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Effect of Pre-drying Treatments on Quality Characteristics of Dehydrated Tomato Slices

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***Abstract*—**Tomato powder has good potential as substitute of tomato paste and other tomato products. In order to protect physicochemical properties and nutritional quality of tomato during dehydration process, investigation was carried out using different drying methods and pretreatments. Solar drier and continuous conveyor (tunnel) drier were used for dehydration where as calcium chloride (CaCl2), potassium metabisulphite (KMS), calcium chloride and potassium metabisulphite (CaCl2 +KMS), and sodium chloride (NaCl) selected for treatment.. lycopene content, dehydration ratio, rehydration ratio and non-enzymatic browning in addition to moisture, sugar and titrable acidity were studied. Results show that pre-treatment with CaCl2 and NaCl increased water removal and moisture mobility in tomato slices during drying of tomatoes. Where CaCl2 used along with KMS the NEB was recorded the least compared to other treatments and the best results were obtained while using the two chemicals in combination form. Storage studies in LDPE polymeric and metalized polyesters films showed less changes in the products packed in metallized polyester pouches and even after 6 months lycopene content did not decrease more than 20% as compared to the control sample and provide extension of shelf life in acceptable condition for 6 months. In most of the quality characteristics tunnel drier samples presented better values in comparison to solar drier.

***Keywords*—**Dehydration, Tomato powder, Lycopene, Browning

I. INTRODUCTION

THE preservation of fruits and vegetables by dehydration offers a unique challenge. Due to the structural configuration of these products, the removal of moisture must be accomplished in a manner that will be least detrimental to the product quality. Tomato has a limited shelf life at ambient conditions and is highly perishable. It creates glut during production season and becomes scanty during off-season. Short shelf life coupled with inadequate processing facilities results in heavy revenue loss to the country. The demand for dehydrated tomato is increasing rapidly both in domestic and in international market with major portion of it being used for preparation of convenience food. Thus, there exists a need to develop suitable technology for processing and preservation of this valuable produce in a way that will not only check losses but also generate additional revenue for the country.

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Tomato as other fruits and vegetables can be dried using various methods. The quality of dehydrated tomato depends on many parameters such as tomato variety, total soluble solid content (oBrix) of the fresh product, the air humidity, the size of the tomato segments, the air temperature and velocity and the efficiency of the drying system. The rate of drying affects the final quality of dehydrated product.

The objectives of the present investigation were: a) to study the effect of different pre treatments on physicochemical characteristics of tomatoes var. Avinash; b) to determine the influence of different types of driers and dehydration conditions on physicochemical properties of tomato slices; and c) to study the lycopene retention and browning reaction as affected by different packaging materials, pre drying treatments and dehydration methods after storage.

II. MATERIALS AND METHODS

A. *Source of material and sample preparation*

Tomatoes of var. Avinash harvested from a farm near the institute and used for the experiments. Tomatoes were sorted and washed with water to remove dirt and soil; further tomatoes were cut into the slices with thickness of 5 mm by using a slicing and dicing machine (HADDLE RG-400, Sweden).

B. *Pre-Treatments given prior to dehydration process*

The Tomato slices were treated as follows: a) Dipping in 1 g/100g $CaCl_2$ in water solution (1:1 w/w) at room temperature for 10 min. b) Dipping in Potassium Metabisulphite (KMS) 0.2 g/100g solution (1:1) at room temperature for 10 min. c) Dipping in 1 g/100g $CaCl_2$ in combination with 0.2 g/100g KMS in an equal mass of water for 10 min. d) Dipping in 7 g/100g NaCl at 80°C for 5 min in an equal mass of solution. The salt concentration and temperature were standardized in preliminary studies. Best combination was selected based on minimum salt absorption and maximum moisture removal. e) Tomato slices dipped in an equal mass of plain water for 10 min at room temperature were considered as control sample.

C. *Chemical analysis*

Moisture content was estimated as described by Rangana [1]. The carbohydrate content in tomato was determined by the phenol- sulphuric acid method [2]. To 0.1 ml of suitably diluted sample, 0.4 ml of distilled water, 0.3 ml of 5 g/100g phenol were added and mixed thoroughly. To this, 1.8 ml of concentrated sulphuric acid was added and mixed. The color obtained was read at 480 nm. Glucose was used as standard. Titrable acidity (TA) was determined according to Rangana [1].

D. Estimation of Lycopene content by HPLC method

Lycopene extraction procedure was similar to the published procedure for carotenoids extraction from vegetables and fruits [3]. For every storage condition, 2 replicate samples of tomato either fresh tomato (10-20 g, in different stages of ripening) or powder (0.3 g, reconstituted by addition of 10 ml of distilled water), vortexed for 1 min, and transferred into a glass fiber filter (10 to 20 µm) Buchner funnel. 40 ml of tetrahydrofuran and methanol (1:1 v/v THF: MeOH) were added and the suspension filtered under vacuum. When needed for additional removal of colour, a second extraction was done with 20 ml THF/ MeOH as described to produce a gray/white precipitate. The combined filtrate was transferred to a separatory funnel. Twenty ml of petroleum ether (40 to 60^{0}C fraction) and 20 ml 10 g/100g sodium chloride solution were added and mixed by careful shaking. The lower THF/MEOH/aqueous phase was drawn off. The upper soluble materials, transferred into a 50 ml flask, and evaporated to dryness under nitrogen. The residue was dissolved, to a final volume of 4 ml of hexane, filtered (0.45µm) and analyzed by high performance liquid chromatography (HPLC). All procedures were performed under reduced light.

Reverse phase HPLC was used with C18 (201 TP540) analytical column (5 µm,25 cm X 4.6 mm; VYDAC, Hesperial, Calif., U.S.A). A 20 µl loop was used for solvent injection. Solvent delivery was achieved with spectra physics Sp8800 system at a flow rate of 1 ml/min. An isocratic mobile phase system of acetonitrile: methanol: 2-propanol (44:54:2 by volume) was used. Detection was monitored with a diode array 1040 A Hewlett Packard absorbance detector that also stored spectral data over the range of 190 to 600 nm for spectrophotometric peak identification. The chromatograms were simultaneously monitored at 350, 470 and 503 nm. Lycopene standard was obtained from Sigma chemical Co. (St. Louis, MO., U.S.A). Peak identification was based on retention time and published absorbance spectral data. Lycopene in extracts of tomato powder was quantified spectrophotometrically using photo diode array detector (λ_{max}=470 nm) using UV-Visible.

E. Dehydration processes

Pre treated tomato slices were drained thoroughly after dip treatments and used for dehydration using two different dehydration techniques.

A pilot-plant scale solar drier was used for the dehydration experiments of tomato. Solar drier had dimensions of 1.0m × 1.0m× 1.5m made from galvanized steel and covered with 5 mm thickness transparent glass with a tilt angle of 30°C facing in South east for optimum solar radiation in Mysore (India) located at 770 m above sea level at 12.18° N 76.42° E . Four flat plate photo cells were provided for drier to absorb the solar energy which is used to run four small fans, so that the circulation of air can facilitate dehydration process. The equipment was kept in open place exposed to the sun light for drying process. Treated tomatoes were loaded into the trays at rate of 3.0 kg/m^2 and dehydration experiments were carried out under direct sunlight during February to May with average sunlight of 10 hrs per day.

Tomato slices were spread on the perforated continuous conveyor (tunnel drier) with a loading density of 4.7 kg/m^2 and moved by low speed of 1 m/hr at 65±2°C with air velocity of 1.2 m/s. Six hours time was needed for tomato slices to come out from the drying chamber.

F. Physicochemical analysis

a) Dehydration Ratio (DR)

Dehydration ratio was calculated as mass of sliced tomato before loading to the drier to mass of dehydrated material at the time of removal from drier [4].

b) Rehydration Ratio (RR)

The rehydration test was conducted as recommended by McMinn and Magee [5] and Prabhajan, Ramaswamay, & Raghavan [6].

c) Non-Enzymatic Browning (NEB)

For estimation of browning reaction, 5 g of the sample was mixed with 100 ml of 60 ml/100ml absolute alcohol in a glass stoppered flask. The mixture was shaken thoroughly, kept for 12 h and then filtered through Whatman No. 4 fitter paper.

G. Storage study

Dehydrated tomato slices were powdered using APEX MILL and packed into metalized polyester film (MP), 25 micron thickness, and low density polyethylene- film (LDPE), 75 micron thickness.

Packages of 25 g of tomato powder were kept at room temperature (22± 2ºC) for storage study. Samples were withdrawn after 1- 2-4 and 6 months to estimate the changes in lycopene degradation and also Non-Enzymatic Browning (NEB) value, during storage period.

H. Statistical analysis

The analysis was carried out in four replicates for all determinations. The mean and standard deviation of means were calculated. The data were analyzed by one-way analysis of variance (ANOVA). A multiple comparison procedure of the treatment means was performed by Duncan's New Multiple Range Test. Significance of the differences was defined as $P<0.05$.

III. Results and Discussion

A. Effects of pre-treatments on the quality characteristics of dehydrated tomato slices

Effects of pre-treatments on the quality characteristics of dehydrated tomato slices during dehydration in different driers are presented in Tables I and II. Results show that pre-treatment with $CaCl_2$ and NaCl increased water removal and moisture mobility in tomato slices during drying and these pre-treatments influenced the drying kinetics of tomato by evident changes in texture of dip treated tomatoes. In comparison with these pre treatments, control samples showed higher final moisture even with one hour longer period of dehydration. Although there was no significant difference in final moisture content of the dehydrated product for both the tomato varieties but slight lower rate of moisture content of tomato slices treated with NaCl, may be due to partial effect of osmotic dehydration, since the pre-treatment was done at 80°C for 5 minutes. Similar observations were reported by Gierschner, John & Philippos [7] and Olorunda, Aworh & Onuha [8].

Sugar content in treated tomato samples were more for all the pre-treatments as compared to the control sample. $CaCl_2$ along with KMS pre treated samples showed higher sugar content followed by $CaCl_2$ and NaCl. Changes in sugar content may be related to two reactions. i.e., non-enzymatic browning which was found to be more in control samples and less in $CaCl_2$ + KMS treatment and also the effect of dip treatment of tomato slices at 80°C using 7 g/100ml NaCl solution. Results obtained are in similar line of reported research data by Gupta & Nath [9] and Gallali, Abujnab & Bannari [10].

Pre treatment of tomato slices with potassium metabisulphite and NaCl samples showed slightly more acidity as compared to the control sample while tomato slices pre-treated with $CaCl_2$ had lower acidity. Comparison of different drying methods indicated higher acidity in samples dried with solar drier, which may be related to the partial fermentation occurred in some trials, due to longer time consumption and pectic enzyme activity in first hours of the process. Similar observation has been made by Okanlawon [11].

Results indicate that hot air drying decreased lycopene retention in tomato slices, subjected to drying, but the rate of degradation was significantly different and pre-treatments influenced the rate of reduction during dehydration process. More Lycopene degradation was observed in control samples for all the experiments, however, potassium metabisulphite had significant protective effect on lycopene degradation and it was more effective when combination of $CaCl_2$+KMS was used. Slightly better colour was observed in the samples treated with $CaCl_2$ and NaCl as compared to the control samples. Results regarding the effect of KMS were qualitatively similar to those reported by Sharma & Maguer [12] and Baloch, Buckle & Edward [13].

During dehydration and subsequent storage the typical red colour of tomato gradually changes to brick-red and then brown. This phenomenon which is known as non-enzymatic browning (NEB) or Millard reaction produces dark pigments and destroys the natural colour of products [14]. Heat damage and browning was observed in all of the pre-treated samples with significant variations in rate of reaction depending upon the treatment used before dehydration. $CaCl_2$ showed independent significant effect to prevent or reduce the rate of browning followed by KMS, and where $CaCl_2$ used along with KMS the NEB was recorded the least compared to other treatments and the best results were obtained while using the two chemicals in combination form. Control sample showed maximum rate of darkening and browning in all the experiments. Potassium metabisulphite is used to protect the carotenoid pigments and colour retention in dehydration and its effect is more known during processing but a definite explanation of the mechanism whereby calcium serve to retard non-enzymatic browning in dehydration of tomato cannot be offered clearly. It has been reported that calcium may be acting in some manner to block the amino group, whereby the latter is restrained from entering into the browning reaction. It is also believed that calcium is capable of forming chelating compounds with organic substances having an alpha amino carboxylic acid structure. Under these circumstances, it would be reasonable to expect that calcium treatment may be applicable to control non-enzymatic browning in many products where this particular type of browning reaction may be a problem [15] , [16].

Dehydration ratio reported as, ratio of mass of tomato slices before loading into the drier to the mass of dehydrated products. Different pre-drying treatments used in this study could influence the dehydration ratio of the tomato slices. NaCl treated samples showed lowest dehydration ratio as compared to other treatments. Since NaCl treatment was done at higher temperature, great part of the juice leached to the osmotic medium. Total moisture content of tomato was partially decreased after pre-drying treatment. Treatment with calcium of cut tissue reduces its respiration and intensifies the repair process [17], the firmness is either maintained or increased [18], [19]. Calcium appears to help maintain structural integrity of membranes and cell walls. Calcium binds to the cell wall and cross- lines, particularly with pectin components of the middle lamella [20], [21]. In view of the above discussion calcium pre-drying treated samples could maintain the better dehydration ratio as compared to the control in all the experiments and losses were less during dehydration process. Combination of calcium chloride and KMS could provide slight improvement in dehydration ratio.

If pre-drying treatment and drying itself would not induce any changes in the material rehydration could be treated as a process reversible of dehydration. In practice most of the changes are irreversible and rehydration cannot be considered simply as a process reversible to dehydration [22]. Rehydration can be considered as a measure of the injury to the material caused by drying and treatment preceding dehydration [23]. Rehydration ratio of dehydrated tomato slices was found to vary from 3.60 to 4.98, which was affected significantly by the pre-treatments. $CaCl_2$ and NaCl had desirable effects, respectively, on rehydration properties of the dehydrated tomatoes while control sample showed minimum rate of rehydration. Due to the effectiveness of KMS on textural quality of tomatoes, combination of $CaCl_2$ with KMS resulted in best rehydration properties and showed a higher value.

TABLE I
EFFECT OF PRE-DRYING TREATMENTS ON QUALITY CHARACTERISTICS OF DEHYDRATED TOMATO SLICES DRIED IN SOLAR DRIER *

Treatment	Moisture (g/100g)	Total sugar (g/100g)	Acidity (g/100g)	Lycopene (mg/100g)	NEB (OD at 420 nm)	Dehydration ratio	Rehydration ratio
$CaCl_2$	6.1±0.1 [a]	48.7±0.2 [a]	5.86±0.03 [a]	90±0.9 [a]	0.69±0.01 [a]	16.8±0.2 [a]	4.51±0.02 [a]
KMS	6.5±0.1 [b]	48.1±0.3 [b]	6.21±0.02 [b]	90±0.6 [a]	0.75±0.02 [b]	18.0±0.3 [b]	4.0±0.02 [b]
$CaCl_2$ +KMS	5.9±0.1 [a]	49.1±0.4 [c]	6.05±0.03 [c]	95±0.4 [b]	0.65±0.02 [c]	16.2±0.1 [c]	4.6±0.03 [a]
NaCl	6.5±0.2 [c]	48.0±0.2 [b]	6.27±0.02 [b]	86±0.8 [c]	0.83±0.03 [d]	13.7±0.2 [d]	4.35±0.03 [c]
Control	6.9±0.2 [b]	47..9±0.1 [b]	6.12±0.04 [d]	84±0.4 [d]	0.88±0.02 [e]	18.1±0.4 [b]	3.72±0.02 [d]
SE	0.108	0.112	0.025	0.384	0.011	0.158	0.11

*Values expressed are means of 4 replicates ± SD
SE = standard error of means
All mean scores, bearing different superscripts in columns differ significantly ($P \leq 0.05$).

TABLE II
EFFECT OF PRE-DRYING TREATMENTS ON QUALITY CHARACTERISTICS OF DEHYDRATED TOMATO SLICES DRIED IN TUNNEL DRIER *

Treatment	Moisture (g/100g)	Total sugar (g/100g)	Acidity (g/100g)	Lycopene (mg/100g)	NEB (OD at 420 nm)	Dehydration ratio	Rehydration ratio
$CaCl_2$	4.8±0.2 [a]	49.4±0.4 [a]	5.7±0.02 [a]	91.1±0.3 [a]	0.53±0.01 [a]	17.0±0.4 [a]	4.74±0.02 [a]
KMS	5.4±0.1 [b]	48.9±0.3 [b]	6.04±0.03 [b]	93.3±0.7 [b]	0.62±0.02 [b]	17.7±0.3 [b]	4.18±0.04 [b]
$CaCl_2$ +KMS	4.5±0.1 [a]	49.1±0.2 [c]	5.82±0.01 [c]	95.1±0.8 [c]	0.49±0.03 [c]	16.1±0.5 [c]	4.76±0.03 [a]
NaCl	5.1±0.2 [a]	48.3±0.1 [d]	6.1±0.03 [b]	89.1±0.8 [d]	0.68±0.02 [d]	14.0±0.3 [d]	4.48±0.01 [c]
Control	6.0±0.3 [b]	48.5±0.4 [d]	5.86±0.02 [c]	89.2±0.6 [d]	0.72±0.01 [e]	17.7±0.2 [b]	3.96±0.02 [d]
SE	0.108	0.092	0.023	0.385	0.01	0.189	0.122

*Values expressed are means of 4 replicates ± SD
SE = standard error of means
All mean scores, bearing different superscripts in columns differ significantly ($P \leq 0.05$).

It is inferred that shrinkage of tomato tissue pre-treated with $CaCl_2$ was not as large as that of raw tomato during drying. Hence, open structure promoted water diffusion and resulted in faster drying and subsequently formation of open structure due to calcium pre-treatment concluded to better rehydration property and reconstitution of the product. (Lewicki, Le & Lazuka, 2002). It is also believed that sodium and chloride ions permeate the vegetable tissue during soaking and reassociate as NaCl crystals on drying inside the cellular compartments. During rehydration there will be increased attraction of water resulting in increased flow into the tissue and therefore improved rehydration.

B. Effect of dehydration methods on quality characteristics of tomato slices

Changes in main quality characteristics of tomato slices during dehydration related to type of drier, used in this study, are presented and compared in Table III.

Although the experiments were carried out with the same raw material and pre-drying treatments, the quality of final products were different as affected by dehydration methods. Lycopene degradation was observed less in tunnel drier as compared to solar drier and also same trend was observed for solar and tunnel dried sample in $CaCl_2$ + KMS treatment for tomato samples. It may be due to protective effect of KMS for lycopene pigment against heat damages. Browning index, which is an indicator of the extent of browning, was higher in solar dried samples than tunnel drying. Direct exposure of thin slices of tomato for longer time of dehydration may be considered as reason of these changes.

There was no significant difference regarding to dehydration ratio although tunnel dried sample showed slightly better ratio in comparison to those other dehydration methods.

Tunnel dried tomato samples attained better rehydration ratio as compared to solar dried samples, probably due to uniform exposure of slices to the drying air condition and better heat transfer, leading to less textural changes during dehydration which subsequently offered higher rehydration ratio of the final product. Solar drier, could not maintain the constant rate of drying due to changes in air temperature, though drying carried out in lower temperature. Slight shrinkage and case hardening caused less reconstitution properties of the dehydrated samples.

Results related to quality of solar dried sample are in agreement with reported value of Suguna, Usha, Screenarayanan, Raghupathy & Gotthandapani [25] on dehydration of mushroom.

C. Storage study

In general, dehydrated and powdered tomatoes have poor lycopene stability unless carefully processed and promptly placed in sealed packages and kept in proper storage conditions. The main causes of tomato lycopene degradation during processing and storage are isomerisation and oxidation. Lycopene content in dehydrated tomato powder was influenced by drying methods, pre-drying treatments and storage condition including packaging material during storage period. All samples showed a progressive loss of lycopene throughout the storage period, with a different rate of degradation and colour changes. Results obtained from analysis of lycopene for stored tomato powder in different packaging material are presented in Tables IV and V. It can be seen that all the pre-treatments have shown a good effect on lycopene retention as compared to the control sample. Lycopene loss was observed 10-20% more, in tomato powders stored in low density polyethylene pouches while metallized polyesters pouches could prevent or delay lycopene degradation during storage. Combination of $CaCl_2$ with KMS had best result, especially in the first two months of storage. There were significantly less changes in the products packed in metallized polyester pouches and even after 6 months lycopene content did not decrease more than 20% as compared to the control sample. Results also show that KMS in combination with $CaCl_2$ or even alone could delay significantly the changes in lycopene degradation during two months of storage and subsequently more protective effect in comparison to other pre-treatments. $CaCl_2$ and NaCl pre-treatment had slight effect on lycopene retention but comparatively higher than control samples. Lycopene retention was observed more in tomato samples dried in tunnel drier as compared to other driers. As it is presented in Tables IV and V there were slight loss of lycopene during first two months and main changes appeared as storage period extended up to six months, even that pre-treatments could maintain very good red color at the end of storage period as compared to the control samples which showed pale red color and lost more than 50-60% of initial red color. Retention of red color was significantly more in case of samples pre-treated with $CaCl_2$+KMS and packed in metallized polyester pouches during storage after 6 months. Previous data reported by [11], [26], [8], [16] support the results in this study.

Browning is as a result of chemical process and is a function of the temperature, the structure of the material and residence time during processing as well as storage period and it may directly affect the sensory and nutritional quality of the dehydrated products. Results of studies on changes in non-enzymatic browning for tomato powders, which were packed and stored in room condition, are presented in Tables VI and VII. The effects of pre-treatment and packaging on the browning index of tomato powders were very evident during storage. The results demonstrate the effectiveness of calcium chloride in increasing the resistance of tomato powder to non-enzymatic discoloration. Calcium chloride used in conjunction

TABLE III EFFECT OF DRYING METHODS ON LYCOPENE, NEB, DEHYDRATION AND REHYDRATION RATIO OF DEHYDRATED TOMATO *

Parameters	Drying method	CaCl2	KMS	CaCl2+ KMS	NaCl	Control
Lycopene (mg/100g)	Solar	90±0.9 [a]	90±0.6 [a]	95±0.4 [b]	86±0.8 [a]	84±0.4 [a]
	Tunnel	91±0.3 [b]	93±0.7 [b]	95±0.8 [b]	89±0.8 [b]	89±0.6 [b]
NEB (OD at 420 nm)	Solar	0.69±0.01 [a]	0.75±0.02 [a]	0.65±0.02 [a]	0.83±0.03 [a]	0.88±0.02 [a]
	Tunnel	0.53±0.01 [b]	0.62±0.02 [b]	0.49±0.03 [b]	0.68±0.02 [b]	0.72±0.01 [b]
Dehydration ratio	Solar	16.8±0.2 [a]	18.0±0.3 [a]	16.2±0.1 [a]	13.7±0.2 [b]	18.1±0.4 [a]
	Tunnel	17.0±0.4 [a]	17.7±0.3 [a]	16.1±0.5 [a]	14.0±0.3 [b]	17.7±0.2 [b]
Rehydration ratio	Solar	4.51±0.02 [a]	4.0±0.02 [a]	4.6±0.03 [a]	4.35±0.03 [a]	3.72±0.02 [a]
	Tunnel	4.74±0.02 [b]	4.18±0.04 [b]	4.76±0.03 [b]	4.48±0.01 [b]	3.96±0.02 [b]

*Values expressed are means of 4 replicates ± SD
All mean scores, bearing different superscripts in columns differ significantly ($P \leq 0.05$).

TABLE IV
EFFECT OF STORAGE PERIOD (MONTHS) ON CHANGES IN LYCOPENE CONTENT OF DEHYDRATED TOMATO SLICES DRIED IN SOLAR DRIER *

Treatment	Packaging material	Storage period (month)					SE
		0	1	2	4	6	
Cacl2	MP	90±0.8 [a]	87±0.5 [b]	82±0.5 [c]	70±0.4 [d]	56±0.4 [e]	0.86
	LD	90±0.8 [a]	86±0.4 [b]	77±0.4 [c]	62±0.4 [d]	50±0.4 [e]	0.83
KMS	MP	90±0.6 [a]	88±0.4 [a]	84±0.3 [b]	76±0.3 [c]	68±0.3 [d]	0.92
	LD	90±0.6 [a]	84±0.5 [b]	79±0.2 [c]	69±0.2 [d]	62±0.2 [e]	0.89
Cacl2+ KMS	MP	95±0.5 [a]	93±0.32 [a]	89±0.3 [b]	84±0.3 [c]	78±0.3 [d]	0.95
	LD	95±0.5 [a]	90±0.2 [b]	85±0.4 [c]	79±0.1 [d]	73±0.4 [e]	0.94
Nacl	MP	86±0.4 [a]	84±0.3 [a]	74±0.2 [b]	57±0.2 [c]	43±0.2 [d]	0.81
	LD	86±0.4 [a]	80±0.3 [b]	69±0.3 [c]	52±0.3 [d]	37±0.1 [e]	0.76
Control	MP	84±0.3 [a]	74±0.4 [b]	68±0.2 [c]	52±0.4 [d]	40±0.2 [e]	0.78
	LD	84±0.3 [a]	70±0.2 [b]	61±0.3 [c]	46±0.3 [d]	32±0.2 [e]	0.74

*Values expressed are means of 4 replicates ± SD
SE = standard error of means
All mean scores, bearing different superscripts in columns differ significantly ($P \leq 0.05$).

TABLE V
EFFECT OF STORAGE PERIOD (MONTHS) ON CHANGES IN LYCOPENE CONTENT OF DEHYDRATED TOMATO SLICES DRIED IN TUNNEL DRIER

Treatment	Packaging material	Storage period (month)					SE
		0	1	2	4	6	
Cacl2	MP	90±0.8 [a]	87±0.5 [b]	82±0.5 [c]	70±0.4 [d]	56±0.4 [e]	0.86
	LD	90±0.8 [a]	86±0.4 [b]	77±0.4 [c]	62±0.4 [d]	50±0.4 [e]	0.83
KMS	MP	90±0.6 [a]	88±0.4 [a]	84±0.3 [b]	76±0.3 [c]	68±0.3 [d]	0.92
	LD	90±0.6 [a]	84±0.5 [b]	79±0.2 [c]	69±0.2 [d]	62±0.2 [e]	0.89
Cacl2+ KMS	MP	95±0.5 [a]	93±0.32 [a]	89±0.3 [b]	84±0.3 [c]	78±0.3 [d]	0.95
	LD	95±0.5 [a]	90±0.2 [b]	85±0.4 [c]	79±0.1 [d]	73±0.4 [e]	0.94
Nacl	MP	86±0.4 [a]	84±0.3 [a]	74±0.2 [b]	57±0.2 [c]	43±0.2 [d]	0.81
	LD	86±0.4 [a]	80±0.3 [b]	69±0.3 [c]	52±0.3 [d]	37±0.1 [e]	0.76
Control	MP	84±0.3 [a]	74±0.4 [b]	68±0.2 [c]	52±0.4 [d]	40±0.2 [e]	0.78
	LD	84±0.3 [a]	70±0.2 [b]	61±0.3 [c]	46±0.3 [d]	32±0.2 [e]	0.74

*Values expressed are means of 4 replicates ± SD
SE = standard error of means
All mean scores, bearing different superscripts in columns differ significantly ($P < 0.05$).

Table VI shows the changes in NEB for tomato powders obtained by solar drier, during storage period. Although the same trends were observed regarding to the effects of pre-treatments but samples showed higher rate of increase in browning specially after second month of storage, when compared to other method. NaCl had little effect on the rate of browning during storage period and presented a light brown sample after six months. Samples from tunnel drier had less NEB and significant changes were observed after three months of storage in case of $CaCl_2$ as well as $CaCl_2$ + KMS pretreatments (Table VII). The browning action was directly related to the packaging materials and it was found in higher amount in the samples stored in low density poly ethylene (LD) for six months as compared to those stored in metallized polyester (MP) at room temperature. Less permeability of metallized polyester films (MP) regarding to the light and oxygen may be considered as a result of retention of higher quality in these packaging materials. Results obtained in this study are in agreement with data reported for mango [27], okra [28] and potato [15].

TABLE VI
EFFECT OF STORAGE PERIOD (MONTHS) ON CHANGES IN NEB IN DEHYDRATED TOMATO SLICES DRIED IN SOLAR DRIER *

Treatment	Packaging material	Storage period (month)					SE
		0	1	2	4	6	
Cacl2	MP	0.69±0.01 [a]	0.78±0.02 [b]	0.86±0.02 [c]	0.98±0.02 [d]	1.15±0.02 [e]	0.013
	LD	0.69±0.02 [a]	0.80±0.02 [b]	0.90±0.02 [c]	1.08±0.03 [d]	1.20±0.02 [e]	0.012
KMS	MP	0.75±0.03 [a]	0.92±0.01 [b]	1.04±0.01 [c]	1.23±0.02 [d]	1.38±0.01 [e]	0.014
	LD	0.75±0.02 [a]	0.94±0.01 [b]	1.08±0.01 [c]	1.29±0.02 [d]	1.46±0.03 [e]	0.013
Cacl2+ KMS	MP	0.65±0.02 [a]	0.68±0.03 [a]	0.76±0.02 [b]	0.89±0.01 [c]	1.01±0.02 [d]	0.01
	LD	0.65±0.01 [a]	0.79±0.02 [b]	0.88±0.02 [c]	1.00±0.02 [d]	1.08±0.01 [e]	0.01
Nacl	MP	0.83±0.01 [a]	0.96±0.01 [b]	1.28±0.03 [c]	1.48±0.02 [d]	1.64±0.02 [e]	0.012
	LD	0.83±0.02 [a]	1.08±0.03 [b]	1.37±0.03 [c]	1.59±0.01 [d]	1.78±0.01 [e]	0.013
Control	MP	0.88±0.03 [a]	1.12±0.01 [b]	1.36±0.02 [c]	1.61±0.02 [d]	1.76±0.02 [e]	0.012
	LD	0.88±0.02 [a]	1.14±0.02 [b]	1.45±0.03 [c]	1.77±0.01 [d]	1.90±0.03 [e]	0.013

*Values expressed are means of 4 replicates ± SD
SE = standard error of means
All mean scores, bearing different superscripts in columns differ significantly ($P \leq 0.05$).

TABLE VII
EFFECT OF STORAGE PERIOD (MONTHS) ON CHANGES IN NEB IN DEHYDRATED TOMATO SLICES DRIED IN TUNNEL DRIER *

Treatment	Packaging material	Storage period (month)					SE
		0	1	2	4	6	
Cacl2	MP	0.53±0.01 [a]	0.57±0.02 [a]	0.64±0.02 [b]	0.75±0.03 [c]	0.82±0.01 [d]	0.014
	LD	0.53±0.01 [a]	0.57±0.02 [a]	0.69±0.02 [b]	0.80±0.03 [c]	0.90±0.02 [d]	0.013
KMS	MP	0.62±0.02 [a]	0.79±0.01 [b]	0.85±0.02 [c]	0.99±0.02 [d]	1.14±0.02 [e]	0.011
	LD	0.62±0.02 [a]	0.86±0.02 [b]	0.90±0.03 [c]	1.01±0.02 [d]	1.26±0.03 [e]	0.012
Cacl2+ KMS	MP	0.49±0.01 [a]	0.52±0.01 [a]	0.60±0.02 [b]	0.66±0.01 [c]	0.76±0.01 [d]	0.01
	LD	0.49±0.02 [a]	0.50±0.01 [a]	0.67±0.02 [b]	0.71±0.01 [c]	0.80±0.02 [d]	0.01
Nacl	MP	0.68±0.01 [a]	0.86±0.03 [b]	0.99±0.03 [c]	1.18±0.02 [d]	1.32±0.03 [e]	0.012
	LD	0.68±0.03 [a]	0.90±0.02 [b]	1.01±0.02 [c]	1.24±0.03 [d]	1.43±0.02 [e]	0.013
Control	MP	0.72±0.03 [a]	0.94±0.03 [b]	1.08±0.03 [c]	1.21±0.02 [d]	1.39±0.03 [e]	0.012
	LD	0.72±0.02 [a]	1.01±0.02 [b]	1.15±0.02 [c]	1.30±0.02 [d]	1.50±0.02 [e]	0.013

*Values expressed are means of 4 replicates ± SD
SE = standard error of means
All mean scores, bearing different superscripts in columns differ significantly ($P \leq 0.05$).

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