

Full Length Research Paper

Effect of pretreatment on physicochemical quality characteristics of a dried tomato (*Lycopersicon esculentum*)

Mavis Owureku-Asare^{1*}, Joyce Agyei-Amponsah¹, Firibu Saalia², Luis Alfaro³,
Luis A. Espinoza-Rodezno³ and Subramaniam Sathivel³

¹Radiation Technology Centre, Biotechnology and Nuclear Agriculture Research Institute, Ghana Atomic Energy Commission, P.O.Box LG 80, Accra, Ghana.

²Department of Nutrition and Food Science, University of Ghana, P.O Box 25, Legon, Accra, Ghana.

³Department of Food Science, Louisiana State University, 111 Food Science Building, Baton Rouge, LA 70803-4200, USA.

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Tomato is highly perishable and drying is a convenient method of extending its shelf life and minimizing postharvest losses. During drying, some nutrients may degrade and thus affect general quality characteristics of the dried tomato. The effect of pretreatment in enhancing drying and product quality of dried tomato was investigated in this study. Slices of tomato were treated by dipping in (a) A solution containing 0.5% sodium metabisulphite for 10 min and (b) 0.1% ascorbic acid + 0.1% citric acid solution for 10 min (1:1) and (c) distilled water for 10 min (control). Convection dehydration was carried out on tomato slices using an electric dehydrator at 55°C for 6 h. Pretreatment of tomato affected some quality attributes such as total solids, lycopene, dehydration ratio, rehydration ratio and colour. Pretreatment with sodium metabisulphite recorded the least lycopene degradation, highest dehydration ratio (19.40 ± 1.03) and also facilitated the drying of tomato better than the other treatments. All the pretreated dried tomato samples produced good visual and exhibited a desirable red colour (a^* values ranging between 24.49 ± 0.44 - 28.34 ± 0.03) which is characteristic of dried tomato products. Pretreatment with sodium metabisulphite before convection drying can enhance the lycopene content which is a desirable quality attribute for dried tomato.

Key words: Convection drying, dried tomato, sodium metabisulphite, pretreatment, drying rate, lycopene.

INTRODUCTION

Tomato (*Lycopersicon esculentum*) is one of the most widely consumed vegetable used in the preparation of many dishes in Ghana (Tambo and Gbemu, 2010).

However because of its short shelf life, poor handling, storage and the lack of proper processing, there is considerable damage and wastage of this seasonal crop

*Corresponding author: E-mail: mowureku.asare@gmail.com.

in Ghana and other many tropical countries where up to fifty percent (50%) of post-harvest losses is recorded for tomato (Kitinoja and Gorny, 2009). One promising method of preventing or minimizing post-harvest losses is by using drying technology to preserve tomato. Drying decreases the water content of the raw product to levels that minimizes its biochemical, chemical and microbiological deterioration. Drying is an attractive technology because it is very simple and can easily be adopted by the farmers, with minimal capital investments.

Tomato can be dried using various methods and the quality of dehydrated tomato product depends on factors such as tomato variety, total soluble solid content (Brix) of the fresh tomato, the rate of drying, the air humidity, the size of the tomato segments, the air temperature and velocity and the efficiency of the drying system (Gowen et al., 2008; Lewicki, 2006). More sophisticated and high capital cost drying technologies such as infrared radiation heating and freeze drying can also be used to obtain dehydrated tomato products.

In determining the method for dehydration, the quality attributes of the final product form is considered. Preservation of the nutritional quality, flavor and visual characteristics significantly influences the operational parameters of the drying method. A criterion such as maximum product temperature and environmental humidity during drying affects the final product quality. Convective drying can be carried out at high temperatures for short times or at lower temperatures for longer times; the former option being usually preferred since it produces less thermal damage and consumes less energy (Velic et al., 2004). In this process, hot air may cause a series of chemical, physico-chemical, physical and biological alterations that can affect the final quality of the dehydrated product.

Lycopene is the primary natural pigment responsible for the red orange colouration in tomato and serves as a biological antioxidant (Ibitoye et al., 2009). The antioxidant activity of lycopene, the most abundant carotenoid in tomato, has been the subject of several studies on fresh tomato and tomato products. Lycopene may degrade during the drying process, reducing the characteristic red colour of tomato. During the drying process and also during storage periods, oxidative damage takes place in tomato (Zanoni et al., 1999; Toor and Savage, 2006; Sharma and Maguer, 1996; Zanoni et al., 2000). In a study by Shi and Maguer (2000), they indicated that the main causes of lycopene degradation during processing and storage are isomerization and oxidation. Pre-treatment of tomato can enhance certain drying characteristics of tomato. Results show that the pre-treatment with CaCl_2 and NaCl increased water mobility in tomato slices during drying and influenced drying kinetics and texture of the dried product (Davoodi et al., 2007).

The objective of this study was to determine the influence of pre-treatments and convection dehydration

on the physicochemical properties of dried tomato.

MATERIALS AND METHODS

Sample preparation

Fresh tomatoes (Roma variety from Mexico) were sorted and washed under running tap water. They were cut into slices of 3/16" (inch) thickness, using a Nemco 56600-3 3/16 Easy Tomato Slicer II, (301 Meuse Argonne Hicksville, OH, USA). This size was selected based on results from preliminary studies.

Pretreatments prior to dehydration process

Sliced tomatoes were divided into three batches, and randomly assigned to three treatments as follows: dipping in (a) a solution of 0.5% sodium metabisulphite for 10 min, (b) a 0.1% ascorbic acid + 0.1% citric acid solution for 10 min (1:1) and (c) distilled water for 10 min at room temperature (served as control).

Dehydration processes

Hot/convection air dehydration

The samples were placed in a hot air dehydrator (Excalibur 3926T 9 tray food dehydrator, IL, USA) and set at 55°C for six hours. The weights of the samples were recorded every hour during the drying period. After drying, the samples were cooled to room temperature and packed in zip lock bags prior to analysis.

Physicochemical analysis

Moisture content and total solids of tomato samples were determined in triplicates (AOAC, 1999). Water activity (a_w) was determined using a water activity meter (Paw kit, Model Series 3 TE, Decagon Devices, Inc., Pullman, WA, USA). Colour of the samples was determined using the chroma meter (LABSCAN XE Hunterlab, VA, USA) and reported in CIELAB colour scales. L^* value being the degree of lightness to darkness, a^* value of the degree of redness to greenness, and b^* value, is degree of yellowness to blueness. The chromameter was calibrated against a white tile ($L^*=100$). The total soluble solids (TSS) of tomato juice were measured in triplicate by a digital Refractometer (AR 200, Reichert Analytical instrument, NY, USA). pH of the tomato juice was determined by a pH meter (Symphony SB70P VWR, Radnor, PA, USA). Total solids was estimated by subtracting moisture content from 100%; Total solids = 100% - moisture content.

Dehydration rate

Twenty grams of sliced tomatoes (pretreated and control) were pre-weighed and placed in a dehydrator adjusted to 50°C. The weight of the samples was checked and recorded every hour. After drying, the samples were placed in a desiccator and packaged into high density polyethylene bags. Dehydration ratio (DR) was calculated as mass of sliced tomato before loading to the dryer to mass of dehydrated tomato at the time of removal from dryer.

$$DR = \frac{\text{Weight of sample before drying}}{\text{Weight of sample after drying}}$$

Table 1. Effect of pretreatment on quality characteristics of fresh tomato samples before drying.

Pretreated fresh tomato	pH	Brix	Moisture (%)	TS (%)	aw	Lycopene (mg/100g)	Colour		
							L*	a*	b*
TC	4.45 ± 0.03 ^a	3.87 ± 0.06 ^c	95.13 ± 0.05 ^a	4.88 ± 0.05 ^b	0.94 ± 0.01 ^a	152.01 ± 1.62 ^a	41.42 ± 0.11 ^a	28.18 ± 0.06 ^a	27.57 ± 0.27 ^a
TAC	4.18 ± 0.03 ^b	4.10 ± 0.01 ^b	94.78 ± 0.4 ^a	5.22 ± 0.40 ^a	0.94 ± 0.00 ^a	145.41 ± 1.95 ^b	41.68 ± 0.02 ^a	26.67 ± 0.02 ^a	27.50 ± 0.07 ^a
TSM	4.40 ± 0.04 ^a	4.20 ± 0.01 ^{ab}	94.9 ± 0.01 ^a	5.10 ± 0.01 ^a	0.92 ± 0.01 ^b	158.45 ± 1.08 ^a	43.00 ± 0.01 ^a	27.49 ± 0.41 ^a	28.59 ± 0.55 ^a

^{a,b}Values expressed are mean values of 3 replicates ± SD. All mean scores, bearing different superscripts in columns differ significantly (p<0.05). TSM- tomato pretreated with 0.5% sodium metabisulphite, TC- control tomato samples pretreated with water, TAC- tomato pre-treated with 0.1% ascorbic acid + 0.1% citric acid.

The rehydration test

This was conducted as recommended by McMinn and Magee (1997a) and Prabhanjan et al. (1995). Five grams sample of the dried tomato was placed in 150 ml of distilled water in a beaker. The beaker was placed on a hot plate and covered with a watch glass. The water was brought to boiling point, taking approximately 3 min, and kept for 5 min. At the end of the rehydration period, the sample was transferred to a Buchner funnel, covered with No. 4 Whatman filter paper, and the excess water removed by applying a slight vacuum. The sample was removed and weighed. The data was calculated in terms of RR as follows:

$$RR = \frac{M_{rh}}{M_{dh}}$$

Where M_{rh} is the mass of the rehydrated sample (kg) and M_{dh} the mass of the sample dried for rehydrated test (kg).

Moisture loss

Three sets of seven samples of fresh pretreated tomato slices and control were weighed into small aluminum dishes (one slice each, weighing about 5 g) and placed in a dehydrator set at 55°C. One dish was removed every hour weighed and placed in a gravity oven (VWR scientific 1350G, VWR company USA) set at 105°C for 24 h to evaluate the moisture loss over time.

Lycopene analysis

The lycopene content (mg/100g total solids) was spectro-

photometrically determined on extracts in petroleum ether in triplicate at 505 nm (Gould and Gould, 1988) using a Helios UV-Visible spectrophotometer (Helios gamma, Thermo Spectronic, Madison, USA). Determinations were done in triplicate and the averages of these triplicate measurements were used.

Scanning electron microscopy (SEM)

Dried tomato slices were cut and subsequently fixed in 2.5% (w/v) glutaraldehyde overnight. It was rinsed extensively with distilled water and dehydrated in ethanol series (30-100%) for 30 min for each sample. Dehydrated fragments were dried at critical-point and mounted onto metal studs, coated with colloidal platinum with EMS 550x sputter coater machine and viewed using a scanning electron microscope (JSM -6610LV, JEOL INC, Peabody MA).

Statistical analysis

Statistical analysis was performed using Minitab Statistical Software Version 15. Analysis of variance (ANOVA) was done to separate differences between means of treatments with Duncan's multiple range test.

RESULTS AND DISCUSSION

Physicochemical characteristics of fresh pre-treated tomato slices

pH of the fresh pre-treated tomato ranged from 4.18 ± 0.03 - 4.45 ± 0.03 (Table 1). There were

significant differences (p = 0.02) in pH within the pretreated fresh tomato. However, the pH of tomatoes that were pre-treated with sodium metabisulphite (TSM) was not significantly different than the control sample (TC). However samples treated with ascorbic acid + citric acid (TAC) showed significantly lower pH, due to the acid nature of the ascorbic and citric acids.

Total soluble solids varied from 3.87 ± 0.06 - 4.20 ± 0.01. Brix for the control, TC (3.87) was significantly lower (p = 0.03) than the pretreated (TAC and TSM) samples. Moisture ranged from 94.78 ± 0.4% - 95.13 ± 0.05% for TAC and TC, respectively. Even though there was a marginal decrease in moisture content for the pre-treated TAC and TSM samples, probably due to osmotic dehydration, the differences in the moisture content of the control and TAC and TSM samples previous dehydration were not significant (p = 0.11).

Significant differences (p= 0.01) in the total soluble solids (TSS) was observed for fresh pre-treated tomato samples. TSS for TC (4.88) was significantly lower (p= 0.025) than TAC and TC. Water activity was significantly lower (p = 0.03) for TSM (0.92±0.01) as compared to TC (0.94 ± 0.01) and TAC (0.94 ± 0.00). High water activity values indicate a short shelf life for fresh tomato samples as bacteria, moulds, and yeast can grow in water activities above 0.9 (Damodaran et al., 2008).

Table 2. Effect of pretreatment on quality characteristics of dried tomato slices.

Pretreated dried tomato	TS (%)	Moisture (%)	aw	Dehydration ratio (DR)	Rehydration ratio (RR)	Lycopene mg/100g	Colour		
							L*	a*	b*
TC	84.32 ± 0.45 ^{bc}	15.68 ± 0.45 ^{bc}	0.40 ± 0.02 ^b	18.33 ± 0.91 ^{ab}	5.10 ± 1.45 ^{ab}	87.52 ± 1.94 ^{bc}	58.03 ± 0.73 ^a	24.49 ± 0.44 ^b	31.76 ± 0.06 ^a
TAC	84.81 ± 0.81 ^b	15.19 ± 0.81 ^b	0.43 ± 0.03 ^{ab}	17.81 ± 0.82 ^b	5.22 ± 1.34 ^a	84.89 ± 1.04 ^c	50.76 ± 0.13 ^b	26.98 ± 0.13 ^{ab}	29.46 ± 0.09 ^b
TSM	85.52 ± 0.65 ^a	14.48 ± 0.65 ^a	0.39 ± 0.03 ^b	19.40 ± 1.03 ^a	5.35 ± 0.93 ^a	92.29 ± 1.68 ^a	54.87 ± 0.01 ^{ab}	28.34 ± 0.03 ^a	32.55 ± 0.04 ^a

^{a,b,c}Values expressed are mean values of 3 replicates ± SD. All mean scores, bearing different superscripts in columns differ significantly ($p < 0.05$). TSM- tomato pretreated with 0.5% sodium metabisulphite, TC- control tomato samples pretreated with water, TAC- tomato pre-treated with 0.1% ascorbic acid +0.1% citric acid.

Lycopene ranged from 145.41 ± 1.95 - $158.45 \pm 1.08/100$ g (dry weight basis) for the fresh tomato samples. The level of lycopene is directly related to ripeness and increased pH (Thompson et al., 2000) and these factors may explain the wide variability of reported lycopene content in raw tomato. In fresh tomato, the content of lycopene was reported to range from 2.5 – 200 mg/100 g on wet weight basis (Takeoka et al., 2001). In this study, control fresh tomato samples had the lowest lycopene content (6.658 ± 0.53 mg/100g) which was significantly ($p = 0.15$) different from the fresh pretreated tomato samples. Colour L* a* and b* values did not significantly ($p > 0.05$) differ for both control and pretreated tomato.

Physicochemical characteristics of pretreated dried tomato

Results in Table 2 show that pre-treatment influenced some quality characteristics of tomato. Control samples TC ($15.68 \pm 0.45\%$) had the highest moisture content. Total solids content was higher in the pre-treated samples as compared to the control sample. The lowest total solids were recorded by TC ($84.32 \pm 0.45\%$). TSM ($14.48 \pm 0.65\%$) showed lowest moisture content and this may be due to partial effect of sodium metabisulphite in enhancing removal of water through osmotic dehydration. Similar observations

were reported by Gierschner and Philippos (1995b) and Olorunda et al., (1990).

The water activity of samples ranged from 0.39 ± 0.03 - 0.43 ± 0.03 and the relatively low water activity in the samples is a good indicator of a more shelf stable product. Water activity (aw) affects the storage stability of foods because some deteriorative processes in foods are mediated by water. The higher the water activity, the more susceptible the product is to microbial spoilage. The lowest water activity was recorded for samples treated with sodium metabisulphite, TSM (0.39). Subsequently, the dehydration ratio (DR) was significantly higher ($p = 0.021$) for TSM than for TAC (17.81 ± 0.82).

Rehydration can be considered as a measure of the injury to the material caused by drying and treatment preceding dehydration (McMinn and Magee, 1997a; Okos et al., 1992). In this study, rehydration ratio (RR) of dehydrated tomato varied from 5.10 ± 1.45 - 5.35 ± 0.93 and was not significantly affected ($p = 0.04$) by pre-treatments. Davoodi et al. (2007) found significant differences between RR of tomato when pretreated with CaCl_2 and NaCl.

Lycopene content varied significantly ($p = 0.04$) among the dehydrated tomato samples (Table 2). Data show that pretreatment with sodium metabisulphite (TSM) preserved lycopene better than treatment with ascorbic acid + citric acid

(TAC) which was not significantly different from the control, TC (87.52 ± 1.94 mg/100 g). TSM samples had the lowest lycopene degradation (92.29 ± 1.68 mg/100 g on dry weight basis) and this may be due to protective effect of sodium metabisulphite for lycopene pigments against heat damage. Similar protective effect has been reported (Davoodi et al., 2007) for lycopene in tunnel dried tomato pretreated with potassium metabisulphite (93.0 ± 0.07 mg/100g) and calcium chloride (91.0 ± 0.8 mg/100g). In this study by (Davoodi et al., 2007), lycopene content of control samples (no pretreatment) was the lowest (89.06 ± 0.6 mg/100g). The main role of bisulphite in dehydration of food products is to inactivate the enzymes that cause enzymatic browning in food products. According to Pizzocaro et al. (1993) bisulphites react with the o-quinones forming colourless complex compounds; additionally, bisulphite act as competitive inhibitors by binding a sulphhydryl group at the active site of the enzyme; thus, the polyphenoloxidase is irreversibly inhibited (Ferrer et al., 1989).

During dehydration and subsequent storage, the typical red colour characteristic of tomato gradually changes to brick-red and then to brown (visual appreciation). This phenomenon which is known as non-enzymatic browning or Millard reaction produces dark pigments and destroys the natural colour of products (Portta and Sandei, 1990).

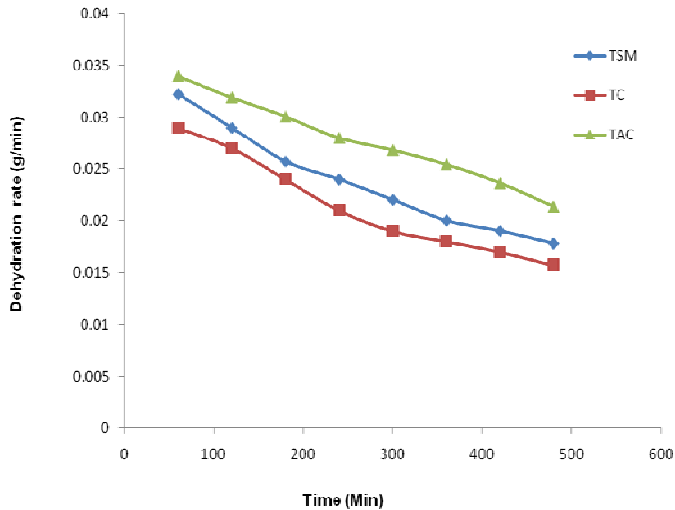


Figure 1. Dehydration rate curves for pre-treated tomato dried at 55°C in hot air convection dehydrator.

Tristimulus colour a^* which measures the degree of redness to greenness in the tomato samples was significantly ($p= 0.035$) higher for pretreated samples TSM (28.34 ± 0.03) and TAC (26.98 ± 0.13) than control samples (24.49 ± 0.44). Lycopene was better protected in TSM than TAC because sulfites blocked the formation of brown pigments in the Maillard reaction pathway (Taylor et al., 1986; Sulaeman et al., 2001).

Dehydration rate

Existing literature (Van Arsdell and Copley, 1963; Mujumdar, 1987) has defined a generalized drying curve that includes a constant drying rate region and falling rate regions. However, not all materials follow this pattern. A constant rate period was not observed during the drying process (Figure 1). However, falling rates were observed in all samples. A substance undergoes a constant drying rate when a film of water is freely available at the drying surface for evaporation into the drying medium. The falling rate regions are indicative of an increased resistance to both heat and mass transfer and occur when the surface water no longer exists and water to be evaporated comes from within the structure and must be transported to the surface (Hawladar et al., 1991).

The moisture content as a function of time is presented in Figure 2. The TC samples recorded the highest final moisture content (7.52%) and TSM the lowest (6.21%) after 11 h of drying. The stationary phase was observed after 10 h. Pretreatment with sulphites act by plasmolyzing cells (Gould and Russel, 1991), which facilitate the drying process unlike the control.

Microstructure of dehydrated tomato

Tomato is considered to be rather complex with an inner

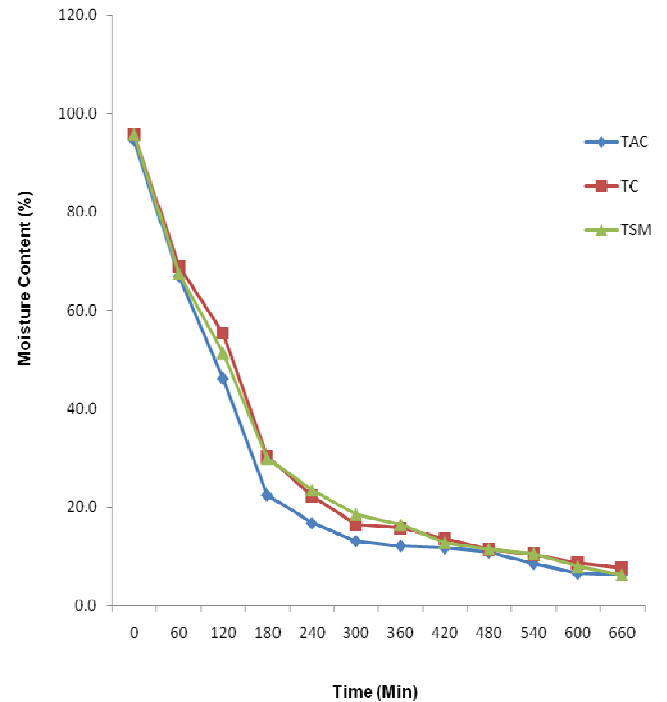


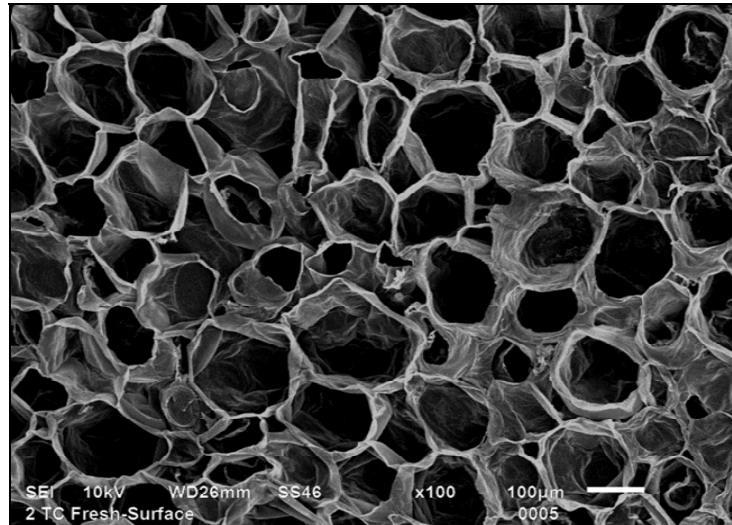
Figure 2. Change in moisture content with time for pretreated tomato dried at 55°C in a hot air convection dehydrator.

wall structure resembling a fibrous material while the pulposus areas which contain the seeds resemble a non-porous material; it is considered to be hygroscopic (Hawladar et al., 1991).

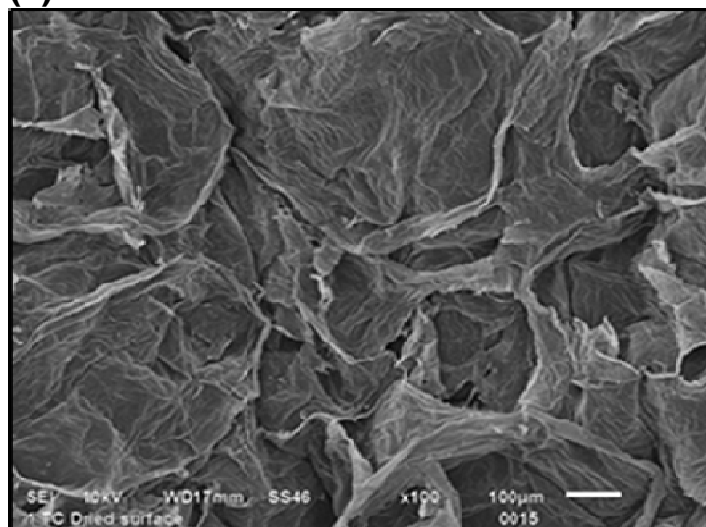
SEM examination of the surface of fresh and dried tomato cell walls revealed pit fields and associated radiating ridges of cross section of the cell walls. SEM of fresh tomato cells (Figure 3a) look firm and intact showing the cell structure. It is clear that in the dried samples (Figure 3b) the cell walls have collapsed due to removal of water. These observations have been explained by Lewicki and Jakubczyk (2004) to be due to shrinkage and creation of internal tensions. Zogzas et al. (1994) also confirmed that, the amount of collapse was proportional to the amount of moisture lost during the hot air drying process.

Conclusion

Pretreatment of tomato had effect on physicochemical quality parameters such as moisture, total solids, lycopene and colour. Pretreatment with sodium metabisulphite facilitated the drying rate of tomato and had the least effect on the reduction of lycopene. However, all the pretreated dried tomato samples produced had good visual appeal and exhibited a desirable red colour which is characteristic of dried tomato products.



(a)



(b)

Figure 3. Scanning electron microscopy (SEM) showing microstructure of pretreated fresh and dried tomato slice. The microstructure of the surface of (a) fresh tomato (b) dried tomato slices is shown in a and b at SEM magnification of 100x.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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