Physicochemical and Technological Studies on Husk Tomato (*Physalis pruinose* L.)

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ABSTRACT

Physicochemical properties, nutritive value and ability to processing of husk tomato (*Physalis pruinosa* L.) "local variety" were carried out. The influence of drying conditions such as pretreatments and drying methods and its effects on acceptability, quality, physicochemical properties and storage stability of the dried product and their application in some food products were also undertaken. The results indicated that combining hot air with microwave drying reduced the drying time by about 35%. The moisture content and the total amount of titratable acidity increased after drying and storage. On the other hand, ascorbic acid content, phenolic compounds, total antioxidant activity, total and free sulphur dioxide content decreased after drying and storage for the different periods at room temperature. Dried husk tomato no longer had any microbial growth and can inhibit the spread of fungi and bacteria. The organoleptic properties of cake containing dried husk tomato and chocolate coated husk tomato were accepted by the panelists with some suggestions.

Keywords: ***Husk tomato, physical and chemical properties, pretreatments and drying, technological utilization***

INTRODUCTION

Many beneficial plant species have been underused or have not been developed to their full potential such as husk tomato. Useful plant species have often been overlooked because they are native to the tropics which are regions neglected by the world's research institutions. (Vietmeyer, 1986). *Solanaceae* is mainly a tropical family of about 75 genera and 2000 species. The genus *Physalis* of family *Solanaceae*, contains about 100 species of annual and perennial herbs (Rubatzky and Yamaguchi, 1997 & Willis, 1966). Generally, goldenberries or husk tomato fruits (*Physalis pruinosa* L.) are eaten fresh. Sometimes they are sweetened by pricking the skin and rolling them in sugar, which they absorb. Also, goldenberries or husk tomatoes are used in sauces and glazes for meat and seafood. The processed fruits are commonly used in preserves such as jams and jellies. Goldenberries are canned whole in syrup and they form what has been called 'a very agreeable raisin', besides, goldenberries are added as an intriguing flavour to desserts. (Popenoe, 1989). Small industries are developed around the husk tomato in some countries but nowhere has it really achieved large commercial success. The plant's productivity in poor soil, its ease of cultivation and low requirement for water and fertilizer has made it an attractive potential crop (Morton, 1987). In Egypt, the cultivation, production, consumption and utilization of goldenberry are given no attention. Fruits are perishable (due to its high moisture content) having a short marketing season. Although, the fruit has a popular sweet taste with acidic nature, high nutritive value and medical importance, it hasn't been so far utilized (Bakry, 2003).

Drying of agricultural products, a common method of natural preservation by reducing the moisture content to a level at which microbial spoilage is minimized and the product is relatively chemically stable has always been a significant contribution to the income of the agricultural societies (Krokida and Marinos-Koouris, 2003 & Abd El-Ghaffar, 2009). Mechanical air dehydration has gained importance because it has many advantages over sun-drying. These include: (a) the process is under better sanitary conditions, (b) drying parameters can be accurately set, controlled and changed over the entire processing time, thus a more consistently uniform product can be achieved with less quality degradation (Barbosa-Canovas and Vega-Mercado, 1996 & Tosun and Delen, 1998). Using convective hot-air drying method in which, food materials are exposed to elevated drying temperatures, leads to an increase in shrinkage and toughness, reduction of both the bulk density and rehydration capacity of the dried product and also causes serious damage in flavour, colour and nutrient content. The major draw-back of convective hot-air drying method, from an energy point of view, is the longer drying period, higher drying temperature and therefore high energy consumption, which may be as high as 6000 kJ/kg of water evaporated (Mujumdar and Menon, 1995, Maskan, 2000 & Alibas, 2007). The desire to reduce the above problems, as well as to achieve fast and effective thermal process lead to the use of microwave and dielectric heating method for food drying. Microwaves are not forms of heat, but rather forms of energy that are manifested as heat through their interaction with materials. It is as if they cause the materials to heat themselves. (Bondaruk, *et al* , 2007).

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Microwave energy is rapidly absorbed by water molecules which, consequently, results in rapid evaporation of water and thus higher drying rates. Therefore microwave drying offers significant energy savings, with a potential reduction in drying times of up to 50% in addition to the inhibition of surface temperature of treated material (Schiffmann, 1995). Drying conditions or drying equipments can be modified to increase overall efficiencies. Hybrid drying techniques can be used, such as combining vacuum or convective drying with electro-technologies such as microwave, radio frequency and infrared heating (Raghavan *et al*., 2005). This research was undertaken to study the physical and chemical properties of fresh husk tomato as well as the influence of the drying pretreatments and the drying methods (oven drying and combined oven drying/microwave drying) on the drying behaviour of the fruit. The effect of drying pretreatments and storage on the chemical composition and the organoleptic characteristics of dried husk tomato as well as the application of the dried fruit on some food products were also studied.

MATERIALS AND METHODS

Materials:

Husk tomato (Physalis pruinosa L.) was purchased from Alexandria Governorate local market, Egypt in February 2011. Olive oil, wheat flour (72% extraction), sugar, butter, liquid milk, eggs, baking powder, salt, vanilla and crude chocolate were purchased from Alexandria market, Egypt. Sodium metabisulphite was obtained from El-Nasr company and sodium carbonate was obtained from El-Gomhoria company, Egypt.

Methods

Technological methods

Husk tomato drying

Husk tomato sample was manually peeled and washed with tap water. Chemical pretreatments consisted of immersing the sample, during a pre-determined time interval, in aqueous suspensions of commercial olive oil and Na_2CO_3 (solution to fruit was 2:1v/w). Solutions of the desired concentration of Na_2CO_3 were prepared in tap water and heated at 50°C, on a hot plate with stirring. Olive oil was then slowly poured into this solution, which was kept under continuous agitation during dipping of berries. The levels of Na_2CO_3 and olive oil concentrations, as well as, time of dipping are shown in Table (1). A full factorial experiment in three factors (A, B and C) with various levels was carried out according to Dean and Voss (2005). Sulphiting of pretreated husk tomato berries was carried out by dipping in 0.1% sodium metabisulphite solution for 2 min (Control sample was sulphited only).

Hot air drying of husk tomato

The prepared husk tomatoes were loaded on wire trays at rate of 1.3 g / cm^2 then dried at 40°C for 4 hrs and continued at 65°C until the moisture content of the samples reached the equilibrium moisture content 10:12%. The dried samples were packed in polyethylene bags and stored at room temperature until used.

Hot air/microwave drying of husk tomato

The most preferable treatment as stated by the panelists (treatment cod. A2B1C2) was dried by hot air/microwave in order to compare it with that dried by hot air (Table 2). Husk tomatoes were loaded in wire trays and dried at 40°C for 4 hrs and continued at 65°C for 6 hrs. The dried berries (about 1 Kg) were placed in glass dish (diameter 28 cm and 1.7 cm depth)at the center of the microwave cavity. The cycle for operating the microwave oven was 1 min ON then 5 minutes OFF. This cycle was repeated until the moisture content of the samples reached the equilibrium moisture content 10:12%. The dried samples were packed in polyethylene bags and stored at room temperature until used.

Table 1. Different pretreatments of husk tomato

Code	Sod. carbonateConc. (%) (A)	Olive oil conc. (%) (B)	Dipping time (min) (C)
A1B1C1	0	0	2
A1B1C2	0	0	4
A1B2C1	0	0.5	2
A1B2C2	0	0.5	4
A2B1C1	3	0	2
A2B1C2	3	0	4
A2B2C1	3	0.5	2
A2B2C2	3	0.5	4
A3B1C1	6	0	2
A3B1C2	6	0	4
A3B2C1	6	0.5	2
A3B2C2	6	0.5	4

Table 2. husk tomato pretreatments for hot air/microwave drying

Code	Sod. carbonateConc. (%) (A)	Olive oil conc. (%) (B)	Dipping time (min) (C)
HA/MW (A2B1C2)	3	0	4

Preparation of cake with dried husk tomato

Cakes were prepared according to the basic formula described by El-Abasy (2011) and Gomez *et al* (2011) with some modifications. The formula included 100 g all purpose wheat flour (72% extraction), 120 g white sugar, 50 g whole egg, 60g liquid milk, 30 g butter, 3 g baking powder. Mechanical mixer (momnanlex, type MAR.765) was used to prepare the cake batter. Batter was first creamed and sugar was added gradually while creaming was continued. Eggs were beaten into the creamed mixture. Flour was sifted with baking powder and added alternately with milk. Dried husk tomato was added to formula at concentration of 15% of wheat flour weight. Cake batter was poured into an aluminum foil pan and baked at 200°C for 25 min. After baking, cakes were removed from the pan, left to cool for 1 h at room temperature, and packed into hermetically sealed plastic bags to prevent drying and subjected to organoleptic test.

Preparation of coated chocolate husk tomato

Crude chocolate was melted by heating in water bath and the dried husk tomato was dipped in the melted chocolate, then removed and cooled to room temperature and packed in polyethylene bags and subjected to organoleptic test.

Drying curve

According to Hamed (2008), the pretreated samples were placed in a dryer (oven dryer or microwave dryer). Weight of the pretreated samples was measured in fixed time intervals and recorded as a function of drying time. The drying data obtained were then expressed as moisture ratio (MR) according to the following equation:

$$MR = \frac{M}{Mi}$$

Where:

MR = Moisture ratio

M = % Moisture content (dry basis) at the fixed time intervals.

Mi = % Initial moisture content (dry basis).

The calculated MR,s were plotted against the drying times to obtain the drying curve.

Sensory evaluation

Appearance, colour, odour, taste, texture and overall acceptability of tested samples were assessed by ten panelists of Food Science and Technology Department, Faculty of Agriculture, Alexandria University, Egypt, using a numerical (hedonic) rating of 1-10 (1= dislike very much, 10= like very much) as described by Abd El-Lahot (2010).

Storage of samples

The dried samples that had high scores by panelists were packaged in bags of polyethylene and stored for a period of six months at room temperature. Samples were taken for analysis every three months of storage. The experiments were performed in nested design according to Dean and Voss (2005).

Method of analysis:

Physical properties:

Fruit weight of fig varieties were measured by sensitive balance (Jadever, Surg-30 * 0.01g). Fruit dimensions (length and width), ostiole width and thickness of skin were measured by micrometer. The fruit index was calculated by dividing the width by the length (width/length) according to Polat and Caliskan (2008). Total soluble solids (TSS) % of fig varieties were determined by using a hand refrectometer (ATAGO, Japan. 0 ≈ 50%) using the method mentioned in A.O.A.C. (2000). The pH values of fresh and dried samples of fig were measured according to El-Abasy (2011). Approximately 5 g sample was homogenized with 30 ml distilled water in homogenizer for 10 min and the filtered solution was used for pH estimation by digital pH meter (Martini, Bench meter Mi 150). Colour of fresh and dried samples of fig was determined using a Hunter Lab Eazy MatchQC (L*, a*, b*) according to Caliskan and Polat (2011). The L* value represents lightness (L* 0 for black, L* 100 for white), whereas the a* scale represents the red/green dimension, with positive values for red and negative ones for green. The b* scale represents the yellow/blue dimension, with positive values for yellow and negative ones for blue. L*, a*, and b* values were measured on three different spots in each samples. The results were recorded as the mean of these measurements. The chroma (C*) value, calculated as = $(a^{*2} + b^{*2})^{1/2}$ indicates colour intensity. Hue angle a parameter that has been shown to be effective in predicting visual colour appearance, was calculated using the formula hue° = $\tan^{-1}$ (b*/a*), where 0◦ or 360◦ = red-purple, 90◦ = yellow, 180◦ = green, and 270◦ = blue.

Chemical analysis:

Fresh and dehydrated samples of fig varieties were minced in Braun mixer and subjected to the following

analysis. Moisture, total, reducing and non reducing sugars, crude protein, crude ether extract, total ash, crude fibre, titratable acidity and ascorbic acid were determined as described by AOAC procedures (2003) unless otherwise stated. Minerals including Ca, Mg were measured described in the AOAC (2000) using Perkin Elmer Atomic Absorption spectrophotometer (Model 2380). On the other hand, K and Na were determined using flame photometer (Model PEP7, U.K.).

Pectin substances were measured according to Bekheit (2002). Fifty g samples were added to 400 ml distilled water and boiled for an hr at a constant volume. The extract was diluted with water to 500 ml in a volumetric flask and then filtered through Whatman paper No. 41. One hundred ml of the filtrate was diluted with an equal volume of distilled water, ten ml of 1N sodium hydroxide solution were added to the mixture and the solution was allowed to stand overnight, then, fifty ml of 1M acetic acid solution were added. After five min later, 25 ml of 1M calcium chloride solution were added. The mixture was allowed to stand for an hr before boiling for one min, followed by hot filtration through a Whatman filter paper No. 41 previously weighed. The filter paper was washed with hot water until all traces of chloride were eliminated. The filter paper with the precipitate was dried at 105°C for 3 hrs and then cooled before weighing. Redrying was carried out for half an hr to ensure that no further weight loss had occurred. The weight of the precipitate represents the weight of the soluble pectin.

The method recommended for determination of total phenols using Folin-Ciocalteau reagent was adapted from Mc Donald *et al* (2001) & Konyaloglu *et al* (2005). Samples (10 g) were extracted by methanol: water (50: 50, v/v) and left for 30 min with stirring. Test solutions of 0.5 ml were added to 4.0 ml of 1M Na_2CO_3. Five milliliters of Folin-Ciocalteau reagent (1:10, v/v) were added and the solutions were allowed to stand at 45°C in water bath for 15 min. Absorbance were measured at 750 nm. The blank consisted of all reagents and solvents without test compounds or standard. The standard was gallic acid prepared in concentrations of 50 to 200 mg/L. This is commonly used as a reference compound. The Phenolic concentrations were determined by comparison with the standard calibration curve. Total phenol values were expressed as gallic acid equivalents (mg g^{-1} dry mass).

According to Caliskan and Polate (2011), the total anthocyanin (TA) content was quantified according to the pH differential method. Absorbance (A) was measured at 520 and 700nm in buffers at pH 1.0 and pH 4.5 where A= A_{520}-A_{700}) ph 1.0- (A_{520}-A_{700}) pH 4.5. The buffers were potassium chloride buffer, 0.025M, pH 1.0 and sodium acetate buffer, 0.4 M, pH 4.5 according to Wrlstad *et al*. (2005). Results were expressed as µg cyaniding-3- rutinoside (molar extinction coefficient of 28,800 and molecular weight of 595.2) (Soloman *et al*., 2006) equivalents per g fresh weight of fruit.

Antioxidant activity was measured by the N,N-dimethyl-*p*-phenylenediamine dihydrochloride (DMPD) according to Fogliano *et al (*1999). Two hundred and nine ml of DMPD were dissolved in 10 ml of deionized water. One ml of this solution was added to 100 ml of 0.1M acetate buffer (pH=5.25) then 0.2 ml of 0.05M ferric chloride solution was added to obtain coloured radical cation ($DMPD^+$) as follows:

One ml of this solution was directly placed in a 1 ml plastic cuvette and its absorbance was measured at 505 nm using Spekol Spectrocolorimeter (Spekol 11, Carlzeiss Jena). Standard solution of the antioxidant compound was prepared as follows: A weight of 0.1 g of ascorbic acid was dissolved in 100 ml of deionized water to obtain 1 mg/ml of ascorbic acid. 10 g samples were extracted by 100 ml methanol and then centrifuged. A volume of 50µl of standard antioxidant or sample extraction was added in the spectrometric cuvette contained 1 ml of $DMPD^+$ solution, and after 10 min at 25°C under continuous stirring, the absorbance was measured at 505 nm. Buffered solution was placed in the reference cuvette.

A dose-response curve was derived for ascorbic acid, by plotting the absorbance at 505 nm as percentage of the absorbance of the uninhibited radical cation solution according to the following equation:

Inhibition of A_{505} (%) = $\left(1-\left(\frac{AF}{A0}\right)\right) \times 100$

Where:

A0= absorbance of uninhibited radical cation.

AF= absorbance measured at 10 min after the addition of antioxidant samples.

Total and free sulphur dioxide as (ppm) were determined using the iodine titration method as described by Ranganna (1995).

The method recommended by Gouda (1974) was used to determine the rehydration ratio. Ten grams of dried samples were placed in 600 ml beaker and a definite volume (100 ml) of tap water was added, covered by watch glass. Boiling was brought within 3 min and continued for 30 min.

$DMPD_{(uncoloured)} + \text{oxidant } (Fe^{3-}) + H^+ \longrightarrow DMPD^+_{(purple\ coloured\ radical\ cation)}$

$DMPD^+_{(purple\ coloured\ radical\ cation)} + AOH_{(antioxidant\ material)} \longrightarrow DMPD_{(uncoloured)} + AO_{(antioxidant\ compounds).}$

The content was then transferred to a Buchnner funnel and left for 1 min before weighing. Rehydration ratio was expressed as the ratio between the drained weight of the rehydration sample and the weight of the dehydration sample.

Microbiological analysis

Microbial analysis was carried out aseptically by mixing 10.0 g of different samples that had the highest scores by panelists along with the control and the stored samples with 90.0 ml sterile 0.1% peptone water using a blender (stainless steel) . Serial dilutions were made. The total aerobic mesophillic bacterial count and yeast/molds count were carried out using nutrient agar at 30°C for 48 h and potato dextrose agar at 25°C for 3-5 days, respectively, according to Oztekin *et al* (2006).

Statistical analysis

The analysis of data was performed as an analysis of variance (ANOVA) and significant differences were assessed with an LSD test ($p<0.05$) according to Dean and Voss (2005) by using statistical software package "STATISTICA 7.0"

RESULTS AND DISCUSSION

Physical properties of fresh husk tomato

Table (3) shows the physical properties of fresh husk tomato. From this Table, it can be concluded that the average fruit weight, length, width, fruit index and the number of fruit per kilogram were 3.92 gm, 1.86 cm, 1.87 cm, 1.01(globose shape) and 319.7. The obtained results are not in accordance with those reported by Abou-Gharbia and Abou-Tour (2001) and Bakry (2003) which may be due to species, environmental and agricultural conditions as well as time of harvesting. On the other hand, the percentage of husk and the yield after dehusking were 7.78 and 92.22%, respectively. The results obtained here are in accordance with those reported by Abou-Gharbia and Abou-Tour (2001) and Bakry (2003).

Table (3) shows also the T.S.S., pH, titratable acidity and T.S.S./acidity and the values were 12.1%, 3.68, 1.72% and 7.39, respectively. The percentage of T.S.S. was nearly close to that reported by Cantwell *et al* (1992) and was very smaller than that presented by Bakry (2003) and Abou-Gharbia & Abou-Tour (2001).The titratable acidity of fresh husk tomato was higher than that reported by Abou-Gharbia and Abou-Tour (2001) and smaller than that mentioned by Bakry (2003), while, the pH value was smaller than that reported by Abou-Gharbia and Abou-Tour (2001) and higher than that presented by Bakry (2003).

Chemical composition of fresh husk tomato

The percentages of moisture, sugars (total, reducing and non-reducing), crude protein, total pectin, crude fibre, total ash, crude ether extract, ascorbic acid and phenolic content of fresh husk tomato are shown in Table (4). Moisture content was 81.49% and agreed well with that reported by Abou-Gharbia and Abou-Tour (2001). Moreover, the sugars (total, reducing and non-reducing) were 54.22, 25.26 and 28.96% on dry weight basis, respectively. Although, the total sugars were similar to that reported by Bakry (2003), reducing sugars were higher than that reported by Abou-Gharbia and Abou-Tour (2001) & Bakry (2003). The obtained results indicated that non-reducing sugars accounted about 52.01% of the total sugars.

Table 3. Physical properties total soluble solids, pH and titratable acidity of fresh husk tomato

Properties	Value*
Weight (gm)	3.92 ± 0.83
Number of fruit per kilogram	319.7 ± 26.1
Length (cm)	1.86 ± 0.14
Width (cm)	1.87 ± 0.20
Fruit index (width/length)	1.01 ± 0.07
Husk (%)	7.78 ± 0.03
Yield after dehusking (%)	92.22 ± 0.03
T.S.S. (%)	12.1 ± 1.9
pH	3.68 ± 0.1
Titratable acidity (%)**	1.72 ± 0.06
Titratable acidity (%)***	9.29 ± 0.34
T.S.S./Acidity	7.39 ± 0.57

* Mean ± S.D

** As (%) citric acid on wet weight basis

*** As (%) citric acid on dry weight basis

Table 4. Chemical composition of fresh husk tomato

Component	Value*
Moisture (%)	81.49 ± 0.20
Total sugars (%)	54.22 ± 1.87
Reducing sugars (%)	25.26 ± 2.16
Non-reducing sugars (%)	28.96 ± 1.56
Crude protein (%)	12.75 ± 0.13
Total pectin (%)	1.29 ± 0.08
Crude fibre (%)	19.38 ± 1.42
Total ash (%)	5.98 ± 0.20
Crude ether extract (%)	4.96 ± 0.17
Calcium (ppm)	113.58
Magnesium (ppm)	317.04
Sodium (ppm)	1106.62
Potassium (ppm)	6034.01
Ascorbic Acid (mg/100g)	178.88 ± 1.62
Phenolic content (mg/gm)**	7.48 ± 0.25
TAC***	21.43 ± 1.24

* Mean ± S.D on dry weight basis
** mg gallic acid.
*** TAC is Total Antioxidant Capacity as ascorbic acid equivalent.

Crude protein content of fresh husk tomato was 12.75% on dry weight basis and this value agreed well with that obtained by Abou-Gharbia and Abou-Tour (2001). They found that the crude protein content was 12.88% on dry weight basis.Total pectin content was 1.29 % and disagreed with that reported by Cantwell *et al* (1992) and Abou-Gharbia and Abou-Tour (2001). On the other hand, crude fibre of husk tomato was 19.38% on dry weight basis. This value was quite close to that reported by Bakry (2003). Total ash content of husk tomato was 5.98% on dry weight basis. This value was nearly quite close to that presented by Abou-Gharbia and Abou-Tour (2001). Also, minerals include Ca, Mg, Na, and K was 113.58, 317.04, 1106.62 and 6034.01 ppm (on dry weight basis), respectively. These values were slightly higher than that reported by Bakry (2003).

Crude ether extract of fresh husk tomato was 4.96% on dry weight basis. This value disagreed with the value reported by Abou-Gharbia and Abou-Tour (2001), who reported that, crude ether extract was 5.70% on dry weight basis. On the other hand, the obtained value was higher than that reported by Bakry (2003), who found that the crude ether extract content of husk tomato was 0.44% on dry weight basis. Ascorbic acid content was 178.88 mg/100gm on dry weight basis. These results are not comparable with those reported by Abou-Gharbia and Abou-Tour (2001). They found that ascorbic acid content of husk tomato was 39.5 mg/100gm. Further, phenolic content as gallic acid and the total antioxidant capacity as ascorbic acid equivalent of husk tomato were 7.48 mg/g and 21.43 mg/g on dry weight basis.

Effect of pretreatments and drying methods on the drying behaviour of husk tomato

The drying curves of all conducted drying tests are illustrated in Figs (1-4). The moisture ratio (MR) was plotted versus drying time for the different pretreatments and the different drying methods.

The presented data in Table (5) indicated that the drying time for husk tomato by hot air varied from 932.3 to 1225 min (15.5-20.34 hr) depending on the pretreatments applied before drying.

The effect of drying by hot air/microwave is shown in Table (5). Hot air/microwave drying had a great effect on reduction of drying time. The drying time decreased from 994.3 to 645.3 min (16.6 – 10.75 hr) for sample A2B1C2 that has been dried by hot air or dried by hot air/microwave, respectively. Hot air/microwave drying decreased the time required to achieve the final moisture content by about 35%. The results also indicated that drying time decreased with increasing Na_2CO_3 concentration with no significant differences between concentration 3% and 6% of Na_2CO_3. The same trend was observed with olive oil concentrations. The drying time decreased from 1106.2 to 1001.5 min (18.43 to 16.7 hr) when olive oil concentration increased from 0 to 0.5%. Also, immersion time had great effect on drying time, when immersion time increased from 2 to 4 min the drying time decreased from 1081.5 to 1026.3 min (18 to 17.1 hr). From the statistical point of view, it can be concluded that the lowest drying time was observed for A2B2C2, A3B2C1 and A3B2C2, respectively.

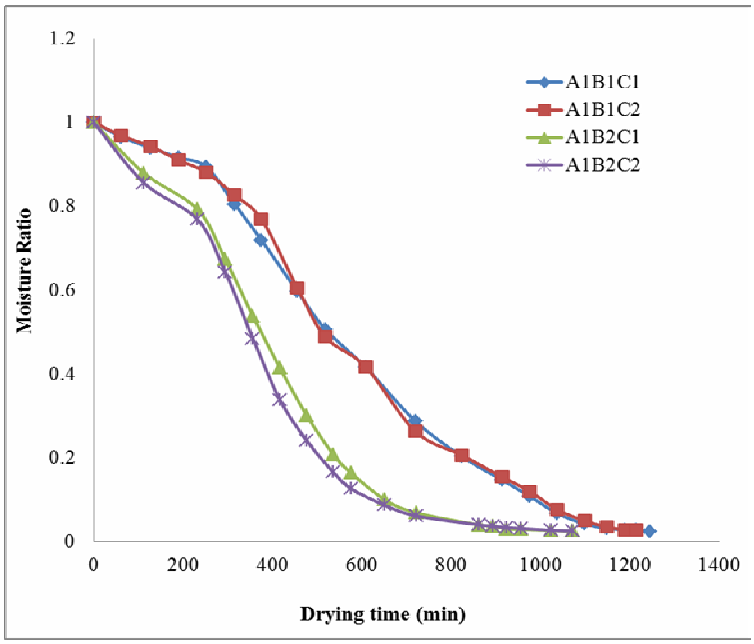

Fig 1. Hot air drying curves of husk tomato at different pretreatments

A1B1C1 = 0% Na_2CO_3, 0% olive oil, 2 min dipping time.
A1B1C2 = 0% Na_2CO_3, 0% olive oil, 4 min dipping time.
A1B2C1 = 0% Na_2CO_3, 0.5% olive oil, 2 min dipping time.
A1B2C2 = 0% Na_2CO_3, 0.5% olive oil, 4 min dipping time.

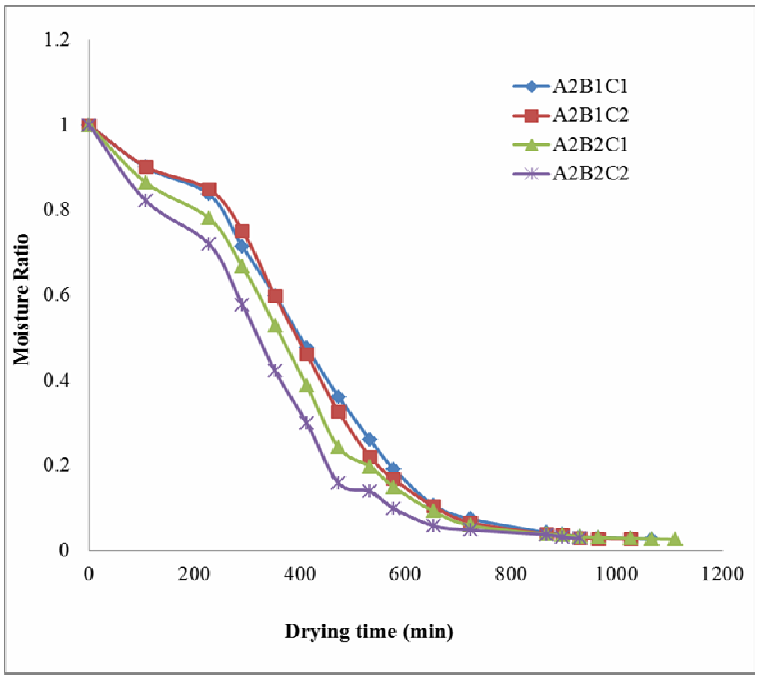

Fig 2. Hot air drying curves of husk tomato at different pretreatments

A2B1C1 = 3% Na_2CO_3, 0% olive oil, 2 min dipping time.
A2B1C2 = 3% Na_2CO_3, 0% olive oil, 4 min dipping time.
A2B2C1 = 3% Na_2CO_3, 0.5% olive oil, 2 min dipping time.
A2B2C2 = 3% Na_2CO_3, 0.5% olive oil, 4 min dipping time.

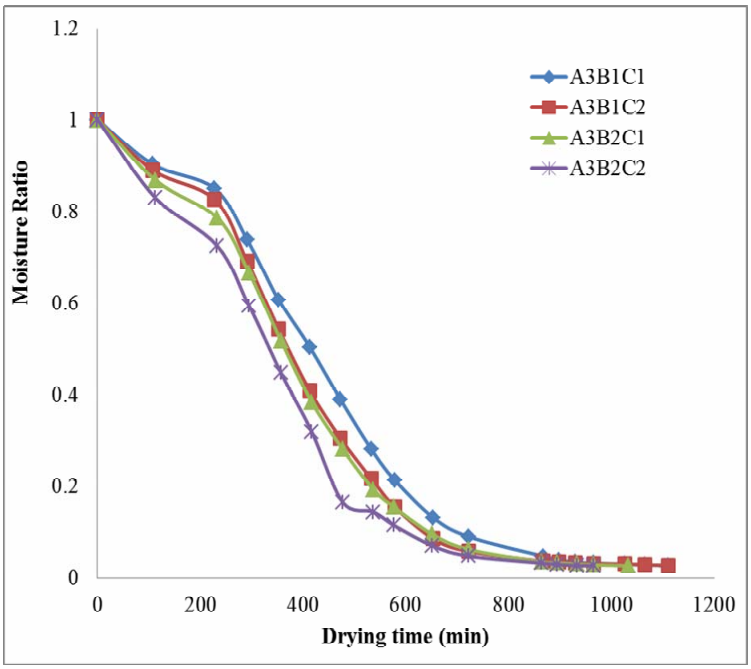

Fig 3. Hot air drying curves of husk tomato at different pretreatments

A3B1C1 = 6% Na_2CO_3, 0% olive oil, 2 min dipping time.
A3B1C2 = 6% Na_2CO_3, 0% olive oil, 4 min dipping time.
A3B2C1 = 6% Na_2CO_3, 0.5% olive oil, 2 min dipping time.
A3B2C2 = 6% Na_2CO_3, 0.5% olive oil, 4 min dipping time.

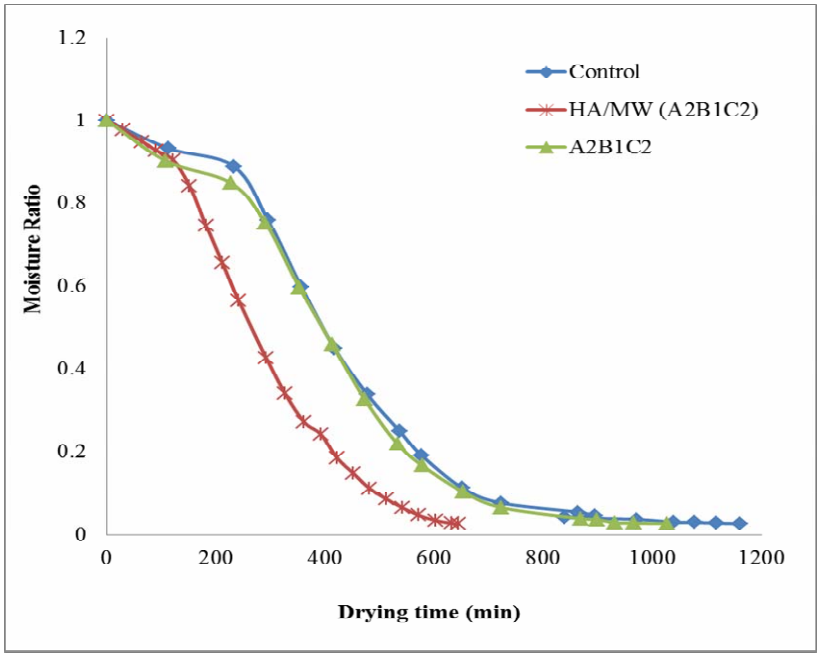

Fig 4.Drying curves of husk tomato at different pretreatments and different drying methods (hot air drying and hot air/microwave drying)

Control = 0% Na_2CO_3, 0% olive oil, 0 min dipping time.
A2B1C2 = 3% Na_2CO_3, 0% olive oil, 4 min dipping time and dried by hot air
HA/MW (A2B1C2) = 3% Na_2CO_3, 0% olive oil, 4 min dipping time and dried by hot air/microwave.

Table 5. Drying time at different pretreatments and different drying methods of husk tomato

Code of treatment	Drying time* (min)
Hot air Drying	
A1B1C1	1225.0 ± 17.3^{a}
A1B1C2	1185.0 ± 27.8^{ab}
A1B2C1	1051.7 ± 19.6^{cd}
A1B2C2	1001.5 ± 69.5^{def}
A2B1C1	1044.3 ± 19.9^{cd}
A2B1C2	994.3 ± 30.7^{efg}
A2B2C1	1087.5 ± 22.6^{c}
A2B2C2	932.3 ± 32.6^{h}
A3B1C1	1085.7 ± 23.0^{c}
A3B1C2	1087.5 ± 22.6^{c}
A3B2C1	984.0 ± 50.0^{fg}
A3B2C2	950.0 ± 16.5^{gh}
control	1161.7 ± 12.6^{b}
Hot air/microwave drying	
HA/MW (A2B1C2)	645.3 ± 4.2^{i}

*Mean ± S.D.

Means in a column not sharing the same superscript are significantly different at ≤ 0.5

Effect of pretreatments on the organoleptic characteristics of dried husk tomato.

All the air dried husk tomato samples were judged by panelists immediately after drying process for appearance, colour, odour, taste, texture and overall acceptability and the results are shown in Table (6).

The appearance of sample A2B1C2 had the highest score followed by A3B2C1 and A2B1C1, respectively. On the other hand, samples A1B1C1, A3B1C2 and A3B2C2 had the lowest score for appearance.

Further, samples A2B1C1 and A2B1C2 had the highest colour score followed by A3B2C1, whereas, A3B1C2 and A3B2C2 had the lowest colour score. No significant differences were noticed between all samples with respect to their odour and texture.

The same trend was observed for taste and overall acceptability. Sample A2B1C2 is moderately high followed by A3B2C1, while sample A1B1C2 had the lowest taste score and sample A3B1C2 had the lowest overall acceptability score.

Table 6. Organoleptic characteristics of air dried husk tomato*

treatment	Appearance	Colour	Odour	Taste	Texture	Overall acceptability
A1B1C1	6.1 ± 2.2^{c}	6.3 ± 2.1^{c}	6.8 ± 2.0^{a}	5.9 ± 2.2^{cd}	6.9 ± 1.9^{a}	6.5 ± 0.5^{cdef}
A1B1C2	6.5 ± 2.1^{abc}	6.6 ± 2.1^{bc}	6.7 ± 1.6^{a}	5.5 ± 2.5^{d}	6.8 ± 2.0^{a}	6.4 ± 0.5^{def}
A1B2C1	7.4 ± 1.2^{ab}	6.6 ± 1.2^{bc}	6.9 ± 1.6^{a}	6.1 ± 1.8^{bcd}	6.4 ± 1.8^{a}	6.7 ± 0.6^{cde}
A1B2C2	7.0 ± 1.5^{abc}	6.9 ± 1.4^{abc}	7.1 ± 1.7^{a}	6.9 ± 1.5^{abc}	7.1 ± 1.3^{a}	7.0 ± 0.1^{bc}
A2B1C1	7.4 ± 1.3^{a}	7.9 ± 0.9^{a}	7.4 ± 1.2^{a}	6.4 ± 1.7^{abcd}	6.9 ± 1.8^{a}	6.7 ± 0.4^{cde}
A2B1C2	7.6 ± 1.4^{a}	7.8 ± 1.1^{ab}	7.5 ± 1.1^{a}	7.6 ± 1.5^{a}	7.4 ± 1.2^{a}	7.6 ± 0.4^{a}
A2B2C1	7.1 ± 2.0^{abc}	7.1 ± 1.9^{abc}	7.1 ± 1.8^{a}	6.6 ± 1.9^{abcd}	7.1 ± 1.2^{a}	6.9 ± 0.2^{bcd}
A2B2C2	6.9 ± 1.5^{abc}	6.8 ± 1.7^{abc}	7.2 ± 1.5^{a}	6.1 ± 1.6^{bcd}	7.0 ± 1.2^{a}	6.6 ± 0.4^{cdef}
A3B1C1	6.9 ± 1.4^{abc}	7.1 ± 1.4^{abc}	7.1 ± 1.6^{a}	6.1 ± 1.7^{bcd}	7.0 ± 1.5^{a}	6.8 ± 0.4^{cde}
A3B1C2	6.1 ± 1.4^{c}	5.9 ± 1.7^{c}	6.9 ± 1.8^{a}	5.7 ± 1.5^{cd}	6.6 ± 1.3^{a}	6.1 ± 0.4^{f}
A3B2C1	7.4 ± 1.0^{a}	7.7 ± 1.0^{ab}	7.1 ± 1.7^{a}	7.3 ± 1.7^{ab}	7.2 ± 1.0^{a}	7.4 ± 0.4^{ab}
A3B2C2	6.1 ± 1.3^{c}	5.9 ± 1.5^{c}	7.1 ± 1.6^{a}	6.1 ± 1.6^{bcd}	6.8 ± 1.3^{a}	6.3 ± 0.4^{ef}
control	6.2 ± 1.8^{bc}	6.1 ± 2.0^{c}	6.6 ± 2.0^{a}	6.4 ± 1.9^{abcd}	6.6 ± 1.7^{a}	6.3 ± 0.3^{ef}

*Mean ± S.D.

Means in a column not sharing the same superscript are significantly different at ≤ 0.

Because sample A2B1C1 and A3B2C1 had relatively higher appearance, colour, odour, taste, texture and overall acceptability comparing with the other samples. So, the storage experiment was carried out only on A2B1C1 and A3B2C1. As the same time, the control sample was used for comparison. Sample A2B1C1 was selected to dry by hot air/microwave to compare it with the hot air drying sample (Fig 5).

The organoleptic characteristics of husk tomato sample (A2B1C2) dried either by hot air drying or by hot air/microwave (HA/MW (A2B1C2)) were presented in Table (7).

The tabulated data indicated that husk tomato sample dried by hot air was highly acceptable than that dried by hot air/microwave with respect to appearance, taste and overall acceptability. On the other hand, no significant differences were noticed between the two samples with respect to their colour, odour and texture.

The dried sample by hot air/microwave (HA/MW (A2B1C2)) was stored at room temperature for 6 months for comparison.

Effect of pretreatments, drying methods and storage on quality of dried husk tomato

Table (8) illustrated the effect of pretreatments, drying methods and storage on quality of dried husk tomato.

The moisture content reduced from 81.49% to 9.84, 11.08, 10.06 and 11.10% for samples A2B1C2, A3B2C1, control and HA/MW (A2B1C2), respectively. Generally, the moisture content increased by increasing time of storage and reached to 12.29, 12.7, 12.53 and 13.72% for samples A2B1C2, A3B2C1, control and HA/MW (A2B1C2), respectively, after six months of storage at ambient temperature. From the statistical point of view it can be revealed that the increment in moisture content of dried husk tomato for samples A3B2C1 and HA/MW (A2B1C2) was slightly higher than that observed in case of A2B1C2 and the control sample. A maximum increase in moisture content of dried husk tomato during storage was found in sample HA/MW (A2B1C2) which has been dried by hot air/microwave. This sample showed significant difference with respect to its moisture content in comparison with the other samples dried by hot air and stored for six months. The increase in moisture content during storage may be due to the permeability of polyethylene pouches to gases including the atmospheric vapour inducing slight rehydration of the dried husk tomato.

The titratable acidity of husk tomato decreased significantly on a dry matter basis after drying. The reduction on acidity may be due to leaching out acids from fruit during blanching or sulphiting before drying. At zero time of storage for dried husk tomato, the percentages of reduction in titratable acidity were 30.57, 36.60, 40.04 and 9.90 % for samples A2B1C2, A3B2C1, control and HA/MW (A2B1C2), respectively. In all cases, the total amount of titratable acidity increased while pH values decreased with increasing the time of storage for dried husk tomato either dehydrated by hot air or by hot air/microwave.

From the obtained data shown in Table (8), it is clear that the drying process caused remarkable significant reduction on ascorbic acid content. The loss of ascorbic acid amounted between 70.22 to 75.15%, and this decrement may be due to the pretreatments such as blanching and the relatively high temperature used during drying process. At the beginning of the storage period, ascorbic acid content was 45.45, 53.27, 44.45 and 45.30 mg ascorbic/100 g sample (on dry weight basis) for samples A2B1C2, A3B2C1, control and HA/MW (A2B1C2), respectively. From the tabulated data, ascorbic acid content decreased by progressing the time of storage and the control sample stored for six months had the lowest ascorbic acid content, being 15.31 mg ascorbic acid/100 g sample (on dry weight basis). From the statistical point of view and during storage, no significant differences were noticed between samples dried either by hot air or by hot air/microwave.

The percentage loss of phenolic content due to drying varied from 27.67 to 47.19%. The percentage loss of phenolic content was slightly lower in case of hot air/microwave drying in comparison with the oven drying process. The total amount of phenolic content decreased with increasing the period of storage. For example, it decreased from 5.11 (zero time of storage) to 2.99 mg gallic acid/g (on dry weight basis) after 6 months of storage of A2B1C2 sample. The same trend had been noticed in case of the control sample. In case of HA/MW (A2B1C2), the reduction in the total phenolic content was slightly lower than that observed in case of the oven drying and the control samples.

The results showed that, large amount of total antioxidant capacity was lost during the drying process and the percentage loss ranged between 56.89 to 67.29%. After drying, the total amount of antioxidant capacity reached 9.24, 7.01, 7.08 and 7.30 mg ascorbic acid equivalent/g sample (on dry weight basis) for sample A2B1C2, A3B2C1, control and HA/MW (A2B1C2), respectively. The reduction in total antioxidant capacity may be due to the pretreatments before drying.

Table 7. Effect of hot air drying and hot air/microwave drying on organoleptic characteristic of dried husk tomato*

Organoleptic characteristics	Treatments	
	Hot air drying	Hot air/microwave drying
Appearance	7.4 ± 1.6^{a}	6.1 ± 1.9^{b}
Colour	7.1 ± 1.7^{a}	6.0 ± 2.0^{a}
Odour	7.25 ± 2.1^{a}	6.25 ± 2.0^{a}
Taste	7.7 ± 1.8^{a}	5.9 ± 1.7^{b}
Texture	7.0 ± 1.8^{a}	6.25 ± 2.0^{a}
Overall acceptability	7.4 ± 0.4^{a}	6.2 ± 0.3^{b}

* Mean ± S.D.

Means in a column not sharing the same superscript are significantly different at ≤ 0.5

Table 8. Effect of pretreatments, drying methods and storage on quality of dried husk tomato*

Treatment	Storage period	Moisture of content (%)	Titratable Acidity** (%)	pH	Ascorbic acid (mg/100g)	Phenolic content (mg gallic acid/g)	TAC*** (mg ascorbic acid equivalent/g)	Total sulphur dioxide (ppm)	Free sulphur dioxide (ppm)	Rehydration ratio
	Fresh	81.49 ± 0.20^{a}	9.29 ± 0.34^{a}	3.67 ± 0.03^{a}	178.88 ± 1.62^{a}	7.48 ± 0.25^{a}	21.43 ± 1.24^{a}	N.D.	N.D.	N.D.
Control	Zero time	10.06 ± 0.26^{g}	5.57 ± 0.04^{f}	3.24 ± 0.03^{b}	44.45 ± 0.47^{c}	4.54 ± 0.48^{c}	7.08 ± 0.90^{c}	241.84 ± 6.23^{d}	171.48 ± 4.55^{a}	1.96 ± 0.17^{a}
	Three months	11.18 ± 0.30^{ef}	6.65 ± 0.05^{de}	3.15 ± 0.02^{c}	17.85 ± 1.13^{fjk}	3.79 ± 0.13^{e}	3.63 ± 0.0^{ef}	203.61 ± 7.58^{e}	84.90 ± 4.09^{d}	1.96 ± 0.07^{a}
	Six months	12.53 ± 0.11^{c}	6.75 ± 0.37^{cde}	3.13 ± 0.01^{c}	15.31 ± 1.35^{k}	2.78 ± 0.25^{f}	2.3 ± 0.38^{f}	189.58 ± 6.46^{ef}	47.82 ± 5.43^{e}	1.92 ± 0.09^{ab}
A2B1C2	Zero time	9.84 ± 0.28^{g}	6.45 ± 0.25^{e}	3.22 ± 0.05^{b}	45.45 ± 1.11^{c}	5.11 ± 0.44^{b}	9.24 ± 0.61^{b}	349.37 ± 10.25^{a}	186.53 ± 30.91^{a}	1.92 ± 0.06^{abc}
	Three months	10.82 ± 0.40^{f}	6.86 ± 0.15^{cd}	3.20 ± 0.02^{b}	21.25 ± 1.70^{de}	4.51 ± 0.49^{c}	5.21 ± 0.50^{d}	255.67 ± 15.06^{d}	111.67 ± 5.89^{c}	1.86 ± 0.05^{abcd}
	Six months	12.29 ± 0.25^{cd}	7.06 ± 0.01^{c}	3.15 ± 0.03^{c}	20.57 ± 2.27^{def}	2.99 ± 0.20^{f}	3.52 ± 0.22^{ef}	204.05 ± 5.99^{e}	90.79 ± 9.35^{d}	1.77 ± 0.09^{de}
A3B2C1	Zero time	11.08 ± 0.72^{ef}	5.89 ± 0.06^{f}	3.22 ± 0.04^{b}	53.27 ± 2.94^{b}	4.10 ± 0.28^{cde}	7.01 ± 1.15^{c}	277.80 ± 26.97^{c}	174.50 ± 6.02^{a}	1.88 ± 0.08^{abcd}
	Three months	11.60 ± 0.54^{de}	6.78 ± 0.05^{cde}	3.14 ± 0.04^{c}	18.00 ± 1.02^{fjk}	3.59 ± 0.28^{e}	3.95 ± 0.17^{de}	197.15 ± 13.83^{e}	99.51 ± 3.32^{cd}	1.85 ± 0.02^{abcd}
	Six months	12.71 ± 0.30^{c}	6.99 ± 0.01^{cd}	3.11 ± 0.01^{cd}	16.62 ± 0.87^{jk}	2.79 ± 0.12^{f}	2.34 ± 1.00^{f}	177.13 ± 6.59^{f}	47.12 ± 4.53^{e}	1.80 ± 0.02^{bcd}
HA/MW (A2B1C2)	Zero time	11.10 ± 0.25^{ef}	8.37 ± 0.13^{b}	3.07 ± 0.03^{de}	45.30 ± 1.88^{c}	5.41 ± 0.21^{b}	7.30 ± 0.42^{c}	308.80 ± 9.72^{b}	129.14 ± 5.15^{b}	1.81 ± 0.10^{bcd}
	Three months	11.26 ± 0.25^{ef}	8.55 ±0.05^{b}	3.03 ± 0.03^{e}	22.80 ± 0.28^{d}	4.34 ± 0.59^{cd}	3.61 ± 0.21^{ef}	201.93 ± 7.57^{e}	97.43 ± 2.72^{cd}	1.78 ± 0.07^{cd}
	Six months	13.72 ± 0.94^{ab}	8.65 ± 0.08^{b}	3.03 ± 0.02^{e}	18.68 ± 2.47^{efj}	3.83 ± 0.17^{de}	2.56 ± 0.16^{f}	192.80 ± 5.59^{ef}	44.84 ± 5.59^{e}	1.64 ± 0.04^{e}

* Mean ± S.D. , Means in a column not sharing the same superscript are significantly different at ≤ 0.5
** Acidity as (%) citric acid.
*** TAC = total antioxidant capacity
N.D. = not determined.
A2B1C2 (3% Na_2CO_3, 0% olive oil, 4 min dipping time and dried by hot air)
A3B2C1 (6% Na_2CO_3, 0.5% olive oil, 2 min dipping time and dried by hot air)
Control sample (0% Na_2CO_3, 0% olive oil, 0 min dipping time and dried by hot air)
HA/MW (A2B1C2) (3% Na_2CO_3, 0% olive oil, 4 min dipping time and dried by hot air/microwave)

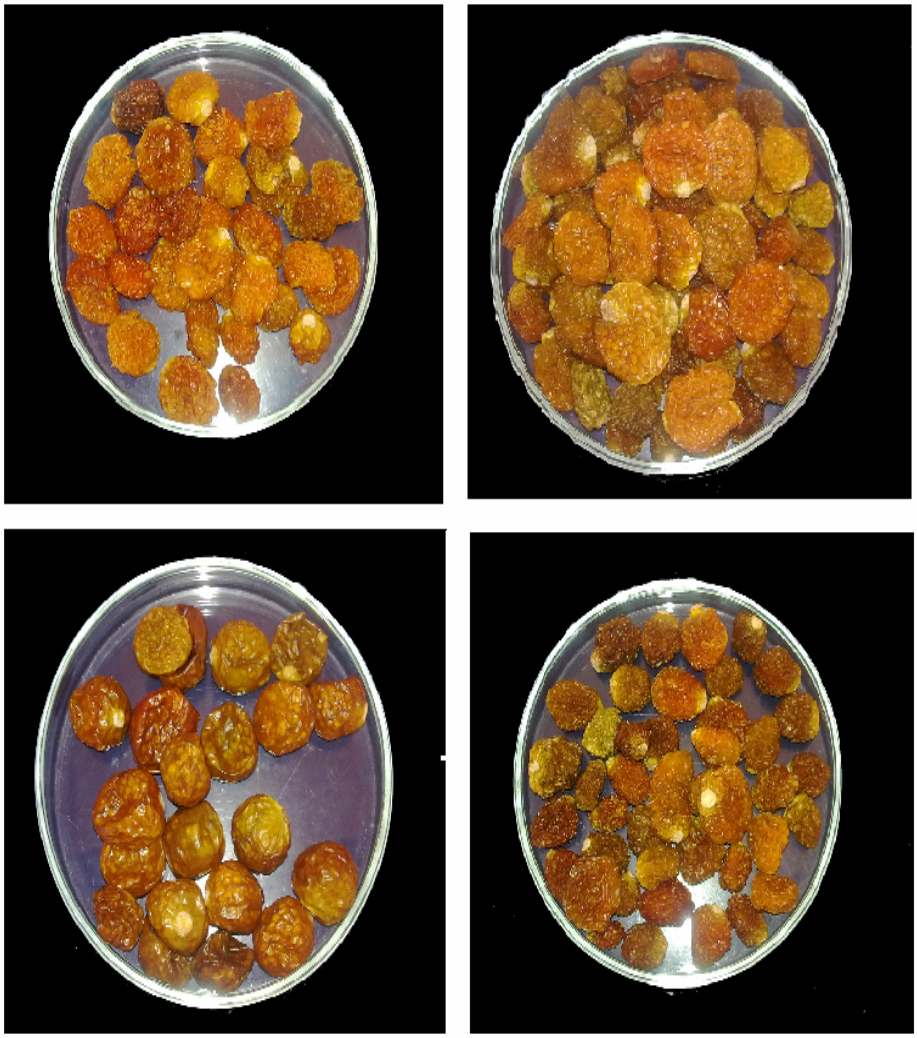

Fig. 5. Dried husk tomato samples

A= A2B1C2 (3% Na_2CO_3, 0% olive oil, 4 min dipping time and dried by hot air)
B= A3B2C1 (6% Na_2CO_3, 0.5% olive oil, 2 min dipping time and dried by hot air)
C= HA/MW (A2B1C2) (3% Na_2CO_3, 0% olive oil, 4 min dipping time and dried by hot air/microwave)
D= Control sample

The results also revealed that the total antioxidant capacity decreased by increasing the time of storage and it reached 3.52, 2.34, 2.3 and 2.56 for A2B1C2, A3B2C1, control and HA/MW (A2B1C2), respectively. The lowest total antioxidant capacity was observed with the control sample. No significant difference was found between the treatments after storing for six months.

From the obtained data, the residual of total SO_2 after drying was 349.37, 277.80, 241.84 and 308.80 ppm and the residual of free SO_2 was 186.53, 174.50, 171.48 and 129.14 ppm for A2B1C2, A3B2C1, control and HA/MW (A2B1C2), respectively. The percentage of total SO_2 loss after three months of storage varied from 15.80 to 34.61% and then reached 21.61 to 41.59 % from initial amount of SO_2 after six months (Table8), and the percentage of free SO_2 loss after three months varied from 24.55 to 50.49% and then reached 51.33 to 65.28% from initial amount of SO_2 after six months (Table 8). Actually, control sample had the lowest percentage losses of total SO_2, while, sample A2B1C2 had the highest percentage losses of total SO_2. On the other hand, A2B1C2 sample had the lowest percentage losses of free SO_2, whereas, A3B2C1 sample had the highest percentage losses of free SO_2.

The rehydration ratio of the dried samples of husk tomato is presented in Table (8). The rehydration ratio after drying ranged from 1.81 to 1.96. Moreover, the control sample had the highest rehydration ratio, while, sample HA/MW (A2B1C2) had the lowest ones. Also, there is no significant difference between samples A2B1C2, A3B2C1 and the control sample. Furthermore, the rehydration ratio decreased during storage and reached 1.77, 1.80, 1.92 and 1.64 after six months of storage for samples A2B1C2, A3B2C1, control and HA/MW (A2B1C2), respectively. As seen from the results, HA/MW (A2B1C2) sample which has been dried by hot air/microwave had the lowest rehydration ratio either after drying or after storage for the different periods and this may be due to the effect of microwave on the physical properties of the dried tissues.

The hunter colour scale parameters, redness (a^*), yellowness (b^*) and lightness (L^*) were used to estimate colour changes after drying process and storage of dried husk tomato. The results are given in Table (9).

Table 9. Effect of pretreatments, drying methods and storage on colour (L^*, a^*, b^*, hue and chroma) of husk tomato*

Treatment	Storage period	L^*	a^*	b^*	Hue*	Chroma*
	Fresh	49.17 ± 1.33^{a}	8.25 ± 3.57^{ab}	21.94 ± 2.04^{a}	69.97 ± 6.55^{a}	23.54 ± 3.12^{a}
Control	Zero time	42.81 ± 1.65^{b}	7.22 ± 1.74^{abc}	11.78 ± 0.91^{bc}	58.53 ± 8.03^{b}	13.91 ± 0.24^{bc}
	Three months	38.19 ± 1.71^{d}	5.00 ± 1.27^{bcde}	5.53 ± 1.91^{e}	74.42 ± 2.96^{def}	7.46 ± 0.24^{ef}
	Six months	35.75 ± 0.12^{ef}	1.92 ± 0.21^{de}	1.73 ± 0.10^{g}	42.03 ± 4.55^{def}	2.59 ± 0.05^{h}
A2B1C2	Zero time	40.67 ± 1.22^{c}	9.06 ± 2.25^{a}	9.97 ± 1.62^{cd}	48.01 ± 2.84^{def}	13.49 ± 2.78^{bc}
	Three months	36.31 ± 0.95^{def}	4.80 ± 1.26^{cde}	5.03 ± 1.53^{ef}	46.51 ± 0.92^{def}	6.94 ± 2.01^{ef}
	Six months	35.52 ± 0.82^{f}	2.93 ± 0.17^{def}	3.05 ± 0.55^{fg}	45.90 ± 3.73^{def}	4.24 ± 0.50^{fgh}
A3B2C1	Zero time	42.71 ± 1.58^{b}	9.01 ± 0.88^{a}	13.10 ± 1.79^{b}	55.40 ± 1.96^{bcd}	15.91 ± 1.91^{b}
	Three months	37.50 ± 0.07^{de}	5.32 ± 0.06^{abcd}	6.21 ± 0.05^{e}	49.39 ± 0.20^{def}	8.17 ± 0.07^{de}
	Six months	35.66 ± 0.71^{ef}	2.10 ± 0.39^{de}	2.76 ± 1.24^{fg}	50.58 ± 9.14^{cde}	3.49 ± 1.20^{gh}
HA/MW (A2B1C2)	Zero time	40.29 ± 0.36^{c}	6.49 ± 0.39^{abc}	8.62 ± 0.10^{d}	53.05 ± 1.93^{bcde}	10.8 ± 0.18^{cd}
	Three months	35.53 ± 0.82^{f}	4.39 ± 0.52^{cd}	4.39 ± 0.08^{ef}	53.25 ± 4.04^{bcde}	6.19 ± 0.23^{efg}
	Six months	33.55 ± 0.95^{g}	2.32 ± 0.54^{de}	1.59 ± 0.15^{g}	59.74 ± 3.80^{b}	2.71 ± 0.27^{h}

*Mean ± S.D.

Means in a column not sharing the same superscript are significantly different at ≤ 0.5

A2B1C2 (3% Na_2CO_3, 0% olive oil, 4 min dipping time and dried by hot air)

A3B2C1 (6% Na_2CO_3, 0.5% olive oil, 2 min dipping time and dried by hot air)

Control sample (0% Na_2CO_3, 0% olive oil, 0 min dipping time and dried by hot air)

HA/MW (A2B1C2) (3% Na_2CO_3, 0% olive oil, 4 min dipping time and dried by hot air/microwave)

Husk tomato was initially light greenish-yellow with colour parameters L^*, a^* and b^* of 49.17, 8.25 and 21.94, respectively. At the end of drying, the lightness decreased in all samples. Pretreated samples A2B1C2 and HA/MW (A2B1C2) had lower value of lightness at zero time and seemed darker in colour compared to the treated sample A3B2C1 and the control ones.

Yellowness value (b^*) decreased after drying , while the redness value (a^*) increased in samplesA2B1C2 and A3B2C1 and decreased in the control sample and HA/MW (A2B1C2). There were significant differences in these parameters between fresh and dried samples. This may be due to decomposition of chlorophyll and carotenoid pigments and the formation of brown pigments.

Chroma and hue angle values were calculated and the results are shown in Table (9). Chroma values decreased after drying. The chroma value indicates the degree of saturation of colour. The best colour intensity (saturation) was found in sample A3B2C1and it decreased from 23.54 to 15.91. Also, hue angle values changed from 69.97 to 48.01, 55.40, 58.53 and 53.05 for pretreated samples A2B1C2, A3B2C1, HA/MW (A2B1C2) and the control sample, respectively.

The effect of storage on colour of the dried husk tomato was also shown in Tables (9). L^*, a^*, b^*, chroma and hue values decreased by increasing the storage period and the colour became darker. This may be due to the reduction in total and free sulphur dioxide used during the pretreatments and thus the browning reactions' happened.

Aerobic mesophilic counts as well as yeast and molds counts were determined and presented in Tables (10). Generally, all counts were less than 25. Thus the results were reported as estimated aerobic plate count (EAPC) or estimated yeast and molds count (EYMC) < 250. These results indicated that there was no longer any microbial growth on husk tomato and no any spread of fungi or yeast.

Application of dried husk tomato

Since the drying process concentrate mostly all the components, the sour or acidic taste was increased which may be appreciated by some customers, whereas others complained about this taste. Therefore, mixing dried husk tomato with food products such as cake and coating the dried husk tomato with chocolate has been suggested to make it more acceptable. The organoleptic characteristics of cake with dried husk tomato and chocolate coated husk tomato are evaluated and presented in Table (11). From the presented data, it can be noticed that the overall acceptability of both products were high. Cake with dried husk tomato is highly accepted by the panelists and this may be due to the high sugar content in the final product. During the organoleptic test, the panelists stated some suggestions as follows:

Table 10. Effect of pretreatments, drying methods and storage on aerobic mesophilic, yeast and molds count of husk tomato

Treatments	Storage time	Dilutions			EAPC*	Dilutions			EYMC**
		10^{-1}	10^{-2}	10^{-3}		10^{-1}	10^{-2}	10^{-3}	
Control	Zero time	1	0	1	< 250	0	0	0	< 250
	Three months	3	2	2	< 250	0	0	0	< 250
	Six months	10	2	1	< 250	0	0	0	< 250
A2B1C2	Zero time	2	1	2	< 250	1	0	0	< 250
	Three months	4	2	2	< 250	1	0	0	< 250
	Six months	8	1	0	< 250	1	0	1	< 250
A3B2C1	Zero time	1	1	0	< 250	8	0	0	< 250
	Three months	3	3	2	< 250	1	0	0	< 250
	Six months	4	3	2	< 250	0	0	0	< 250
HA/MW (A2B1C2)	Zero time	1	1	0	< 250	0	0	0	< 250
	Three months	1	4	2	< 250	0	0	0	< 250
	Six months	3	3	1	< 250	0	0	0	< 250

* EAPC estimated aerobic plate count

** EYMC estimated yeast and molds count

A2B1C2 (3% Na_2CO_3, 0% olive oil, 4 min dipping time and dried by hot air)

A3B2C1 (6% Na_2CO_3, 0.5% olive oil, 2 min dipping time and dried by hot air)

Control sample (0% Na_2CO_3, 0% olive oil, 0 min dipping time and dried by hot air)

HA/MW (A2B1C2) (3% Na_2CO_3, 0% olive oil, 4 min dipping time and dried by hot air/microwave)

Table 11. The organoleptic characteristics of cake with dried husk tomato and coated chocolate husk tomato*

Parameters*	cake with dried husk tomato	coated chocolate husk tomato
Appearance	8.0 ± 1.3	7.2 ± 1.6
Colour	8.4 ± 1.0	7.7 ± 1.2
Odour	8.2 ± 1.3	8.2 ± 1.3
Taste	7.9 ± 1.2	7.5 ± 1.3
Texture	8.0 ± 1.2	7.6 ± 1.2
Overall acceptability	8.1 ± 1.3	7.6 ± 1.4

* Mean ± S.D.

- Cutting dried husk tomato to small pieces before immerge it in cake to increase uniformity and improve the appearance.
- Increase the layers of chocolate by dipping dried husk tomato in melted chocolate several times to enhance the appearance and improve the taste.
- Mixing butter and milk during melting chocolate before immersing dried husk tomato through it, to give it polish appear and colour and enhance the nutrition value and improve the taste.

As a conclusion, combining hot air with microwave drying reduced the drying time by about 35%. On the other hand, the organoleptic properties of cake containing dried husk tomato and husk tomato coated with chocolate were accepted by the panelists with some suggestions for further studies.

REFERENCES

Abd El-Ghaffar, E.A. 2009. Astudy on kinetics of drying process of some fruits and vegetables . Ph.D. Thesis, Food Sci. Dept. Fac. of Agric., Ain Shams Univ., Egypt.

Abd El-Lahot, M.S.R. 2010. Effect of roasting and storage processes on chemical and physical properties of coffee. M.Sc. Thesis, food science and technol. Fac. of Agric., Alex. Univ., Egypt.

Abou-Gharbia, H.A. & Abou-Tour, E.M. 2001. Properties and processing of husk tomato (*Physalis pruinosa* L.). Minufiya J. Agric. Res., 26: 761-781.

Alibas, I. (2007). Microwave, air and combined microwave-air drying parameters of pumpkin slieces LWT-Food Sci. and Technol., 40: 1445-1451.

Amer, B.M. 1999. Determination of drying rate of fruits as a function of the affecting factors under conditions suiting solar drying. M.Sc. Thesis, Agricultural Eng. Dept., Faculty of Agric., Cairo Univ., Egypt.

Association of Official Analytical Chemists (AOAC) 2003. Official methods of analytical .Helrich, K. 17 th ed. Virginia, USA.

Association of Official Analytical Chemists (AOAC) 2000. Official methods of analytical. 17th ed. Gaitherburg: Maryland, USA.

Babalis, S.J. & Belessiotis, V.G. 2004. Influence of the drying conditions on the drying constants and moisture diffusivity during the thin-layer drying of figs. J. food Eng., 65 : 449-458.

Bakry, N.A. 2003. The chemical composition and processing of goldenberry *(Physalis peruviana)* grown in Egypt. M. Sc. Thesis, Public Health science(food analysis). High Institute of Public Health. Alex. Univ., Egypt.

Barbosa-Canovas, G.V. & Vega-Mercado, H. 1996. Other Methods of Dehydration of Foods and Packaging Aspects. In: Barbosa- Canovas, G.V. and Vega-Mercado, H. (Eds.), Dehydration of Foods. New York: Chapman & Hall : 289–320.

Bekheit, A.A.A. 2002. Production and evaluation of Egyptian date sheets and pastes. M. Sc. Thesis, Food Sci. and Tech. Dept. Fac. of Agric., Cairo Univ., Egypt.

Bondaruk, J., Markowski, M. & Blaszczak, W. 2007. Effect of drying conditions on the quality of vacuum-microwave dried potato cubes. J. Food Eng., 81: 306–312.

Caliskan, O. & Polat, A.A. 2011. Phytochemical and antioxidant properties of selected fig (*Ficus carica* L.) accessions from the eastern Mediterranean region of Turkey. Scientia Hort., 128 : 473–478.

Cantwell, M., Flores-Minutti, J. & Trejo-Gonzalez, A. 1992. Developmental changes and postharvest physiology of tomatillo fruits (*Physalis ixocarpa* Brot.). Scientia Hort., 50: 59-70.

Dean, A. & Voss, D. 2005. Design and Analysis of Experiments Springer - Verlag, New York.

El-Abasy, A.E.M. 2011. Formulation and evaluation of some functional juice mixes and bakery products. M. Sc. Thesis, food science and technol. Fac. of Agric., Alex. Univ., Egypt.

Fogliano, V., Verde, V., Randazzo, G. & Ritieni, A. 1999. Method for measuring antioxidant activity and its application to monitoring the antioxidant capacity of wines. J. Agric. Food Chem., 47: 1035-1040.

Gomez,M., Ruiz, E. & Oliete, B. 2011. Effect of batter freezing conditions and resting time on cake quality. LWT - Food Sci. and Technol., 44: 911-916.

Gouda, M.S.M. 1974. Chemical and technological studies on imported varieties planted in Egypt. M. Sc. Thesis, Food Sci. and Tech. Dept. Fac. of Agric., Alex. Univ., Egypt.

Hamed, E.Y. 2008. Drying grapes using microwave. M. Sc. Thesis, Agricultural engineering. Fac. of Agric., Alex. Univ., Egypt.

Konyaloglu, S., Saglam, H. & Kvcak, B. 2005. a-Tocopherol, flavonoid, and phenol contents and antioxidant activity of ficus carica leaves. Pharmaceutical Biol., 43: 683–686.

Krokida, M.K. & Marinos-Koouris, D. 2003. Rehydration kinetics of dehydrated products, J. Food Eng., 57 : 1-7.

Maskan, M. 2000. Microwave/air and microwave finish drying of banana, J. Food Eng., 44: 71–78.

McDonald S., Prenzler, P.D., Antolovich M. & Robards K. 2001: Phenolic content and antioxidant activity of olive extract. Food Chem. 73: 73–84.

Morton, J.F. 1987. Cape Gooseberry. In: Julia, F. , Morton, J. and Miami, F.L. (Eds.), Fruit of warm climates. Sanfransisco: Freeman Co, :430-434.

Mujumdar, A.S. & Menon, A.S. 1995. Drying of solids: principles, classification, and selection of dryers. In: Mujumdar, A.S.(Eds.), Handbook of Industrial Drying. Marcel-Dekker Inc., New York, USA, 1: 1–39.

Oztekin, S., Zorlugenc, B. & Zorlugenc, F.K. 2006. Effects of ozone treatment on micro flora of dried figs. J. Food Eng., 75: 396–399.

Polat, A.A. & Caliskan, O. 2008. Fruit characteristics of table fig (*Ficus carica*) cultivars in subtropical climate conditions of the Mediterranean region. New Zealand J. Crop and Hort. Sci., 36 :107-115.

Popenoe, H. 1989. Lost Crops of The Incas. Washington DC. National Academy Press.

Raghavan, G.S.V., Rennie, T.J., Sunkja, P.S. , Orsat, V. , Phaphuangwittayakul, W. & Terdtoon, P. 2005. Overview of new techniques for drying biological materials with emphasis on energy aspects. Braz. J. Chem. Eng., 22 : ????-????

Ranganna, S. 1995. Handbook of Analysis and Quality Control for Fruit and Vegetable Products. 2nd ed. Tata McGraw-Hill Publishing Company Limited. New Delhi.

Rubatzky, V. and Yamaguchi, M. 1997. World Vegetables. 2nd ed. New York: Alan R liss INC.

Schiffmann, R.F. 1995. Microwave and Dielectric Drying. In: Mujumdar, A.S. (Eds.), Handbook of Industrial Drying. New York, USA, :345–372.

Tosun, N. and Delen, N. 1998. Minimising of contaminaton of aflatoxigenic fungi and subsequent aflatoxin development in fig orchards by fungicides. Acta Hort., 480: 193–197.

Vietmeyer, N.D. 1986. Lesser-known plants of potential use in agriculture and forestry. Science, 232 : 1379-1384.

Willis, J.C. 1966. A Dictionary of Flowering Plants and Ferns. Cambridge, UK: Cambridge Univ Pess.

الملخص العربي

دراسات فيزوكيميائية وتكنولوجية على الحرنكش

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تم دراسة الصفات الفيزوكيميائية للحرنكش للوقوف على القيمة الغذائية وقابليتها للتصنيع. كما اشتملت الدراسة التعرف على الطريقة المثلى لتجفيف ثمار هذه الفاكهه ومدى تأثير المعاملات قبل التجفيف على التقبل والصفات الفيزوكيميائية والثبات التخزينى لهذا المنتج الغف وامكانية الإستفادة به فى بعض المنتجات الغذائية. ولقد أدى إستخدام الدمج بين التجفيف بالهواء الساخن والميكروويف إلى خفض زمن التجفيف بمقدار ٣٥%. ولقد حدث زيادة فى المحتوى الرطوبى والحموضة التنقيطية الكلية بعد التجفيف والتخزين. وعلى الجانب الآخر حدث إنخفاض ملحوظ فى كل من حامض الأسكوربيك والمواد الفينولية والنشاط المضاد للاكسدة وكلاً من ثانى اكسيد الكبريت الكلى والحر بعد التجفيف والتخزين لفترات مختلفة على درجة حرارة الغرفة. كما وجد ان المحتوى الميكروبى للثمار الغفة منخفض جداً ولم يحدث زيادة ملحوظة مع التخزين. أثبتت الدراسة أن الخواص الحسية للكيك المحتوى على الحرنكش الغف أوالحرنكش المغطى بالشيكولاته كانت متقبلة مع وجود بعض الإقتراحات.