Effects of Chemical Pretreatments on Physiochemical and Drying Characteristics of Solar-Dried Tomato *(Lycopersicon esculantum)* Slices

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Abstract

The research was planned to study the impacts of chemical pre-treatments on physiochemical and drying attributes of solar-dried tomato (Var. Srijana) slices. Completely randomized Cut tomato slices were pretreated by plunging in solution of 0.2% Potassium metabisulphite (KMS), 1% calcium chloride ($CaCl_2$), 3% sodium chloride (NaCl) and 0.2% KMS alongside 1% $CaCl_2$ arrangement freely for 10 minutes which was then subjected to solar drying. Five kilograms of tomato were used for each treatment and completely randomized design was used with five treatments including control (without any pre-treatment) and triplicate analysis. Acidity increased in pretreated items compared to control item aside from item pretreated with NaCl (4.42). Results demonstrated that KMS treated sample indicated higher maintenance of carotenoids (33.54mg/100g) and lycopene (16.21mg/100g) content while vitamin C content was higher (34.65g/100 g) in sample pretreated with KMS+$CaCl_2$. Non-enzymatic browning (NEB) was found to be increased in control sample (1.01) and least (0.51) in $CaCl_2$ treatment. Here, rehydration proportion was most minimal for control item (0.22) with the high dehydration ratio of 16.47. From the microbial investigation, it was found that yeast and mould count was inside permissible farthest point (103-104 CFU/g) just for items pretreated with KMS, $CaCl_2$ and KMS+$CaCl_2$. From the investigation of drying curve, the drying pattern for all the artificially pretreated and untreated tomato cuts was observed to be same. It can be reasoned that pretreatments deliver considerable change in the quality of tomato.

Keywords: *Acidity, Ascorbic acid, Carotenoids, Lycopene, Dehydration ratio*

Introduction

Tomato *(Lycopersicon esculantum)* belongs to the family of *Solanaceae*. It is a rich source of vitamin C and a plant pigment lycopene which are important nutrients required in the human daily diet (Adebisi et al. 2014). Srijana is most common hybrid variety of tomato crop grown in Terai and mid-hills of Nepal. Its productivity is reported to be 30.9 Mt/ha in the open field condition and more than 80 t/h under plastic house (Chapagain et al. 2011 and 2014). The production of tomatoes was 386824.6 Mt with the average yield of 19.3 Mt/ha (MoAD, 2016). Tomatoes are highly perishable and cannot be stored in ambient condition for a longer period. Its perishable nature has resulted in additional spoilage during handling, transportation, storage and distribution resulting in a huge amount of post-harvest losses (PHL) of tomatoes (Udas et al. 2005). Various researchers have carried out the postharvest loss (PHL) assessment in tomatoes. The estimated PHL in tomato is found to be 33%, which is significantly higher than other vegetables (HVAP, 2011). Udas et al. (2005) estimated 3% and 7% PHL of tomatoes in the eastern region of Nepal in collection centre and retailers respectively. Gautam et al. (2017) reported 2%, 8%, 6% and 9% PHL of tomatoes in farmers' field, collectors, wholesalers and retailers respectively in the value chain. Hence, in Nepal, farmers are losing bulk of produce along with significant amount of capital every year and the country, on the other hand, is obliged to import tomatoes from India at higher prices to meet consumers' demand (HVAP, 2011).

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Drying can be an effective method for preserving perishable produce like tomatoes that help to remove excess of moisture resulting in a dried tomato with low water activity (aw) (Fellows, 2000). The quality of dried tomato depends upon the initial quality of tomato like °Brix, acidity, moisture, drying rate, etc. (Mohseni and Ghavidel, 2011). On the other hand, use of solar drying in rural areas is common, economically feasible, easy to operate and also an improved alternative to the traditional sun drying. On the contrary, difficulties have arisen in producing high quality dried products of consumers' demand due to various undesirable changes that occur during drying. These reactions are those which result in quality losses, particularly nutrient losses and other deteriorations caused by browning reactions. Hence, pretreatments with various chemicals before drying have been used in order to minimize adverse changes during drying of tomatoes (Mohseni and Ghavidel, 2011 and Mozumder et al. 2012). Treatments of fresh tomatoes prior to drying can help in better retention of nutrients, lengthen shelf- life, reduction of microbial flora and better retention of sensory quality (Ghavidel and Davoodi, 2009 and Sheshma and Raj, 2014). Further, it is also necessary to identify the pretreatment effect on drying characteristics such as drying curve, dehydration ratio, rehydration ratio and coefficient of rehydration (COR). The objective of the study was to study the effect of pre-treatments on quality of solar-dried tomato slice.

Materials and Methods

Materials

Matured and fully ripened tomatoes of cultivar *Srijana* were purchased from a *Tarkhaagal* vegetable farm located in Dadhikot, Bhaktapur, Nepal. Locally fabricated solar dryer (3 trays, position inclined about 30˚, dimension of each tray = 0.9×0.42 m^2) was used for drying.

Preparation of Tomato Slices

Purchased tomatoes were sorted for quality fruits and rotten, injured, and over and under-ripened were discarded. Only fully matured tomatoes of uniform size were taken. Pedicel of tomatoes were removed and followed by washing with 200 ppm sodium hypochlorite solution to reduce microbial population, dirt, and dusts. Then, the tomatoes were sliced to about 5 mm thickness using a very sharp stainless steel knife. All equipments used in this process such as chopping board, knives, trays as well as working area were sanitized properly with 75% iso-propyl alcohol.

Pretreatments

Altogether five types of pretreatments were used viz., potassium metabisulphite (KMS) solution (0.2%), calcium chloride ($CaCl_2$) solution (1%), sodium chloride (NaCl) solution (3%), a mixed solution containing 0.2% KMS and 1% $CaCl_2$ (Ghavidel and Davoodi, 2009; Latap and Barrett, 2006; Mozumder et al. 2012 and Sheshma and Raj, 2014) and one was Control, which was not treated with any chemicals. Sliced tomatoes were dipped in these pretreatment solutions in 1:1 ratio (w/w). Tomato slices were dipped (soaked) for 10 minutes in these pretreatment solutions. After 10 minutes, soaked tomato slices were removed from pretreatment solution and were spread out thinly over blotting paper for about 10 minutes, in order to remove excess water from the surface, followed by solar drying (20-50°C and 35-80% relative humidity) for 30-35 hours. The coding of sample is presented in table 1.

Table 1: The product code according to pretreatment chemicals used prior to drying

Product code	Pretreatment chemical used
A	KMS (0.2%)
B	$CaCl_2$ (1%)
C	NaCl (3%)
D	$CaCl_2$ (0.2%) + KMS (1%)
E	Control (No chemical pretreatment was carried out)

Chemical Analysis

Chemical properties (moisture, acidity, ash, vitamin C and reducing sugar) of fresh and solar-dried tomato were determined as per AOAC, 2005. Moisture content was determined by drying the sample in a hot air oven at 70±1°C to a constant weight. The sample was titrated by N/10 NaOH solution and % acidity was expressed as citric acid. Ash content was determined by incinerating the sample at 550°C in a muffle furnace. Vitamin C content of samples was determined by 2, 6-Dichloro-Indophenol visual titration method. Reducing sugar was determined using Lane and Eynon method.

For carotenoid, sample (fresh and solar dried) was extracted in mortar and pestle using 85% acetone till the residue is colorless followed by filtration of acetone extract in 250 ml volumetric flask. Then, filter paper was washed and made up volume with acetone up to mark. 50 ml of this extract was transferred into separating funnel containing 50 ml petroleum ether. Water was added from sides of funnel until the water layer is apparently free of all the fat-soluble pigments. Water layer was drained off while the petroleum ether layer was washed 5 to 10 times with 10 ml portions of distilled water until the ether layer is free of acetone. Ether extract was transferred into 100 ml volumetric flask, diluted to volume with ether and mixed. To this extract 3 to 5g of anhydrous Na_2SO_4 was added (Rangana, 2008). Finally, OD of color at 470 nm, 653 nm and 662 nm was taken using ether as blank. Concentrations of carotenoids and chlorophyll-a and chlorophyll-b were determined according to the equations reported by (Lichtenthaler and Wellburn, 1983) as follows:

$$\text{Total carotenoids}, Cc = (1000Abs470 - 2.270Ca - 81.4Cb)/227$$

$$\text{Chlorophyll-a}, Ca = 11.75Abs662 - 2.3500Abs645$$

$$\text{Chlorophyll-b}, Cb = 18.61Abs645 - 3.960Abs662$$

Where Abs is the absorbance, Ca is the chlorophyll-a, Cb is the chlorophyll-b, and Cc is the carotenoid content in (µg of carotenoids/100g of sample).

For lycopene, 5 to 10g of sample (fresh and solar dried tomato) was repeatedly extracted in mortar and pestle until the residue was colorless. Acetone extract was then transferred to a separating funnel containing 25 ml petroleum ether and was mixed gently. Also, distilled water was added slowly from wall of separating funnel and two phases were allowed to separate. Lower, aqueous-acetone phase was discarded while the petroleum ether extract containing lycopene pigment was washed with distilled water for 5-6 times to remove residual acetone. Petroleum ether extract was transferred into 100 ml volumetric flask by passing through funnel with anhydrous sodium sulfate to remove residual water and was diluted to mark with petroleum ether (Rangana, 2008). Lycopene content was calculated using following formula:

$$\text{mg of lycopene per 100g} = \frac{3.1206 \times \text{OD of sample} \times \text{volume made up} \times 100}{\text{cm of cell} \times \text{weight of cell} \times 1000}$$

For non-enzymatic browning (NEB), 5g of dried sample was mixed with 100 ml of 60 ml/100 ml absolute alcohol in a glass-stoppered flask. The mixture was shaken thoroughly, kept for 12 hrs and then filtered through Whatman No. 4 filter paper. OD of the filtrate was taken at 420 nm (Ghavidel and Davoodi, 2009).

Drying Characteristics

Drying characteristics such as drying pattern, dehydration ratio, rehydration ratio and coefficient of reconstitution (COR) of solar-dried tomato slices were determined as described by Al-Amin et al. (2015) and Mozumder et al. (2012). The weight of tomato slices was measured in every 30 minutes during solar drying until the constant weight of dried slices was achieved. Data obtained were evaluated by plotting in a graph. Dehydration ratio was calculated as the mass of sliced tomato before loading to the drier to the mass of dehydrated material at the time of removal from drier (Mozumder et al. 2012). Rehydration ratio of dried tomato slices was determined by boiling 5 to 10g of the sample in 100 ml water for 10 min. Rehydration ratio was calculated as the ratio of the weight of dried sample used for the test to the drained weight of the rehydrated sample. The COR was calculated by dividing rehydration ratio by dehydration ratio.

Microbial Analysis

Microbial analysis of tomato was also carried out according to the Chapagain et al. (2013).Yeast and mould count of freshly harvested tomato, tomato washed with sodium hypochlorite, tomato after pretreatment and solar-dried tomato slices was determined using potato dextrose agar as media. The plates were kept in the incubator at 37°C for 48 hours. The colonies appeared on each plate were enumerated and microbial growth was expressed in CFU/g of sample.

Experimental Design and Data Analysis

The completely randomized design with five treatments was laid out and triplicates analysis of each sample was carried out. Mean, standard deviation and coefficient of variance (CV%) was calculated by using MS-Excel 2010 version. The obtained data were analyzed for the difference by analysis of variance using SPSS (version 20), at 95% level of significance by using the Tukey test.

Results and Discussion

The chemical analysis of tomatoes and dried tomato slice is shown in table 2 and table 3 respectively.

Table 2: Result of chemical analysis of fresh tomato

Parameter	Obtained value
Moisture (%)	93.68±0.01
Vitamin C (mg/100g)	40.11±0.27
Acidity (%citric acid)	0.51±0.12
Ash (%)	3.65±0.03
Total carotenoids (mg/100g)	75.73±0.01
Lycopene (mg/100g)	17.27±0.01
Reducing sugar (mg %)	150.74±1.34

Values are mean of three replicate determination and values after the sign (±) indicate standard deviation

Table 3: Result of chemical analysis of dried products

Parameters	Product A	Product B	Product C	Product D	Product E	CV(%)
Moisture (%)	13.46±0.02	11.11±0.02	10.40±0.01	10.19±0.01	12.12±0.02	11.7
Acidity (%citric acid)	6.61±0.25^{a}	6.82±0.14^{a}	4.42±0.22^{b}	8.02±0.08^{c}	5.73±0.07^{d}	21.2
Ash (%)	5.11±0.03^{a}	4.43±0.04^{b}	6.94±0.03^{c}	5.51±0.02^{d}	5.82±0.02^{e}	16.7
Vitamin C (mg/100g)	14.16±0.35^{a}	28.57±0.29^{b}	31.52±0.38^{c}	34.65±0.29^{d}	8.64±0.27^{e}	48.6
Total Carotenoids (mg/100g)	33.54±0.01^{a}	22.8±0.01^{b}	19.68±0.01^{c}	21.99±0.01^{d}	12.41±0.01^{e}	34.4
Lycopene (mg/100g)	16.21±0.01^{a}	13.48±0.01^{b}	12.39±0.01^{c}	14.84±0.01^{d}	7.76±0.01^{e}	24.9

Values are mean of three replicate determination and values after the sign (±) indicate standard deviation; Superscript letters (a-e) indicate significant difference ($p < 0.05$) among different pretreated dried tomato slices. Means with the same letter within a row are not significantly different ($p<0.05$)

Here, moisture content has been reduced from 93.68% of fresh tomato to 10-14 % in solar dried tomato items, which is within an acceptable limit as moisture content over 15% advances enzymatic responses and connections between constituents of the dried item bringing about nutrient loss (Ukegbu and Okereke, 2013). The high titratable acidity of dried tomato items contrasted with fresh tomato might be because of a lessening in moisture content, in light of the fact that as the moisture content declines, the estimation of other parameter builds (Ghavide and Davoodi, 2009; Mozumder et al. 2012; and Owusu et al. 2012). Ash content was observed to be more in dried tomato than that of fresh tomato. A similar outcome was detailed by Famurewaand Raji (2011). Vitamin C content was observed to be low in dried tomato tests as opposed to fresh tomato. This could be credited to oxidative reaction due to heat, light, oxygen, moisture and metal particles (Latapi and Barrett, 2006 and Ukegbu and Okereke, 2013). The higher maintenance of Vitamin C in KMS pretreated product contrasted with the control product could be because of the impact of sulfur dioxide which causes the inactivation of the endogenous compounds, for example, ascorbic acid oxidase, cytochrome oxidase and peroxidase (Latapiand Barrett, 2006; and Sheshma and Raj, 2014). Carotenoids content was observed to be high in fresh tomato than that of dried tomato. Reduction in carotenoids contents of dried tomato might be expected due to the exposure of tomato slices to air during drying as the carotenoids are highly sensitive to oxygen (Sahin et al. 2011). In case of dried sample, total carotenoids content was found more in KMS treated sample (33.54mg/100g) and was low in the control sample (12.41mg/100g). Mohamed and Hussein (1994) reported that sodium metabisulfite treatment was able to reduce oxidation of carotenoid in carrots. Results demonstrated that pre-treatment affected the lessening of lycopene in dried tomato. Lycopene degradation was found to be high in the control i.e. untreated sample (7.76mg/100g). However, sample pretreated with KMS had shown better retention of lycopene (16.21mg/100g) followed by sample pretreated with KMS+$CaCl_2$ (14.84%).

The result of analysis of reducing sugar and NEB of dried tomato slices showed that there is a relation between these two parameters, which is shown in Fig. 1.

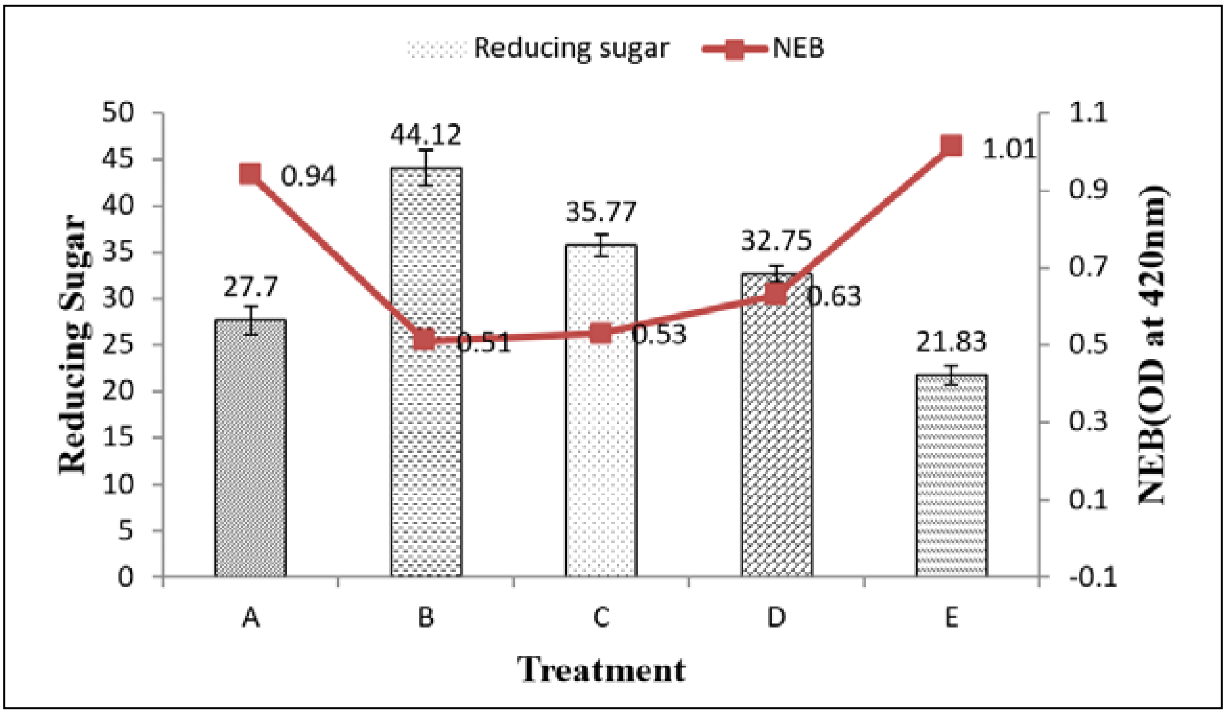

Figure 1 Relation between reducing sugar content and NEB of dried tomato slices.

Here, the changes in reducing sugar content could be related to non-enzymatic browning reaction which was found to be more in control sample and less in pretreated samples. The low reducing sugar in control sample (21.83 mg%) could be linked with its high NEB index (1.01), as the NEB involves the reactions of sugar with proteins and amino acids in food to give complex brown pigments called melanoidins (Ghavidel and Davoodi, 2009 and Sheshma and Raj, 2014). It was found that among all four chemical treatments, KMS was less effective and $CaCl_2$ was most effective in controlling NEB in solar-dried tomato slices. Sheshm and Raj, 2014 also found $CaCl_2$ pretreatment most effective. However, mechanism of retardation of NEB by calcium has not been explained clearly. According to Baloch et al. (1997) calcium may act to block the amino group to enter into browning reaction. Also, calcium with organic substances of food having alpha amino carboxylic acid structure can form a chelating compound that may prevent NEB in dried food products (Ghavidel and Davoodi, 2009). The inhibitory effect of KMS to NEB is due to SO_2 as reported by Burton et al. 1963.

The drying characteristics of pretreated tomato slice are shown in table 4 and fig. 2 (drying curve) respectively.

Table 4: Dehydration characteristics of dried products

Parameters	Product A	Product B	Product C	Product D	Product E	CV(%)
Dehydration ratio	14.34±0.16[a]	12.65±0.21[b]	11.83±0.09[c]	12.07±0.63[bc]	16.47±0.42[d]	14.4
Rehydration ratio	0.25±0.02[a]	0.26±0.01[a]	0.24±0.01[ab]	0.27±0.01[a]	0.22±0.01[b]	7.7
Coefficient of reconstitution (COR)	0.016±0.00[a]	0.022±0.00[b]	0.019±0.00[c]	0.022±0.00[b]	0.015±0.01[a]	17.2

Values are mean of three replicate determination and values after the sign (±) indicate standard deviation; Superscript letters (a-d) indicate significant difference ($p < 0.05$) among different pretreated dried tomato slices. Means with the same letter within a column are not significantly different ($p < 0.05$)

Here, low dehydration ratio of NaCl pretreated product may be due to the leaching of tomato juice to osmotic medium i.e. NaCl solution (Ghavidel and Davoodi, 2009 and Sheshma and Raj, 2014). It was also found that KMS and $CaCl_2$ both in combination and independently have played a significant role in improving dehydration ratio and minimization of weight losses during drying. Treatment with calcium reduces respiration and intensifies the repair process of cut tissue thereby maintaining firmness (Izumi and Watada, 1994, Picchioni et al. 1994 and Rosen & Kader, 1989). It was found that rehydration ratio was lowest for control product and highest for product pretreated with KMS+$CaCl_2$. A similar observation was found by Ghavidel and Davoodi (2009). The result shows that rehydration ratio was better for product pretreated with KMS than pretreated with NaCl. The low rehydration ratio of products pretreated with NaCl could be due to an accumulation of salt crystals on the dried tomatoes thereby decreasing water adsorption during hydration (Latapiand Barrett, 2006). COR provides an idea about the rehydrating ability of the dried product. Kaymak-Ertekin (2002) found that mechanically dried carrots possess better reconstitution properties than solar dried which could be due to the change in drying rates of these two methods. Higher coefficient of reconstitution in mechanical drying is due to higher drying rates than that of solar drying (Al-Amin et al. 2015).

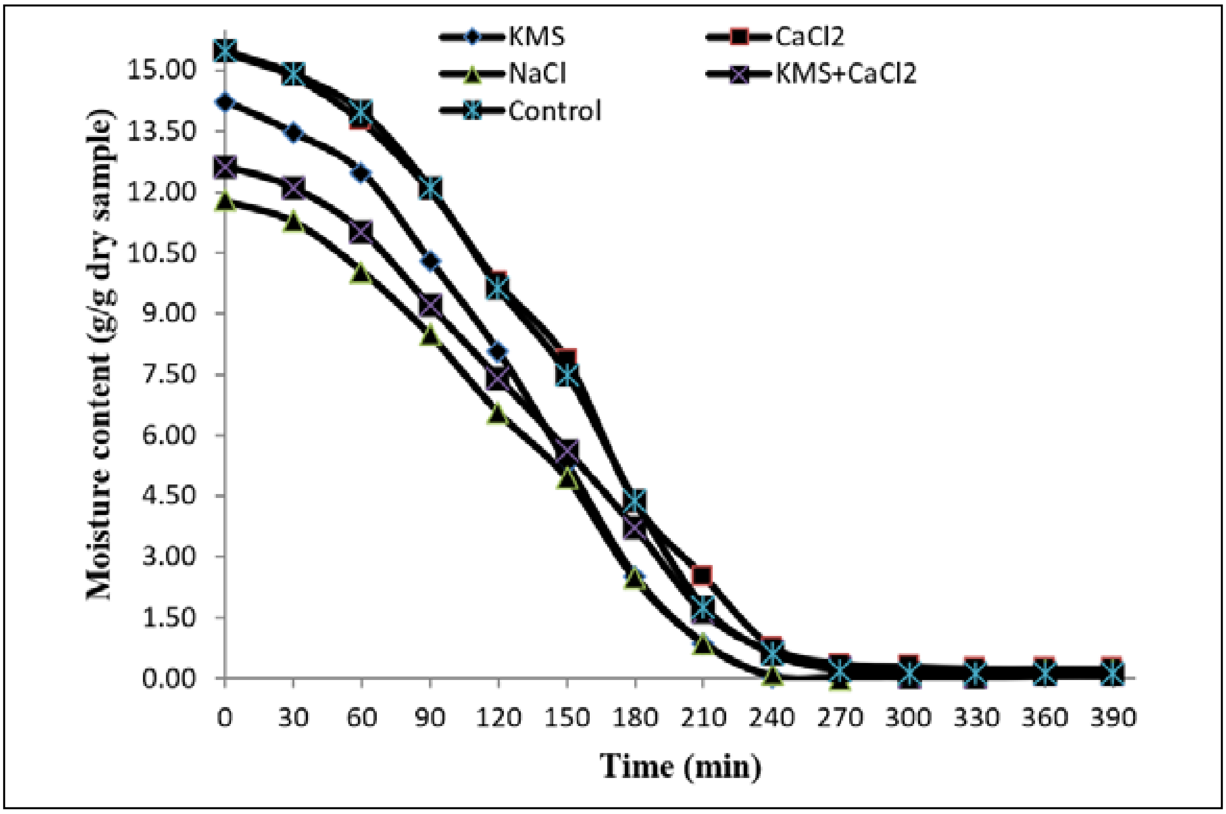

Figure 2 Drying curve of pretreated and untreated solar dried tomato slices

A rapid rate of water removal from tomato slices was observed for about 4 hours then very slowly until the dried tomato slices achieved equilibrium moisture (Figure 2). From fig. 2, it was also observed that moisture removal from a tomato slice was not constant i.e. drying curve does not fall constantly. This could be due to the variable temperature of the solar dryer where sudden rise and fall in temperature was noticed throughout the drying period. Here, recorded temperature of solar dryer ranged from 20°C-50°C. A drying pattern for all chemically pretreated and untreated tomato slices was found to be same. Also, the drying curve was affected by temperature and RH of solar drier during drying (Fellows, 2000 and Sabarez, 1998).

The Yeast and Mould Count (YMC) of dried tomato slices obtained from different chemical pretreatment including fresh tomatoes were determined and the result obtained was expressed in colony forming unit (CFU) per gram of product as shown in Table 5.

Table 5: Yeast and mould count during a different stage of tomato drying

Product	CFU/g of product
Fresh tomato	TMC (Too many to count)
Fresh tomato washed with NaOCl (200 ppm)	Nil
Dried KMS treated tomato slice	8×10^3
Dried $CaCl_2$ treated tomato slice	1×10^4
Dried NaCl treated tomato slice	1.2×10^6
Dried KMS+$CaCl_2$ treated tomato slice	4×10^3
Dried untreated tomato slice	1×10^7

It was found that YMC on fresh (raw) tomato was too many to count (TMC). Such a high microbial load may be due to the contamination occurred during and after harvesting of tomatoes. Tomato fruit washed with 200 ppm sodium hypochlorite solution was found to be free of any form of yeast and mould which could be due to the action of chlorine. It was found that there was a growth of yeast and mould in both pretreated and untreated solar-dried tomato slices at different concentration. The difference in concentration of yeast and mould growth may be attributed to the role of different pretreatment chemicals in microbial growth inhibition. Low YMC in $CaCl_2$ treated dried samples may be due to the high osmotic pressure created by calcium chloride, which leads to the dehydration and plasmolysis of microbial cells and inhibition of microbial growth. Also, the chloride ion is toxic to microbes (Kharel and Hashinaga, 2010; Ediriweeraet al. 2012).The YMC observed in solar dried tomato slices both pretreated and untreated were above the permissible limits (103/g for fungi) as reviewed by Victor et al. 2017. Latapi and Barrett (2006) found that KMS treated tomatoes was better than other treatment, which was similar to the result obtained. Sra et al. (2014) revealed that YMC for KMS treated carrot sample was in the lower side than untreated sample.

Conclusion

This study leads to the conclusion that chemical pretreatment done prior to drying has a significant effect on quality (chemical, physiological and microbial) of solar dried tomato slices. The pretreated samples showed the better retention of bioactive components (Vitamin C, total carotenoids and lycopene) compared to control sample. From this study, it was also found that pretreatment with chemicals did not affect the drying curve.

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