Blanching, salting and sun drying of different pumpkin fruit slices

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Abstract The study was aimed at assessing the quality of pumpkin (*Cucurbita Spp.*) slices that were subjected to pre-drying treatments and drying using two drying methods (uncontrolled sun and oven) fruit accessions. Pre-drying had significant ($P \leq 0.05$) effect on the quality of dried pumpkin slices. 10 % salt solution dipped pumpkin fruit slices had good chemical quality. The two-way interaction between drying methods and pre-drying treatments had significant ($P \leq 0.05$) effect on chemical qualities. Pumpkin subjected to salt solution dipping treatment and oven dried had higher chemical concentrations. Among the pumpkin fruit accessions, pumpkin accession 8007 had the superior TSS, total sugar and sugar to acid ratio after drying. Among the three pre-drying treatment, salt solution dipping treatment had significant ($P \leq 0.05$) effect and the most efficient pre-drying treatment to retain the quality of dried pumpkin fruits without significant chemical quality deterioration. Salt dipping treatment combined with low temperature (60 °C) oven air circulation drying is recommended to maintain quality of dried pumpkin slices. However, since direct sun drying needs extended drying time due to fluctuation in temperature, it is recommended to develop or select best successful solar dryer for use in combination with pre-drying salt dipping or blanching treatments.

Keywords Pumpkin · Salting · Blanching · Pre-drying treatment · Drying · Chemical quality · Accession · Ethiopia

Introduction

In Africa, farmers produce pumpkin in their gardens together with cereals, in farms near fences for the plants to easily creep on fences and houses, marginal or waste land, on decaying hay and heap of cow dung. Pumpkin cultivars that are being produced by farmers are not yet well identified and characterized. Suitable agro-ecologies for pumpkin cultivation aiming at better performance of cultivars, suitable fruit quality and seed storage methods for the extension of their shelf life and for different fruit utilization as a food was not well studied. There are wide variations in fruit size, weight, shape, color, vine length and branching, leaf size, overall fruit subjective and chemical qualities and seed size among varieties that are under utilization in African countries such as Ethiopia.

In Ethiopia, pumpkins are widely grown for their fruit utilization that are effectively and efficiently being used for stew preparation to be consumed with Ethiopian traditional spongy thin-layer bread (*injira*) made from cereal grain called *teff*. The other most important food product from pumpkin fruit is dried pumpkin which is called ‘*Duba quanta*’ although the effects of drying are not studied. This dried product is used for making delicious stew called ‘*Duba Wett*’ and highly used during the period of food scarcity. Pumpkin is a seasonal crop that has been used for human food. Thus, drying can be a useful preservation technique for the storage of pumpkin for long period.

The dried pumpkin can be stored for a long period of time due to low activities of microorganisms and enzymes resulting from lower water activities in the final dehydrated products compared to fresh once (Alibas 2007). This leads to high shelf life which contributes to food security. Pre-drying treatments like blanching and dipping in salt solution could also be used to improve quality. Pre-drying treatments could be used to preserve color and flavor, minimize nutrient loss, stop decomposition (enzyme action), and ensure more even drying and to extend storage the shelf life of

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pumpkin (Alibas 2007). Similarly, blanching is carried out to improve food quality by inactivating enzymes, reducing microorganisms and preserve the natural color when pumpkin after blanching is subjected to drying (Brennand 1994). Although, traditionally in Ethiopia consumers pre-treatment and sundry pumpkin fruit aiming at long term storage for use during off season as part of food security schedule, there is no drying research activity. These implicated the need for research on the effects of two pre-drying treatments (blanching and salt water dipping) and two drying methods (sun and oven) on the chemical quality of pumpkin fruit slices. The objective of this study is, therefore, to evaluate the effects of pre-drying treatments and methods of drying on some chemical qualities of pumpkin fruit.

Materials and methods

Sample production The pumpkin fruits with their viable seeds were collected from the Jijiga, Dire-Dawa, Kulubi, Harar and Lange market based on their morphological characteristics and variation by taking growing areas in to consideration. Twenty pumpkin fruit accessions collected from eastern Ethiopia with the reference codes of 8007, 7607, 4707, 4007, 5207, 7807, 3607, 8807, 1907, 8307, 1407, 6907, 3407, 7207, 2807, 7107, 3907, 9107, 7707 and 1307 were used for the study. Then, these 20 accessions were grown in the Haramaya University Research Farm during the main growing season. All the 20 pumpkin accessions were produced in the same experimental plot in three replications. The Haramaya University is located at latitude of 9° 26' N and longitude of 42° 03' east and an altitude of 1,980 m.a.s.l. The rainfall of the area is bimodal (in April and August) type with an average annual rainfall of 790 mm. The mean annual temperature is 17 °C with mean minimum and maximum temperatures of 3.8 and 25 °C, respectively. The mean relative humidity is 50 %, varying from 20 to 81 % and the soil type of the area is well-drained deep clay loam type. After maturity of the fruits 20 pumpkin accessions were used for fresh fruit quality assessment. Samples of three fruits from each accession were taken for the analysis.

Experiment design The experimental design consists of 20 pumpkin accessions, three pre-drying treatments (blanching, salting and control (untreated)) and two drying methods (oven and sun drying). 300 g of slices were used for each treatment replications. The experiment was conducted in split plot with three replications. The two drying methods were used as the main plot while the two pre-drying treatment by 20 pumpkin fruit accessions treatment combinations were used as the sub plot. From the three fruits that were randomly selected from each accession, three fourth was taken from each of the three

fruits, sliced and mixed together. Then, 300 g of pumpkin fruit slices were weighed and subjected to the three pre-drying treatment (salting, blanching and control) for both drying conditions (oven and sun).

Sample preparation Three mature fruits were randomly selected from each 20 pumpkin fruit accessions. The fruits were washed, peeled and chopped into uniform strips of 2.54 cm. The fiber and seed were scraped off. The peeled strip was then cut into uniform slabs of 40 mm length, 20 mm width and then sliced into 5 mm thickness (Are'valo-Pinedo and Fernanda 2006). Pumpkin slices were weighed and blanched in water at 60 °C blanching temperature for 1 min in a constant temperature hot water bath. After blanching, the samples were drained and the slices were spread for drying (O'Dell 1999). On the other hand, other groups of pumpkin slices were weighed and then dipped in a 10 % salt solution for 10 min. The slices were drained well and spread for drying using two drying conditions (oven and uncontrolled sun drying) (Mayor et al. 2006).

Drying Three hundred grams of sample slices were used in each treatment. The samples were arranged in a single thin-layer and were removed every 2 h for weighing during drying in an oven at 60 °C and uncontrolled sun drying until the moisture content of the dried pumpkin slices become 10 %. The relative humidity of the ambient air during drying was measured by the hygrometer (model No. 8612, sensitivity±1.09). The relative humidity varied between 20 % and 43.5 % while remained to be 6.5 % for open sun drying and oven drying, respectively. The dry-bulb temperature was measured using the same hygrometer and was varied between 20.2 and 30.2 °C for sun drying and kept constant at 60 °C for oven drying, respectively.

Initial moisture content Initial moisture content of pumpkin fruit was determined by oven drying method using samples of fresh pumpkin weighing 100 g at 70 °C until the weight of the dried sample became stable according to the procedure of AOAC (1984).

Total soluble solids The total soluble solid (TSS) of dried pumpkin fruit was determined following the procedures as described by Awole et al. (2011), Tigist et al. (2011), Workneh et al. (2011). The dried pumpkin fruit was re-hydrated back to its initial moisture content using the methods of Dahlman and Forst (2001). An aliquot of juice was extracted from the re-hydrated pumpkin fruit using a juice extractor. Then, 50 ml of the slurry was filtered using cheesecloth. The TSS content was determined by Abbe refractometer with a range of 0–32 °Brix by placing one to two drops of clear juice. The refractometer was washed

with distilled water and dried before use and between each sampling. The refractrometer was standardized against distilled water (0 % TSS).

pH values The pH value of dried pumpkin fruit was measured using the method of Nunes and Emond (1999). An extract of an aliquot of juice was extracted from the rehydrated pumpkin fruit slices and filtered with cheesecloth. Then, the pH value of the pumpkin fruit juice was measured using the Metrohn 691 pH meter.

Titrateable acidity Total titrateable acidity (TA) of the pumpkin fruit was measured according to Maul *et al.* (2000). The decanted clear juice was used for the analysis of TA. The TA was expressed as percent citric acid by titrating 10 ml of rehydrated dried fruit juice with 0.1 N NaOH to pink end point (persisting for 15 s.).

Ascorbic acid Ascorbic acid (AA) content was determined by the 2, 6-dichlorophenol indophenols methods (AOAC 1970). An aliquot of 10 ml of rehydrated dried pumpkin fruit juice was diluted to 50 ml with three percent metaphosphoric acid in a 50 ml volumetric flask. Then, the aliquot was titrated with the standard dye to a pink end point (persisting for 15 s.). The ascorbic acid content is then calculated from the titre value.

Sugar analysis Reducing and total sugars were estimated by using the calorimetric methods (Somogyi 1945). An aliquot of juice was extracted and the clear juice (10 ml) was added to 15 ml of 80 % ethanol, mixed, and heated in a boiling water bath for 30 min. After extraction, 1 ml of saturated lead acetate ($\text{Pb}(\text{CH}_3\text{COO})_2 \cdot 3\text{H}_2\text{O}$) and 1.5 ml of saturated sodium hypophosphate (Na_2HPO_4) were added and the contents were mixed by gentle shaking. After filtration, the extract was made up to 50 ml with distilled water. An aliquot of 1 ml extract were taken and diluted to 10 ml with distilled water. Then, 0.5 ml aliquot of extract was taken and made up to 1 ml. To this 1 ml of copper reagent was added in a test tube and heated for 20 min in a boiling water bath. After heating, the contents were cooled under running tap water without shaking. Arsenomolybdate color reagent was added, mixed, made up to 10 ml, and left for about 10 min to allow color development, after which the absorbance was determined by a spectrophotometer at 540 nm. For total sugar determination, sugar was first hydrolyzed with 1 N HCl by heating at 70 °C for 30 min. After hydrolysis, the determination of total sugar was made by following the same procedure employed for the reducing sugar. Blanks were prepared using distilled water instead of extract.

Sugar to acid ratio The sugar to acid ratio of the fruits was calculated by dividing TSS to total TA of the fruits (FAO 2001).

Data Analysis The experimental design was arranged with 20 pumpkin accessions, three pre-drying treatments and two drying methods in split plot with three replications. Significance tests were made by the analysis of variance (ANOVA) for completely randomized design (CRD) and in split plot design according to Gomez and Gomez (1984). ANOVA was carried out with an MSTAT-C software package (MSTAT, Michigan Univ. East Lansing). Comparisons of the treatment means were done using Duncan's multiple range test (Duncan 1955).

Results and discussion

Drying time The initial moisture content of pumpkin fruit ranged from 89 % for pumpkin accession 8007 to 94 % for pumpkin fruit accession 1307. The moisture loss was faster during oven drying than during uncontrolled sun drying (Fig. 1). The oven dried pumpkin fruit slices required about 20 h to reach 10 % moisture content while sun drying took 28 h to attain the moisture content of 10 %. This result agrees with the finding of Rahman and Lamb (1991) who reported that oven drying enhances moisture loss from the fruit and vegetables when compared with uncontrolled sun drying. Sun drying requires longer drying time and depends on the environmental conditions such as ambient air temperature and relative humidity (Rajkumar 2007). On the other hand, pumpkin fruit accessions had significant ($P \leq 0.05$) influence on the time of drying (Fig. 1). The time taken for all pumpkin fruit accession to reach 10 % moisture content ranged from 20.3 to 28.3 h. Pumpkin fruit accession 8007 took short drying time of 20.3 h to attain 10 % of moisture content which was followed by accessions 5207.

Fig. 1 Mean moisture loss of pumpkin fruit subjected to sun and oven drying conditions

The three pre-drying treatments had significant ($P \leq 0.05$) effect on the time of drying (Table 3). Salted pumpkin fruit slices that was dried in the oven had significantly ($P \leq 0.05$) shorter time of drying (23.8 h) and was followed by blanched pumpkin fruit slices (24.2 h) while untreated control pumpkin fruit slices took longer time of drying (25.1 h). This result was found to be in positive agreement with the findings of Mayor et al. (2006) that clearly showed that salt solution dipping reduces the time of drying. The data presented in this study confirmed that the main advantage of pre-drying treatment is shortening the time of drying and then resulting in lower energy requirements for drying (Tsotsas and Mujumdar 2012). Blanching reduces the time of drying through reducing the firmness of fruit tissue and facilitates moisture diffusion from sample fruit slices and thereby reducing the required time of drying (Brennand

1994). Blanching is one of the most widely used pre-drying treatments in the dehydration procedures of most fruits and vegetables (McBean et al. 1964). Research reports clearly showed that using appropriate drying conditions and pre-drying treatment significantly reduces the drying time of other fruit and vegetables (Park et al. 2002; Simal et al. 1997).

The two-way interaction between drying methods and pre-drying pretreatment significantly ($P \leq 0.05$) affected the drying time of pumpkin accession (Tables 1 and 2 and Fig. 2). Salted pumpkin fruit accession that were subjected to oven-drying required short drying time (18 h) which was followed by blanched oven dried sample (20 h) to attain 10 % moisture content. Sun dried pumpkin fruit took relatively longer drying time (32 h) to attain 10 % moisture content (Table 3).

Table 1 The pooled effect of drying methods, accessions and pre-drying treatment on chemical composition and drying time of the 20 pumpkin accessions

Factor	Level	TSS ($^{\circ}$ Brix)	TS (g 100 g $^{-1}$)	RS (g 100 g $^{-1}$)	Drying Time (h)
Drying methods	Oven	8.5 ^a	5.4	3.2	21.0 ^b
	Sun	8.1 ^b	5.3	3.2	28.0 ^a
	SE($\pm$)	0.554	0.053	0.022	0.131
	LSD	0.317	NS	NS	1.450
Accessions	8007	11.8 ^a	9.3 ^a	5.0 ^{bc}	20.3 ^d
	7607	10.4 ^c	8.0 ^c	5.4 ^{ab}	20.3 ^d
	4707	10.8 ^b	8.9 ^b	5.9 ^a	20.3 ^d
	4007	10.2 ^d	7.8 ^c	4.3 ^d	20.3 ^d
	5207	9.8 ^e	7.2 ^d	4.6 ^{cd}	22.3 ^c
	7807	9.4 ^f	7.1 ^d	4.7 ^{cd}	22.3 ^c
	3607	9.2 ^g	6.8 ^e	3.8 ^e	22.3 ^c
	8807	8.8 ^h	5.5 ^g	3.8 ^e	22.7 ^c
	1907	8.9 ^h	6.0 ^f	3.0 ^{fg}	25.0 ^b
	8307	8.4 ⁱ	5.1 ^h	3.2 ^f	25.0 ^b
	1407	7.9 ^j	9.3 ^a	2.2 ^{ij}	25.0 ^b
	6907	7.6 ^k	4.7 ⁱ	3.1 ^f	25.0 ^b
	3407	7.5 ^k	4.3 ^j	2.7 ^{f-h}	26.3 ^b
	7207	6.7 ^m	4.2 ^{jk}	2.6 ^{g-i}	26.3 ^b
	2807	7.1 ^l	3.5 ^m	1.8 ^{jk}	26.3 ^b
	7107	7.4 ^k	3.7 ^{lm}	2.3 ^{h-j}	26.3 ^b
	3907	5.4 ^p	4.0 ^{kl}	1.1 ^l	28.3 ^a
	9107	6.0 ⁿ	2.5 ^o	1.5 ^{kl}	28.3 ^a
	7707	6.5 ^m	2.5 ^o	2.0 ^j	28.3 ^a
	1307	5.8 ^o	3.1 ⁿ	1.3 ^l	28.3 ^a
SE($\pm$)		0.103	0.224	0.167	0.376
LSD		0.224	0.281	0.479	1.382
Pre-treatments	Control	7.5 ^c	5.3	3.2	28.3 ^a
	Blanching	8.3 ^b	5.4	3.2	24.2 ^b
	Salting	9.0 ^a	5.4	3.2	21.0 ^c
	SE($\pm$)	0.040	0.030	0.027	0.146
LSD		0.087	NS	NS	0.535
CV (%)		3.13 %	6.06	9.11	6.52

$n=3$

Means followed by the same letter in a column are not significantly different from each other at the 0.05 level of significance. TSS total soluble solid; TS total sugar; RS reducing sugar

Table 2 Two-way interaction effect of methods of drying and pre-drying treatment on the chemical composition and time of drying of pumpkin fruit accession

Treatments		TSS (°Brix)	AA (mg 100 g ⁻¹)	TA (% citric acid)	TSS/TA Ratio	drying Time (hr)	pH values
Drying methods + Pre-drying treatment							
Oven drying	Control	7.8 ^c	3.3 ^c	3.2 ^b	2.7 ^c	24.5 ^c	5.4 ^c
	Blanching	8.5 ^c	4.0 ^c	2.4 ^d	3.4 ^c	20.4 ^d	5.9 ^b
	Salting	9.2 ^a	5.1 ^a	1.7 ^f	4.3 ^a	18.0 ^e	6.3 ^a
Sun drying	Control	7.3 ^f	3.0 ^f	3.7 ^a	2.5 ^f	32.0 ^a	5.1 ^{cd}
	Blanching	8.2 ^d	3.6 ^d	2.7 ^c	3.1 ^d	28.0 ^b	5.7 ^{bc}
	Salting	8.8 ^b	4.6 ^b	2.0 ^e	3.9 ^b	24.0 ^c	6.1 ^{ab}
S.E (±)		0.033	0.025	0.315	0.057	0.206	0.008
LSD		0.087	0.065	0.011	0.032	0.757	1.560
CV (%)		3.13	4.870	1.410	3.960	6.520	0.032
Sign.		$P \leq 0.05$	$P \leq 0.05$	$P \leq 0.05$	$P \leq 0.05$	$P \leq 0.05$	$P \leq 0.05$

$n=3$

Means followed by the same letter in a column are not significantly different from each other at the 0.05 level of significance. TSS total soluble solid; AA ascorbic acid; TA total titratable acidity

Total soluble solids TSS content of pumpkin was significantly ($P \leq 0.05$) affected the two drying methods. The TSS content of sun dried pumpkin was found to be lower when compared to that of the oven dried pumpkin fruit slices (Table 2). Eissen et al. (1985) showed that the sun drying took longer drying time causing loss of some volatile oils, esters and readily oxidizable substances like ascorbic acid during the drying process.

The pumpkin accessions had significant ($P \leq 0.05$) effect on the TSS content of the dried fruit. Pumpkin fruit with accessions 8007 had the highest TSS content (11.8 °Brix) while accession number 3907 had the lowest value of TSS (5.4 °Brix). The result of this study, agreed with the report of Culpepper and Moon (1945) and Murakami et al. (1992), which found the variation in TSS in different pumpkin genotype.

Generally, the TSS of dried pumpkin fruit was found to be higher when compared to the TSS content of fresh pumpkin fruit slices of the accessions. The reason for the increment of TSS content of pumpkin fruit that was subjected 10 % salt solution dipping treatment could be associated with the fact that salt moves from high concentration region in the solution to the pumpkin fruit slice. Since salt is one of the components of TSS it may increase the TSS of dried pumpkin fruit (Daniel et al. 1995; Harvey et al. 1997) which was noticeable in this results.

Overall, the dried pumpkin fruits retained the TSS content due to salt solution treatment. Salting showed about 16.2 % more TSS than the TSS content in the control samples. The TSS content of slices that were subjected to blanching had 13.0 % more TSS over the fruits dried without pretreatment. The results of this experiment are in agreement with the finding of Mayor et al. (2006) which

showed that pre-treating pumpkin fruit with salt solution before drying reduces nutrient lose and reduces the time of drying. Lenart (1996) also reported that pre-drying treatment of pumpkin fruit increases the TSS content of dried fruit. TSS of fruit includes sugar, organic acids, amino acids, soluble pectins, and mineral salts (Rahman and Lamb 1991; Karathanos et al. 1995). Thus, salting could be a reason for the slight increment of TSS content in the slices that were subjected to blanching.

Fig. 2 Mean moisture content of pumpkin fruit of accession 1307 subjected to different pre-drying treatments under oven and sun drying

Table 3 Two-way interaction effects of accessions and pre-drying treatment on total soluble solid ($^{\circ}$ Brix) content of 20 pumpkin accessions

Accession	Pre-drying treatments		
	Control	Blanching	Salting
8007	10.9 ^{cde}	11.9 ^b	12.6 ^a
7607	9.5 ^{ijk}	10.5 ^{ef}	11.3 ^c
4707	9.9 ^{ghi}	10.9 ^{cde}	11.7 ^b
4007	9.3 ^{ikl}	10.3 ^{fg}	11.0 ^{cd}
5207	8.9 ^{lmn}	9.9 ^{ghi}	10.7 ^{def}
7807	8.6 ^{no}	9.5 ^{ijk}	10.3 ^{fg}
3607	8.3 ^{opq}	9.3 ^{iklm}	10.0 ^{gh}
8807	7.9 ^{qrst}	8.9 ^{mn}	9.6 ^{hij}
1907	8.1 ^{qr}	9.0 ^{lm}	9.8 ^{hi}
8307	7.6 ^{tuv}	8.5 ^{nop}	9.2 ^{klm}
1407	7.2 ^{vwxy}	8.0 ^{qrs}	8.5 ^{no}
6907	7.0 ^{xyz}	7.6 ^{stuv}	8.2 ^{opqr}
3407	6.9 ^{xyz a'}	7.5 ^{tuv}	8.1 ^{pqr}
7207	6.1 ^{c'd' e' f'}	6.7 ^{z a' b'}	7.3 ^{vw}
2807	6.5 ^{a' b'c'}	7.2 ^{vwxy}	7.7 ^{rstu}
7107	6.8 ^{yz a' b'}	7.4 ^{uvw}	8.0 ^{qrs}
3907	4.7 ^{j'}	5.5 ^{h' i'}	6.1 ^{d' e' f'}
9107	5.5 ^{g'h'i'}	6.0 ^{e'f'}	6.5 ^{a' b'c' d'}
7707	5.9 ^{f' g'}	6.5 ^{a' b' c'}	7.1 ^{wxyz}
1307	5.1 ^{i'}	5.8 ^{f' g' h'}	6.4 ^{b' c' d' e'}
SE(±)	0.11		
LSD	0.39		
CV(%)	3.13		

n=3

Means followed by the same letter are not significantly different from each other at the 0.05 level of significance

The reason for the increment of TSS in blanched pumpkin fruit slices over untreated pumpkin fruit is that blanching reduce loss of quality of dried product by shortening the drying period and by the inactivation of the enzymes responsible for the loss of compounds and by stabilizing pectin and also coagulating such components (Brennand 1994; Lenart 1996; Simal et al. 1997; Park et al. 2002).

The two-way interaction between drying methods and pre-drying treatment significantly ($P \leq 0.05$) affected the TSS content of dried pumpkin fruit accessions (Table 2). Salted and fruit dried in the oven had the highest TSS content (9.2° Brix) while the lowest TSS content (7.3° Brix) was recorded in untreated (sun dried without pre-treatment) pumpkin fruit slices which is in agreement with the findings of several reports (Lenart 1996; Simal et al. 1997 and Park et al. 2002). Rajkumar (2007) also reported that treating fruit and vegetables before drying saves lose of volatile compound and vitamins later during drying which could better explain the result of this study.

The two-way interaction effect of accession and pre-drying treatment was significant ($P < 0.05$) on the TSS content of dried fruit of the 20 pumpkin accessions (Table 4). Salt solution treated and dried fruit of pumpkin accession 8007 had the highest TSS content (12.6° Brix) which was followed by same accessions that was subjected to blanching before drying (11.9° Brix). Non-treated control pumpkin fruit slices from accession 3907 had the lowest TSS content (4.7° Brix). In general, pumpkin fruit slices dipped in 10 % salt solution contains more TSS content for all accessions which was followed by blanched pumpkin fruits slice samples. The result clearly showed that the importance of pre-treatments to improve the quality of dried slices which are in agreement with the finding of Mayor et al. (2006) that reported using salt solution as a pre-drying treatment improves the TSS of pumpkin fruit.

Sugar content The total sugar content of dried slices was significantly ($P \leq 0.05$) affected of pumpkin fruit accessions

Table 4 Two-way interaction effects of accessions and pre-drying treatments on sugar to acid ratio of 20 pumpkin accessions

Accessions	Pre-drying treatments		
	Control	Blanched	Salted
8007	2.9 ^{opq}	4.2 ^g	5.9 ^a
7607	2.5 ^{stu}	3.7 ^{hi}	5.2 ^c
4707	2.6 ^{rst}	3.8 ^h	5.4 ^{bc}
4007	2.6 ^{stu}	3.7 ^{hi}	5.4 ^{bc}
5207	2.4 ^{tuv}	3.6 ^{ij}	5.2 ^c
7807	2.3 ^{uvw}	3.4 ^{ikl}	4.9 ^d
3607	2.4 ^{uvw}	3.5 ^{ijk}	5.2 ^c
8807	2.2 ^{vw}	3.3 ^{klm}	4.9 ^{de}
1907	2.4 ^{uvw}	3.6 ^{hij}	5.5 ^b
8307	2.2 ^w	3.3 ^{lm}	4.9 ^{de}
1407	2.2 ^{vw}	3.4 ^{ikl}	5.2 ^c
6907	2.0 ^{xy}	3.0 ^{nop}	4.4 ^f
3407	2.1 ^{xy}	3.1 ^{mno}	4.7 ^e
7207	1.9 ^{yz}	2.8 ^{pqr}	4.4 ^{fg}
2807	2.1 ^{xy}	3.1 ^{mn}	4.9 ^d
7107	2.1 ^{xy}	3.1 ^{mn}	4.8 ^{de}
3907	1.5 ^l	2.4 ^{uvw}	3.7 ^{hi}
9107	1.8 ^z	2.7 ^{qrs}	4.3 ^{fg}
7707	2.0 ^{xy}	3.2 ^{lmn}	5.3 ^{bc}
1307	1.7 ^z	2.7 ^{qrs}	4.4 ^f
SE(±)	0.06		
LSD	0.21		
CV(%)	3.96		
Sign.	***		

Means followed by the same letter are not significantly different from each other at the 0.05 level of significance

(Table 4). The total sugar content of dried pumpkin fruit ranged from 3.0 to 9.3 g 100 g⁻¹. The sample slices from pumpkin fruit accession 8007 had the highest total sugar content while the slices from accession 9107 (2.5 g 100 g⁻¹) had the lowest total sugar content. The result corresponds with the report of Culpepper and Moon (1945) and Murakami et al. (1992) that showed the presence of a great variation in the total sugar content of pumpkin varieties. In this study, drying methods and pre-drying treatments had no significant ($P \geq 0.05$) effect on the total sugar content of dried pumpkin fruit sample slices. Similarly, Wagne et al. (2001) also reported that drying can not affect the sugar content of fruit and vegetables which is in agreement with the findings of this study. Similarly, significant ($P \leq 0.05$) difference was observed in reducing sugar content of dried pumpkin fruit accessions. Higher concentration of reducing sugar (5.9 mg 100 g⁻¹) was recorded in dried fruit of pumpkin accession number 4707 with about 3.5 % increase when compared to the concentration of reducing sugar in the fresh pumpkin fruit. The lowest (1.14 g 100 g⁻¹) reducing sugar content was recorded in pumpkin fruit accession 3907 which also had about 6 % more than the concentration reducing sugar that was found in the fresh fruits. Neither the two-way nor the three-way interaction had significant effect on the total and reducing sugar contents which is in agreement with the findings of Wagne et al. (2001).

Titrateable acidity The drying methods significantly ($P \leq 0.05$) affected the TA of dried pumpkin fruit. Oven dried pumpkin fruit had the lowest TA (2.4 %) when compared to the TA of pumpkin fruit dried under open sun drying (2.8 %) (Table 2). Many studies reported that organic acids are produced within the fruit from stored carbohydrate material (Sakiyama and Stevens 1976). The increment of TA in sun drying samples may be due to the conversion of carbohydrate to this acid through extended time of drying. Brennand (1994) also reported that the extended time of drying in sun dried fruit and vegetables cause high quality losses.

The pumpkin accessions had effect ($P \leq 0.05$) on the TA of dried fruits which varied between 2.1 and 3.0 % in this study (Table 2). Pumpkin accessions 8007, 7607 and 4707 had the highest titrateable acid content while the lowest TA was recorded in accession 7707. Sudhakar et al. (2003) showed that pumpkin fruit quality is highly influenced by genetic factor which corresponds to the result of the current study. Seymour and McGlasson (1993) also reported fruit compositions like TA vary from cultivar to cultivar and from year to year among cultivar which is clearly shown in this study.

Pre-drying treatment significantly ($P \leq 0.05$) affected the TA of the pumpkin cultivar. The untreated pumpkin fruit had the highest TA (3.4 %) which was about 35.6 % more than those of the TA of the blanched fruits and 87.4 % more

than the TA of fruit slices subjected to 10 % salt solution dipping. The result agrees with the previous report that showed dipping product in osmotic solutions and blanching reduce fruit acidity by leaching the titrateable acid from the product, by reducing the action of microorganism and enzyme in the product (Ponting 1973; Brennand 1994).

The two-way interaction between drying methods and pre-drying treatment had highly significant ($P \leq 0.05$) effect on the TA content of 20 dried pumpkin fruit. Control sun dried pumpkin fruit that were had the highest TA (3.7 %) which was followed by control pumpkin fruit subjected to sun drying (3.2 %). The lowest TA content was recorded in oven dried pumpkin fruit slices dipped in 10 % salt solution before drying. The quality of dried product can be improved by using appropriate pre-drying treatment and good drying conditions (Mujumdar 1997; Rajkumar 2007). Dipping of fruit and vegetable in osmotic solution (salt and sugar) before drying improves the nutrient content (Karathanos et al. 1995; Lenart 1996; Park et al. 2002).

Ascorbic acid The drying condition significantly ($P \leq 0.05$) affected the ascorbic acid (AA) content of the pumpkin fruit accessions where oven dried fruits recorded to contain the higher AA than the sun dried pumpkin fruits (Table 2). This result agrees with the report of Nunes and Emond (1999) which showed the sensitivity of AA to temperature and sun light which could be attributed to that the reason for the higher loss is usually associated with sun drying methods than those which were subjected to oven drying.

Pumpkin accessions had significant ($P \leq 0.05$) effect on the AA content of the pumpkin fruit slices. The AA content varied between 2.2 and 5.9 mg 100 g⁻¹. Pumpkin fruit of accession number 8807 (5.9 mg 100 g⁻¹) had the highest AA content which was followed by accession number 3607 (5.7 mg 100 g⁻¹). The lowest AA content was recorded in pumpkin fruit slices from accession number 7207 (2.2 mg 100 g⁻¹). Similarly, the pre-drying treatments had significant ($P \leq 0.05$) effect on the AA content. Higher value of AA (4.9 mg 100 g⁻¹) was found in the dried fruits slices that were subjected to salt solution dipping treatments before drying while the lowest AA content was recorded in untreated (control) pumpkin fruit (3.1 mg 100 g⁻¹).

The interaction effect of pre-drying treatment and drying methods was significant ($P \leq 0.05$) effect on the AA content of dried fruits (Table 2). The AA content of salted and oven dried pumpkin fruit slices was found to be the highest compared to the AA contents of the remaining pre-drying treatment and drying methods or their combinations. This could be due to the fact that salt can deactivate the enzyme by rapid loss of water. The result of this study is in agreement with the finding of Shi et al. (1999). Brennand (1994) also indicated that blanching reduces the loss of AA content in dried pumpkin fruit slices by reducing the spoilage by

microorganisms, stopping ripening processes and coagulating some of the soluble constituents. Other research report also showed that blanching reduces the loss of AA by reducing the action of peroxides enzyme activity that causes significant loss of AA (Rajkumar 2007). Generally, dried pumpkin fruit slices had significantly ($P \leq 0.05$) lower AA content compared with the AA content of the fresh pumpkin fruit slices. The reduction in AA of sun dried pumpkin fruit slices was significantly ($P \leq 0.05$) higher than those oven dried ones. Rajkumar (2007) reported that the uncontrolled sun drying fruit and vegetables can cause significant losses of AA content of fruit and vegetables. The loss of AA in pumpkin fruit dipped in 10 % salt solution before drying was significantly ($P \leq 0.05$) and which was followed by the loss of AA in blanched pumpkin fruit under both drying conditions. The reduction of AA content was higher for untreated (control) pumpkin fruit slices that were dried by both drying methods. Many researcher reported that drying significantly cause the loss of AA (Brennand 1994; Takeoka et al. 2001) which agrees with the findings of the present study. It was also reported that pre-drying treatment significantly reduces the loss of AA of other fruits and vegetables during drying (Shi et al. 1999), which was also confirmed by the data presented in this study.

pH Value Oven drying had significant ($P \leq 0.05$) effect on the pH value of dried pumpkin slices. Oven dried fruits had more pH value than sun dried fruits slices (Table 2). The reduction in pH value of sun dried pumpkin fruit slices may be due to synthesis of organic acid from carbohydrate over the extended period when fruit slices are subjected to sun drying (Sakiyama and Stevens 1976). Paulson and Stevens (1974) showed that pH value was highly correlated with TA which is in harmony with the present result reported in this study.

There was significant ($P \leq 0.05$) difference among the pH values of the dried pumpkin fruit accessions. The pH values of the dried fruits ranged between 5.1 and 6.2 mg 100 g⁻¹. The earlier studies by Paulauskiene et al. (2006) also showed that there was great variation in pH values of pumpkin genotypes. Drying appeared to slightly decrease the pH of all pumpkin fruit. Higher pH value was found in dried pumpkin fruit with accession number 7707 (6.2) while the lowest (5.1) pH value was recorded in accession number 4707. This accession also had the highest titratable acidity in the dried fruits slices.

On the other hand, pre-drying treatment significantly ($P \leq 0.05$) affected the pH value of dried pumpkin fruit (Table 2). The fruit slices dipped in 10 % salt solution had the highest value that was followed by blanched. Untreated control pumpkin fruit slices had the lowest pH value. The pumpkin fruits slices that were subjected to the blanching treatment had intermediate pH value which was significantly ($P \leq 0.05$) different from both untreated and salted fruits slices.

The previous works also showed that pre-drying treatments increases the pH value and reduces the fruit acidity of pumpkin fruits (Ponting 1973). The pH value of pre-treated pumpkin fruit may be reduced due to the increment of TA of dried pumpkin fruit since pH value and TA had inverse relationship (Paulson and Stevens 1974).

Total soluble solid to acid ratio Drying methods had significant ($P \leq 0.05$) effect on the TSS to TA ratio (Table 2). Oven dried Pumpkin fruit had about 21.9 % TSS/TA ratio than the value in sun dried pumpkin fruit slice samples. There was significant ($P \leq 0.05$) difference in the TSS/TA ratio among the pumpkin fruit accessions. The TSS/TA ratio varied between 2.5 and 4.3. Pumpkin fruit accession number 8007 had the highest TSS/TA, which was followed by TSS/TA ratio of accession number 4707 (3.9). Pumpkin fruit accession 3907 was found to have lowest TSS/TA ratio which was lower by 27.2 % from average value of the accessions and 41.5 % lower than accession that have the highest value of TSS/TA (4707) respectively under both drying conditions and three pre-drying treatments. Fruit TSS/TA is highly related with the flavor and sensory quality of pumpkin fruit. Pumpkin fruit with high TSS and acid content have good flavor and sensory quality (Daniel et al. 1995). The result of this finding agrees with the findings of Harvey et al. (1997) which indicated that the TSS and titratable acid content of pumpkin fruit vary from genotype to genotype.

The TSS/TA ratio were also significantly ($P \leq 0.05$) affected by the three pre-drying treatments where salted pumpkins slices had the highest TSS/TA ratio. The untreated control fruit slices had the lowest TSS/TA ratio. 10 % salted solution dipped pumpkin fruit slices had the highest sugar to acid ratio (4.3) which was followed by blanched pumpkin fruit slices (3.4). The untreated pumpkin fruit slice samples had the lower (2.7) TSS/TA ratio. Dried fruits that received blanching treatment recorded intermediate TSS/TA ratio which differed significantly TSS/TA ratio from fruit slices that were subjected to the other two pre-drying treatments.

The two-way interaction between drying methods and pre-drying treatments was found to be significant ($P \leq 0.05$) on the changes in the TSS/TA ratio of the dried pumpkin fruit accessions (Table 3). Salted and oven dried pumpkin fruit slices had the highest TSS/TA ratio (4.3) which was followed by the TSS/TA ratio of salted and sun dried pumpkin fruit slices (3.9). The lowest TSS/TA ratio was recorded in the control and sun dried (2.5) pumpkin fruit slices. Since, the TA content of the untreated pumpkin fruit slices was very high, the ratio of TSS/TA was high in untreated pumpkin fruits slices.

The two-way interaction between accessions and pre-drying treatments was significant ($P \leq 0.05$) difference on sugar to acid ratio of dried pumpkin (data not shown). Pumpkin fruit accession 8007 subjected to 10 % salt solution dipped treatment had the highest TSS/TA ratio (5.9) which was followed by

pumpkin accession 4707 subjected to the same pre-drying treatments (5.4). The lowest TSS/TA ratio was recorded in the untreated pumpkin fruit slices from accession number 3907 that had the lowest TSS/TA (1.5). In general, the untreated sun dried pumpkin fruit had the highest TSS/TA ratio which was preceded by blanched pumpkin fruit dried under both drying conditions. Salted pumpkin fruit had the lowest TSS/TA ratio. Pre-drying treatment improve the quality of fruit by reducing the losses of flavoring substance, reducing the action of microorganism, reducing the action of enzymes and by reducing the loss of some soluble substance (Ponting 1973).

Conclusion

Accession had significant ($P \leq 0.05$) influence on TSS, TS, RS, AA, TA, pH value, sugar to acid ratio and the time of drying. Pumpkin fruit accession 8007 had the highest TSS, TS and sugar to acid ratio. Pumpkin accession 8807, 4707, and 7707 had highest AA, RS and TA, and pH value after drying, respectively. Pre-drying treatments had significant ($P \leq 0.05$) effect on changes in dried pumpkin fruit slices. Salted pumpkin fruit slice sample had the highest TSS, AA, sugar to acid ratio, pH value, lower TA and shorter time of drying. The untreated pumpkin fruit slices had the lowest chemical concentration after drying with the longest time of drying of 28.3 h. Among the three pre-drying treatment used salt solution dipping treatment was efficient pre-drying treatments in many ways. The two way interaction effect of drying methods and pre-drying treatment was significant ($P \leq 0.05$) on changes in quality. Drying methods (oven and sun) had significant ($P \leq 0.05$) effect on changes in chemical quality of pumpkin fruits. Oven dried pumpkin fruit slices had the highest TSS, AA and pH value and TSS/TA ratio, lower TA and shorter time of drying. Sun dried pumpkin fruit had lower TSS, AA and pH value and TSS/TA ratio, higher TA and longer time of drying. The two-way interaction between accessions and pre-drying treatments was found to be significant on changes in quality attributes of dried pumpkin fruit slices, at 0.05 levels of significance. Pumpkin accessions 8007, 8807, 4707 and 7707 had superior nutritional quality after drying. Among the three pre-drying treatments used, salt solution dipping was efficient pre-drying treatment to improve the quality of the dried pumpkin fruit slices.

References

- Alibas I (2007) Microwave, air and combined microwave-air-drying parameters of pumpkin slices. Uludag University, Faculty of Agriculture, Department of Agricultural Machinery, Bursa, pp 1445–1452
- AOAC (1970) Official methods of analysis, 12th edn. Association of Agricultural Chemists, Washington, DC
- AOAC (1984) Official methods of analysis, 14th edn. Association of Official Analytical Chemists, Washington DC
- Are VPA, Fernanda EX (2006) Kinetics of vacuum drying of pumpkin (*Cucurbita maxima*): modeling with shrinkage. *J Food Eng* 76 (4):562–567
- Awole S, Kebede W, Workneh TS (2011) Postharvest quality and shelf life of some hot pepper varieties. *J Food Sci Technol*. doi:10.1007/s13197-011-0405-1
- Brennand CP (1994) Home drying of food. Cooperative Extension Service, Utah State University, Logan, Utah, p 330
- Culpepper CW, Moon HH (1945) Differences in the composition of the fruits of *Cucurbita* varieties at different ages in relation to culinary use. *J Agric Res* 71:111–136
- Dahlman J, Forst C (2001) Solar dehydrator, drying fruits and vegetables. University of Georgia extension bulletin, pp 12
- Daniel AL, Brecht JK, Sims CA, Maynard DN (1995) Sensory analysis of bush and vining types of tropical pumpkin. *Proc Fla State Hort Soc* 108:312–316
- Duncan DB (1955) Multiple range test and multiple F tests. *Biometrics* 11:1–42
- Eissen W, Muhlbauer W, Kutzbach HD (1985) Solar drying of grapes. *Dry Technol* 3(1):63–74
- FAO (2001) Principles and practices of small- and medium-scale fruit juice processing. FAO, Rome, Italy
- Gomez KA, Gomez AA (1984) Statistical procedures for agricultural research. John Wiley and Sons, New York
- Harvey WJ, Grant DG, Lammerink JP (1997) Physical and sensory changes during development and storage of Buttercup squash. *N Z J Crop Hortic Sci* 25:341–351
- Karathanos VT, Kostropoulos AE, Saravacos GD (1995) Air drying of somatically dehydrated fruits. *Dry Technol* 13(5–7):1503–1521
- Lenart A (1996) Osmo-convective drying of fruits and vegetables: technology and application. *Dry Technol* 14(2):391–413
- Maul E, Sargent SA, Sims CA, Balaban MO (2000) Tomato flavor and aroma quality as affected by storage temperature. *J Food Sci* 65:1228–1237
- Mayor L, Moreira R, Chenlo F, Sereno MA (2006) Kinetics of osmotic dehydration of pumpkin with sodium chloride solutions. *J Food Eng* 74(2):253–262
- Mcbean DMG, Johnson AA, Pitt JI (1964) The absorption of sulfur dioxide by fruit tissue. *J Food Sci* 29:257–260
- Mujumdar AS (1997) Drying fundamentals. In: Baker CGJ (ed) Industrial drying of foods. Blackie Academic and Professional, London, pp 7–30
- Murakami M, Himoto JM, Natsuga KI (1992) Analysis of pumpkin quality by near infrared reflectance spectroscopy. Department of Agricultural Engineering, faculty of agriculture, Hokkaido University, Sapporo
- Nunes MC, Emond JP (1999) Chlorinated water treatments affects post harvest quality of green bell peppers. *J Food Qual* 22:353–361
- O'Dell A (1999) Home drying of fruit and vegetable. Extension Service. West Virginia University, Virginia, pp 4–7
- Park KJ, Vohnikova Z, Brod FPR (2002) Evaluation of drying parameters and desorption isotherms of garden mint leaves (*Mentha crispa* L.). *J Food Eng* 51:193–199
- Paulauskiene A, Danilcenko H, Jariene E, Gajewski M, Seroczyńska A, Szymczak P, Korzeniewska A (2006) Quality of pumpkin fruits in relation to electrochemical and antioxidative properties. *Vegetable crops research bulletin* 65 research institutes of vegetable crops, skierniewice, Nowoursynowska, Warszawa 166:02–787
- Paulson K, Stevens MA (1974) Relationships among titratable acidity, pH and buffer composition of tomato fruits. *J Food Sci* 39:254–357
- Ponting JD (1973) Osmotic dehydration of fruits—recent modification and applications. *Process Biochemistry*, 8, 18–20. quality of fruits and vegetables, Volume II. Processed Fruits and Vegetables, 2nd Edition. CRC Press, Boca Raton, FL, pp 190–130
- Rahman S, Lamb J (1991) Air drying behavior of fresh and osmotically dehydrated pineapple. *J Food Process Eng* 14:163–171
- Rajkumar P (2007) Comparative performance of solar cabinet, vacuum assisted solar and open sun drying methods. Department of

- Bioresource Engineering McGill University, Montreal. Department of Bioresource Engineering McGill University, Montreal, pp 1–15
- Sakiyama R, Stevens A (1976) Organic acid accumulation in attached and detached tomato fruits. *J Am Soc Hortic Sci* 101:394–396
- Seymour GB, Mcglasson WB (1993) Melons. In: Seymour GB, Taylor GE, Tucker GA (eds) *Biochemistry of fruit ripening*. Chapman and Hall, London, pp 273–286
- Shi J, Maguer ML, Kakuda Y, Liptay A, Niekamp F (1999) Lycopene degradation and isomerization in tomato dehydration. *Food Res Int* 32:15–21
- Simal S, Deya E, Frau M, Rossello C (1997) Simple modeling of air drying curves of fresh and somatically pre-dehydrated apple cubes. *J Food Eng* 33:139–150
- Somogyi M (1945) A new reagent for the determination of sugars. *J Biol Chem* 160:61–68
- Sudhakar, Jagdish PS, Upadhyay AK, Ram D, Mathura R (2003) Ascorbate and carotenoid content in an indian collection of pumpkin (*Cucurbita moschata* Duch. ex Poir). *Cucurbit Genetics Cooperative Report*. Indian Institute of Vegetable Research, Gandhi Nagar, Naria
- Takeoka GR, Dao L, Fless S, Gillespie DM, Jewell WT, Huebner B (2001) Processing effects on lycopene content and antioxidant activity of tomatoes. *J Agric Food Chem* 49:3713–3717
- Tigist M, Workneh TS, Woldetsadik K (2011) Effects of variety on the quality of tomato stored under ambient conditions. *J Food Sci Technol*. doi:10.1007/s13197-011-0378-0
- Tsotsas E, Mujumdar AS (2012) *Modern drying technology, energy savings*, vol 4. Wiley-VCH Verlag GmbH and Co. KGaA, pp 376
- Wagne K, Mary EM, Clarence EJ (2001) *Drying foods at home. Consumers and family science*. University of Wisconsin, Madison, pp 1–4
- Workneh TS, Osthoff G, Steyn MS (2011) Effects of preharvest treatment, disinfections and storage environment on quality of tomato. *J Food Sci Technol*. doi:10.1007/s13197-011-0391-3