Biological Forum – An International Journal **16(11): 16-20(2024)**

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Standardization of Pre-treatments for Retention of Functional Quality in Dehydrated Tomato Slices

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(Received: 05 August 2024; Revised: 04 September 2024; Accepted: 04 October 2024; Published: 14 November 2024)
(Published by Research Trend)

ABSTRACT: This study focuses on the standardization of pre-treatments to enhance the functional quality of dehydrated tomato slices. Various concentrations of NaCl (3%, 5%, and 7%) and $CaCl_2$ (0.5%, 1%, and 1.5%) were tested to determine their effectiveness in preserving key quality attributes. The treatment with 5% NaCl followed by 1% $CaCl_2$ was found to be the most effective, retaining maximum levels of ascorbic acid, antioxidant activity, total phenols, and lycopene. This combination also achieved superior rehydration ratio and minimized non-enzymatic browning and moisture content. Data analysis using ANOVA confirmed significant differences among treatments, with critical differences evaluated at a 5% probability level. The findings underscore the potential of optimized pre-treatments in preserving the nutritional and physical quality of dehydrated tomato products.

Keywords: Dehydrated tomato slices, pre-treatment, Pusa rakshit.

INTRODUCTION

Tomato (*Solanum lycopersicum*) is a widely consumed vegetable, rich in lycopene, polyphenols, vitamins A, C, E and bioactive compounds like lycopene and phenolic compounds, which offer several health benefits (Pernice *et al*., 2010). Tomatoes are also a key source of dietary nutrients and phytochemicals that contribute to a balanced diet. As a popular ingredient in fresh and processed forms like soups, juices, sauces and ketchup, tomatoes are increasingly valued for their nutritional properties. With the rising demand for convenience foods and the limited shelf life of fresh tomatoes, the processed tomato industry has grown significantly, particularly for dehydrated products (Purseglove *et al.,* 2001). The global demand for dehydrated tomatoes has surged due to their convenience, long shelf life, portability concentrated flavour, versatility and nutritional content. However, the dehydration process is highly sensitive to various pre-treatment and drying conditions, which significantly impact the final product's quality). Retaining the functional properties of tomatoes such as flavour, colour, texture and the most important its nutritional value during dehydration remains a challenge. These properties are not only crucial for consumer acceptance but also for preserving the health benefits of tomatoes. To mitigate this, pre-treatments like blanching, osmotic dehydration and enzymatic treatments are commonly used to protect these sensitive compounds. Additionally, the drying technique itself, whether conventional methods such as air drying or more advanced techniques like freeze-drying or microwave drying, plays a significant role in determining the retention of these bioactive compounds

Despite the extensive use of various pre-treatment and drying methods in the food industry, there is still a lack of comprehensive understanding regarding how different combinations of these processes affect the functional quality of dehydrated tomatoes. This knowledge gap highlights the need for standardized pre-treatment and drying protocols to ensure consistent product quality, nutritional retention, and sensory appeal. The optimization of these processes is also essential from both a product development and industrial efficiency standpoint, as it can lead to more sustainable and cost-effective dehydration methods. Through the establishment of standardized protocols, we can easily mitigate these challenges and will be able to provide practical guidelines for the food industry, improving the quality, nutritional value, and shelf life of dehydrated tomato products.

Several pre-treatment techniques, such as osmotic dehydration, have shown promise in enhancing the retention of important nutrients and improving the final product's texture. Among these, salt and calcium-based treatments, such as sodium chloride (NaCl) and calcium chloride ($CaCl_2$), are widely used for their ability to influence water retention, texture, and nutritional stability during drying. NaCl is known to reduce moisture content through osmotic dehydration, which may enhance the retention of soluble compounds like sugars, acids and antioxidants (Lewicki *et al.,* 2002). Calcium chloride, on the other hand, strengthens cell walls and helps preserve texture, potentially protecting bioactive compounds such as ascorbic acid and

lycopene during drying. Sodium metabisulfate along with calcium chloride as well as ascorbic acid and citric acid were also used to evaluate the effect of pretreatment on several tomatoes which significantly help in preserving nutritionally quality of dried tomatoes in terms of total phenolic and carotenes (Mwende *et al.*, 2018; Dufera *et al.,* 2021).

Therefore, in this study, we aim to investigate the different concentration of pre-treatment to preserve the functional properties of tomatoes during dehydration, ensuring that the final product meets the expectations of consumers and the requirements of the food industry. By focusing on key quality attributes such as moisture content, titrable acidity, sugars, ascorbic acid, lycopene, and antioxidant activity, the research aims to identify optimal strategies for preserving the nutritional and sensory properties of tomatoes. The results will be significant for improving the quality and efficiency of dehydrated tomato production, providing valuable insights for both industrial-scale processors and consumers seeking high-quality, nutritious, and convenient tomato products.

MATERIALS AND METHODS

A. Experimental materials

Tomato cultivars var. Pusa Rakshit were procured from the Division of Vegetable Science ICAR-IARI New Delhi. To standardize the pretreatment and suitability to dehydration for retention of physiochemical properties. $Cacl_2$ (0.5, 1, 1.5 %) and NaCl (2, 5, 7%) were used for pretreatment with cabinet dryer.

B. Optimization of pretreatment

To optimize the pretreatment the cultivars Pusa Rakshit were cut into 5 mm thick slices and treated with different concentration of $CaCl_2$ (0.5%, 1% and 1.5%) and salt (NaCl 2%, 5%, 7%) by dipping into the solution and then these prepared slices were spread on perforated aluminum tray size of about (40x50cm) with the tray load of 2 kg/m^2 and dried in cabinet drier at a temperature of 60±2°C for 8 hours up to a moisture of 8-10% present in the slices. Dehydrated tomato samples were evaluated for moisture content, acidity, lycopene content, total phenol content, antioxidant activity, total sugars and NEB.

C. Determination of physico-chemical properties of dehydrated tomato slices

Moisture content

A 5g sample was initially placed in a petri dish and dried at 60°C until its weight stabilized. Between each weighing, the petri dish and its contents were cooled in a desiccator to ensure accuracy (AOAC, 1980). Moisture content of the sample was expressed in g/100g of sample.

$$M = \frac{w_i - w_f}{w_i} \times 100$$

Where,

M = Moisture content of sample, %

Wi= Initial weight of sample, g

Wf= Final weight or weight of the sample, g

Titrable acidity (TA). 10g of fresh samples and 0.5g of dried samples were obtained, crushed in a mortar and pestle, and the volume was increased to 100ml. 10 ml of the filtrate was collected as an aliquot to titrate against 0.1N NaOH after the sample was filtered using Whattman No. 42 filter paper.

(AOAC, 1980). The titrable acidity was expressed as g citric acid/kg tomato, according to the following equation:

$$\text{Titrable acidity (g citric acid/kg)} = \frac{V \times 0.1 \times 1000 \times 0.064}{\text{wt. of sample}}$$

Where,

0.1 is the normality of NaOH (N),

0.064 is the conversion factor for citric acid,

V is the volume of NaOH required (mL)

Weight of tomato juice sample used (g)

Lycopene content (LC). Two grams of the sample were crushed two or three times using 80% acetone. Following the pooling and transfer of all the extracts to a separating funnel, 20 mL of 5% sodium sulfate and 10 to 15 mL of petroleum ether were added. After the lower aqueous layer was decanted, 10–15 mL of petroleum ether was added. The carotenoid containing organic layer was collected and the absorbance was noted at 502 nm (Ranganna, 1986).

$$\text{Lycopene}\left(\frac{\text{mg}}{100\text{ g}}\right) = \frac{(3.12 \times \text{OD} \times \text{volume made up (ml)} \times 100)}{\text{weight of sample (g)} \times 100}$$

Total phenol content (TPC). The total phenolic content was determined using the Folin-Ciocalteu reagent (FCR) based on the method by Singleton and Rossi (1965), with slight modifications for this study. This assay relies on the oxidation of phenols in an alkaline environment, where the Folin-Ciocalteu reagent—a blend of phosphotungstic and phosphomolybdic acids—undergoes reduction to form blue oxides of tungsten and molybdenum, generating a blue-colored complex known as molybdenum blue. For sample preparation, 5 g of fresh tomato and 2 g of dried tomato were weighed and finely ground using a mortar and pestle in 80% ethanol. The homogenized mixtures were then centrifuged at 10,000 rpm for 15 minutes at 4°C. The supernatant was collected, and the residual solids were re-extracted using five times the initial volume of 80% ethanol. The combined supernatant was used for the phenolic content assay. In the assay, 0.1 ml of the sample extract was mixed with 2.9 ml of distilled water and 0.5 ml of 1N Folin-Ciocalteu reagent. After gentle mixing for 2–3 minutes, 2 ml of 20% Na_2CO_3 was added, and the solution was incubated in the dark for 30 minutes to develop a bluish-black color. Absorbance was measured at 750 nm using a Perkin-Elmer UV-VIS spectrophotometer. A gallic acid standard curve (0–800 mg/L) was prepared for quantification. The total phenolic content was expressed as 'mg gallic acid equivalent (GAE)/100 g of fresh weight.

$$\text{Total phenol content (mg of GAE/100g)} = \frac{A \times \text{Volume made up (ml)} \times \text{Dilution Factor} \times 100}{\text{Aliquot taken (ml)} \times \text{Weight of sample (g)} \times 1000)}$$

Where,

$$A = \frac{(Abs.750 - Intercept)}{Slope}$$

Total antioxidant activity (TAA). The antioxidant activity of tomato was assessed using the DPPH (2, 2-diphenyl-1-picrylhydrazyl-hydrate) method, following the protocol by (Miller *et al.*, 1997) with minor modifications. The DPPH assay is a widely used, straightforward colorimetric technique to evaluate the ability of antioxidant molecules to neutralize free radicals. In this method, an antioxidant donates a hydrogen atom (H+) to the DPPH radical, reducing it to DPPH and causing a color change from purple to yellow. This reduction is accompanied by a decrease in absorbance at 517 nm, which indicates the antioxidant capacity of the sample.

A 5g sample of tomato was crushed with 80% ethanol to estimate antioxidant activity. After that, 15 ml of ethanol is added to the centrifuge tube, and it is centrifuged for 15 minutes at 4,000 °C and 10,000 rpm. Remove approximately 0.1 ml of the supernatant and add 3.9 ml of DPPH solution. The absorbance at 517 nm was then measured after the sample had been left to react with DPPH for 30 minutes in the dark.

$$\text{DPPH scavenging activity (\%)} = \frac{\text{Absorbance of DPPH blank} - \text{Absorbance of sample}}{\text{Absorbance of DPPH blank}}$$

$$\text{Activity (µ mol/mg)} = \frac{\text{\% inhibition} \times \text{volume made up}}{0.61 \times 1000 \times \text{wt of sample}}$$

Total Sugars (TS). Total sugar content was determined by measuring a specific amount of the sample, grinding it with a mortar and pestle, and diluting it with double-distilled water to a final volume of 100 mL. To this, 2 mL of 45% lead acetate was added for impurity removal, followed by a 10-minute rest period. Subsequently, 2 mL of 22% potassium acetate was added, and the volume was adjusted to 250 mL. The mixture was then filtered using whatman No. 42 filter paper. From the filtrate, 50 mL was taken, and 5 mL of HCl was added before leaving the sample in a dark place for 24 hours or overnight. Afterward, 1–2 drops of phenolphthalein indicator were introduced, and the solution was neutralized with 40% NaOH until a light pink color appeared, after which the solution was diluted to 100 mL with double-distilled water.

For analysis, titration was performed against Fehling's solutions A and B, which were previously standardized using a methylene blue indicator. The sample was added drop-wise from a burette until a brick-red endpoint was achieved, in accordance with AOAC (1980) guidelines.

$$\text{Total Sugars (\%)} = \frac{\text{Fehling factor} \times 250 \times 100 \times 100}{50 \times \text{Titrated value} \times \text{wt.of sample}}$$

Fehling factor = 0.038

Non -Enzymatic browning. Two gram of dried sample was soaked in 40 mL (67 % alcohol) and ground using a mortar and pestle. After allowing the mixture to stand overnight, the optical density (OD) was measured at 420 nm using a spectrophotometer, with 67% alcohol serving as the blank(Ranganna, 1986).

C. Statistical analysis

The data obtained during the study were analyzed statistically using the analysis of variance (ANOVA) method as outlined by Gomez and Gomez (1984). When the variance (F-value) was found to be significant, the critical difference (C.D.) was calculated and compared at a 5% probability level to evaluate differences among the treatments.

RESULTS AND DISCUSSION

Standardization of pre-treatments for retention of functional quality in dehydrated tomato slices

Moisture content. The amount of moisture in dried tomato slices (Pusa Raskhit) varies depending on the treatment concentration and drying temperature. Moisture content was low in dried tomato slices treated with 5% NaCl and then with 1.5% $CaCl_2$. This may be attributed to the rapid removal of surface moisture from the tomato slices, along with a partial effect of osmotic dehydration, as NaCl draws water from the inner tissues of the slices. The sodium ions promote the formation of an open structure, allowing for the quick removal of water (Lewicki *et al.,* 2002). Similar observation has been made by Mohseni *et al.* (2011) in dehydrated tomato slices.

Titrable acidity. Titrable acidity in dried tomato slices was higher than fresh one.Among the pretreatments, the 5% NaCl treatment had the highest level of TA (0.86%), followed by the sample treated with 1% $CaCl_2$. This may be due tothe high temperatures in cabinet drying which lead to the formation of various organic acids through the maillard reaction (Dufera *et al.,* 2021). 7% NaCl treated sample show lower acidity because of more leaching of organic acids from tomato slices as compared to slices treated with 5% NaCl. Similar findings have been reported by (Ghavidel *et al.,* 2010) in dehydrated tomato powder.

Total Sugar. The data depicted in Table 1 reveal that treated sample had more total sugar content then control sample. Ascorbic acid, phenolic compounds, and flavonols are the primary components of total sugars. The 5% NaCl treatment demonstrated a higher sugar content compared to other treatments, likely due to the protective effect of NaCl in minimizing oxidative reactions during dehydration. Additionally, the treatment resulted in a reduced moisture level on the surface of the tomato slices. Similar findings have been support by Mohseni *et al.* (2011); Davoodi *et al.* (2007) that reported similar results in tomato slices and powder respectively.

Ascorbic acid content. According to the ascorbic acid content data shown in Table 1, the sample treated with 5% NaCl exhibits good ascorbic acid retention (27.54 mg/100g) during dehydration, followed by a sample treated with 1% $CaCl_2$ (25.70 mg/100g). The ascorbic acid content in dehydrated tomato slices is lower than in fresh samples, as ascorbic acid is thermo-sensitive,

and high temperatures cause a significant reduction in its levels. This may be due to the degradation of ascorbic acid through its oxidation to dehydroascorbic acid, followed by hydrolysis to 2, 3-diketogulonic acid and subsequent polymerization. The 5% NaCl treatment showed better retention of ascorbic acid compared to both the 7% NaCl and 1% $CaCl_2$ treatments. Similar finding have been reported by Chang *et al.* (2006) in hot-air dried tomatoes.

Lycopene content. It has been shown that lycopene content varies with different concentration of pre-treatment. Sample treated with 5% NaCl show highest amount of lycopene content (11.7 mg/100g) and lowest reported in 7% NaCl treated sample (Table 1). This may be attributed to the protective effect of NaCl on the lycopene pigment, which provides reduced degradation of lycopene during heat treatment. These findings align with those reported by Farooq *et al. (*2020) regarding the dehydration of tomato powder.

Total Phenols. Table 1 shows that treated sample contain higher total phenol content as compared to control sample. When compared to the control, the 5% NaCl treatment had the highest total phenol concentration in dried tomato slices, followed by the 2% and 7% NaCl treatments. This may be due to enhanced protection provided by NaCl and calcium chloride which provide protective effect to phenolic compounds in dried tomato slices from oxidative reactions and tissue damage. Furthermore, the processing likely facilitates the release of bound phenolic compounds by breaking down cellular structures. While the disruption of cell walls during processing could activate oxidative and hydrolytic enzymes that degrade antioxidants in fruits, the high temperatures involved in processing may deactivate these enzymes. This thermal inactivation likely prevents the loss of phenolic acids, thereby contributing to an overall increase in total phenolic content (Chang *et al.,* 2006).

Antioxidant activity. The dried tomato slices treated with 5% NaCl exhibited more antioxidant activity than the control sample, which had poor antioxidant activity retention. This may be due to better protection offered by NaCl treatment which limit the oxidative changes that occur during dehydration and left less moisture in the surface of the tomato as compared to control sample. Similar findings have been reported by Davoodi *et al.* (2007) in tomato powder.

Non-enzymatic browning (NEB). Non-enzymatic browning, primarily through the maillard reaction, is responsible for the formation of dark pigments, which can compromise the natural color of products. According to the antioxidant activity data in Table 1, the treated sample had higher antioxidant activity than the control. In comparison to $CaCl_2$ and control, NEB for the sample treated with 5% NaCl was lower after 7% NaCl treatment. This effect may be attributed to the protective role of NaCl in preserving carotenoid pigments and maintaining color stability during dehydration. In the case of $CaCl_2$, calcium inhibits amino acids involved in the maillard reaction, thereby reducing color degradation. Similar finding have been reported by Baloch *et al.* (1997) in dried tomato powder.

Table 1: Effect of treatments on chemical constituents of dehydrated tomato slices.

Pre treatment	Conc.	Moisture (%)	Acidity (%)	Total Sugar (mg/100g)	Ascorbic Acid (mg/100g)	Lycopene Content (mg/100g)	NEB (OD) 420nm	TPC (mg/100g)	Antioxidant(µ mole TE/g)
$CaCl_2$	0.5	4.96c	0.78e	28.21e	20.93f	8.04e	0.721c	38.8c	24.10d
	1	4.94c	0.84b	28.79d	25.70b	10.13b	0.651d	41.5b	32.10b
	1.5	5.69a	0.81c	27.96f	25.18c	8.17e	0.809b	41.13b	20.30e
NaCl	2	5.36b	0.83b	29.46c	24.10d	9.76c	0.515e	46.73a	29.10c
	5	4.02e	0.86a	31.5a	27.54a	11.7a	0.388f	47.13a	35.80a
	7	4.63d	0.80cd	29.83b	22.50e	8.91d	0.514e	35.66d	28.70c
	Control	5.72a	0.79de	26.56g	19.32g	7.81f	0.907a	31.3e	19.60f
	SE(m)	0.042	0.006	0.06	0.05	0.07	0.006	1.57	1.52
	C.D. AT 5%	0.17	0.01	0.18	0.16	0.22	0.01	0.47	0.72
	C.V. (%)	1.44	1.34	0.364	0.40	1.36	1.70	0.67	0.23

MC=Moisture Content, TA = Titrable acidity, LC = Lycopene content, TS = Total Sugar, TAA = Total Antioxidant Activity, TPC = Total Phenol Content, AA = Ascorbic acid, NEB = Non-Enzymatic Browning, RR= Rehydration Ratio, SE (m) = Standard error mean, C.D. = critical difference at 5% level, C.V. = critical variance

CONCLUSIONS

The study evaluated various pre-treatments, including NaCl at concentrations of 3%, 5%, and 7%, and $CaCl_2$ at concentrations of 0.5%, 1%, and 1.5%, to determine their effectiveness in retaining the nutritional quality of dehydrated tomato slices. Among all the treatments tested, the combination of 5% NaCl and 1% $CaCl_2$ proved to be the most effective. This treatment preserved the highest levels of ascorbic acid, antioxidant activity, total phenols, and lycopene, which are critical indicators of nutritional value and functional quality. Additionally, it demonstrated superior rehydration capacity, indicating better structural integrity upon rehydration, while minimizing non-enzymatic browning and maintaining low moisture content. These findings highlight the potential of this specific pre-treatment in enhancing the nutritional and physical quality of dehydrated tomato slices, making it

a promising approach for food processing and storage applications.

FUTURE SCOPE

Studies may focus on enhancing bioactive compound retention, assessing consumer acceptability, and evaluating the environmental and economic impact of these processes. Additionally, innovative techniques such as nanotechnology or natural additives could be investigated to improve functional quality and sustainability.

Acknowledgement. I would like to express my sincere gratitude to the Division of Food Science & Post Harvest Technology, ICAR-IARI New Delhi, for providing the essential facilities needed to conduct this research. I am also deeply thankful to my research guide, Dr. V.R. Sagar, for their invaluable guidance and constructive feedback throughout this project. Lastly, I extend my heartfelt appreciation to my family and friends for their continuous support during my research endeavors.
Conflicts of Interests. None.

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How to cite this article: Rajan Mahendra, Anurag Saurabh, S. Abarna and Vidya Ram Sagar (2024). Standardization of Pre-treatments for Retention of Functional Quality in Dehydrated Tomato Slices. *Biological Forum – An International Journal, 16*(11): 16-20.