ORIGINAL SCIENTIFIC PAPER

Effect of Drying Methods on Physicochemical Properties of Pretreated Tomato (*lycopersicon esculentum mill.*) Slices

John Owusu[1,3]*, Haile Ma[1,2], Zhenbin Wang[1], Agnes Amissah[3]

[1]*School of Food and Biological Engineering, Jiangsu University, 301 Xuefu Road, Zhenjiang 212013, P. R. China.*
[2]*Key Laboratory for Physical Processing of Agricultural Products, 301 Xuefu Road, Zhenjiang 212013, P. R. China*
[3]*Hospitality Department, Koforidua Polytechnic, P. O. Box KF 981, Ghana.*

Summary

The effect of drying methods on the physicochemical properties of white vinegar and sodium chloride/white vinegar mixture pre-treated tomato slices was studied at drying temperatures of 45 and 55 °C. The physicochemical parameters investigated included pH, titratable acidity, total soluble solids, taste index, as well as colour and browning index. Significantly higher moisture was removed in the treated samples than the control one. The dried tomato slices had higher titratable acidity but lower total soluble solids compared to the fresh sample. At 45 °C the titratable acidity for treated samples was significantly higher ($p<0.05$) than that of the control. However, the pH of the control sample was significantly higher ($p<0.05$) than the treated ones. With the exception of the sodium chloride/ white vinegar treated samples, the other two samples experienced a reduction in total soluble solids with increasing drying temperature. The brix/acidity index or taste index of the treatments were significantly higher ($p<0.05$) at 45 °C than at 55 °C. The control recorded a significantly higher taste index value at 45 °C but significantly lower value at 55 °C than the pre-treated samples. The control experienced the least colour quality change but gave the highest browning index value. The sodium chloride/ white vinegar mixture was much effective in reducing browning process compared to the pre-treatment with white vinegar.

Keywords: total soluble solids, titratable acidity, drying, browning, sodium chloride

1. INTRODUCTION

Tomato (*Lycopersicon esculentum Mill.*) is one of the major vegetables in the world. Food and Agricultural Organization Statistics (FAOSTAT, 2010) indicates that the second most cultivated vegetable in the world was tomato, which gave a worldwide production of more than 100 million tons per annum. In Africa, tomato was the ninth commodity and first vegetable in terms of value in the year 2008. In the same year China was the world's largest producer of tomato (FAOSTAT, 2004).

Tomato is known to contain lycopene, a carotenoid which is more efficient in quenching singlet oxygen than other carotenoids (Di Mascio et al., 1989). Epidemiological studies have established that lycopene has a protective effect against prostate cancer (Schwarz et al., 2008). Raw tomato contains less available lycopene than the processed one, and this is because there is a protein-lycopene complex which when broken by processing, releases free lycopene by cis-isomerisation (Hadley et al., 2002).

Fresh tomato is perishable-and to extend its shelf life one form of processing or the other is needed. This reduces post harvest losses and ensures the availability of tomato year-round. Processing helps to lessen the need to till the land continuously, and thus reduces the adverse environmental effect. Many authors have processed tomato into different forms, including juice, ketchup, paste, sauce, soup and powder. In order to ensure the consumer acceptability of the processed product, its properties should not deviate too much from the fresh. Drying is one of the most important processing methods of tomato. Many chemicals including sodium chloride, calcium chloride, potassium metabisulphite and sucrose have been used by many authors (Lewicki et al., 2002; Davoodi et al., 2007; Souza et al., 2007; Marfil et al., 2008) as pre-treatment for tomato drying. The literature is however, limited in the use of white vinegar and sodium chloride/white vinegar mixture as pre-treatment for tomato drying. In addition many investigators have not looked at drying of tomato sliced into one-eighth.

The physichochemical properties of tomato such as pH, titratable acidity, brix, taste index, ash, and total solids are among the important determinants of its consumer acceptability. Titratable acidity and pH are interrelated in terms of acidity, but have different impacts on food quality (Sadler and Murphy, 2010). The total acid available to react with sodium hydroxide solution during titration is titratable acidity whiles the pH gives a measure of the strength of the acid in food (Underhill, 1989). The impact of an acid on food flavour is much more determined by titratable acidity than pH (Sadler and Murphy, 2010). The brix also influences the flavor of food, but the best predictor of an acids flavor impact is the brix/acidity ratio or taste index (Sadler and Murphy, 2010). The pH of food gives an indication of its resistance to microbial attack (Underhill, 1989). Lower pH values have been found to give greater protection to tomato against *Bacillus coagulans* (Rice and Pederson, 1954). Drying may have an effect on pH as well as the brix/acidity ratio. The taste of food is also a very important property. The taste index is used as a measure of degree of taste a food possesses. The drying effect on the properties listed above may also be of interest to food consumers.

The present study was aimed at the use of white vinegar and sodium chloride/white vinegar mixture as pre-treatment for tomato sliced into one-eighth and dried at 45 and 55°C, and the effect on the physicochemical properties such as ash content, pH value, titratable acidity (TA), total soluble solids (TSS) and taste index.

Corresponding author: mhl@ujs.edu.cn

2. MATERIALS AND METHODS

2.1 Determination of moisture content, ash content, pH, total soluble solids, titratable acidity and taste index

The tomatoes for the research were obtained from a local market in China. Samples of tomatoes were selected from the lot based on colour and size uniformity. They were washed three times with tap water, rinsed with distilled water and then wiped with an absorbent paper. Afterwards they were sliced into one-eighth. The slices were pre-treated as follows: treatment 1 (T1) - 60% white vinegar (v/v), treatment 2 (T2) – 0.5492% sodium chloride (w/v) plus 10% white vinegar (v/v) and treatment 3 (T3) – No pre-treatment (Control). The slices were pretreated for 10 min, and the water drained. Moisture content (MC) was assayed using the AOAC (2000) method and total solid was calculated using the formula:

$$\text{\% Total solids} = 100 - \text{\% moisture content} \quad (1)$$

Ashing of the tomato samples was carried out according to the AOAC (2000) method. Five gram dried tomato powder sample was put in a porcelain crucible and ashed in a muffle furnace at 550 °C for 24 hr. The ash was weighed using a balance (Sartorius BS224S, Germany, accuracy-0.0001 g) and the value obtained expressed as percentage using the formula:

$$\text{\% Ash (Wet basis)} = \frac{\text{Mass of ash} \times 100\%}{\text{Mass of fresh sample}} \quad (2)$$

Fresh tomato sample was blended using a Kenwood blender (Philips HR 2006, China). The homogenate was then centrifuged at 1500 rpm for 10 min, and the supernatant used for TSS, pH and TA determinations. In the case of the dried sample 1 g tomato powder was blended with 40 ml of water, filtered with Whatman No. 1 filter paper, and 10 ml aliquot used for the analysis. Total soluble solid was determined by using Abbe Refractometer (WAY-2S, China) with an in-built temperature compensation mechanism, in accordance with AOAC (2000) method. The pH was measured with a pH meter (PHS-2C Precision pH/mV meter, China). Standard buffer solutions of pH 7 and 4 were used to standardize the pH meter, after which pH was determined. The method for TA was according to (Sadler and Murphy, 2010) where 10 ml tomato juice was titrated against 0.1 N Sodium hydroxide solution to a pink end-point using phenolphthalein indicator. The TA was calculated using the formula:

$$\text{TA (\% wt/vol)} = \frac{N \times V_1 \times \text{Eq.Wt}}{V_2 \times 10} \quad (3)$$

Where N = normality of NaOH, V_1= volume of NaOH, V_2 = volume of sample and Eq.Wt = equivalent weight of predominant acid (citric acid)

The taste index was calculated using the formula:

$$\text{Taste Index} = \frac{\text{Total soluble solids (}^{o}\text{B)}}{\text{Titratable Acidity (\%)}} \quad (4)$$

2.2 Colour parameters

Colour of dried tomatoes was measured using an automatic colour difference meter (DC-P3, Beijing, China). In every measurement a white standard board was used to calibrate the instrument. Three replicate measurements were made in each case. CIELab values for the samples L*, a* and b* were obtained. L* indicates lightness (ranging from 0 to 100), with 0 being black and 100 being white. The coordinates a* measures red (+) and green (-), and b* is for yellow (+) and blue (-) (Wrolstad and Smith, 2010). According to (Shi et al., 1999), a*/b* is commonly used as an index to report the colour quality (brightness of red colour) of tomato. The a*/b* values of the fresh and dried samples were calculated. In addition 100-L* values were also calculated and used to express browning index (Fernandez-Artigas et al., 1999).

2.3 Drying procedure

The tomato slices were dried using an adjustable cabinet oven dryer (Shanghai Experimental Apparatus Company Limited, 101C-3B). The dryer operates at a voltage of 230/380 V, frequency of 50 Hz, power of 59 kW, and has a maximum operating temperature of 300° C. Two drying temperatures, i.e 45 and 55 °C were studied. The moisture content of the tomato slices were monitored and measured every 2 hours until equilibrium moisture content was obtained.

2.4 Statistical analysis

Data collected were subjected to one-way analysis of variance (ANOVA) using statistical package for social scientists (SPSS) and differences were separated using the least significance difference (LSD)

3. RESULTS AND DISCUSSION

3.1 Drying curves

The drying curves of the tomato slices dried at 45 and 55 °C are shown in Figs. 1 and 2. Drying at 45 °C followed a falling rate period throughout. However at drying temperature, 55 °C, drying initially followed the falling rate, but became almost constant for some time before the falling rate period was resumed. Both constant and falling rate periods in microwave assisted hot air ventilation drying of tomato slices have been reported (Workneh et al., 2011). At drying temperature 45 °C it took 45.6, 44, and 44.8 h for T1, T2, and T3 respectively to dry to equilibrium moisture content of 15% (dry basis). Also at drying temperature 55 °C, T1, T2, and T3 took 44, 43.9, and 49.5 h respectively to dry to 15% moisture content (dry basis). The treated samples dried faster than the control at 55 °C. Acid blanched carrots samples were reported to dry faster than the

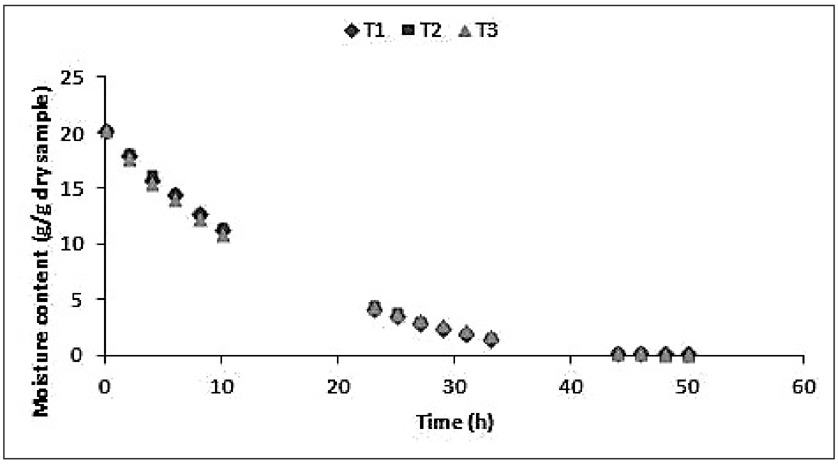

Figure 1. Drying curve of dried tomato slices at 45 °C

untreated samples and samples soaked in water (Hiranvarachat et al., 2011). In addition Doymaz (2010) reported faster drying rate for citric acid-treated red apples compared with the control. The acetic acid in the samples treated with vinegar might have facilitated the loosening of the cell wall structure, thereby enhancing water removal (Micheli, 2001). In addition the sodium chloride in T2 might have brought about osmotic removal of moisture. Mohseni and Ghavidel (2011) have reported the enhancement of moisture removal by sodium chloride treatment in tomato slices. The time taken to achieve equilibrium moisture content of 15% (dry basis) for T1 (white vinegar-treated sample) at 55 °C was slightly shorter than that at 45 °C, but for T2 (sodium chloride/white vinegar-treated sample) it was the same at both temperatures, and in the case of T3 (control), there was a 10.5% increment in the drying time from 45 °C to 55 °C. Drying time generally reduces with increasing temperature, however, in the present study T2 and T3 did not exhibit this trend. The nearly constant rate period (Fig.2) experienced by the samples may account for this observation.

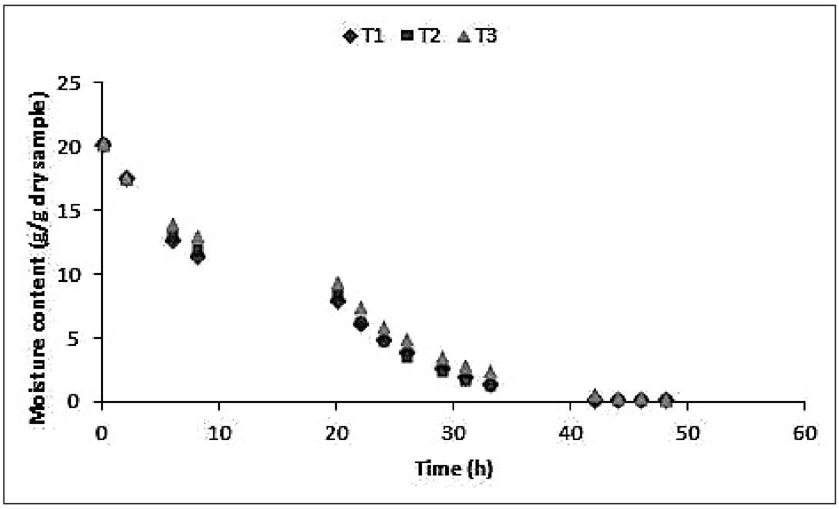

Figure 2. *Drying curve of dried tomato slices at 55 °C*

3.2 Physicochemical properties of fresh and dried tomato

The results on moisture content of the pre-treated tomatoes are shown in Table 1. These results are comparable to the 94.4% reported for sundried tomato (Sohail et al., 2011), and 94.45% reported for SEL-7 tomato genotype (Gupta et al., 2011). The moisture content (MC) of T1 and T2 were not significantly different, however each of them was significantly higher than T3. The results indicate that significantly much moisture was removed in T1 and T2 compared to T3. Even though the MC in T1 and T2 were not significantly different, the latter removed much moisture, and this may be due to the osmotic ability of sodium chloride in the sodium chloride/white vinegar pre-treatment. Increased moisture removal for sodium chloride-treated dried tomato was reported (Davoodi et al., 2007; Ghavidel and Davoodi, 2010).

Means with the same superscripts are not significantly different (p>0.05). Means were calculated from triplicate measurements.

Also the dry matter content of T3 was significantly higher than that of T1 and T2, but the differences between the two were not statistically significant (Table 1). The ash content of each treatment differed from all the others significantly (Table 1), and was slightly lower than 0.48 and 0.53% (wet basis) previously reported for two different genotypes of tomato (Gupta et al., 2011). Motegaonkar and Salunke (2012) also found ash content of 0.508% (wet basis) in tomato. Ash gives an idea about the mineral composition of food (Harbers, 1994). The ash content of T2 was significantly higher than that of T1 and T3. The presence of sodium chloride in T2 may account for this observation.

The fresh tomato recorded pH and titratable acidity (TA) values of 4.24±0.1 and 0.24±0.05% respectively (Table 1). Mean pH of 4.38 and 4.02 were reported for fresh tomato by Kerkhofs et al. (2005) and Muratore et al. (2008) respectively. The TA values of the dried tomatoes slices were significantly higher than the fresh sample (Tables1). Both TA and pH of all tomato treatments were found to be statistically significant in terms of temperature (Table 1). The TA increased with increasing drying temperature, however, the pH showed a decreasing trend. This observation has also been reported by (Hamdy and Gould, 1962). Drying of leeks at 63 ± 2 °C for 3 h with an air velocity of 2.5 m/s led to an increase in TA but a decrease in pH (Ozgur et al., 2011). The results on TA agree with what was reported by (Toor and Savage, 2006) for tomatoes semi-dried at 42 °C, in which TA increased upon drying. In addition Purkayastha and Mahanta (2011) reported an increase in TA from 0.3867±1.01 to 0.427±0.03 (% citric acid) for the tomato cultivar *sel-2* upon drying. The increase in TA with drying temperature may be due to the organic acids in tomato becoming more concentrated while the reduction in pH with drying tem-

Table 1. *Physicochemical properties of fresh and dried tomato*

Fresh sample	T1	T2	T3	Physicochemical property			
MC (%)	95.4±0.1^{a}	95.5±0.1^{a}	94.9±0.5^{b}	PH	TSS	TA	TSS/TA
DM (%)	4.6 ±0.1^{a}	4.5±0.1^{a}	5.1±0.5^{b}				
ASH (%w.b)	0.40 ±0.00^{a}	0.43±0.01^{b}	0.38±0.01^{c}				
	Fresh sample			4.24±0.01^{a}	4.9±0.1^{a}	0.24±0.00^{a}	20.4±4.7^{a}
Sample dried at 45	T1			4.20±0.01^{b}	3.90±0.10^{b}	0.47±0.02^{b}	8.3±0.74^{b}
	T2			4.30±0.01^{c}	3.80±0.10^{b}	0.45±0.00^{b}	8.4±0.22^{b}
	T3			4.48±0.01^{d}	4.40±0.00^{c}	0.32±0.00^{c}	13.8±0.00^{c}
Sample dried at 55	T1			4.14±0.01^{e}	2.90±0.02^{d}	0.70±0.01^{d}	4.1±0.09^{d}
	T2			4.27±0.01^{f}	3.86±0.01^{b}	0.64±0.00^{e}	6.0±0. 02^{e}
	T3			4.36±0.00^{g}	1.93±0.01^{e}	0.70±0.00^{d}	2.8±0.01^{d}

Means with the same superscripts are not significantly different (p>0.05). Means were calculated from triplicate measurements.

perature may be due to increased dissociation of the organic acids with temperature. At 45 °C, TA of T1 and T2 were significantly higher than that of the control. Sodium chloride-treated tomato slices dried in solar and tunnel driers were reported to have a slightly higher acidity than the control (Ghavidel and Davoodi, 2010). In addition potassium metabisulphite/sodium chloride pretreated dried tomato slices were reported to have slightly higher acidity than the control (Davoodi et al., 2007). The TA of T1 and T2 were not significantly different. The results showed that the pH of T1 was significantly lower than that of T2 and T3 ($p<0.05$). Also T2 had a significantly lower pH than T3. Rice and Pederson (1954) have reported greater inhibition of *Bacillus coagulans* at lower pH in tomatoes. Thus after drying, T1 may have a better microbiological stability than T2 and T3.

The TSS of the fresh tomato was 4.9±0.1 °Brix, and is similar to 5.1 ± 0.09 and 4.7 ± 0.10 °Brix reported for Flavourine and Tradiro tomato cultivars (Toor and Savage, 2006). Gupta et al. (2011) also reported TSS of 5.1 and 5.5 °Brix for two genotypes of tomato. The fresh tomato had significantly higher total soluble solids (TSS) than the dried samples (Table 1). This is in disagreement with what was reported by Ashebir et al. (2009) where TSS of untreated tomato slices increased upon drying. The TSS of all the treatments differed significantly at temperatures 45 °C and 55° C. With the exception of T2, there was a reduction in TSS of T1 and T3 with increasing temperature. The TSS of T1 was significantly different from T2 and T3, and T2 was also significantly different from T3. The decrease in TSS upon drying and with increasing drying temperature may be due to caramelization (Smith and Hui, 2004). In the present study the TSS of treated samples at drying temperature 55° C was significantly higher than the control (Table 1). This agrees with what was reported for calcium chloride-treated and calcium chloride/potassium metabisulphite-treated dried tomato slices (Ghavidel and Davoodi, 2010).

The brix/acidity (TSS/TA) index or taste index of the treatments were significantly higher at 45 °C than at 55 °C (Table 1). The TSS/TA index of T3 was significantly higher than that of T1 and T2. The respective TSS/TA indices for T3, T2 and T1 at 45°C were 13.8, 8.4 and 8.3. Brix/acidity is considered to be the best predictor of an acids flavor impact on food (Sadler and Murphy, 2010). Tomato has a good flavor when it has TSS/TA ratio greater than or equal to 10 (Kader et al., 1978). The TSS/TA values greater than or equal to 10 have been reported for tomatoes (Caliman et al., 2010). Purkayastha and Mahanta (2011) also reported 12.360 TSS/TA index value for sel-3 tomato cultivar. The higher the TSS/TA index the sweeter and less tart a food product is. In the present study T3 had a TSS/TA index greater than 10 and, which was significantly higher than that of T1 and T2 at 45 °C, therefore T3 may be sweeter and less tart in taste. However, at 55 °C, T2 was significantly higher in terms of TSS/TA index compared to T1 and T3. The significantly higher TSS/TA index value for T3 at 45 °C and T2 at 55 °C may be due to the highest TSS but lowest TA values they recorded.

3.3 Colour parameters

The colour quality indicators (a*/b*) are shown in Table 2. At both drying temperatures the control sample gave a higher (a*/b*) value than the treated ones. This is similar to those reported for cherry tomato dried at 40 and 60 °C (Muratore et al., 2008). At 45 °C, the percentage reduction in colour quality, upon drying, recorded for T1 was 4, percentage increment for T2 and T3 respectively were 2.5 and 4. However, at 55 °C the recorded percentage reductions were 52, 48 and 47 for T1, T2 and T3 respectively. The value a*/b* is commonly used as an index to report the colour quality (brightness of red colour) of tomato (Shi et al., 1999). Shi et al. (1999) have reported a 50% decrease in a*/b* and (Kerkhofs et al., 2005) have also reported a 25% decrease in a*/b* value of dried tomato. In addition, Ashebir et al. (2009) reported a significant reduction in a*/b* upon drying of tomato slices. On the other hand a 37-42% increase in a*/b* for dried tomato varieties Tradiro and Flavourine, and 26% for Excell have been reported (Toor and Savage, 2006). The present results indicate that at 45 °C, T2 and T3 experienced percentage increase in colour quality over the fresh sample whiles T1 showed a reduction. Also at 55 °C, all the three treatments recorded percentage decrease in colour quality. This was as a result of decrease in a* but increase in b*. At the lower temperature T3 experienced the highest colour quality increment followed by T2. The least reduction in percentage colour quality was recorded by T3, followed by T2 and T1. At both temperatures, the control gave the best percentage colour quality retention followed by T2.

Table 2. *Colour parameters*

	Treatments at different drying temperatures					
	T1		T2		T3	
Colour parameter	**45 °C**	**55 °C**	**45 °C**	**55 °C**	**45 °C**	**55 °C**
a* (fresh sample)	20.05±0.01	32.67±0.02	20.05±0.01	32.67±0.02	20.05±0.01	32.67±0.02
b* (fresh sample)	25.19±0.02	30.19±0.01	25.19±0.02	30.19±0.01	25.19±0.02	30.19±0.01
a* (dried sample)	22.56±0.01	20.30±0.03	24.40±0.02	22.13±0.02	23.91±0.02	23.38±0.01
b* (dried sample)	29.45±0.06	38.86±0.06	29.89±0.04	39.58 ±0.11	28.76±0.09	41.22±0.05
a*/b* (fresh sample)	0.80±0.00	1.08±0.00	0.80±0.00	1.08±0.00	0.80±0.00	1.08±0.00
a*/b* (Dried sample)	0.77±0.00	0.52±0.00	0.82±0.00	0.56 ±0.00	0.83±0.00	0.57±0.00
% change in a*/b*	-4	-52	+2.5	-48	+4	-47
L*	51.24±0.03	64.35±0.01	52.22±0.05	67.56±0.02	49.89±0.04	61.96±0.02
100-L*	48.76±0.03	35.7±0.01	47.78±0.05	32.4±0.02	50.11±0.04	38.0±0.02

Means were calculated from triplicate measurements

Lightness, L* values of treated samples were higher than the control at drying temperatures 45 °C and 55 °C (Table 2). Muratore et al. (2008) reported similar results for dried cherry tomato at 40 and 60 °C. In addition the L* values of both treated and the control sample increased with drying temperature. Dried green kiwifruits were reported to have increased L* values with increasing drying temperature (Diamante et al., 2010). Abano et al. (2011) have reported increased L* values from 45 to 50 °C for garlic samples treated with citric acid and potassium metabisulphite. Browning index values calculated as 100-L* (Fernandez-Artigas et al., 1999) are shown in Table 2. The 100-L* values for all treatments were higher at 45 °C than 55 °C. At 45 °C the values were 50.11±0.04, 48.76±0.03 and 47.78±0.05 respectively for T3, T1 and T2. Also at 55 °C, T3, T1 and T2 recorded 38.0±0.02, 35.7±0.01 and 32.4±0.02 respectively. The decrease in browning index with temperature was unexpected because browning generally increases with temperature. The tomato slices experienced case hardening at 55 °C, and moisture removal slowed down, some hours after commencement of drying (Fig. 2), and this might have accounted for the decrease in browning index value. The results show that at both temperatures browning was highest in T3 followed by T1 and T2. This means that the sodium chloride/vinegar mixture was more effective in browning reduction than the white vinegar pre-treatment. Browning reduction in sodium chloride-treated tomato slices compared with the control was previously reported (Mohseni and Ghavidel, 2011).

4. CONCLUSION

The purpose of this study was to investigate the drying effect of pre-treated tomato slices on the physicochemical properties pH value, titratable acidity, total soluble solids, brix/acidity index, colour quality changes and browning index. The titratable acidity for treated samples were significantly different ($p<0.05$) from the control one. However, the pH of the control was significantly higher ($p<0.05$) than the treated samples, indicating that the pre-treated dried samples have better preservation potential than the control. With the exception of sodium chloride/white vinegar mixture-treated samples, there was a reduction in TSS of the other two treatments with increasing drying temperature. The brix/acidity (TSS/TA) index or taste index of the treatments were significantly higher ($p<0.05$) at drying temperature of 45 °C compared to 55 °C. Even though the control gave the least colour quality reduction, it also showed the greatest browning index. The treated samples exhibited lower browning index compared to the control.

AKNOWLEDGEMENT

This project was funded by the Priority Academic Program Development (PAPD) of Jiangsu Higher Education Institutions.

REFERENCES

Abano E. E., Ma H., Qu W., Teye E. (2011) Modelling pre-treatments effect on drying kinetics of garlic (*Allium sativum L.*) slices in a convective hot air dryer. *African Journal of Food Science,* 5 (5) 148-155.

AOAC (2000) Official Methods of Analysis of the Association of Official Analytical Chemists. 17th ed. AOAC International, Maryland.

Ashebir D., Jezik K., Weingartemann H., Gretzmacher R. (2009) Change in colour and other fruit quality characteristics of tomato cultivars after hot-air drying at low final-moisture content. *International Journal of Food Science and Nutrition,* 60 (7) 308-315.

Caliman F. R. B., da Silva D. J. H., Stringheta P. C., Fontes P. C. R., Moreira, G. R., Mantovani, E. C.(2010) Quality of tomatoes grown under a protected environment and field conditions. *IDESIA (Chile),* 28 (2) 75-82.

Davoodi M. G., Vijayanand P., Kulkari S. G., Ramana K. V. R. (2007) Effect of different pre-treatments and dehydration methods on quality characteristics and storage stability of tomato powder. *LWT-Food Science and Technology*, 40 1832-1840.

Diamante L., Durand M., Savage G., Vanhanen L. (2010) Effect of temperature on the drying characteristics, colour and ascorbic acid content of green and gold kiwifruits. *International Food Research Journal*, 17, 441-451.

Di Mascio P., Kaiser S., Sies H. (1989) Lycopene as the most efficient biological carotenoid singlet oxygen quencher. *Archives Biochemistry and Biophysics*, 274 532-538.

Doymaz I. (2010) Effect of citric acid and blanching pretreatments on drying and rehydration of Amasya red apples. *Food and Bioproducts Processing,* 88 124-132.

FAOSTAT (2010). http://faostat.fao.org/site/1367/Default.aspx. Accessed: 24.02.2011.

FAOSTAT (2004). Core Production data database. Food and Agricultural Organization of the United Nations. http://faostat.fao.org/site/567/ Default.aspx#ancor. Accessed: 24.02.2011.

Fernandez-Artigas P., Guerra-Hernandez E., Garcia-Villanova B. (1999) Browning indicators in model systems and baby cereals. *Journal of Agriculture and Food Chemistry,* 47 2872-2878.

Ghavidel R. A., Davoodi M. G. (2010) Studies on Physicochemical Properties of Tomato Powder as Affected by Different Dehydration Methods and Pretreatments. *World Academy of Science, Engineering and Technology*, 69 596-605.

Gupta A., Kawatra A., Sehgal S. (2011) Physical-chemical properties and nutritional evaluation of newly developed tomato genotypes. *African Journal of Food Science and Technology*, 2(7) 167-172.

Hadley C. W., Miller E.C., Schwartz S. J., Clinton S. K. (2002) Tomatoes, Lycopene, and Prostate Cancer: Progress and Promise, *Experimental Biology and Medicine*, 227 869-880.

Hamdy M. M., Gould W. A. (1962) Varietal differences in tomatoes: a study of alpha-keto acids, alpha-amino compounds and citric acid in eight tomato varieties before and after processing. *Journal of Agriculture and Food Chemistry,* 10 499-503.

Harbers L. H. (1994) Ash Analysis. In: Nielson S. S. (ed): Introduction to the Chemical Analysis of Foods. str. 113-121. Jones and Bartlett, Boston.

Hiranvarachat B., Devahastin S., Chiewchan N. (2011) Effects of acid pretreatments on some physicochemical properties of carrot undergoing hot air drying. *Food and Bioproducts Processing*, 89 116-127.

Kader A. A., Morris L. L., Stevens M.A., Albright-Holton M. (1978) Composition and flavor quality of fresh market tomatoes as influenced by some postharvest Handling procedures. *Journal of the American Society for Horticultural Science*, 113 742-745.

Kerkhofs N. S., Lister C.E., Savage G. P. (2005) Change in colour and antioxidant content of tomato cultivars following forced-air drying. *Plant Foods for Human Nutrition*, 60 117-121.

Lewicki P. P., Vule H., Pamaranska-Lazuka W. (2002) Effect of pre-treatment on convective drying of tomatoes. *Journal of Food Engineering*, 54 141-146.

Marfil P. H. M., Santos E. M., Telis V. R. N. (2008) Ascorbic acid degradation kinetics in tomatoes at different drying conditions. *LWT-Food Science and Technology*, 41 1642-1647.

Micheli F. (2001) Pectin methylesterases: cell wall enzymes with important roles in plant physiology. *Trends in Plant Science*, 6 414-419

Mohseni S., Ghavidel R. A. (2011) Effect of pre-drying treatments on quality characteristics of dehydrated tomato slices. *World Academy of Science, Engineering and Technology*, 59 2205-2215.

Motegaonkar M. B., Salunke S. D. (2012) The Ash and Iron Content of Common Vegetable Grown in Latur District, India. *Research Journal of Recent Sciences,* 1(4) 60-63.

Muratore G., Rizzo V., Licciardello F., Maccarone E. (2008) Partial dehydration of cherry tomato at different temperature, and nutritional quality of the products. *Food Chemistry*, 111 887-891.

Ozgur M., Akpinar-Bayizit A., Ozcan T., Yilmaz-Ersan L. (2011) Effect of dehydration on several physico-chemical properties and the antioxidant activity of leeks (*Allium porrum L.). Notulae Botanicae Horti Agrobotanici Cluj-Napoca,* 39 (1) 144-151.

Purkayastha M. D., Mahanta C. L. (2011) Physicochemical properties of five different tomato cultivars of Meghalaya and their suitability in food processing. *African Journal of Food Science,* 5 (12) 657-667.

Rice A. C., Pederson C. S. (1954) Factors influencing growth of *Bacillus coagulans* in canned tomato juice. 2. Acidic constituents of tomato juice and specific organic acids. *Food Research,* 19 124-133.

Sadler G. D., Murphy P. A. (2010) pH and Titratable Acidity. In: Nielson S. S. (ed): Food Analysis. str. 219-238. Springer Science + Business Media, LLC2010. New York, USA.

Schwarz S., Obermuller-Jevic U. C., Hellmis E., Koch W., Jacobi G., Biesalski, H-K. (2008) Lycopene inhibits disease progression in patients with benign prostate hyperplasia. *Journal of Nutrition,* 138 49-53.

Shi J., Le Maguer M., Kakuda Y., Liptay A., Niekamp, F. (1999) Lycopene degradation and isomerization in tomato dehydration. *Food Research International*, 32 15-21.

Smith J. S., Hui Y. H. (2004) Food Processing: Principles and Applications. Blackwell Publishing Professional, USA.

Sohail M., Ayub M., Ahmad I., Dad F. (2011) Physico-chemical and microbiological evaluation of sun dried tomatoes in comparison with fresh tomatoes. *Pakistan Journal of Biochemistry and Molecular Biology*, 44(3) 106-109.

Souza J. S., Medeiros M. F. D., Magalhaes M. M. A., Rodrigues S., Fernandes F. A. N. (2007) Optimization of osmotic dehydration of tomatoes in a ternary system followed by air-drying. *Journal of Food Engineering*, 83 501-509.

Toor R. K., Savage G. P. (2006) Effect of semi-drying on the antioxidant components of tomatoes. *Food Chemistry*, 94 90-97.

Underhill J. E. (1989) pH without pain. The Grapevine: A newsletter for winemakers in British Columbia.

T.S. Workneh T. S., Raghavan V., Gariepy Y. (2011) Microwave Assisted Hot Air Ventilation Drying of Tomato Slices. Proceedings of 2011 International Conference on Food Engineering and Biotechnology. IPCBEE. Vol. 9. IACSIT Press, Singapore.

Wrolstad R. E., Smith D. E. (2010) Colour Analysis. In: Nielson S. S. (ed): Food Analysis. str. 575-586. Springer Science + Business Media, LLC2010. New York. USA.