

ASSESSMENT OF THE EFFECT OF DIFFERENT PRESERVATION TECHNIQUES ON THE LEVEL OF ANTIOXIDANT VITAMINS AND TOTAL ANTIOXIDANT CAPACITY IN TOMATO (*SOLANUM LYCOPERSICON*)

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Abstract

This study compared the effects of different preservation methods on the nutritional value of tomatoes. Five methods were evaluated: freezing, shade drying, microwave drying, hot air drying and sun drying. The levels of vitamin A, C, E, beta-carotene and lycopene were determined in all the samples using HPLC. Total antioxidant capacity was determined in all the samples using the Trolox equivalent antioxidant capacity (TEAC) method. The fresh sample serves as control. The amount of vitamin A, C, E, beta-carotene and lycopene in the fresh tomato samples were found to be 2.60 ± 0.04 , 30.23 ± 2.51 , 1.52 ± 0.19 , 9.94 ± 0.92 and 21.09 ± 1.12 mg/100g respectively. The total antioxidant capacity in the fresh sample was found to be $20.72 \mu\text{mol Trolox/g DW}$. A significant decrease in the amount of vitamin A, C and E in frozen, shade dried, microwave dried, hot air dried and sun-dried samples were seen when compared with control ($p < 0.05$). A significant decrease in the content of beta-carotene and lycopene was also seen in shade dried, microwave dried, hot air dried and sun-dried samples when compared with control ($p < 0.05$). A reduction in total antioxidant capacity was seen in all the samples when compared with control and the percentage reduction was found to be 7.77, 25.05, 39.82, 48.89 and 56.71 % in frozen, shade dried, microwave dried, hot air dried and sun-dried samples of tomato respectively when compared with control. The results showed that freezing was the most effective method for retaining the nutritional value of tomatoes, followed by shade drying with the order of retention being: fresh > frozen > shade drying > microwave drying > hot air drying > sun drying. The findings suggest that freezing can be useful method for preserving the nutritional value of tomatoes and provide insights into the optimal preservation strategies for maintaining tomato quality.

Keywords: Tomato, Vitamin A, Vitamin C, Vitamin E, Beta-carotene, Lycopene, Total antioxidant capacity

Introduction

Tomato is a member of solanaceae family which includes several other economically important crops such as potato, pepper (*Capsicum annuum L*), and egg plant (*Solanum melongena L*) representing one of the most valuable plant families for vegetable fruit crops. Tomatoes contain many health promoting compounds and are easily integrated as a nutritious part of balanced diet (Marti et al. 2016). Vegetables make up a major portion of the human diet in many parts of the world and play a significant role in human nutrition especially as sources of vitamins, minerals and dietary fibers (Kaur et al, 2024). The nutritional importance of tomatoes is largely explained by their various health-promoting compounds, including vitamins, carotenoids, and phenolic compounds (Ganugi et al., 2023). These bioactive compounds have a wide range of physiological properties that includes, anti-inflammatory, anti-allergenic, antimicrobial, vasodilatory, antithrombotic, cardio-protective, and antioxidant effects (Szabo et al., 2019 and Ratto et.al 2022). Tomatoes are rich in carotenoids, representing the main source of lycopene in the human diet (Ali et al., 2020). Carotenoids and polyphenolic compounds contribute to the nutritional value of tomatoes and improve their functional attributes and sensory qualities, including taste, aroma, and texture (Raiola et al., 2014; Marti et al., 2016).

Vitamins are an organic molecule that have diverse biochemical functions and an organism needs in small quantities for the proper functioning of its metabolism. Vitamins are classified as fatand water-soluble and cannot be synthesized by the organism, therefore must be obtained through diet. Tomatoes are a nutrient-dense fruit rich in antioxidants, including vitamins C and E, beta-carotene, and lycopene, which contribute to their high total antioxidant capacity. These antioxidants play a crucial role in protecting against oxidative stress, inflammation, and chronic diseases such as cancer, cardiovascular disease, and neurodegenerative disorders (Ayoka et al, 2022; Muscolo et al, 2024). The total antioxidant capacity of tomatoes is a key indicator of their nutritional value, reflecting the cumulative effect of individual antioxidants and their interactions. Understanding the antioxidant profile and total antioxidant capacity of tomatoes is essential for evaluating their potential health benefits and optimizing their use in various applications, from fresh produce to processed products (Bianchi et al., 2023).

The preservation techniques and drying conditions of vegetables such as tomato and pepper have great effect on the vitamin levels. The temperature, drying time, and the intensity of the light have an effect on the nutrient level of dried foodstuff. While most foods are naturally dried under the sunlight, they might be dried in hot air ovens, drying tunnels, and freeze drying under vacuum (Ahmed et al, 2013; Bakar et al 2020). Tomatoes grow on vines and are at their freshest from May to October. It is plentiful during the summer months. Various preservation techniques are available to consume seasonal foodstuffs in all seasons. Since tomato is a seasonal vegetable, this study is planned to determine the optimal use of tomato in all seasons.

Tomatoes are a rich source of antioxidant vitamins and bioactive compounds, making them a valuable component of a healthy diet. However, the preservation and processing of tomatoes can significantly impact their nutritional content, particularly the retention of antioxidant vitamins and total antioxidant capacity. With the increasing demand for processed tomato products, it is essential to assess the effects of different preservation techniques on the nutritional quality of tomatoes. This study aims to investigate the effect of different preservation techniques such as freezing, shade drying, sun drying, hot air drying and

microwave drying on the level of vitamin C, A, E, beta-carotene, lycopene and total antioxidant capacity in tomato, providing valuable insights for the food industry, consumers, and nutritionists seeking to optimize the nutritional benefits of tomato and tomato-based products.

MATERIALS AND METHODS

Materials

Fresh tomatoes were collected from the farm in Kabo local government, Kano State. The collected tomatoes were cleaned immediately. The sample was identified at department of biological sciences Bayero University Kano. Three samples of cleaned tomatoes were randomly taken into each container. The fresh tomato samples were analyzed as soon as the tomatoes were collected, while shade dried, sun dried, hot air dried and microwave dried samples were analyzed after ten days of drying. The frozen sample was kept at -20°C in the freezer until assayed.

Drying process

Microwave drying: The fresh sample of tomato was weighted and placed in the microwave then the samples were subjected to microwave with full power 6 times for 5 min. After microwave irradiation, total weight loss was 75% according to the method of Baker et al. (2020).

Sun drying: The fresh samples were sun-dried in well-ventilated place indoor under sun light for 7 days up to the total weight loss of 75% according to the method of Baker et al. (2020).

Shade drying: The fresh samples were shade-dried in well-ventilated place indoor under indirect sun light for 9 days up to the total weight loss of 75%

Hot air drying: Samples were processed by drying at 50°C. Drying was performed after cutting the sample to a thickness of 3 mm. The dryer is equipped with thermostat and temperature was continuously checked during drying by laboratory thermometer as well. Samples were dried to a residual moisture content of 15-20%. Time of drying was 24 hours at 50°C. Fresh tomatoes were homogenized before analyzing by kitchen hand blender at least three minutes which were then processed according to the method used by Mendelová et al (2013).

Determination of vitamin A, vitamin E, β - carotene and lycopene

3.0 g from each tomato sample was weighed and 7.0 mL ethyl alcohol was added. The suspension was shaken well in a vortex mixer and then centrifuged for three minutes at 4500 rpm. The solution was filtered (Whatman No 1). 0.5 mL n-hexane was added to the filtrate. This way, vitamin A, vitamin E, β -carotene and lycopene were extracted to the n-hexane phase. This extraction process was replicated. The n-hexane phases were collected and dried with nitrogen gas until dryness. The residue obtained was dissolved in 0.6 mL methyl alcohol and taken up in vials of HPLC which was then ready for HPLC analysis. Supelcosil LC-18 column (25.0 cm x 4.6 mm x 5.0 μ m) was used in the determination of vitamin A, vitamin E, β -carotene and lycopene using a mixture of acetonitrile: methanol: water (63:33:4 v/v) as mobile phase. The mobile phase flow rate was set at 1.0 mL/min. The wavelength for each

parameter was set for vitamin E 296 nm, vitamin A 326 nm, β -carotene 454 nm, and lycopene 474 nm (Ibrahim et al., 2017).

Determination of vitamin C

3.0 g from each tomato sample was weighed and 1.0 mL of 0.5 M perchloric acid was added to each homogenate, to precipitate the proteins. The mixture was placed in a vortex shaker. Each sample was made up to 6.0 mL with deionized water and centrifuged for 10 minutes at 4500 rpm. The supernatant was then filtered (Whatman No 1). 1.0 mL filtrate taken up in vials of HPLC. Vitamin C was determined according to the method used by Ibrahim et al., (2017). Column Exsil 100-5 ODS (25 cm, 4.6 mm ID, 5 μ m) was used with KH_2PO_4 buffer (pH = 4 with H_3PO_4) as mobile phase at a flow rate of 1.0 mL/min.

Total antioxidant capacity Determination

Total antioxidant capacity was determined by TEAC (Trolox Equivalent Antioxidant Capacity) method. The ABTS free radical-scavenging activity was determined according to the method described by Re et al., (1999) and Cakmak et.al (2020). The stock solutions including 7.0 mM ABTS solution and 2.4 mM potassium persulfate allowed to stand in the dark at room temperature for 12–16 h. The ABTS $^{\cdot+}$ solution was diluted with phosphate buffer (pH=7.4) to obtain an absorbance of 0.800 ± 0.010 at 734 nm. Then 20 μ L of the sample or Trolox standard was added to 2.0 mL ABTS $^{\cdot+}$ solution and allowed to stand at room temperature for 15 minutes then absorption was measured at 734 nm. Previously prepared ABTS $^{\cdot+}$ solution used as the control group. All measurements were performed in four parallel for every sample. The percentage inhibition of ABTS $^{\cdot+}$ was calculated using the formula given below:

$$\% \text{ inhibition} = \frac{A_{C(0)} - A_{A(t)}}{A_{C(0)}} \times 100$$

where $A_{C(0)}$ is the absorbance of the control at $t=0$ minute, and $A_{A(t)}$ is the absorbance of the (Trolox + ABTS $^{\cdot+}$) or (Sample + ABTS $^{\cdot+}$) at $t=15$ minute. The free radical scavenging capacity of the sample was calculated as percent inhibition of ABTS $^{\cdot+}$. The standard calibration curve was generated using Trolox concentration of 1.0-4.0 μ g ml $^{-1}$. The antioxidant capacity of the sample was calculated as Trolox equivalent as μ mol Trolox/g DW.

Statistical Analysis

All measurements were taken in triplicate, and the mean $\pm$ standard deviation was computed. SPSS 10.0 for Windows was used to analyze variance (ANOVA) on the findings. P-values < 0.05 were used to signify statistical significance.

RESULTS

In this research work, the amount of vitamin A was found to be 2.60 ± 0.04 mg/100g (Table 1) in fresh tomato sample which serves as control. After subjecting the sample to different pretreatment, the values were found to be 2.13 ± 0.07 , 1.81 ± 0.07 , 1.76 ± 0.03 , 1.49 ± 0.05 and 0.95 ± 0.06 mg/100g in frozen, shade dried, microwave dried, hot air dried and sun-dried

samples of tomato respectively (Table 1). A significant decrease ($p < 0.05$) was seen in all the values when compared with the value of the fresh sample (control).

In this study, content of vitamin C in fresh tomato sample (control) was found to be 30.23 ± 2.51 mg/100g (Table 1). After different treatment, the values were found observed to be 19.15 ± 1.67 , 9.54 ± 1.43 , 7.32 ± 0.98 , 6.11 ± 0.76 and 3.75 ± 0.31 mg/100g in frozen, shade dried, microwave dried, hot air dried and sun-dried samples of tomato respectively (Table 1), where a significant decrease ($p < 0.05$) was seen in all the values when compared with the value of the fresh sample (control).

In this work, the amount of vitamin E in fresh tomato sample (control) was found to be 1.52 ± 0.19 mg/100g (Table 1). After application of different preservation methods, the values were found to be 1.24 ± 0.07 , 1.11 ± 0.05 , 1.09 ± 0.08 , 0.95 ± 0.04 and 0.78 ± 0.05 31 mg/100g in frozen, shade dried, microwave dried, hot air dried and sun-dried samples of tomato respectively (Table 1), where a significant decrease ($p < 0.05$) was seen in all the values when compared with the value of the fresh sample (control).

The content of beta-carotene in this study was found to be 9.94 ± 0.92 mg/100g (Table 1) in fresh tomato sample (control). After different treatment, the values were found to be 9.66 ± 0.11 , 7.31 ± 0.32 , 6.75 ± 0.61 , 5.71 ± 0.54 and 4.22 ± 0.43 mg/100g in frozen, shade dried, microwave dried, hot air dried and sun-dried samples of tomato respectively (Table 1), where a significant decrease ($p < 0.05$) was seen in all the values except that of the frozen sample when compared with the value of the fresh sample (control).

The amount of lycopene in this study was found to be 21.09 ± 1.12 mg/100g (Table 1) in fresh tomato sample (control). After different treatment, the values were found to be 20.74 ± 1.53 , 17.52 ± 1.61 , 15.43 ± 1.11 , 14.43 ± 1.21 and 9.77 ± 0.81 mg/100g in frozen, shade dried, microwave dried, hot air dried and sun-dried samples of tomato respectively (Table 1), where a significant decrease ($p < 0.05$) was seen in all the values except that of the frozen sample when compared with the value of the fresh sample (control).

In this study, the fresh tomato sample (control) was found to have a total antioxidant capacity value of $20.72 \mu\text{mol Trolox/g DW}$. After different treatment, the value was found to be 18.11, 15.53, 12.47, 10.59 and $8.97 \mu\text{mol Trolox/g DW}$ in frozen, shade dried, microwave dried, hot air dried and sun-dried samples of tomato respectively (Table 2). These values show a 7.77, 25.05, 39.82, 48.89 and 56.71 % decrease in total antioxidant capacity in frozen, shade dried, microwave dried, hot air dried and sun-dried samples of tomato respectively when compared with control (Figure 1).

Table 1: The content of vitamin A, C, E, Beta-carotene and Lycopene in fresh, frozen, shade dried, microwave dried, hot air dried and sun-dried samples of tomato (mg/100g).

	Fresh	Frozen	Shade dried	Microwave dried	Hot air dried	Sun dried
Vitamin A	2.60 ± 0.04	2.13 ± 0.07	1.81 ± 0.07	1.76 ± 0.03	1.49 ± 0.05	0.95 ± 0.06
Vitamin C	30.23 ± 2.51	19.15 ± 1.67	9.54 ± 1.43	7.32 ± 0.98	6.11 ± 0.76	3.75 ± 0.31
Vitamin E	1.52 ± 0.19	1.24 ± 0.07	1.11 ± 0.05	1.09 ± 0.08	0.95 ± 0.04	0.78 ± 0.05
Beta-carotene	9.94 ± 0.92	9.66 ± 0.11	7.31 ± 0.32	6.75 ± 0.61	5.71 ± 0.54	4.22 ± 0.43
Lycopene	21.09 ± 1.12	20.74 ± 1.53	17.52 ± 1.61	15.43 ± 1.11	14.43 ± 1.21	9.77 ± 0.81

Table 2: Total antioxidant capacity in fresh, frozen, shade dried, microwave dried, hot air dried and sun-dried samples of tomato.

	Fresh	Frozen	Shade dried	Microwave dried	Hot air dried	Sun dried
TEAC ($\mu\text{mol Trolox/g DW}$)	20.72	18.11	15.53	12.47	10.59	8.97

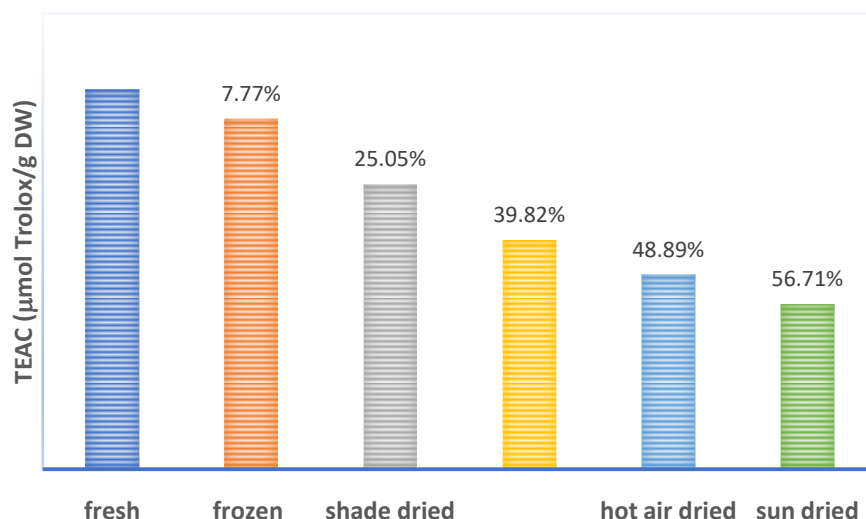


Figure 1: % Decrease in total antioxidant capacity compared to the fresh samples

DISCUSSION

Tomatoes are a perishable fruit that require proper preservation techniques to extend their shelf life and maintain their nutritional value. Various drying methods are commonly employed to preserve tomatoes. Each method has its unique advantages and disadvantages, affecting the retention of bioactive compounds, antioxidant activity, and overall quality of the dried product (Al-Juhaimi et. al, 2018; Bhatkar et. al, 2021; Arkain and Alibas, 2025). Vitamin A is one of the fat-soluble vitamins found in tomato which is important in maintaining various bodily functions, from vision health to immune function and skin health (Carazo et.al, 2021; Menezes and Almeida 2024). The results obtained in this study indicate the amount of vitamin A to be highest in the fresh sample and lowest in the sundried sample (Table 1). However, these results shows that the preservation methods affect the amount of vitamin A in the tomato sample as shown in Table 1. Our findings are in line with the results obtained by Baker et.al (2020) which also shows a significant decrease in the amount of vitamin A in the fruit of *Opuntia ficus-indica* in sun and microwave-dried samples in comparison with fresh sample. In another study conducted in tomato and okro, the amount of vitamin A was also reported to be significantly higher in the fresh samples than in the dried samples (Obasi et.al, 2025).

Vitamin C is a vital antioxidant that plays a pivotal role in immune function, collagen production, iron absorption, prevention of scurvy and maintenance of healthy skin, gums and

blood vessels. It is also reported to reduce the risk of arteriosclerosis, cardiovascular disease and some cancer types (Ibrahim et.al, 2021; Alberts et.al, 2025). In our study, the vitamin C level was seen to be lower in the sundried sample and higher in the fresh sample (Table 1). The frozen and shade dried samples showed a higher content of vitamin C than the sundried sample which is statistically significant ($p < 0.05$). The amount of vitamin C was found to significantly decrease in microwave and sundried samples of *Opuntia ficus-indica* as revealed by Baker et.al (2020). In another study, Obasi et.al (2025) revealed the amount of vitamin C in fresh tomato sample to be 36.59 ± 0.23 mg/100g and the value was decreased to 10.96 ± 0.06 , 10.00 ± 1.17 and 8.33 ± 0.01 mg/100g after oven drying at 50°C , 60°C and solar respectively. These findings are in line with our results which also shows a significant decrease in the content of vitamin C in tomato after hot air drying at 50°C (Table 1).

Vitamin E is a strong antioxidant that plays an important role in protecting the cell from the deleterious effect of free radicals, stabilization of biological membranes and immune system function (Fatima et.al, 2025). In this study, the vitamin E content was seen to be highest in fresh sample and lowest in the sun-dried sample (Table 1). In a study carried out by Nenad (2017), the amount of vitamin E was also lower in dried (60°C) tomato sample compared to the fresh sample. Also, Baker et.al (2020) revealed a significant decrease in the level of vitamin E in sun dried and microwave dried samples of *Opuntia ficus-indica* when compared to the fresh sample.

Beta-carotene is primarily known for its role as a provitamin A, meaning it's converted into vitamin A in the body, which is essential for vision, immunity, and skin health. Additionally, beta-carotene functions as an antioxidant, protecting cells from damage caused by free radicals and potentially reducing the risk of chronic diseases like cancer and heart disease (Anand et.al, 2022). In this study, the amount of beta-carotene was seen to highest in the fresh sample and lowest in the sun-dried sample (Table 1). Comparing the frozen sample with the fresh sample showed no significant difference (Table 1). However, shade dried and microwave dried sample were significantly higher than the sundried sample (Table 1). Reports have indicated a significant decrease in beta-carotene content in green leafy vegetables after open sun drying (Mulokozi & Svanberg, 2003), which is in line with our findings also indicating a significant decrease in beta-carotene level after sun drying. Smith et al. (2018) also revealed a significant decrease in the amount of beta-carotene after outdoor solar drying of tomato and mango when compared to the fresh samples. In another experiment, drying at a temperature of 55°C showed a significant decrease in the amount of beta-carotene in tomato compared to the fresh sample (Surendar et al., 2018).

Lycopene, a carotenoid primarily found in tomatoes and tomato products, is a powerful antioxidant with numerous potential health benefits. It plays a role in protecting against oxidative stress, reducing the risk of certain cancers, and supporting overall health (Shafe et.al, 2024). In this work, the value of lycopene significantly decreased after drying under the shade, microwave, hot air and sun. However, the lowest amount was seen in the sundried sample when compared with fresh sample. Previous work showed a significant decrease in lycopene content in tomato after drying under different temperature range (Mendelová et.al, 2013; Peng et.al, 2024). In another experiment, drying at a temperature of 55°C showed a significant decrease in the amount of lycopene in tomato compared to the fresh sample (Surendar et.al, 2018). This work is also in line with our findings.

Total antioxidant capacity is the overall ability of a substance or sample to neutralize free radicals and reactive oxygen species (ROS), thereby protecting against oxidative stress. It's a

measure of the combined effect of all antioxidants in a system, not just the activity of individual molecules (Silvestrini et.al, 2023). In the present study, the total antioxidant capacity was seen to reduced to more than half in the sun-dried sample when compared to control (Figure 1 & Table 2). The frozen, shade and microwave dried samples showed a better antioxidant capacity than the hot air- and sun-dried samples (Figure 1 & Table 2). In a recent work carried out by Gębczyński et.al, (2024), there results showed that the freezing method is a better technique that retain the antioxidant activity green legume vegetables. These findings are in line with our findings where the frozen samples better retain the antioxidant activity of tomato by showing only 7.77% decrease compared with the fresh sample (Figure 1). Arkain and Alibas (2025), also reported a significant decrease in antioxidant capacity in medlar fruit when dried by different temperature, microwave and naturally using the TEAC (ABTS) method. However, there findings shows that the microwave and hot air techniques better retain the antioxidant activity than the natural method when compared with control which is also in line with our results (Figure 1, Table 2).Also, in line with our work, Yildiz et.al, (2024), reported a significant decrease in antioxidant capacity (TEAC) in Persimmon (*Diospyros kaki* L.) fruit after microwave drying.

Among themethods used in this study, freezing is generally considered to be the best method for preserving the nutritional content of tomatoes because it helps to preserve the delicate vitaminsfound in the tomatoes, preserve antioxidant activity and minimize nutrient degradation. While freeze-drying is considered to be one of the best methods for preserving nutritional content, other methods used in this experiment were also found to be effective like the shade drying which was seen to preserve the nutrients by avoiding high temperatures and direct sunlight unlike the results from hot air and sun-dried samples. This method was found to retain more than 50% of the nutrients in the tomato sample with the exception of vitamin C and also shows a higher antioxidant activity retention compared to microwave, hot air and sun-dried samples. Microwavedrying is one of the advanced methods with numerous advantages including high thermal efficiency, shorter drying time and improved product quality (Abano et al 2012). However, the effectiveness of this method depends on the specific conditions used in its application. Our results indicate a better nutrient retention by using the microwave drying technique when compared with the hot air and sun drying method. A lot of studies have indicated that freeze drying and microwave drying are better methods of retaining the nutrients of fruits and vegetables compared to hot air drying (at 90⁰C and above) and sun drying (Farina et.al, 2020; Kumar et.al, 2020). The hot air drying also shows effectiveness as the vitamins were retain and the total antioxidant activity reduction was 48.89% compared to the fresh sample value.The sun drying methodwas found to be less effective which may be due to exposure to direct sunlight which can cause nutrient degradation and loss of color. Our results shows that all the parameters were significantly affected by the sun drying method and more than half of the antioxidant capacity was lost as a result of the sun drying method. Vitamin C is very sensitive to heat and that's why its most affected by the sun drying method.

CONCLUSION

This study evaluated the effects of different preservation methods on the nutritional value of tomatoes. The results showed that freezing was the most effective method for retaining the nutritional value of tomatoes, followed by shade drying. The order of retention was found to be: fresh > frozen > shade drying > microwave drying > hot air drying > sun drying. These findings suggest that freezing can be a useful method for preserving the nutritional value of tomatoes, especially for long-term storage. The results of this study can inform the

development of optimal preservation strategies for tomatoes, ultimately helping to maintain their nutritional value and quality. This study can also provide insights for the food industry and consumers seeking to optimize the nutritional benefits of dried tomato products.

RECOMMENDATIONS

Subsequent experiment should be carried out by using different temperature adjustments for hot air drying and also different microwave set ups as it will help in proving the best conditions to better use the methods. Total phenolic content and water-soluble vitamins (B-complex) should also be investigated under the drying conditions in tomato samples.

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