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Influence Of Pre-treatments And Drying Temperatures On The Drying Rate And Quality Characteristics Of Dehydrated Tomato Powder

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Abstract

The effect of pre-treatments and drying temperatures on the drying rate and quality characteristics of tomato were studied. Fresh tomatoes were washed and sliced to a thickness of 5 mm, one part was dried raw (T0), others were pre-treated with vinegar solution (T1), vinegar mixture/sodium chloride (T2), saline solution (T3) and dried at different temperatures of 40, 50, 60, 70ºC in a cabinet dryer. The moisture removal from samples in the cabinet was measured every 5 hours and the quality characteristics were also analyzed. Results revealed that samples dried at higher temperatures recorded higher drying rates and better dehydration ratio irrespective of the pre-treatments. The moisture content of pretreated samples decreased with increase in drying temperatures. Pre-treatments did not have significant effect on vitamin C, lycopene and β-carotene contents. Pretreated samples dried at lower temperatures had better quality of vitamin C retention meanwhile pretreated samples dried at higher temperatures showed higher lycopene and β-carotene contents.

Keywords: *Tomato, Pre-treatments, Drying Temperature, Quality Characteristics, Tomato Powder.*

1. Introduction

Processing of vegetable crops are essential for extending their shelf-life without further deterioration in the quality of the final product. Several processing techniques have been employed on an industrial scale to preserve vegetable crops and the major ones are canning, freezing, addition of chemical preservatives and dehydration. Among these, drying mostly employed in developing countries with poorly established low-temperature and thermal processing facilities, has been used for many years for the preservation of vegetables crops [1]. It offers an effective means of preservation as it reduces postharvest losses and offset the shortages in supply. Drying is a simple process and involves the application of heat to vaporize moisture from a product in order to attain a desired moisture content. The removal of moisture brings about substantial reduction in weight and volume of the final product, prevents microbial activity, minimize physical and chemical changes during storage, enables storability of the product under ambient temperatures.

Cameroon is one of the largest producers of vegetable crops in Africa. One of the most widely cultivated vegetable crop in Cameroon is tomato (*Lycopersicon esculentum* Mill.) and it is easily grown in all western highlands and agro-ecological zones of the country with average yield of 14 metric tons per hectare [2]. According to [3] tomato is a rich source of lycopene (60-90 mg/kg) which act as an antioxidant, neutralizing free radicals that can damage cells in the body inhibiting different types of cancer, vitamin C (160-240 mg/kg), polyphenols (10-50 mg/kg) and small quantities of vitamin E (5-20 mg/kg) and also excellent source of minerals and vitamins.

The production of tomato in Cameroon increases daily but unfortunately, these tomatoes are seasonal products for example when they are in season, there is usually a surplus of the product but since they have a short storage life, excess tomato go to waste and the product becomes scanty during off season. Furthermore, tomato has a limited shelf life at ambient conditions and are highly perishable in its natural form and will undergo rapid deterioration few days after harvest, thus altering all their required quality attributes. Different products including juice, ketchup, paste, and sauce have been prepared from fresh tomato in order to extend the storage life of these products, but these processed products have shorter shelf life due to their high moisture content. In order to prolong the shelf life and ensure the availability of tomato throughout the year, tomato has to processed into powder which will help reduce wastage during production season. [4] reported that if tomato powder can be prepared then it will help to reduce wastage, price and increase the availability of powdered tomato throughout the year. [5] reported that tomato dried powder is most accessible and convenient form to use in most ready-to-eat products.

In order to improve quality of dehydrated tomato powder and minimize adverse changes during drying, pretreatments using chemicals including sodium chloride, calcium chloride, and potassium metabisulphite have been carried out by many authors prior to drying of tomato [6], [7] and [8]. To date, there have been very limited published studies concerning the use of white vinegar, Sodium chloride/white vinegar mixture as pre-treatment for tomato drying.

Hence, the objective of this study was to determine the effects of pre-treatments (white vinegar, sodium chloride/white vinegar mixture and saline solution) and different drying temperatures on the drying rate and quality characteristics of pre-treated dehydrated tomato powder

2. Materials and methods

2.1 Experimental Design

In order to attain the objectives of this project, a 3×5 factorial experiment in a randomized complete block design (RCBD) was used. In the design, five (5) levels of temperature (T), and three (3) levels of treatment (t) was used. The temperatures used were 40, 50, 60 and 70ºC. These temperatures were used were based on the findings of [4] who reported that best drying temperature for tomato are low temperature of 55ºC. Some of the tomatoes were pre-treated by dipping in white vinegar, some dipped in Sodium chloride/white vinegar, others dipped in Sodium chloride solution while some were dried in their natural state. Each test run was replicated (R) thrice making a total of 45 test runs.

2.2 Collection and Pre-treatments of Samples

Fresh, firm and ripe tomato fruits were bought from Mokolo market in Yaounde, Cameroon. Mature tomatoes were selected from the lot based on freshness, colour and size uniformity. They were washed several times with tap water, rinsed with distilled water and then wiped with an absorbent paper.

The sterile tomatoes were sliced into uniform thickness of 5 mm and were then pre-treated as follows:

- Treatment 0 (T0) - No pre-treatment (Control)
- Treatment 1 (T1) - 40% white vinegar (v/v)
- Treatment 2 (T2) - 40% white vinegar (v/v) plus 5% Sodium chloride (w/v),
- Treatment 3 (T3) - 5 % Saline solution (w/v)

Tomatoes slices were soaked in those solutions for 1 hour at room temperature before drying.

2.3 Drying process of tomato samples

The treated tomato slices were dried using a cabinet oven dryer (Memmert, Germany). Five drying temperatures (40, 50, 60, and 75ºC) were studied. The samples were weighed at an interval of 5 hours with a weighing balance (Mettler Toledo MS303S, Switzerland) and the weights were recorded. This was conducted until equilibrium moisture content was obtained

2.4 Drying Rate

It was determined following the method described by [4]. This was done by measuring the weight of samples as drying took place. Drying rate was expressed mathematically as follows:

$$\text{Drying rate} = \frac{(W1 - W2)}{T} \quad (1)$$

Where, W1= weight of product before drying
W2= weight of product after drying
T= drying time
Drying rate was expressed in (g/hr)

2.5 Dehydration ratio (DR)

Dehydration ratio was determined according to the method described by [10] where weights of tomatoes before and after drying were recorded and calculated using the formula:

$$\text{Dehydration ratio} = \frac{\text{Mass of sample before drying}}{\text{Mass of sample after drying}} \quad (2)$$

2.6 Preparation of tomato powder

After drying, the treated tomato slices where allow to cool at room temperature, then ground using a laboratory grinder to produce different sets of tomato powder. The tomato powder was then packaged in sealed containers for further studies.

2.7 Determination of quality characteristics

The moisture content, total ash content, pH, and titratable acidity of the treated dehydrated tomato powders were determined in triplicates according to the standard methods of AOAC [9]. Rehydration ratio were determined using method as descried by [10]. Browning reaction was determined using method described by [11]. Vitamin C, lycopene and β-carotene content were determined following the method described by [12]

2.8 Statistical analysis

All analyses were carried out in triplicates and data collected were subjected to one-way analysis of variance (ANOVA) using STATGRAPHICS Centurion. The least significant difference (LSD) was used to test for difference between means and significance was defined at $P<0.05$.

3. Results and discussion

3.1 Effect of pre-treatments and drying temperatures on drying rate and dehydration ratio

The effect of pre-treatment and drying temperature on drying rate of tomato are presented in table 1. Drying rate increases as the temperature increases for all the pre-treatments as shown in fig 1 and this implied that drying temperature had significant effects on drying rate. Drying rate increased progressively from an average of 14.30g/hr at 40ºC to an average of 22.29g/hr at 70ºC for all pre-treatments. Drying rates at the different pre-treatments were not significantly different from one another at all drying temperatures as shown in fig 2. This implies that pre-treatments did not have significant effect on drying rate. [4] reported that drying rate generally increases with increasing temperature meanwhile pre-treatments had no significant effect on drying rate and the present study exhibit this trend.

Different pre-treatments used in this study had significant effects on the dehydration ratio. Samples treated with T2 showed highest dehydration ratio as compared to other treated samples at all drying temperatures. The combine effect of the osmotic ability acetic acid and sodium chloride in the samples treated with T2 could provide slight improvement in dehydration ratio by enhancing moisture loss and this led to tomato slices of reduced mass since juice was partially leached to the osmotic medium before drying. Similar trend has been observed by [10] who reported that tomato slices pretreated with sodium chloride (NaCl) trigger leaching of juice from tomato into the osmotic medium. There was no significant difference regarding to dehydration ratio with respect to drying temperatures although pre-treated samples dried at 70ºC for all treatments showed slightly better ratio in comparison to those of other drying temperatures.

Table 1. Effect of Pre-treatment and Drying Temperature on Drying Rate

Pre-treatments	D T (ºC)	DR	Drying rate (g/hr)
T0	40	16.12[a]	14.21[a]
	50	16.16[a]	16.33[b]
	60	16.18[a]	18.26[c]
	70	16.98[a]	22.15[d]
T1	40	15.12[a]	14.35[a]
	50	15.36[a]	16.42[b]
	60	15.48[a]	18.45[c]
	70	15.95[a]	22.37[d]
T2	40	12.32[a]	14.33[a]
	50	12.36[a]	16.40[b]
	60	12.38[a]	18.43[c]
	70	12.92[a]	22.34[d]
T3	40	14.32[a]	14.31[a]
	50	14.38[a]	16.38[b]
	60	14.42[a]	18.39[c]
	70	14.91[a]	22.30[d]

Means indicated by the same letter are insignificantly different at $P < 0.05$

Note: DT=Drying temperature, DR=Dehydration ratio

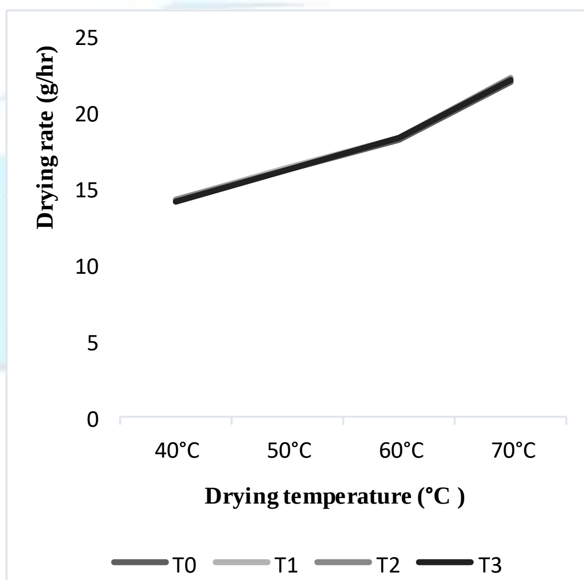

Fig. 1. Effect of drying temperatures on drying rate

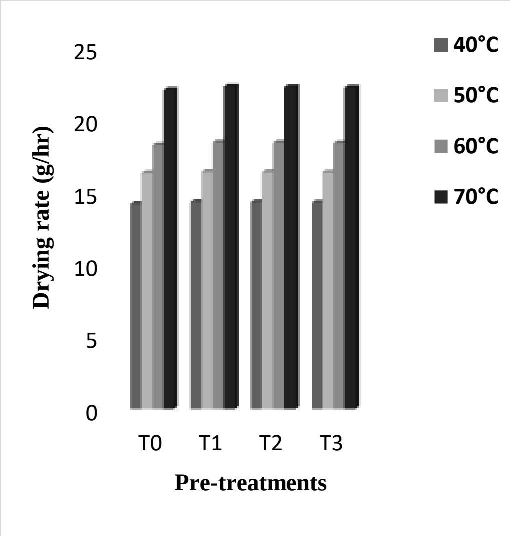

Fig. 2. Effect of pre-treatments on drying rate at different drying temperatures.

3.2 Effect of different pre-drying treatments and drying temperatures on the quality characteristics of dehydrated tomato powder

Effects of pre-treatments and drying temperatures on quality characteristics of dehydrated tomato powder are presented in table 2. From the table it was evident that pre-treatments have significant effects on moisture content of samples at all drying temperatures. Pre-treatments with T1, T2 and T3 enhanced water removal from tomato slices before the drying process. The increase in moisture loss in the pretreated samples can be due to the osmotic ability acetic acid in the T1, osmotic ability of sodium chloride in the T3 and combine effect of the osmotic ability of sodium chloride and acetic acid in the T2 which enhanced moisture removal thus decreasing the moisture content of the dehydrated tomato powder. Increased moisture removal for sodium chloride treated dried tomato was reported by [7], [11], [13] and [14]. In comparison with these pre-treatments, control sample showed higher moisture content. Furthermore, there was a tendency of decreasing moisture content with increase drying temperatures for all the pre-treatments. This decrease in moisture content may have occurred due to the fact that increase in temperature triggers the softening of the cell wall tissues of all pretreated tomatoes thus rendering the cell membranes more permeable to moisture transfer. Our results are similar to that obtained by [15] who reported that moisture content of all pre-treated tomatoes decreased as the drying temperature was increased from 45ºC to 55ºC.

The rehydration ratio was significantly affected by the pre-treatments. The samples pre-treated with T2 and T3 showed better rehydration property because sodium and chloride ions permeate the tomato during soaking and re-associate as sodium chloride (NaCl) crystals on drying inside the cellular compartments. Our result follows a similar trend to that of [10], who reported that, sodium chloride (NaCl) treated tomato powder revealed higher rehydration ratio when compared to calcium chloride ($CaCl_2$), potassium metabisulphite (KMS), calcium chloride and potassium metabisulphite ($CaCl_2$ + KMS) treated tomato powders. Drying temperatures had significant effects on the rehydration ratio. Rehydration ratio was highest at 40ºC and lowest at 70ºC for all treatments and this probably due to the fact that lower drying temperatures leads to less textural chances of the tomato during dehydration which leads to a higher rehydration ratio of the final product.

Pre-treatments had significant effects on the pH and titratable acidity of the dehydrated tomato powders at all drying temperatures. Samples treated with T2 showed highest titratable acidity followed by samples treated with T3 and finally by samples treated with T1 for each drying temperature. The titratable acidity of these pre-treated samples were significantly higher ($p<0.05$) than that of the control sample T0. Meanwhile the pH of samples treated with T1 showed slightly higher pH values than that of the samples treated T2 and T3. In comparison to the control sample, it was observed that the pH values of the treated samples were significantly lower ($p<0.05$) than that of the control T0. The higher acidity and lower pH in T1, T2 and T3 treated samples may have resulted due to the presence of acetic acid and sodium chloride. Sodium chloride-treated tomato slices dried in solar and tunnel driers were reported to have a slightly higher acidity than the control [11]. In addition, potassium metabisulphite/sodium chloride pretreated dried tomato slices were reported to have slightly higher acidity than the control [7]. Drying temperature had significant effects on both titratable acidity and pH for all pre-treatments, the titratable acidity increased with increasing drying temperature, meanwhile, the pH decreased with increase in drying temperature. The increase in titratable acidity with increase in drying temperature may be due to the organic acids in tomato becoming more concentrated due to the increased moisture loss while the reduction in pH with increase in drying temperature may be due to an increased dissociation of the organic acids with temperature. Similar trend has also been reported by [15]. Our findings are also similar to the postulations of [16] who reported that drying of leeks led to an increase in TA but a decrease in pH. The results of titratable acidity is in accordance with the report of [17] on mango powder who observed an increase in titratable acidity upon drying.

Pre-treatments did not have significant effect on the vitamin C content of the dehydrated tomato powder at all drying temperatures as shown on table 3 and fig 3. Meanwhile drying temperature had significant effects on the vitamin C content of dehydrated tomato powders. Vitamin C content was highest at 50°C and 60°C and lowest at 70°C for all pre-treatments as shown in fig 4. This reflects the fact that vitamin C is a very heat-labile component and its retention is affected by thermal treatments therefore it will show decreasing trend with increase in drying temperature. [18] investigated that drying tomatoes at 42°C during 18 hours led to ascorbic acid losses between 17-27% according to tomato varieties.

Carotenoids (antioxidants) of tomatoes have significant importance to human health and may be considered a valuable property of tomatoes therefore, it is important to minimize losses of these compounds during processing of tomatoes. In this study, pre-treatments had significant effect on the lycopene and β-carotene contents at all drying temperatures as shown on fig 4 and fig 5 respectively. Dehydrated tomato powder pre-treated with T2 recorded the highest lycopene and β-carotene contents and this might be due to the fact that, this pre-treatment has a protective effect on lycopene and β-carotene. Similar trends were reported by [10] who reported that the use of potassium metabisulphite and calcium chloride had significant protective effect on lycopene degradation and it was more effective when combination of CaCl2+KMS was used. Drying temperatures employed had significant effects on the lycopene and β-carotene contents of the dehydrated tomato powders for all the pretreatments as shown in fig 4 and 5 respectively. Lycopene and β-carotene contents increases as dying temperature increases except at drying temperature of 70°C where it was observed that there was significant decrease in Lycopene and β-carotene contents. Lycopene and β-carotene contents were highest at 60°C and lowest at 40°C at all levels of pre-treatments which reflect that the lycopene content increases with increase in drying temperature. The apparent increase in lycopene with increase in drying temperature can be attributed to the loss of water from tomato slices and the remaining lycopene got concentrated in the dried tomato powder.

Table 2. Effect of pre-treatments and drying temperature the on quality characteristics of tomato powder

Parameters	D T (°C)	Pre-Treatments			
		T0	T1	T2	T3
M C (%)	40	38.64^{a}	31.03^{b}	20.65^{c}	24.12^{d}
	50	25.64^{b}	20.14^{c}	12.78^{d}	14.36^{e}
	60	12.63^{c}	10.93^{d}	6.65^{e}	7.12^{f}
	70	9.64^{d}	7.36^{e}	5.65^{f}	6.12^{g}
NEB	40	2.04^{a}	1.64^{b}	1.01^{c}	1.13^{d}
	50	2.46^{b}	1.76^{c}	1.09^{d}	1.20^{e}
	60	2.74^{c}	1.84^{d}	1.15^{e}	1.26^{f}
	70	2.88^{d}	1.92^{e}	1.26^{f}	1.38^{g}
RR	40	0.93^{a}	1.23^{b}	1.89^{c}	1.35^{d}
	50	0.84^{b}	1.19^{c}	1.78^{d}	1.24^{e}
	60	0.71^{c}	1.11^{d}	1.64^{e}	1.18^{f}
	70	0.68^{e}	1.06^{e}	1.51^{f}	1.10^{g}
TA	40	0.20^{a}	0.33^{b}	0.77^{c}	0.60^{d}
	50	0.37^{b}	0.41^{c}	0.82^{d}	0.74^{e}
	60	0.46^{c}	0.52^{d}	0.90^{e}	0.80^{f}
	70	0.52^{d}	0.64^{e}	1.02^{f}	0.92^{g}
pH	40	4.94^{a}	4.34^{b}	4.28^{c}	4.31^{d}
	50	4.89^{b}	4.29^{c}	4.17^{d}	4.20^{e}
	60	4.77^{c}	4.19^{d}	4.09^{e}	4.15^{f}
	70	4.46^{d}	4.06^{e}	3.99^{f}	4.07^{g}
Vitamin C (mg/100g)	40	40.01^{a}	40.25^{a}	40.19^{a}	40.22^{a}
	50	57.84^{b}	57.68^{b}	57.32^{b}	57.35^{b}
	60	57.81^{b}	57.88^{b}	57.65^{b}	57.47^{b}
	70	35.86^{c}	35.43^{c}	35.46^{c}	35.34^{c}
Lycopene (mg/100g)	40	76.23^{a}	76.79^{a}	76.89^{a}	76.22^{a}
	50	85.77^{b}	85.68^{b}	85.92^{b}	85.15^{b}
	60	93.60^{c}	93.71^{c}	93.85^{c}	93.07^{c}
	70	85.45^{d}	85.68^{d}	85.73^{d}	85.11^{d}
β-carotene (mg/100g)	40	30.19^{a}	30.25^{a}	30.65^{a}	30.41^{a}
	50	46.28^{b}	46.37^{b}	46.58^{b}	45.38^{b}
	60	52.25^{c}	52.48^{c}	52.67^{c}	52.45^{c}
	70	40.14^{d}	40.31^{d}	40.47^{d}	40.39^{d}

Means indicated by the same letter are insignificantly different at $p < 0.05$

Note: DT = drying temperature, MC = moisture content, TA = titratable acidity, NEB = non-enzymatic browning, RR = rehydration ratio

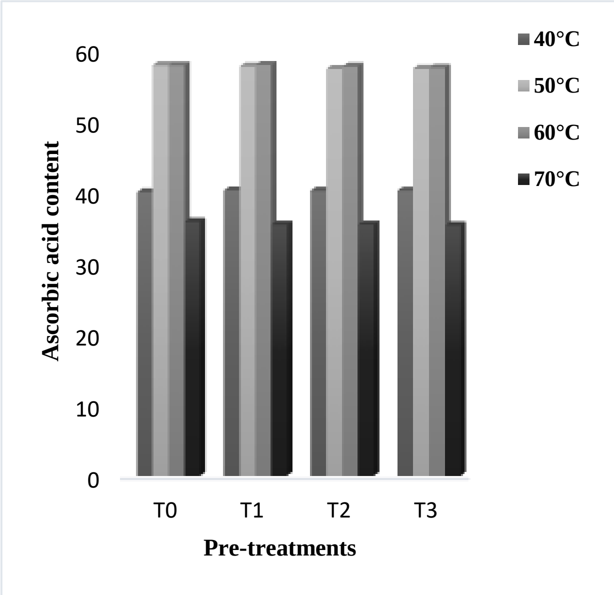

Fig. 3. Effect of pre-treatments and drying temperatures on vitamin C content

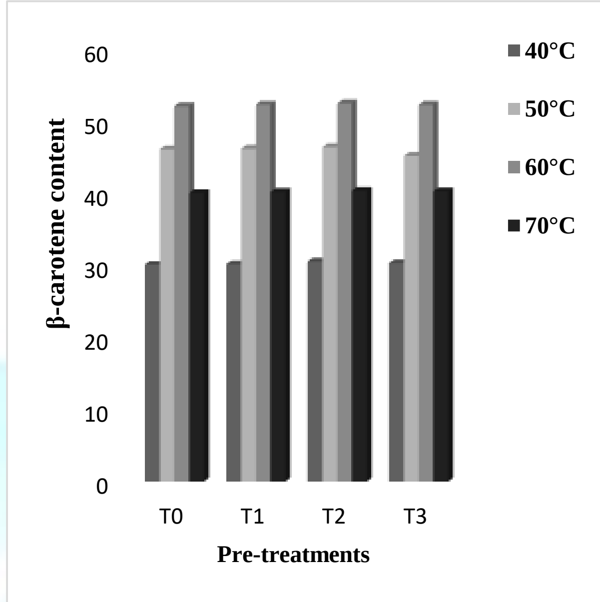

Fig. 5. Effect of pre-treatments and drying temperatures on β-carotene contents

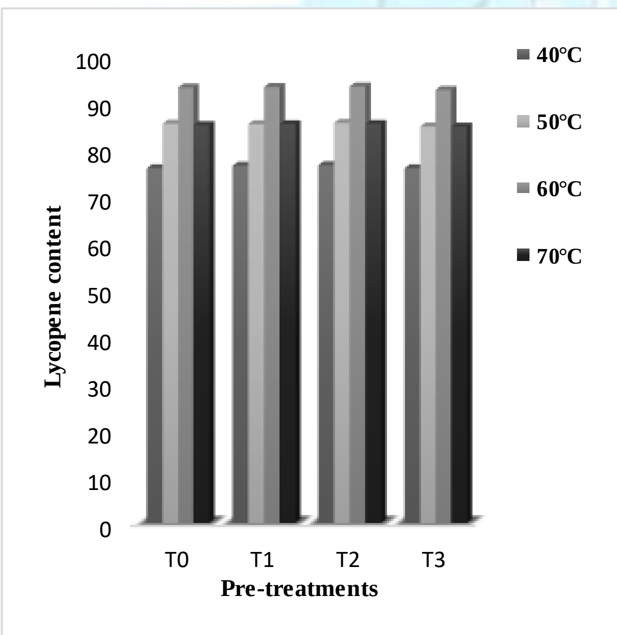

Fig. 4. Effect of pre-treatments and drying temperatures on lycopene content

4. Conclusion

The purpose of this study was to investigate the effect of pre-treatments and drying temperatures on the drying rate and quality characteristics of dehydrated tomato powder. This study revealed that at higher temperatures, tomato dry faster than at lower temperatures irrespective of the pre-treatment used. The moisture content, dehydration ratio, rehydration ratio and titratable acidity of treated samples were significantly different ($p<0.05$) from that of the control. However, the pH and non-enzymatic browning of the control were significantly higher ($p<0.05$) than the treated samples indicating that the pre-treated dehydrated samples have better preservation potential than the control. The vitamin C content of the dehydrated tomato powder reduces as drying temperature increases irrespective of the pre-treatments. This indicates that drying at very high temperatures has adverse effect on vitamin C of tomato. Lycopene and β-carotene content increase as drying temperature increases but significantly decreased at 70^{o}C. This shows that drying at higher temperature degrades lycopene and β-carotenes of tomato. Therefore, to obtain the best quality dehydrated tomato powder with better drying rates, good physicochemical and antioxidants properties, fresh tomatoes should be cut into slices, then pre-treated with 50% white vinegar/sodium chloride solution then followed by drying at a temperature of 60^{o}C and finally powder the pre-treated dried tomato slices into tomato powder which may be the best conservation method for the community.

Conflict of interests

The authors have not declared any conflict of interests

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