Chemical Composition, Bioactive Compounds and Organoleptic Characteristics of Osmotic-Air Dried Apple (Cubes and Slices)

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ABSTRACT

The effect of osmotic-air dried treatments on the chemical composition, minerals, Vitamin C, pectin, polyphenolic compounds, antioxidants, colour and sensory properties of apple (slices and cubes) were determined comparing with fresh apples. The results indicated that, the moisture content of osmotic-air dried samples ranged from 2.07 to 2.67% compared to 85.48% for fresh apples. Osmotic-air drying process caused a reduction in crude protein, crude ether extract, crude fiber and vitamin C, while the nitrogen free extract (NFE) increased. In addition, increasing the concentration of the soaking sucrose solution to 50% led to more reduction in the previous mentioned nutrients. Also, nutrient contents of apple slices were lower than those of apple cubes. All osmotic-air dried apples had significantly higher content of sugars and acidity with lower pectin content than those of the fresh apples. In addition, increasing the sucrose solution concentration caused a significant increase in the sugar content. It is obvious generally that mineral contents (phosphorous, calcium, iron and sodium) of all the osmotic-air dried apples were lower than those of the fresh ones. Apple samples soaked in 40% sucrose solution had higher mineral contents than those soaked in 50% sucrose solution. Also, apple cubes had higher mineral contents than apple slices. Osmotic-air drying process reduced the total phenolic contents and antioxidant activity. The reduction was higher in apples soaked in 50% sucrose solution than those soaked in 40% sucrose solution and for apple slices comparing to apple cubes. The correlation coefficient reveals a positive relationship between antioxidant activity and total phenolic compounds. Also, osmotic-air dried apples had slightly lower colour lightness values than the fresh ones. The results also showed that apple soaked in 50% sucrose solution were higher in overall acceptability values than those of apples soaked in 40% sucrose solution. Generally apple slices had higher values than cube ones.

Key Words: Osmotic air dried apple, chemical composition, biochemical compounds, organoleptic characteristics.

INTRODUCTION

Apple is a highly favoured fruit, owing to their unique flavor characteristics. The apple is low in calories, but it is a rich source of vitamins A, C and a good supplies of minerals. It also contains several interesting compounds possessing possible health promoting abilities due to their function as antioxidants, or modulators of enzyme activity. Recent studies show that these bioactive compounds decrease the incidence of diabetes, cancer and heart disease (Elss *et al*., 2006).

Apple is also another important dietary source of nutrients and phytochemicals. It is consumed fresh, dried, pured, or juice (Purée) (Guyot *et al.,* 2003, Deng & Zhao, 2008, Oszmianski *et al.*, 2008).

Phytochemicals in apples also have antioxidative, anti hypercholesterolemic, and anticarcinogenic properties, and may reduce the risk of developing coronary heart disease, diabetes, or asthma (Boyer & Liu, 2004). The polyphenolic content of apples include procyanidins, hydroxyl cinnamic acid, dihydrochalcones, flavones, flavan-3-ols, ascorbic acid, and anthocyanins in peel of red varieties (Guyot *et al.,* 2003, Corey *et al.,* 2011).

Conventional dehydration of apple slices leads to a product of dark colour, leathery texture, and poor flavour with a loss of nutritive values (Taiwo *et al.,* 2001). Also, it requires high temperature , velocity of drying air and takes long time (Lewicki & Jakubczyk, 2004).

Osmatic dehydration, termed as dewatering and impregnation soaking process fluids (DISP), is a useful technique for the concentration of fruits and vegetables, realized by placing the solid food, whole or in pieces, in aqueous solution of sugars or salts of high osmotic pressure (Mandala *et al.,* 2005). Osmotic dehydrated products that lose about

70% of their water content are ready to eat and can be consumed as snake items or shakes (after grinding and mixing with milk or other liquid foods). Osmo-dehydrated food can therefore be used in the dairy, bakery and candy industries (Warczok, 2005).

Gonzalez & Valdez (1991) reported that, Anna apple have 0.79% (dry matter) crude fiber. However, Nasr (1994) reported that, the percentage of crude fiber of Anna apple was 7.83% (wet matter).

The amount of overall acids expressed as % malic acid among fresh and dried Idared apple slices resulted in no statistically significant variations. The acidity of fresh sample was 3.25% and dried sample was 1.49% (Dobricevic, 1998). Moreover, Teo *et al.* (2006) reported that, apple (*Malus domestica*) had 64.5± 5.4 mg/g malic acid.

Vitamin C had been considered to be one of the most prevalent antioxidative components of fruits and vegetables and exerts substantial chemopreventive effects without apparent toxicity at relatively high level (Lee *et al.,* 2003). Franquin *et al.* (2005) reported that, mature-green Golden apple (*Spondias cytherea sonnerate*) had 52.0 mg vitamin C/100 g fresh material.

Nasr (1994) reported that the percentage of pectin of Anna apple was 5.97%.

Gorinstein *et al.* (2001) studied the main minerals in whole apple and its pulp, and peel. They found that calcium content was 5.02 , 3.82 and 12.6 mg/ 100 g for whole fresh fruit, pulp and peel, respectively.

Apples are good source of phenolic compounds. The total extractable phenolic content has been investigated and it was ranging from 110-357 mg/100 g fresh apple (Wang *et al.,* 1996). The total phenolic contents of the flesh, flesh + peel, and peel of four apple varieties were determined by Wolfe & Liu (2002). It ranged from 159 to 588 mg Gallic acid equivalents/ 100g

The majority of the antioxidant capacity of a fruit or vegetable may come from compounds such as flavonoides, isoflavonoides, flavones, anthocyanins, catechins and isocatechins rather than from Vitamin C, E or β-carotene (Wang & Prior, 1996). Wolfe & Liu (2002) determined, the total antioxidant activity of the apple flesh, flesh + peel, and peel of four apple varieties. They stated that the total antioxidant activity of peels was greater than that of the flesh or flesh + peel for all varieties.

Colour is an important food quality arttribute for most consumers. It is an index of the inherent good qualities of a food. One obstacle in the dehydration is the discolouration due to browning (Kutyla-Olesiuk *et al.,* 2013). Colour measurements of osmotically dehydrated samples are studied by Chavan & Amarowicz, (2012), they observed that, as far as the osmotic dehydration progresses, the luminosity decreases and the yellowness increases. Sensory evaluation is an important factor of the quality determination for a food product since it represents the consumer's appreciation of the product. Different factors are important to the consumers and can be determined simply by being in contact with the food, such as texture, colour and aroma (Beaudry, 2001).

The present study was carried out to determine the effect of osmotic-air dried treatments on the chemical composition, minerals, vitamin C, polyphenolic compounds, antioxidants, colour values and sensory properties of apple slices and cubes.

MATERIALS AND METHODS

Materials

Anna Apples (*Malus doestic*) were bought randomly from local market at Alexandria. The fruits were sorted, washed, and packaged in box and stored in refrigerator at 4°C and 90% RH until processing. Batch of the fruits were kept frozen until used for further chemical analysis.

Methods:

Osmotic dehydration (OD)

The fruits were washed, peeled and cutted manually into cubes and slices. The thickness was approximately (2 ×2 ×2 cm for cube and 0.4-0.5 cm for slice). The samples were soaked in 0.5% citric acid for 5 min then rinsed. The concentration of osmotic solutions were 40%, 50% and 60%. The cubes and slices were immersed in osmotic sucrose at a ratio of 4:1 (w/w) fruit to sugar for 6, 8, 10 and 12 hrs at room temperature. At the end of the osmotic process periods, samples were drained, blotted with absorbent paper to remove excess solution. Then, samples were air dried at 70° until the samples reached the equilibrium moisture content of 2-3%.

Proximate chemical composition

Moisture (method No. 952.4), crude protein (method No. 955.04), crude ether extract (method No. 948.22), crude fiber (method No. 935.53), ash (method No. 935.53) and ascorbic acid (method No. 967.21) were determined according to the AOAC (2003). Nitrogen-free extract (NFE) content was estimated by difference according to the following equation:

NFE = 100– % of (rude protein + crude ether extract + crude fiber + ash).

Total sugars, pectin and acidity

Total sugars were determined after hydrolyzing with hydrochloric acid according to the method of the AOAC (2003). Pectin content was determined as calcium pectate following the method described in Person, (1981). Titratable acidity (TA) was determined by titration with 0.1 N NaOH and was expressed as malic acid as mentioned by the AOAC (2003).

Minerals

Calcium and iron were determined using Buck Scientific 210-VGP Atomic Absorption Spectrophotometer according to the (AOAC) (2003). Phosphorous was determined by the colourimetric method as reported by Person (1981). Sodium was estimated by Flame Photometer, 410 Coring (AOAC, 2003).

Total Phenolic Content

Total phenolic contents were determined colourimetrically as tannic acid by Folin-Denis reagent method after extracting with methanol containing 0.1% HCl according to Wolfe & Liu (2003). Standard curve was prepared using standard tannic acid solution (0.1 mg/mg).

Antioxidant activity

The antioxidant activity of apple samples based on coupled oxidation of β-carotene and linoleic acid were evaluated following the methods of Taga *et al.* (1984).

Colour

The colour was measured using a Hunter colorimeter (Minolta chroma-meter CR-200 version 3.0, Minolta Camera Handels GmbH, Ahrensburg, Germany) and the L* (Lightness), a* (red saturation index) and b* (yellow saturation index) values were used to define the colour (Ranganna, 1979).

Sensory Evaluation

Sensory properties including colour, crispness, texture, flavour, taste and overall acceptability for dried apples were determined by 10 member panelists of Food Science and Technology Department, Faculty of Agriculture, Alexandria University, Egypt, using the hedonic scale method rating of 1-10 (1 = dislike extremely, 10 = like extremely), (Ranganna, 1979).

Statistical analysis

Statistical analysis, standard deviation of means, analysis of variance, including the study of homogeneous groups established throughout the Least Significant Difference (LSD) test, stepwise multiple regression analysis were performed using the statgraphics plus 4.0 program. Also, the correlation coefficient between antioxidant activities and the total phenolic contents was determined (Falade & Aworth, 2005).

RESULTS AND DISCUSSION

Preliminary experiments on the sensory attributes of osmotic-air dried apples soaked in 40%, 50% and 60% sucrose solutions for 6, 8, 10 and 12 hrs, followed by air drying (at 70°C) until the samples reached the equilibrium moisture content of 2-3% were carried out to choose the best treatments. The panelists favored (slices or cubes) samples soaked in 40% and 50% sucrose solutions for 12 hrs. Therefore these treatments were selected for the further experiments, as demonstrated in the previous work by Qubasi, *et al.* (2015).

Proximate chemical composition of dried apples:

The data in Table (1) show the proximate chemical composition of osmotic-air dried apples. It can be seen that the moisture content of osmotic-air dried samples ranged from 2.07 to 2.67% compared to 85.48% for fresh apples. The lowest value was for osmotic-air dried apple slices (2.07%) soaked in 40% sucrose solution. Also, the same results were found by Lewicki & Pawlak (2005). These results were in accordance with Baljeet *et al.* (2012) who reported that increasing time of osmosed peach fruit (halves) from 1 to 6 hrs in 50% sugar solution decreased the moisture content from 3.89 to 2.1%.

The data in Table (1) also show that dehydration process and increasing the percentage of sucrose solution during the osmosis up to 50% caused a slight decrease in protein content. Miranda *et al.* (2009) stated that the loss in protein of dehydrated apples could be due to denaturation or changes in solubility during drying. Another possible cause is the release of amino acids from the proteins following denaturation, which could then react with other compounds such as sugars to produce dark brown-coloured polymers, called melanoidines, via the Millard reaction.

Crude ether extract content of osmotic-air dried samples was in the range of 0.33 to 0.47% for both apple cubes and slices, respectively, while it was 3.31% for the fresh ones on dry basis. Also, it is obvious that there was a relatively significance difference between the crude ether extract content of osmotic-air dried apple cubes and slices. The reduction in the crude petroleum ether extract content of the dried apples may be due to enzymatic hydrolysis during the first drying period (Miranda *et al*., 2009). Also, the results in Table (1) show that, there was a significant reduction of the crude fiber content of osmotic-air dried apples compared to that of the fresh apples. Moreover, crude fiber content of osmo-air dried apple cubes soaked in 50% sucrose solution was lower than that of the samples treated with 40% sucrose solution. The data in Table (1) illustrated that ash content was decreased by dehydration processes. Moreover, the concentration of sucrose solution which was used in osmotic-air dried apple (cubes and slices) had a remarkable and significant effect on the ash content. The ash content decreased significantly with increasing sucrose concentration. It was 0.56% and 0.51% for osmotic-air dried apple cubes and slices soaked in 40% sucrose solution, respectively.

At the same time, the ash content decreased to 0.14%for both apple cubes and slices when the sucrose solution used was at 50%. These findings are due to leaching out of some minerals during the soaking process especially at high concentration of the sugar solution. These results agreed well with those of Peiro *et al.* (2006) and Miranda *et al.* (2009) who found that the loss of minerals were related to osmotic dehydration of grape fruit, due mainly to differences in solubility and leaching of inorganic compounds to the osmotic solution.

The nitrogen-free extract (NFE) content of the osmotic-air dried apples increased compared to that of fresh apples (Table 1). Also, it increased significantly with increasing the concentration of osmotic solution. The data obtained in the present study complied with the results of Bidaisee & Badrie (2001) who found that fresh cashew apples had 8.07% total sugars and increased to 85.58% in dried candied cashew apple. They reported that the high sugar content of candied product can be attributed to the highly concentrated syrup used in osmotic dehydration. Also, the data shown in Table (1) indicated that the osmotic-air drying method caused a higher reduction of vitamin C for both apple slices and cubes compared to the fresh apples. It ranged from 5.15 to 7.52 mg/100 g (dry matter) in osmotic-air dried apples while it was 17 mg/100 g (dry matter) for fresh apples with percentage of reduction ranging from 55.76 to 69.70%. However, the concentration of osmotic solution affected significantly vitamin C content of apple samples, since apple cubes soaked in 40% sucrose solution had higher vitamin C content than that soaked in 50% sucrose solution. Also, the results are in good agreement with Nunez-Mancilla *et al.* (2013) who reported that the increment in concentration of sucrose medium raised the ascorbic acid oxidation in osmotic dehydrated papaya. Blanda *et al.* (2009), Abraham *et al.* (2010) and Phisut *et al.* (2013) mentioned

Table 1: Proximate chemical composition of osmotic-air dried apples (on dry weight basis)

Parameters %	Fresh apples	Osmotic-air dried apples				LSD
		Soaked in 40% sucrose solution		Soaked in 50% sucrose solution		
		Cubes	Slices	Cubes	Slices	
Moisture	84.48**^{a}	2.59^{d}	2.07^{g}	2.33^{f}	2.67^{e}	0.01182
Crude protein	3.09^{a}	2.91^{e}	2.98^{b}	2.85^{d}	2.78^{e}	0.01672
Crude ether extract	3.31^{a}	0.33^{e}	0.47^{b}	0.33^{e}	0.36^{d}	0.02644
Crude fiber	2.02^{a}	1.27^{d}	1.39^{c}	0.73^{g}	1.06^{f}	0.01672
Ash	2.54^{a}	0.56^{d}	0.51^{e}	0.14^{f}	0.14^{f}	0.02600
Nitrogen-free extract*	89.04^{g}	94.93^{e}	94.65^{d}	95.95^{a}	95.66^{b}	0.28960
Vit. C	17.00^{a}	7.52^{d}	5.18^{f}	6.90^{e}	5.15^{f}	0.03110
% Reduction in Vit. C	0	55.76^{d}	69.52^{b}	59.41^{c}	69.70^{a}	0.02376

* By difference.

** Means between columns sharing the same letters are not significantly different, using the revised LSD test at P≤ 0.05 level.

that, during osmotic process some micronutrients were leached into the treating solution in addition to other chemical and biochemical reactions. The reduction in the ascorbic during and after osmotic process was due to leaching out of the content from materials. Pereira *et al.* (2006) found that more concentrated osmotic solution resulted in higher water loss and then increasing flow of micronutrients to osmotic solution. Also, it can be seen that apple cubes retained more vitamin C content comparing to the apple slices either the samples soaked in 40% or 50% sucrose solution (Table 1). These results are in accordance with that of Marfil *et al.* (2008) who reported that the reduction rate in vitamin C content was higher for slices than for cubes.

Total sugars, pectin and titratable acidity:

Total sugars content of osmotic-air dried apple cubes and slices are presented in Table (2). Generally, all osmotic-air dried samples had significantly higher content of sugars than that of the fresh apples. Also, increasing the concentration of sucrose solution caused a significant increase in the sugar content of osmo-dehydrated samples. The total sugars of osmotic-air dried samples were in the range of 70.99% to 86.14%. The highest value was 86.14% for apple slices soaked in 50% sucrose solution. The increment of total sugars content was due to the solute gain action during osmosis treatment. These results are in accordance with those of Dixon & Jen (1977) who reported that fructose, glucose and sucrose contents of fresh apple slices increased after 4 hrs of soaking in 70% sucrose solution. Monnerat *et al.* (2010) found that total sugars content of osmosed apples soaked in 50% commercial sugar for 8 hrs, increased from 13% (on wet basis) in fresh apple to 38.49% in osmosed apple.

Table 2: Total sugars, pectin and titratable acidity (TA) of osmotic-air dried apples (on dry weight basis)

Parameters %	Fresh apples	Osmotic-air dried apples				LSD
		Soaked in 40% sucrose solution		Soaked in 50% sucrose solution		
		Cubes	Slices	Cubes	Slices	
Total sugars	55.13*^{e}	70.99^{d}	72.36^{e}	84.60^{b}	86.14^{a}	0.01295
Pectin	10.64^{a}	6.85^{e}	7.41^{d}	3.05^{g}	3.72^{f}	0.01750
TA	1.03^{g}	1.90^{c}	1.39^{d}	1.27^{e}	1.20^{f}	0.02148

* Means between columns sharing the same letters are not significantly different, using the revised LSD test at P≤ 0.05 level.

The results in Table (2) also show that pectin content of osmotic-air dried apples was lower than that of fresh apples. In addition, increasing sucrose concentration of soaking solution caused a significant reduction in the pectin content of osmotic-air dried samples. The pectin content of fresh apples was 10.64%. Meanwhile, the pectin content was in the range of 3.05 to 7.41% in the osmotic-air dried samples. The lowest value was (3.05%) for apple cubes treated with 50% sucrose solution, while the highest value was (7.41%) for apple slices soaked in 40% sucrose solution. Peiro *et al.* (2006) studied the flow of soluble micronutrients such as galacturonic acid. They found that the galacturonic acid decreased during osmosing process.

The data in Table (2) significantly show that all dehydrated apple samples had higher titratable acidity (TA) values than that of the fresh ones. Meanwhile all osmotic-air dried apple slices had lower TA values than that of apple cubes, soaked in 40% or in 50% sucrose solution. In addition, increasing the concentration of sucrose in the soaking solution caused a significant decrease in the TA content of osmotic-air dried samples. The reduction in the acidity was due to the loss of organic acids along with water during osmosis (Moy *et al.* 1978). Also, Lal *et al.* (2004) and Sagar & Kumar (2006) reported that titratable acidity of Aonla apple decreased after OD and drying due to leaching out of the contents.

Mineral contents:

Table (3) shows the mineral contents (phosphorus, calcium, iron and sodium) of apple cubes and slices compared to the fresh apples. Generally, it is obvious that mineral contents of all dried samples were lower than those of fresh apples. It can be seen that a significant decrease was observed in phosphorus content of both apple cubes and slices as a result of osmotic-air drying compared to the fresh apples. The mineral contents of osmotic-air dried apples, soaked in 40% sucrose solution, were higher than those soaked in 50% sucrose solution. The geometry of dried samples affected the mineral content in the present study, since the mineral contents were generally higher in apple cubes than those of slices. The phosphorus content

Table 3: Mineral contents of osmotic-air dried apples (on dry weight basis)

Parameters Mg/100g	Fresh apples	Osmotic-air dried apples				LSD
		Soaked in 40% sucrose solution		Soaked in 50% sucrose solution		
		Cubes	Slices	Cubes	Slices	
Phosphorus	147.0*a	69.0ab	55.0b	50.0b	43.0b	0.0827
Calcium	46.0a	30.0a	22.0a	28.0a	20.0a	0.0292
Iron	3.6a	2.3a	1.7a	2.0a	1.3a	0.0324
Sodium	5.0a	2.0a	2.0a	2.0a	1.0a	0.0320

* Means in the same columns sharing the same letters are not significantly different, using the revised LSD test at P≤ 0.05 level.

were 69 and 50 mg/100g for apple cubes soaked in 40 and 50% sucrose solution, while it was 55 and 43 mg/100 g for apple slices soaked in 40 and 50% sucrose solution, respectively. Similary, calcium content was higher in the samples soaked in 40% than those soaked in 50% sucrose solution. The calcium content was higher in apple cubes than that of slices. The same trend was observed for iron and sodium contents. Perio *et al.* (2006) studied the flow of soluble micronutrients such as minerals and they found that calcium content was higher in fresh grapefruit than that of the osmosed grapefruit with 29% loss. Also, the same trend was observed for phosphorous content which was higher in fresh fruits than in osmosed ones with 52% loss.

Total phenolic contents:

The total phenolic contents of osmotic-air dried apple (slices and cubes) compared to the fresh apples are given in Table (4).

The results show that the total phenolic contents of osmotic-air dried apples were less than that of fresh apples. It can be seen that osmotic-air drying reduced the total phenolic contents of apple samples, it was 664.50 mg tannic/100 g (dry matter) for fresh apples and decreased to 156.36-222.16 mg tannic/100 g for dried samples. The data in Table (4) also show that concentration of the sucrose solution affected significantly the total phenolic contents of apple samples. The highest reduction in phenolic contents was 75.73% for apple slices treated with 50% sucrose solution, while the lowest reduction was 65.52% for apple slices treated with 40% sucrose solution. These results are in a good agreement with those of Stajanovic & Silva (2007) and Nuez-Mancilla *et al.* (2013), who reported that osmotic concentration caused a loss in phytonutrients like total phenolics for berries.

Apple samples soaked in 40% sucrose solution had higher total phenolics content than those soaked in 50% sucrose solution. In addition, the geometry of cuting apples had noticeable effect on the total phenolic contents. Cube samples had higher total phenolic contents than slice ones for both apple samples soaked either in 40% or 50% sucrose solution.

Antioxidant activity

The antioxidant action is one of the physiological functions in foods, it is supposed to protect human beings from oxidative damages, resulting in the prevention of various diseases, (Prior & Guohua, 2000, Liu *et al.,* 2002, Wolfe & Liu, 2003).

The data in Table (5) show the antioxidant activity (AA) of osmotic-air dried apples compared to the fresh ones. The antioxidant activity of the fresh apples was 76.80% whereas the AA% of BHT was 84.53%. On the other hand, the osmotic-air drying generally, caused a significant degradation in the antioxidant activity of the products. The concen-

Table 4: Total phenolic contents of osmotic-air dried apples (on dry weight basis)

Parameters (%)	Fresh apples	Osmotic-air dried apples				LSD
		Soaked in 40% sucrose solution		Soaked in 50% sucrose solution		
		Cubes	Slices	Cubes	Slices	
Total phenolics mg tannic/100 g sample	664.50*a	222.16c	191.12e	185.76f	156.36g	0.0925
Reduction %	0	65.52e	73.44b	71.17d	75.73a	0.0584

* Means in the same columns sharing the same letters are not significantly different, using the revised LSD test at P≤ 0.05 level.

Table 5: Antioxidant activity of fresh and osmotic-air dried apples (cubes and slices)

Parameters (%)	Fresh apples	Osmotic-air dried apples: Soaked in 40% sucrose solution		Osmotic-air dried apples: Soaked in 50% sucrose solution		BHT*	LSD
		Cubes	Slices	Cubes	Slices		
AA% (After 60 min of incubation)	76.80**b	61.86d	53.06f	36.00g	24.00h	84.53	0.0930
Reduction %	0	19.75e	30.91c	53.12b	68.75a	0	0.0857

* BHT: butylated hydroxytoluene (as standard)
** Means in the same columns sharing the same letters are not significantly different, using the revised LSD test at P≤ 0.05 level.

tration of soaking sucrose solution affected significantly the antioxidant activity, since the AA% decreased to 53.06 and 61.86% for dried apple slices and cubes soaked in 40% sucrose solution, respectively and to 24.00 and 36.00% for samples soaked in 50% sucrose solution. These results are in a good agreement with Nunez-Mancilla *et al*. (2013), who reported that soaking strawberry in 40% sugar solution showed a decrease in the total antioxidant activity. Moreover, the shape of the fruits affected significantly the antioxidant activity of the osmotic dehydrated apples. Antioxidant activity of apple slices is lower than that of the apple cubes. Stajanovic & Silva (2007) reported that antioxidant activity was low in osmotic air dried blueberries. Combination of high temperature, high sugar concentration caused largest negative influence on the antioxidant activity.

Correlation coefficient between the antioxidant activities (AA) and the total phenolic contents of osmotic-air dried apples are shown in Table (6). The data revealed that there was a positive relationship between antioxidant activity and the phenolic contents for all the osmo-dehydrated samples, since very strong correlation coefficients (R) were obtained (R was 1 for all samples). The results confirmed that the phenolic compounds in the osmo-dehydrated apples were the most responsible element for the AA of the samples. These results are in accordance with Amakura, *et al.* (2000) who revealed a positive correlation between total phenolics and AA in blueberry jam (r = 0.57) and stated that the phenolic contribution to AA is mostly due to some phenolics (such as anthocyanins) among the total phenolics.

Colour parameters:

The colour measurements of osmotic-air dried apple (slices and cubes) compared with the fresh apples are given in Table (7). The data in Table (7) show that lightness (L*) values were high in osmotic-air dried apples however, L* value is the highest in the fresh apple and apple slices soaked in 40% sucrose solution. The main reason for the high L* value for osmotic-air dried apples was sugar impregnation which maintain lightness, resulting in a final product close to that of fresh fruits (Mandala, *et al.*, 2005). The a* and b* values were higher in

Table 6: Correlation coefficient between total phenolics and antioxidant activity of osmotic-air dried apples

Parameters (%)	Osmotic-air dried apples: Samples Soaked in 40% sucrose solution		Osmotic-air dried apples: Samples Soaked in 50% sucrose solution		LSD
	Cubes	Slices	Cubes	Slices	
Total phenolics	191.12*b	222.16a	156.36d	185.76c	0.0050
AA	53.06b	61.86a	24.00d	36.00c	0.0225
R			1		

* Means in the same columns sharing the same letters are not significantly different, using the revised LSD test at P≤ 0.05 level.

Table 7: Colour parameters of fresh and osmotic-air dried apples (cubes and slices)

Parameters %	Fresh apples	Osmotic-air dried apples: Soaked in 40% sucrose solution		Osmotic-air dried apples: Soaked in 50% sucrose solution		LSD
		Cubes	Slices	Cubes	Slices	
L*	82.54**a	80.83b	82.55a	67.29f	69.31e	0.01308
a*	-12.01g	-2.66f	-0.13e	2.54a	-0.04d	0.01400
b*	14.52f	15.13e	16.47c	29.35a	26.10b	0.01850

L* (brightness) & a* (redness) & b* (yellowness).
** Means in the same columns sharing the same letters are not significantly different, using the revised LSD test at P≤ 0.05 level.

osmotic-air dried apples (cubes and slices) than in the fresh ones and generally the colour tends to be yellow to red.

The geometrical shape had a significant effect on the colour values since the apple cubes had less L* value than that of the slices. The high L* values represent less darkening in the colour of samples soaked in 40% sucrose solution than the other dried samples. This may suggest the influence of the high sugar concentration with the temperature of air drying on decreasing these values and changing the colour. Moreover, Osorio *et al.* (2007) reported that during the osmotic dehydration process, the loss of colour is one of the most significant changes. An increment was found in the L^*, a^* and b^* values after osmosis process.

Sensory Attributes:

Table (8) shows the sensory attributes of osmotic-air dried apples (cubes and slices). It can be seen that there were significant differences between osmotic-air dried apples regarding to sensory attributes of cubes and slices. The panelists favored the samples soaked in 50% sucrose solution. In addition, the apple slices were more preferable concerning to colour, taste, flavour and texture than those of apple cubes, soaked in 40% or 50% sucrose solution. These results agreed with Jeyaraman & Dasagupta (1992) who reported that more sugar intake in highly concentrate solution increases the sweetness and consumer acceptability of the osmotic-air dried fruit products. The overall acceptability of osmotic-air dried apple slices soaked in 50% sugar solution was higher than that of osmotic-air dried apple slices soaked in 40% sugar solution. Sahari *et al*., (2006) studied the sensory evaluation of sliced peach during sun drying and osmotic dehydration. The results showed that the sensory analysis of osmotic-air dried apples had better colour, appearance and chew ability properties as compared with the fresh.

Table 8: Sensory attributes of osmotic-air dried apples (Cubes and slices).

Parameters	Osmotic-air dried apples				
	Soaked in 40% sucrose solution		Soaked in 50% sucrose solution		LSD
	Cubes	Slices	Cubes	Slices	
Colour	8.00^{*c}	8.70^{a}	6.70^{d}	8.50^{b}	0.01240
Taste	6.90^{c}	8.20^{a}	6.40^{d}	8.00^{b}	0.02480
Flavour	6.50^{c}	8.90^{b}	6.40^{d}	9.00^{a}	0.01710
Texture	7.50^{d}	8.20^{b}	7.60^{e}	8.30^{a}	0.03739
Overall acceptability	7.40^{d}	8.50^{b}	7.50^{c}	8.70^{a}	0.02150

* Means in the same columns sharing the same letters are not significantly different, using the revised LSD test at $P \leq 0.05$ level.

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التركيب الكيماوي والمكونات النشطة حيويا والخواص الحسية لمكعبات وشرائح التفاح المجففة إسموزيا

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تم دراسة التجفيف تحت الضغط الإسموزي المتبوع بالهواء الساخن علي التركيب الكيماوي، المحتوي من المعادن، فيتامين ج، البكتين، الفينولات الكلية والنشاط المضاد للأكسدة والخواص العضوية الحسية لشرائح ومكعبات التفاح. وذلك مقارنة بالتفاح الطازج.

وجد من الدراسة ان محتوي الرطوبة للعينات المجففة إسموزيا يتراوح من ٢,٠٧ - ٢,٦٧٪ مقارنة بـ ٤٨,٨٥٪ للتفاح الطازج. وقد أدي التجفيف الاسموزي الى انخفاض في محتوي كل من البروتين الخام، المستخلص الاثيري الخام، الالياف الخام، الرماد وفيتامين ج بينما ارتفع المستخلص الخالى من النيتروجين. أيضا وجد أن زيادة تركيز محلول النقع إلى ٥٠٪ سكروز قد أدى إلى انخفاض أكبر في العناصر الغذائية سابقة الذكر. وكان الانخفاض فى محتوي شرائح التفاح من تلك العناصر الغذائية بمعدل أعلي من مكعبات التفاح. وقد لوحظ ايضا ان التفاح المجفف بالضغط الاسموزي كان أعلي في محتواه من السكريات الكلية والحموضة التنقيطية وأقل في المحتوي من البكتين مقارنة بالتفاح الطازج. وأدت زيادة تركيز المحلول السكري الي زيادة معنوية في محتوي التفاح من السكريات الكلية وانخفاض معنوي في كل من البكتين والحموضة التنقيطية.

من الواضح بصفة عامة ان المحتوي من المعادن (الفوسفور - الكالسيوم - الحديد والصوديوم) في كل عينات التفاح المجففة إسموزيا كان أقل منه في التفاح الطازج. وقد احتوت عينات التفاح التي تم نقعها في محلول سكروز ٤٠٪ علي محتوي من المعادن أعلي من تلك المنقوعة في محلول سكروز ٥٠٪. أيضا كان محتوي مكعبات التفاح من المعادن أعلي من الشرائح. وقد أدت عملية التجفيف الاسموزي الي انخفاض معنوي في الفينولات الكلية ونشاط مضادات الاكسدة. وكان الانخفاض أكبر في حالة النقع في محلول سكروز ٥٠٪ عن تلك المنقوعة في محلول سكروز ٤٠٪ وأيضا لشرائح التفاح مقارنة بمكعبات التفاح. وبحساب معامل الارتباط وجد أن هناك ارتباطاً موجباً بين النشاط المضاد للأكسدة والمحتوي من المواد الفينولية الكلية لكل عينات التفاح المجففة.

وكان لون عينات التفاح المجففة اسموزيا أقل في درجة الإضاءة مقارنة بالتفاح الطازج. وقد أوضحت النتائج أيضاً أن عينات التفاح المجففة إسموزيا باستخدام محلول سكروز ٥٠٪ أعلي في درجة التقبل الكلي عن تلك المنقوعة في محلول سكروز ٤٠٪. وكانت شرائح التفاح الأعلي في هذه الخواص من المكعبات.