the methods to remove SO_2 from fruit juices. Thus, lower retention of SO_2 in freeze dried product could be

attributed to the application of vacuum during freeze drying process.

Effect of drying methods on phytonutrients and antioxidant activity of tomato slices

Ascorbic acid

The highest ascorbic acid retention was for T3 tomato slices (64.25 mg/100g) followed by T4 sample (60.97 mg/100g) as perceived from Table 1. Lower value of ascorbic acid in the T4 slices compared to T3 is due to loss of ascorbic acid during blanching and dipping treatments. Lowest ascorbic acid content was found in T1 tomato slices due to oxidation of ascorbic acid in the presence of air and high temperature (Leoni, 2002). T2 sample was found to have 56.09 mg/100g of ascorbic acid. Freeze dried samples had more ascorbic acid compared to hot air dried samples may be due to application of vacuum during freeze drying process that exerted minimal effect on vitamin C (Shofian *et al*., 2011).

Total carotenoids

Total carotenoid content in T2 slices was the highest (141.35 mg/100g), followed by T3 and T4 slices (Table 1). The lowest total carotenoid content was observed in T1 slices (120.30 mg/100g). Sulphite, as an antioxidant stabilizes carotenoids in dehydrated vegetables such as carrot (Sra *et al*., 2011). This may be why degradation of carotenoids is prevented in T2 slices compared to T1 samples. However, the degradation of carotenoids observed as a result of dehydration of tomato slices (T1), may be attributed to their sensitivity to heat, light and oxygen (Sharma and Le Maguer, 1996). Total carotenoids in T3 and T4 tomato slices were at par (138.61 and 134.55 mg/100g, respectively), thus, showing negligible effect of sulphur in retaining total carotenoids during freeze drying process.

β-carotene and lycopene

The β-carotene and lycopene content of T2 slices were 20.46 and 14.69%, respectively higher than T1 slices (Table 1). Loss of lycopene in T1 samples may be attributable to its isomerization and oxidation. Anguelova and Warthesen (2000) reported that environmental factors such as light, air and temperature may be very important for the isomerization and auto-oxidation of lycopene in tomato products. Among the drying methods, T2 had 2.73 and 5.53%, respectively higher beta-carotene content than T3 and T4 freeze dried slices. Likewise, lycopene content of T2 slices were found to be slightly higher (0.92 and 2.40%, respectively) than T3 and T4 slices. The higher value of lycopene in T2 tomato slices may be due to the fact that the cell walls and the bonding force between lycopene and the tissue matrix are broken down by the heating process (Chang *et al*., 2006) and antioxidative effect of potassium metabisulphite in preventing oxidation of lycopene (Davoodi *et al*., 2007).

Total phenols

Total phenols were found to be the highest in T1 tomato slices (Table 1). This is due to the formation of oxidized compounds which led to overestimation of total phenols owing to the general nature of folin-ciocalteau chemistry, which measures total phenolics and other oxidation substrates (Singleton and Rossi, 1965; Singleton *et al*., 1999). Total phenols in T3 and T4 tomato slices were 470.44 and 431.23 mg/100g, respectively. Lower value of total phenols in T4 samples compared to T3 slices is due to leaching losses of phenols during blanching and dipping treatments (Dansesi and Bordoni, 2008). Among the drying treatments, 8.87% increased total phenols were found in T2 samples than T3 samples. This may be due to either thermally induced extraction of antioxidant molecules (phenols) that were previously complexed or polymerized, or retention of active compounds caused by inactivation of enzymes involved in their catabolism (Scalzo *et al*., 2004). In the present study, the former statement may explain the reason for increased total carotenoids in hot air dried slices as enzyme inactivation has been done during blanching treatment. In addition, antioxidant effects of sulphur dioxide might have prevented oxidation of total phenolics.

Antioxidant activity

Highest antioxidant activity was recorded in T2 tomato slices (42.64%) due to high phenolic content and other phytonutrients, followed by T3 (40.64%), T4 (39.01%) and least in T1 tomato slices (32.28%) as shown in Table 1. Lowest antioxidant activity in T1 slices is due to lowest retention of phytonutrients such as ascorbic acid, total carotenoids and phenolic compounds. Though phenolic compounds were found to be the highest for the control air dried tomato slices but this was due to the overestimation of phenols and oxidized substrate by folin-ciocalteau method as these overestimated phenols did not contributed to antioxidant activity. Antioxidant activity of T2 and T3 tomato slices was found to be at par with just 2 % higher antioxidant activity in T2 slices. On observing DPPH radical behavior during the DPPH assay it was found that all dried slices gave maximum antioxidant activity at 2 min. and thereafter absorbance was consistent over reaction times (Fig. 1).

Effect of storage on physico-chemical properties of dried tomato slices

Total solids and titratable acidity

Drying method, treatment and storage, but no interaction, affected total solids content of dried tomato slices (Table 2). Total solids were found to decrease with storage period. Total solids decreased from 93.59 to 90.45% in hot air dried tomato slices (T1, T2) and 92.12 to 88.09% in freeze dried tomato slices (T3, T4) after 6 months of storage. The moisture gain as the storage period progressed might have been due to the hygroscopic nature of dried products, storage conditions as well as the nature of packaging (Robertson, 1993). The decrease was found to be more in freeze dried slices compared to hot air dried slices due to the porous structure of freeze dried tomato slices making it hygroscopic in nature. Porous structure of freeze-dried samples reportedly results in higher

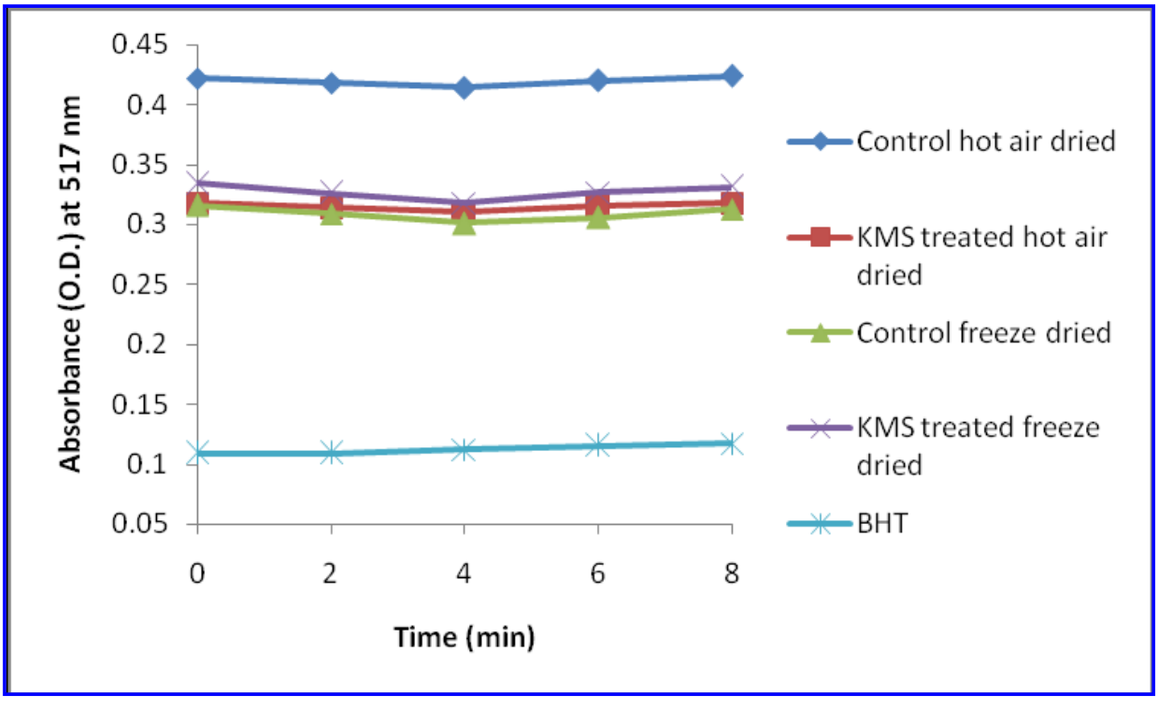

Fig. 1: Effect of drying methods on antioxidant activity (%) of dried tomato slices

adsorptive capacity than powders produced by other drying methods (Tang and Chen, 2000; Quing-guo *et al*., 2006).

Table 2: Effect of drying method, treatment and storage on titratable acidity, rehydration ratio and total solids of dried tomato slices

Source	Titratable acidity (%) Rehydration ratio			Total solids (%)
Drying method × Treatment				
Hot air dried	T1	3.06^{a}	5.62^{d}	93.87^{a}
	T2	2.90^{a}	5.77^{c}	93.32^{ab}
Freeze dried	T3	3.19^{a}	6.45^{b}	92.50^{ab}
	T4	3.14^{a}	6.82^{a}	91.74^{b}
Drying method × Storage time				
Hot air drying	0	2.98^{a}	5.69^{a}	93.59^{a}
	1	2.94^{ab}	5.62^{ab}	93.18^{ab}
	2	2.91^{ab}	5.59^{abc}	92.88^{abc}
	3	2.89^{ab}	5.56^{bc}	92.39^{bc}
	4	2.87^{ab}	5.53^{bc}	92.06^{c}
	5	2.83^{ab}	5.50^{c}	91.10^{d}
	6	2.80^{b}	5.49^{c}	90.45^{d}
Freeze drying	0	3.16^{a}	6.63^{a}	92.12^{a}
	1	3.11^{ab}	6.60^{a}	91.55^{ab}
	2	3.07^{abc}	6.58^{ab}	90.87^{bc}
	3	3.03^{bc}	6.54^{bc}	90.42^{cd}
	4	3.00^{bc}	6.49^{bc}	90.12^{d}
	5	2.97^{c}	6.35^{c}	88.57^{e}
	6	2.96^{c}	6.32^{c}	88.09^{e}

Means with different letters in the same column are significantly different for p≤0.05
T1- Control hot air dried tomato
T2- 4% KMS hot air dried tomato
T3- Control freeze dried tomato
T4- 4% KMS freeze dried tomato

Titratable acidity of the slices was significantly (p≤0.05) affected by drying method, treatment, storage and interaction between drying method and treatment (Table 2). There was a significant reduction of acidity during storage period. Hot air dried (T1, T2) and freeze dried (T3, T4) tomato slices had titratable acidity in the range of 2.98-2.80% and 3.16-2.96%, respectively during 6 months storage. The decrease in acidity in the present study might have been due to the reaction of acid with basic minerals present in the dried product or also due to any other biochemical interactions resulting in binding of acid with the other components with the passage of time.

Rehydration ratio

Storage time significantly (p≤0.05) affected rehydration ratio. Interactions between drying method and treatment, drying method and storage and individually drying method, treatment and storage significantly affected rehydration ratio (Table 2). Rehydration ratio decreased with storage time. Rehydration ratio in freeze dried and hot air dried tomato slices were found to be decreased by 4.90% and 3.64%, respectively over six months storage. Weier and Stocking (1949) found that the loss of rehydration was due to changes in macromolecular components including cellulose, pectin, hemicelluloses and protein which are adversely affected during treatment, dehydration and storage. Kapoor and Aggarwal (2015) also found decrease in rehydration ratio of sulphite treated carrot slices during storage period of 4 months.

Effect of storage on phytonutrients and antioxidant activity of dried tomato slices

Phytonutrients

All main effects, and most interactions, significantly (p≤0.05) affected ascorbic acid, total carotenoids, β-carotene, lycopene, total phenols and antioxidant activity. The highest order interaction was used to explain results. Most phytonutrients were reduced over the length of storage regardless of drying method and treatment (Table 3 and 4).

Total carotenoids and β-carotene in all dried samples decreased over time (Table 3). Total carotenoids and β-carotene in T1 dried sample were reduced by 38.14 and 48.51%, respectively after 6 months of storage. On the other hand, lower reduction of total carotenes (19.12%) and beta carotene (20.74%) was found in T2 samples. Decrease in the carotenoid content in the

present study is parallel to sulphur dioxide loss and lycopene degradation during storage and the effect of environmental factors cannot be ignored.

Table 3: Effect of drying method, treatment and storage on total carotenoids (mg/100g), beta-carotene (mg/100g) and lycopene (mg/100g) of dried tomato slices

Source		Total carotenoids	Zβ-carotene	Lycopene
Drying method × Treatment				
Hot air dried	T1	120.30^{d}	74.28^{d}	44.52^{c}
	T2	141.35^{a}	89.48^{a}	51.06^{a}
Freeze dried	T3	138.61^{b}	87.10^{b}	50.59^{ab}
	T4	134.55^{c}	84.79^{c}	49.86^{b}
Drying method × Storage time				
Hot air drying	0	130.82^{a}	81.88^{a}	47.79^{a}
	1	121.68^{b}	76.82^{b}	44.00^{b}
	2	114.83^{c}	73.22^{c}	41.53^{c}
	3	109.87^{d}	69.11^{d}	39.50^{d}
	4	105.35^{e}	64.73^{e}	37.54^{e}
	5	103.62^{f}	62.99^{f}	36.98^{ef}
	6	102.88^{f}	62.06^{f}	36.32^{f}
Freeze drying	0	136.58^{a}	85.94^{a}	50.22^{a}
	1	126.73^{b}	79.84^{b}	47.33^{b}
	2	120.31^{c}	74.33^{c}	43.48^{c}
	3	113.08^{d}	68.52^{d}	40.78^{d}
	4	107.76^{e}	64.84^{e}	37.99^{e}
	5	105.36^{f}	63.16^{f}	37.08^{f}
	6	104.37^{g}	62.00^{g}	36.80^{f}

Means with different letters in the same column are significantly different for p≤0.05
T1- Control hot air dried tomato
T2- 4% KMS hot air dried tomato
T3- Control freeze dried tomato
T4- 4% KMS freeze dried tomato
Total carotenoids and β-carotene

Similarly, T3 and T4 dried samples resulted in 32.04 and 29.67 % reduction of total carotenoids and 42.53 and 34.81% reduction in β-carotene, respectively over storage months. On comparing the carotenoid content of T2 and T4 dried sample, better carotenoids were retained in T2 samples. Okos *et al*. (1992) reported that higher level of lipid oxidation was found in freeze-dried foods as compared to air dried ones because freeze-dried products are more susceptible to oxygen than air dried products due to their highly porous structure and carotene reduction was found to be higher during storage than that occurring in drying process. Moreover, less retention of SO_2 in T4 sample as compared to T2 sample (Table 5), explains more loss of carotenes during storage of pre-treated freeze dried sample as compared to KMS treated hot dried sample.

Lycopene

There was significant (p≤0.05) reduction of lycopene content during storage (Table 3). After six months storage, reduction in lycopene content was 30.36 % in T1 and 22.59 % in T2 tomato slices. This observation disclosed that KMS treatment had a salutary effect on the retention of lycopene in the dried product. Zanoni *et al*. (1999) observed a marked loss of lycopene in dried tomato halves during storage in air and darkness at 37°C. Among the freeze dried samples, T3 and T4 dried slices showed 24.63 and 24.07 % reduction of lycopene, respectively. Decrease in lycopene content may be due to its co-planarity structure being very reactive to oxidation (Lin and Chen, 2005).

Ascorbic acid

A significant (p≤0.05) reduction in ascorbic acid was found during storage period (Table 4). There were 25 and 22.13 % reduction of ascorbic acid in T1 and T2 tomato slices, respectively. On the other hand there were 29.28 and 25.18 % reduction of ascorbic acid in T3 and T4 slices, respectively. Higher reduction of ascorbic acid in freeze dried samples compared to hot air dried samples may be because freeze-dried products are more susceptible to oxygen degradation than air-dried products due to their highly porous structure (Okos *et al*., 1992). Similarly, Rai and Jain (1970) reported heavy loss of Vitamin C in freeze dried vegetables despite of packing under nitrogen. Sulphite treated samples retained more ascorbic acid than control samples due to antioxidant effect of sulphites as they prevent

oxidative spoilage by acting as oxygen scavenger and reducing agent (Gould and Russel, 1991).

Table 4: Effects of drying method, treatment and storage on ascorbic acid (mg/100g), total phenols (mg GAE/100g) and antioxidant activity (%) of dried tomato slices

Source	Ascorbic acid	Total phenols	Antioxidant activity	
Drying method × Treatment				
Hot air dried	T1	51.36^{d}	692.38^{a}	32.28^{c}
	T2	56.09^{c}	512.18^{b}	42.64^{a}
Freeze dried	T3	64.25^{a}	470.44^{c}	40.64^{ab}
	T4	60.97^{b}	431.23^{d}	39.01^{b}
Drying method × Storage time				
Hot air drying	0	53.72^{a}	602.28^{a}	37.46^{a}
	1	48.84^{b}	578.77^{b}	36.45^{b}
	2	46.41^{c}	538.41^{c}	32.29^{c}
	3	43.33^{d}	518.99^{d}	30.05^{d}
	4	41.10^{e}	449.91^{e}	28.11^{e}
	5	39.99^{f}	444.49^{f}	27.45^{e}
	6	39.15^{g}	439.77^{g}	26.03^{f}
Freeze drying	0	62.61^{a}	450.83^{a}	39.82^{a}
	1	58.25^{b}	423.71^{b}	32.84^{b}
	2	53.15^{c}	389.97^{c}	26.53^{c}
	3	49.53^{d}	354.47^{d}	23.71^{d}
	4	45.53^{e}	325.50^{e}	19.28^{e}
	5	43.38^{f}	319.92^{f}	18.02^{f}
	6	42.70^{g}	315.23^{g}	16.93^{g}

Means with different letters in the same column are significantly different for p≤0.05
GAE- Gallic acid equivalent
T1- Control hot air dried tomato
T2- 4% KMS hot air dried tomato
T3- Control freeze dried tomato
T4- 4% KMS freeze dried tomato

Total phenols

Estimation of total phenolic content revealed that there were 47.56 and 24.82% reduction in phenolic content in T1 and T2 dried tomato slices, respectively after six months of storage (Table 4). Whereas, in T3 and T4 slices, reduction of phenols was found to be 45.05 and 40.85%, respectively. Zhao *et al*. (2008) reported that increased temperature and storage time led to oxidation and polymerization of phenolic compounds. Higher value of total phenols in T1 slices as compared to other samples is due to overestimation of oxidized substrate formed during hot air drying signifying the importance of KMS treatment in preventing formation of oxidized products.

Overestimated phenolic values did not correlated with antioxidant activity as T1 slices retained least antioxidant activity during storage period of six months.

Antioxidant activity

A significant (p≤0.05) reduction of antioxidant activity in all dried tomato slices was found during storage (Table 4). In T1 samples antioxidant activity reduced from 34.28 to 20.98 % after six months of storage (treatment mean, data shown). The decrease in antioxidant activity is due to decrease in the phytonutrients during storage such as ascorbic acid, total carotenoids, beta-carotene, lycopene and total phenols. Antioxidant activity in T2 slices reduced from 42.64 to 31.09 % after six months of storage. Antioxidant activity in T3 and T4 slices decreased from 40.64 to 18.54 % and 39.01 to 15.32 % after six months of storage, respectively (treatment mean data shown). However, the interaction among drying method, treatment and storage was found to be non-significant.

Higher antioxidant activity retention was found in T2 samples when compared with T4 samples. This is due to less SO_2 retention (Table 5) and open porous structure in freeze dried samples leading to more deterioration of phytonutrients due to oxidation during storage (Okos *et al*., 1992) as compared to hot air dried samples which have shrinked structure. Behavior of DPPH radical after reaction with antioxidant compounds observed during each storage month is depicted in Fig. 2. Antioxidant activity of T2, T3 and T4 dried tomato slices decreased sharply during 2nd month storage and thereafter the decrease was found to be consistent with storage months. However, in case of T1 slices

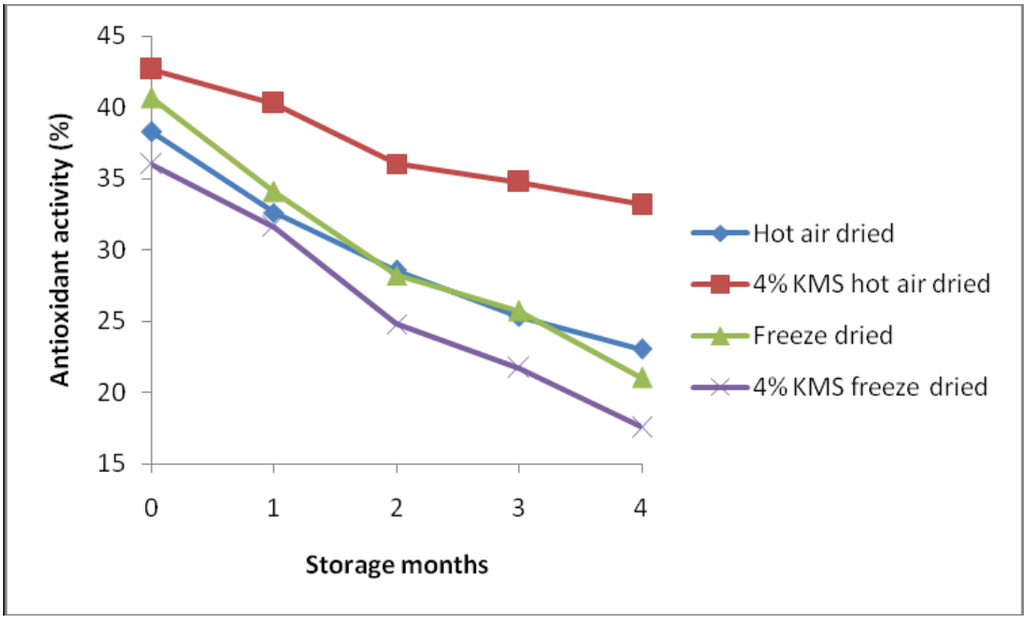

Fig. 2: Effect of storage on antioxidant activity (%) of dried tomato slices

the antioxidant activity decreased sharply during 1st month of storage followed by consistent decrease till six months storage.

Sulphur dioxide

It is clear from Table 5 that substantial amount of sulphur dioxide was lost during six months of storage. Initially, the SO_2 content of T2 was found to be 1127.24 ppm and T4 was found to be 518.88 ppm. With increasing storage temperature, there was a significant loss of sulphur dioxide. Among the treated samples, T2 and T4 slices were found to have 678.83 ppm and 98.51 ppm SO_2, respectively after 6 months of storage period. Similarly, Latapi and Barrett (2006) have found significant losses in sulfur dioxide content in all sulfured sun-dried tomatoes after three months of storage. Decreases in sulphur dioxide content increase susceptibility of phytonutrients towards oxidation, leading to their deterioration. As a result, the phytonutrients ascorbic acid, total carotenoids, β-carotene, lycopene and phenolics decreased with decreasing SO_2 concentration over time. Cumulative decrease of phytonutrients may result in reducing antioxidant activity as phytonutrients are positively correlated with antioxidant activity.

Table 5. Effect of storage on SO2 retention (ppm) of dried tomato slices

Storage month	SO_2 retention (ppm)	
	T2	T4
0	1127.24[a]	518.88[a]
1	1023.15[b]	363.70[b]
2	933.17[c]	269.53[c]
3	877.59[d]	192.88[d]
4	795.11[e]	150.63[e]
5	701.27[f]	106.72[f]
6	678.83[g]	98.51[g]

Means with different letters in the same column are significantly different for p≤0.05

T2- 4% KMS hot air dried tomato

T4- 4% KMS freeze dried tomato

CONCLUSION

The present investigation establishes freeze drying technique to retain better phtyochemical compounds

and antioxidant activity compared to hot air drying technique in case of untreated samples. However, for the sulphite treated samples, more antioxidant activity was observed in hot air dried tomato slices compared to freeze dried samples due to beneficial effects of sulphur dioxide on retention of antioxidants whereas SO_2 had negligible effects on retention of phytonutrients in KMS treated freeze dried samples. Blanching and dipping treatment also led to loss of phytonutrients in addition to drying. The future emphasis can be given to optimize the packaging material and pre-treatments for better preservation of phytonutrients in tomatoes.

REFERENCES

Anguelova, T. and Warthesen, J. 2000. Lycopene stability in tomato powders. *J. Food Sci*. **65(1):** 67-70.

Beecher, G.R. 1998. Nutrient content of tomatoes and tomato products. *Proc. Soc. Exp. Biol. Med*. **218(2):** 98-100

Brand-Williams, W., Cuvelier, M.E. and Berset, C. 1995. Use of a free radical method to evaluate antioxidant activity. *LWT-Food Sci. Technol*., **28:** 25-30

Chang, C.H., Lin, H.Y., Chang, C.Y. and Liu, Y.C. 2006. Comparisons on the antioxidant properties of fresh, freeze-dried and hot-air-dried tomatoes. *J. Food Engg*., **77(3):** 478–485

Correia, A.F.K., Loro, A.C., Zanatta, S., Spoto, M.H.F. and Vieira, T.M.F.S. 2015. Effect of temperature, time and material thickness on the dehydration process of tomato. *Int. J. Food Sci*. http://dx.doi.org/10.1155/2015/970724.

Danesi, F. and Bordoni, A. 2008. Effect of home freezing and Italian style of cooking on antioxidant activity of edible vegetables. *J. Food Sci*., **73:** H109-H112

Davoodi, M.G., Vijayanand, P., Kulkarni, S.G. and Ramana, K.V.R. 2007. Effect of different pre-treatments and dehydration methods on quality characteristics and storage stability of tomato powder. *LWT-Food Sci. Technol*., **40:** 1832-1840.

Ghavidel, R.A. and Davoodi, M.G. 2010. Studies on physiochemical properties of tomato powder as affected by different dehydration methods and pre-treatments. *World Academy Sci. Engg. Technol.,* **69:** 596-605.

Gomez, A.K. and Gomez, A.A. 2010. Statistical procedures for Agricultural Research, John Wiley and Sons, New York, USA.

Gould, G.W. and Russel, N.J. 1991. Food preservatives. New York: AVI.

Harik-Khan, R.I., Muller, D.C. and Wise, R.A. 2004. Serum vitamin levels and the risk of asthma in children. *Am. J. Epidemiol.*, **159(4):** 351-357.

Jalili, M. and Ansari, F. 2015. Identification and Quantification of 5-Hydroxymethylfurfural in Food Products. *Nutr. Food Sci. Res*. **2:** 47-53.

Kapoor, S. and Aggarwal, P. 2015. Drying method affects bioactive compounds and antioxidant activity of carrot. *Int. J. Veg. Sci*., **DOI:**10.1080/19315260.2014.895474.

Kaur, C., George, B., Deepa, N., Singh, B. and Kapoor, H.C. 2004. Antioxidant status of fresh and processed tomato- A Review. *J. Food Sci. Technol*., **41:** 479-486.

Krajcovicova-Kudlackova, M. and Dusinska, M. 2004. Oxidative DNA damage in relation to nutrition. *Neoplasma* **51(1):** 30-33.

Latapi, G. and Barrett, D.M. 2006. Influence of pre-drying treatments on quality and safety of sun-dried tomatoes. Part I: Use of steam blanching, boiling brine blanching and dips in salt or sodium metabisulfite. *J. Food Sci*., **71:** S24-S31.

Leoni, C. 2002. Improving the nutritional quality of processed fruits and vegetables: the case of tomatoes, In: 'Fruit and Vegetable Processing: Improving Quality' p. 83-122, Woodhead Publishing Ltd and CRC Press, LLC, Cambridge.

Lin, C.H. and Chen, B.H. 2005. Stability of carotenoids in tomato juice during storage. *Food Chem*., **90:** 837-46.

Nour, V., Trandafir, I. and Ionica, M.E. 2011. Effects of pre-treatments and drying temperatures. *South Western J. Hortic. Biol. Environ*., **2:** 5-24.

Okos, M.R., Campanella, O., Narsimhan, G., Singh, R.K. and Weitnauer, A.C. 1992. Food Dehydration. In: 'Handbook of Food Engineering' Heldman, D.R., Lund, D.B. Eds. p. 601-744, Boca Raton, FLA: Taylor & Francis.

Pant, K., Dhawan, S.S., Goyal, R.K. and Dhawan, K. 2004. Effect of pre-drying treatments on nutritional quality of Aonla (*Emblica officinalis* Gaertn.). *Indian Food Pack*. **58:** 67-70.

Paulus, W. 2005. Directory of Microbicides for the Protection of Materials: A Handbook. Springer Science & Business Media.

Prajapati, V.K., Nema, P.K. and Rathore, S.S. 2011. Effect of pre-treatment and drying methods on quality of value-added dried aonla (*Emblica officinalis* Gaertn) shreds. *J. Food Sci. Technol*., **48:** 45-52.

Qing-guo, H., Min, Z., Mujumdar, A., Wei-hua, D. and Jin-cai, S. 2006. Effects of different drying methods on the quality changes of granular edamame. *Drying Technol*., **24**: 1025-1032.

Rai, M.M. and Jain, N.L. 1970. Some studies on the freeze-drying of common vegetables. *J. Food Sci. Technol*., **7 (Supl.):** 22-28.

Ranganna, S. 1997. Manual of Analysis of Fruit and Vegetable Products, 2nd ed. Tata McGraw Hill Publishing Company Ltd. New Delhi.

Ratti, C. 2001. Hot air and freeze drying of high-value foods: A review. *J. Food Engg*., **49:** 311-319.

Robertson, G.L. 1993. Food packaging, principles and practice. Marker Dekker Inc, New Zealand.

Ruck, J.A. 1969. Chemical methods for analysis of fruit and vegetable products. Research branch Canada Dept. of Agriculture, Summerland.

Scalzo, R.L., Iannoccari, T., Summa, C., Morelli, R. and Rapisarda, P. 2004. Effect of thermal treatments on antioxidant and antiradical activity of blood orange juice. *Food Chem*., **85:** 41-47.

Sharma, S.K. and Le Maguer, M. 1996. Kinetics of lycopene degradation in tomato pulp solids under different processing and storage conditions. *Food Res. Int*., **29:** 309-315.

Shi, J., Le Maguer, M., Kakuda, Y. and Liptay, A. 1999. Lycopene degradation and isomerisation in tomato degradation. *Food Res. Int*., **32:** 15-21.

Shofian, N.M., Hamid, A.A., Osman, A., Saari, N., Anwar, F., Dek, M.S.P. and Hairuddin, M.R. 2011. Effect of freeze-drying on the antioxidant compounds and antioxidant activity of selected tropical fruits. *Int. J. Mol. Sci*., **12:** 4678-4692.

Singleton, V.L., Orthofer, R. and Lamuela-Raventos, R.M. 1999. Analysis of total phenols and other oxidation substrates and antioxidants by means of Folin-Ciocalteu reagent. *Methods in Enzymology* **299:**152-178.

Singleton, V.L. and Rossi, J.A. Jr. 1965. Colorimetry of total phenolics with phosphomolybdic-phosphotungstic acid reagents. *Amer. J. Enol. Viticult.,* **16:** 144-158.

Sra, S.K., Sandhu, K.S. and Ahluwalia, P. 2011. Effect of processing parameters on physico-chemical and culinary quality of dried carrot slices. *J. Food Sci. Technol*., **48:** 159-166.

Swain, J. and Hillis, W.G. 1959. The phenolics constituents of *prumas domestical*- The qualitative analysis of phenolics constituents. *J. Sci. Food Agric*., **10:** 63.

Tang, Y.C. and Chen, B.H. 2000. Pigment change of freeze-dried carotenoid powder during storage. *Food Chem*., 69: 11-17.

Weier, T.E. and Stocking, C.R. 1949. Histological changes induced in fruits and vegetables by processing. *Adv. Food Res*., **2:** 297-341.

Woodroof, J.G. and Luh, B.S. 1975. Commercial Fruit Processing. The AVI publishing company, Westport Connecticut.

Zanoni, B., Peri, C., Nani, R. and Lave, V. 1999. Oxidative heat damage of tomato halves as affected by drying. *Food Res. Int*., **31:** 395-401.

Zhao, G.Y., Zong, W. and An, G.J. 2008. Effect of storage on cloud stability of cloudy apple juice. *Food Sci. Technol. Int*., **14:** 105-113.