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Effect of some Different Drying Methods on Quality Criteria of Dried Fig Fruits

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ABSTRACT

The objective of this investigation was aimed to study the Effect of microwave- air drying and microwave-vacuum drying on the physical, chemical and sensory properties of dried fig and cost of operation. Chemical Composition,(Moisture, protein (N × 6.25), ether extract, ash , fiber contents, total carbohydrates content, total sugar, reducing and non-reducing sugars); physiochemical attributes (Color (O.D), T.S.S (%),T.A.% (as citric acid), pH value, Rehydration ratio and Shrinkage (%)); antioxidant compounds (*L*-Ascorbic acid, Total phenolic compounds and Total flavonoids); antioxidant activity of 2,2,-diphenyl-1-picrylhydrazyl and sensory evaluation of fig fruits compared to conventional air drying(AD) and vacuum drying(VD) methods. The obtained results showed that, the drying rate of tested samples by using the microwave-air convection drying method(MWAD) was faster than those for drying rate of air convection drying method at the corresponding drying condition(60ºC and 1.5 m/s air velocity). and the microwave vacuum drying system(MWVD) could produce final dried product throughout short time not exceeded than 120, min, whereas this require 36 hr.by using vacuum drying system. The microwave energy assisted with the different drying system especially with air convection and vacuum drying systems leading to sharply reduce the drying time, and thus lead to a reduction cost of the dried products. The fig samples dried by using MWAD and MWVD were the best for the most of physicochemical quality properties such as color, rehydration ratio and shrinkage rate when compared with the similar samples dried by AD which needed the long time. The dried fig by using MWVD method had the higher amount of total phenolic compounds (245.11 mg/100g DM) than that found in other drying methods. Followed by the dried samples using MWAD (237.23 mg/100g DM), which was near to the samples dried by using VD method (235.86 mg/100g DM), while the lowest amount of total phenolic compounds (218.32 mg/100g DM) was found in dried fig by using AD method. The MWVD drying process caused, in general, a highly retention of total flavonoids in dried fig samples at a wide rates depending upon the drying time, followed by MWAD drying process as compared to the AD and VD drying methods. The samples dried in MWVD and MWAD exhibited more the ability to quench the DPPH radical obviously than those found in the samples dried by AD or VD methods. The fig samples dried by using both MWAD and MWVD exhibited good sensory properties and better acceptability when compared with the samples dried by AD and VD, especially with AD.MW-related drying can meet the four major requirements in drying of foods: short time of operation, energy efficiency, cost of operation, and quality of dried products.

Key words: Microwave drying, Microwave-Air drying Air drying, vacuum drying, sensory quality, antioxidant compounds, and antioxidant activity.

Introduction

There is increasing market demand for dehydrated fruits and vegetables worldwide Zhang *et al*. (2006). Dehydration removes the majority of water from fruits and vegetables and highly improves the shelf life of the final dried products resulting from reduced water activity. Drying of fruit and vegetables using high temperature and for long drying time by conventional heating results in the damage of quality of the final dried products. Viswanathanl *et al*. (2003).This is partly attributed to the fact that fruits and vegetables are subjected to low drying rate during the falling drying rate period in many of the conventional drying methods such as airflow drying, vacuum drying, and freeze-drying. Zhang *et al*. (2003), Zhang *et al*. (2005) and Clary *et al*. (2005).The most important fruit and vegetables quality known to be affected by high temperature drying for long time includes nutritional value, structural properties and sensory attributes. In conventional hot air ventilation heating or drying, long exposure time is required to reduce food water content down to lower safe moisture content. The acceptability (visual appeal, taste, aroma, flavour and texture), structural property and nutritional value of fruits and vegetables are also highly affected. Zhang *et al*. (2003), Zhang *et al*. (2005), Warchalewski *et al*. (1998) and Krokida and Maroulis, (2001).

Microwave heating is used in many processes such as baking, pre-cooking and drying industry. Microwaves cover a range of frequencies from 300 MHz to 30 GHz and the wavelength from 1 mm to 1 m

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Ozbek and Dadali, (2007). The typical frequency used in microwave ovens is 2450 MHz. The microwave energy is absorbed by food materials and is converted into heat due to two mechanisms: the ionic interaction and the dipolar rotation. Salt and water are common molecules in most foods. Salt molecules are vibrated due to ionic interaction. On the other hand, the vibrations of water molecules are due to the dipolar rotation Sahin, and Sumnu, (2006).

Several researchers have worked on the conventional hot air drying of food materials such as rough rice Hacıhafızog *et al*. (2008), green beans Doymaz, (2005) and Sahin and Sumnu, (2006). , soybeans Hutchinson and Otten, (1983) and Kitic and Viollaz, (1984) and canola Zare *et al.* (2009). All studies show that the application of the conventional drying methods consumes long drying time and high amount of energy. Application of microwave heating in conjunction with the hot air drying would lead to a great reduction in drying time. Several studies have been performed in this way from which the works of Prabhanjan *et al.* (1995)on carrot, Ren and Chen, (1998) on ginseng roots, Funebo and Ohlsson, (1998) on apples and mushrooms, McMinn, (2006) on lactose powder and Wang *et al.* (2007) on apple, are of interest. Sharma and Prasad, (2001) studied on the drying of garlic cloves with hot air and combined microwave–hot air methods. The combined microwave-hot air drying were carried out at the air temperatures of 40, 50, 60 and 70 °C, and air velocities of 1.0 and 2.0 m/s by the use of microwave power of 40 W. The combined microwave-hot air drying caused a significant reduction in drying time of about 80-90 % in comparison with the conventional drying. Kouchakzade and Shafeei, (2010) have recently investigated the drying of two varieties of Iranian pistachio under microwave-convective treatment. Drying curves were fitted with seven moisture ratio models. They observed that the Page model Agrawal and Singh, (1977) represented the best agreement with the experimental data according to the R^2 and X^2 of curves fitting. The experiments were carried out in less than 30 min during hot air-microwave drying of pistachios. Applying microwave power for drying of food materials can increase their final quality Sharma and Prasad, (2001) and Walde *et al.* (2002). Furthermore, studies indicate that microwave drying of grains before grinding helps reduce power consumption which is important in milling industries Walde *et al.* (2002).

Microwave assisted air drying is one of the methods where hot air drying is combined with microwave heating in order to enhance the drying rate. Microwave heating can be combined with hot air in three different stages of the drying process. At the initial stage, microwave heating is applied at the beginning of the dehydration process, in which the interior gets heated rapidly. At a rapid drying period, a stable temperature profile is established in such a way that the vapor is forced outside due to an improved drying rate. This creates a porous structure called 'puffing' which can further facilitate the mass transfer of water vapor. At the reduced drying rate period or at the final stage of drying, the drying rate begins to fall where the moisture is present at the center and with the help of microwave heating, vapor is forced outside in order to remove bound water (Zhang *et al*., 2006).

In recent years, microwave drying has gained popularity as an alternative drying method for a wide variety of food and agricultural products, although microwave drying research so far focused mainly on the fundamental aspects than industrial application. The idea to combine fast heating of microwave and low temperature convective drying has been investigated by a number of researchers. Zhang *et al*. (2005) reported a review on trends in microwave-related drying of fruits and vegetables indicating the advantages of combining conventional drying methods with microwave heating. The review also clearly indicates that combination of drying methods leads to better drying processes than using microwave or conventional drying methods alone. Microwave heating is based on the transformation of alternating electromagnetic field energy into thermal energy by affecting the polar molecules of a material. Heating of bulk foods can easily be achieved by microwave heating than by conventional heating, which is one of the most important characteristics of this drying technology. Zhang *et al*. (2006) and Mullin, (1995). The convective mode of heat transfer is used in conventional heating which is followed by conduction where heat must diffuse in from the surface of the material deep into fruits and vegetables. However, microwave leads to a volumetric heating which means that all the materials can be heated to the desired temperature at the same time. In microwave heating microwave energy is directly absorbed and converts it into heat inside fruits and vegetables. This leads to movement of moisture by diffusion from the deep interior section of fruits and vegetables to the surface.

Zhang *et al*. (2003) and Zhang *et al*. (2005) reported that hot air ventilation drying of produce at high temperature for long time causes a significant damage to nutritional value as well as sensory quality of fruits and vegetables. However, microwave drying of fruits and vegetables results in high temperature efficiency, shorter drying time and result in better product quality compared to conventional hot air ventilation drying. Viswanathanl *et al*. (2003), Prabhanjan *et al*. (1995), Mullin, (1995) and Ren and Chen, (1998).

In microwave heating, heat is generated throughout the material, leading to faster heating rates, compared to conventional heating where heat is usually transferred from the surface to the interior. Poonnoy *et al*. (2007)

Microwave drying is caused by water vapour pressure differences between interior and surface regions, which provide a driving force for moisture transfer. As a result, microwave treatment can greatly reduce the drying time of the biological products without quality degradation. Based on this analysis the present study was aimed to study the Effect of microwave assisted hot air drying and vaccum drying on operating Cost analysis, physiochemical attributes and quality Criteria of fig fruits compared to air convection drying and vacuum drying methods.

Materials and Methods

Samples of fig fruits (ficus carica) variety (Conadria) green ripe fig were from El-kaliopia governorate. Fig fruits were washed thoroughly with tap water, cracked, blanched in hot water at 90°C for 5min and then sulphurized with immersion in 0.2% (2gm\L) sodium meta bisulfite solutions for 30 min. After that, the fruits were drained and divided into 4 groups. Then the 4 groups carefully set up as a single layer on the drying tray for use in the drying experiment. The figs of group 1 was dried by air drying method, group 2 was dried by microwave air drying method, group 3 was dried by vacuum drying method and the group 4 was dried by microwave vacuum drying method.

Chemicals, reagents used:

All chemical reagents used in present study were analytical grade. Folin-Ciocalteu, Gallic acid**,** Mediums (plat count agar**,** Potato dextrose agar (PDA))**.** All chemicals were purchased from El- Gamhouria Trading for Chemicals and Drugs Company, Egypt.

Cost analysis:

El- Awady *et al*. (1988) reported that the total cost per unit product is broken down into:

Fixed costs:

a) Depreciation = cost now – salvage value / total expected life in years.
(Salvage = 10% of cost now)

b) Interest on investment = (0.5 (Depreciable cost) + estimated savage) x interest rate (Interest rate is assumed 0.11)

c) Taxes and insurance = (0.5(Depreciable cost) + estimated savage) x combined rate (Combined rate =1.5%)

Operating costs:

a) Fuel, power and utilization
b) Maintenance and labor (maintenance = 3% cost now)

Gross Chemical Composition:

Moisture, protein (N × 6.25), ether extract, ash and fiber contents of fresh and dried figs were determined using the methods described by the A.O.A.C., (2005) Total carbohydrates content was calculated by differences as followed:

% Carbohydrates = 100 - the sum of (% moisture+% protein + % fat + % ash).

Determination of sugars:

The total, reducing and non-reducing sugars in figs, under investigation were determined by the official Lane-Eynone titratable method as described in A.O.A.C., (2005).The fruit extract sample was clarified by lead acetate and excess of lead acetate was precipitated by sodium oxalate. The reducing sugars and total sugars were determined in the clarified solution applying the official Lane-Eynone titrimetric method and the non-reducing sugars were calculated from the difference between the percentage of reducing and total sugar.

Colour: (Optical density measurement)

Colour was determined as the optical density of the diluted centrifuged extracts water of fruit flesh. 1g of the prepared samples were extracted with distilled water (200 ml) and the absorbance was measured at 340 nm using Perkin Elmer Lambda UV/VIS Spectrophotometer according to Hilphy *et al*. (2008).

Total Soluble Solids (T.S.S):

For the determination of total soluble solids, the fresh fig fruits was homogenized and then centrifuged at 1500 r/m for 10 min. The supernatant was used to measure the soluble solids according to the method described by A.O.A.C., (2005) using a refractometer, Carl Ziess, Jena (Germany) and the results were reported as °Brix at 20°C.

The Titratable Acidity (TA):

The titratable acidity (TA) for fresh fig fruits was determined according to the method described by A.O.A.C., (2005) TA was analyzed in triplicate and expressed as citric acid equivalents.

The pH Value:

Fresh fig fruits was homogenized and then evaluated as the method described by A.O.A.C., (2005) pH value determination was carried out by a Jenway 3505 pH Meter (UK) with a combined pH electrode at 25°C.

Rehydration Ratio (RR):

The rehydration capacity was used as a quality characteristic of the dried product (Velić *et al*. 2004) expressed in the rehydration rate – RR (Lewicki, 1998). Approximately 2 g (± 0.01 g) of the dried sample was placed in a 250 ml laboratory glass box (two analyses for each sample), 150 ml distilled water was added and the glass box was covered and heated to boil within 3 minutes. The content of the laboratory glass box was then gently boiled for 10 more min and then cooled. The cooled content was filtered for 5 min under vacuum and weighed. The rehydration ratio was calculated as:

$$RR = \frac{Wr}{Wd}$$

where:
Wr - drained weight (g) of the rehydrated sample.
Wd - weight of the dry sample used for rehydration.

Shrinkage (%):

Shrinkage is usually expressed by the volume ratio of sample before and after drying.A few researchers have expressed shrinkage as a function of the change of selected dimensions of the samples, measured with vernier or digital callipers (Hatamipour and Mowla, (2003), Karathanos *et al*. (1996) and Mayor and Sereno, (2004). Mostly, it was expressed in terms of the apparent volume (Eq. 1). This volume can be measured by the Archimedes principle or by a number of displacement techniques.

$$S = \frac{V_0 - V_d}{V_0} \times 100$$

Where, S (%) of shrinkage, V_d is the apparent volume of the sample after drying, cm3 andV0 is the apparent volume of the raw sample, cm3. Initially covered with paraffin oil then Volume changes due to sample shrinkage were measured by a water displacement method as described by (Sjoholm and Gekas, 1995). Measurements were made as quickly as possible (less than 30 s) to avoid water uptake by samples. to displace sample in order to estimate sample volume gravimetrically.

Determination of ascorbic acid:

Ascorbic acid content was estimated in fresh and dried fruit and vegetable according to A.O.A.C., (2005) using 2, 6 dichlorophenol-indophenols by titratable method. Result was expressed as mg ascorbic acid per 100 gm samples.

Total Phenolics:

The measurement of total phenolics (TPs) content was conducted according to the modified Folin-Ciocalteu colorimetric method Singleton *et al*. (1999). Each sample was measured at 760 nm using an UV/Vis spectrophotometer (Spekol 11, No. 849101,). Gallic acid was used as a standard and results were expressed as gallic acid equivalents (GAE) per 100 g DM. The linear reading of the standard curve was from 0 to 600 µg of gallic acid /milliliter.

Total Flavonoids:

Total flavonoids were analyzed according to the method reported by Toor and Savage, (2006) and Zhishen *et al*. (1999). The samples absorbance was measured at 510 nm on a spectrophotometer (Spekol11, No. 849101,) against the blank (water) and the total flavonoids was determined from the standard curve. Flavonoid content was expressed as mg Rutin equivalents/ 100 g DM.

Antioxidant Activity with the 2,2,-diphenyl-1-picrylhydrazyl Radical Scavenging Method.

The extraction of fruit samples for the determination of antioxidant activity was made according to the same protocol as for total phenolics. The free radical scavenging activity of fig extracts was measured according to the 2,2,-diphenyl-1-picrylhydrazyl method reported by Brand-Williams *et al*. (1995) with some modifications. A methanolic solution (50 µL) of extract was placed in 96-well microplates, and 200 µL of a 0.1 mmol L^{-1} methanolic solution of DPPH was added and allowed to react in the dark at room temperature. The decrease in absorbance of DPPH at 520 nm was measured at 5 min intervals by a spectrophotometer (MRX Dynex Technologies), until the absorbance stabilized (30 min). Methanol was used as blank solution, and a DPPH solution without test samples served as the control. All sample analyses were performed in triplicate. The DPPH radical scavenging activity of fig methanolic extracts was expressed as milligrams of ascorbic acid equivalents per 100 g.

Organoleptic evaluation:

Organoleptic evaluation was used to differentiate between the fig, samples dried by different drying methods under this study. Sensory evaluation was carried out by 10 panels from educational organization members of Food Science and Technology Department, Faculty of Agriculture, Cairo, Al-Azhar University. Organoleptic test of dried samples were given to the panelists for quantitative expression of the quality and sensory parameters.The sensory technique was carried out by using a hedonic test ten-point scale according to Gallali *et al*. (2000):

Statistical Analysis:

Data were subjected to the statistical analysis according to Analysis of Yariance (ANOY A) of Completely Randomized Design as described by Gomez and Gomez, (1984) Treatment means were compared using the Least Significant Differences (LSD) at 0.05 level of probability and Standard Error. Computations and statistical analysis of data were done using facilities of computer and statistical analysis system package (1985).

Results and Discussion

Total protein concentration Effect of different drying methods on the falling rate period (Elapsed time) of moisture content in produced dried figs fruits.

The relation between moisture content and elapsed time to reach the required moisture content (drying curves) of dried tested fig fruits for air convection (AD) compared with combined microwave-air convection (MWAD) drying methods at constant conditions (60ºC and 1.5 m/s air velocity) are shown in Table (1) and Fig (1), as well as the curves of moisture ratio versus drying time (drying curves) of the same tested samples dried by using vacuum drying (VD) compared with combined microwave-vacuum (MWVD) drying methods are also shown in Table (2) and Fig (2).

From the obtained data in Table (1) and Figures (1), it could be observed that the elapsed drying time to reach the adequate moisture content (20.98) in the final product of dried fig (tested fruits) by using the air convection drying method requires 20 hr. While, by using the combined microwave-air convection (MWAD) drying method to get the adequate moisture content with the limits of 20.87 % for fig samples were only 90 minutes.

Table 1: Effect of Air convection (AD) and Microwave-Air convection (MWAD) drying methods at 60ºCand 1.5 m/s air velocity on the falling rate period of moisture content (%) for dehydrated tested figs fruits .

Moisture content (%) of tested figs fruits during drying by AD and MWAD			
Drying time (hr)	Air convection drying (AD)	Drying time (min)	Microwave-Air convection drying (MWAD)
0	71.59	0	71.59
2	64.43	10	64.43
4	57.27	20	57.27
6	50.11	30	50.11
8	44.74	40	42.95
10	39.37	50	35.80
11	34.90	60	30.43
12	30.43	70	25.95
14	25.95	80	23.27
16	23.27	90	20.87
18	22.19		
20	20.98	-	-

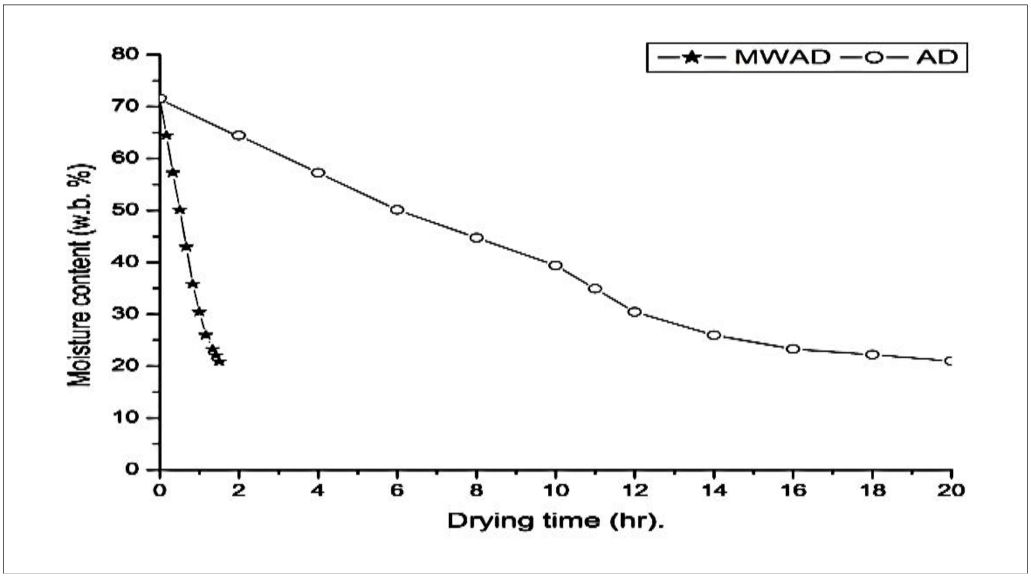

Fig. 1: The drying rate (moisture content and elapsed drying time) of fig dried by air convection (AD) and combined microwave-air convection (MWAD) drying methods.

These results may be due to the microwave energy may cause quickly removing of the moisture content from the product and lead to rapid in the drying rate. A combined microwave-hot air drying (MWHA) technique may be a better alternative way. This method provides a higher drying rate and a better quality of product compared to microwave drying or hot air drying (Chandrasekaran *et al*., 2013). This is because the hot air helps evaporate the surface moisture that is diffused from the inner layer of the drying product.

Better energy efficiency and dried product quality can be obtained by microwave drying which provides a higher drying rate than hot air drying (Dev *et al*., 2011). Microwave energy can be quickly directly absorbed by moisture in drying material (Puente-Díaz *et al*., 2013) and lead to heat generation within material (Orsat *et al*., 2007 and Varith *et al*., 2007). The high heating rate of microwaves raises the product temperature rapidly, causing high vapour pressure to develop inside the product (Nahimana and Zhang, 2011), resulting in a very rapid transfer of water to the surface of the product.

From the previous discussion, it could be showed that the drying rate of tested samples by using the microwave-air convection drying method was faster than those for drying rate of air convection drying method at the corresponding drying condition (60ºC and 1.5 m/s air velocity). Where, the falling rate period of fig samples was more 13 times when used the microwave-air convection drying method than those obtained by using the air convection drying method.

These results are in agreement with the data obtained by Sharma and Prasad, (2004) they reported that the drying time can be greatly reduced and the quality of finished product insured by applying the microwave energy to the dried material. Lowered pressure can additionally shorten the drying time.

To compare the effect of vacuum drying VD and the combined microwave-vacuum drying MWVD methods of tested fruits (fig) on the drying kinetics such as the curves of moisture ratio versus drying time under processing parameters (60ºC and 600 mbar vac.) are listed in Table (2) and Figures (2).

As illustrated in the obtained results, it could be noticed that the elapsed drying time to reach the adequate moisture content in the final dried tested samples by using vacuum drying method (VD) requires a much longer drying time, since it was 36 hours, to reach the moisture content of fig 20.30 %. Meanwhile, the same tested samples were required a shorter time to reach the desired moisture content in the final products when used the microwave-vacuum drying MWVD method, where the tested fig were required only 2 hour (120 min.) to reach the same moisture content 20.66. by using MWVD drying method. These results are coincident with those obtained by Therdthai and Zhou, (2009) who reported that a reduction in drying time of mint leaves under microwave- vacuum drying by 85–90% compared to hot air drying. These results are in accordance also with the data was obtained by Nahimana and Zhang, 2011; Huang *et al*., 2012).

The clear variance noted in present work is that the microwave vacuum drying system could produce final dried fig product with low moisture throughout short time not exceeded than 120, min, whereas this require 36, hr. by using vacuum drying system. This too much wide variation of drying time between them mainly related to drying mechanism that applied with microwave vacuum drying system. Explained this wide variation of drying times attributed to the mechanisms of water evaporation that concerned with air convection and microwave-air convection drying systems.

Table 2: Effect of Vacuum drying(VD) and Microwave-Vacuum (MWAD) drying methods at 60ºC and 600 mbar vac. on the falling rate period of moisture content (%) for dehydrated tested fruits and vegetables.

Moisture content (%) of tested figs fruits during drying by VD and MWVD			
Drying time (hr)	Vacuum drying (VD)	Drying time (min)	Microwave-Vacuum Drying (MWVD)
0	71.59	0	71.59
2	68.01	10	64.43
4	64.43	20	57.27
6	60.85	30	50.11
8	57.27	40	42.95
10	53.69	50	37.58
12	50.11	60	34.36
14	46.53	70	31.14
16	42.95	80	27.92
18	39.37	90	24.70
20	35.80	100	23.27
22	33.11	110	22.47
24	30.43	120	20.66
26	28.19	-	-
28	25.95	-	-
30	24.61	-	-
32	23.27	-	-
34	22.28	-	-
36	20.30	-	-

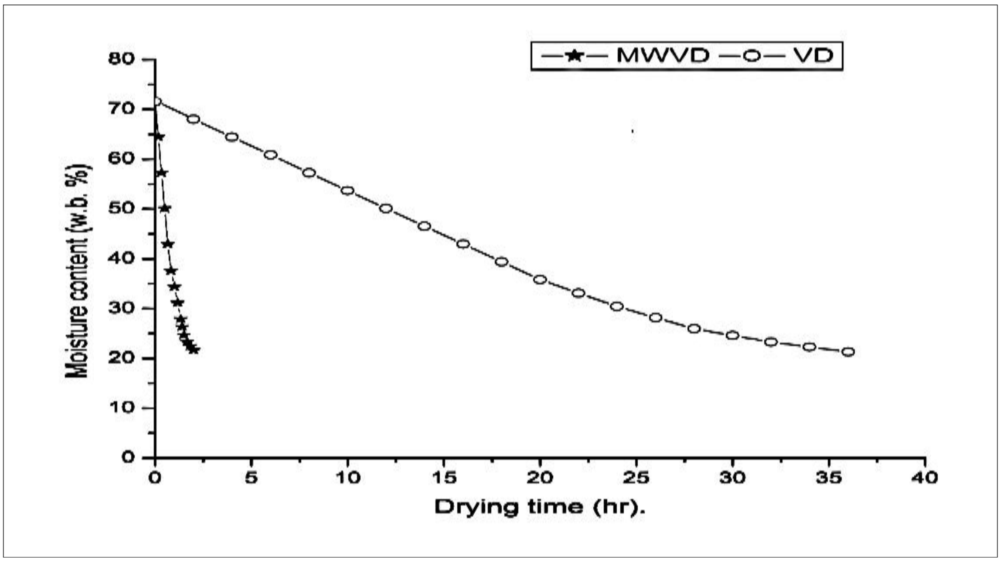

Fig. 2: The drying rate (moisture content and elapsed drying time) of fig dried by vacuum (VD) and combined microwave-vacuum (MWAD) drying methods.

Drying time of dehydrated fig fruits by using different drying methods.

The final drying time of fruits (fig) by using air convection drying AD and vacuum drying VD methods as compared to the combined microwave-air convection MWAD and microwave- vacuum drying MWVD methods are shown in Table (3)

Table 3: Drying time of dehydrated fig fruits and vegetables by using air convection AD and vacuum drying VD compared to microwave-air convection MWAD and microwave- vacuum drying MWVD methods.

Products	Drying time of dehydrated tested fruits and vegetables using AD and VD compared with MWAD and MWVD			
	Drying time (min) by AD	Drying time (min) by MWAD	Drying time (min) by VD	Drying time (min) by MWVD
Fig	1200	90	2160	120

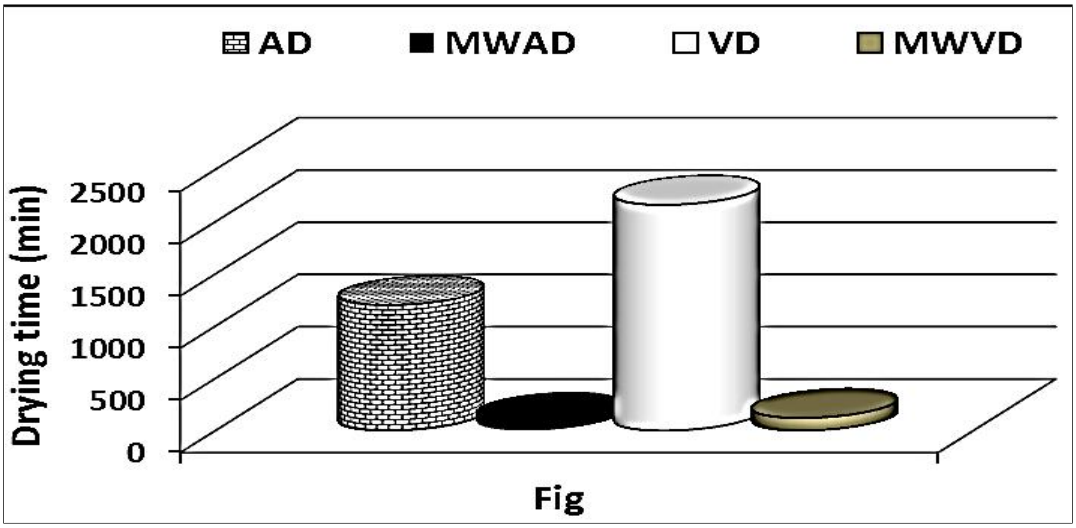

Fig. 3: Drying time of dehydrated fig fruits using AD and VD methods as compared to MWAD and MWVD methods.

From the obtained data, it could be indicated that the much longer drying time was obtained by using the vacuum drying method for fig tested samples, since it was 2160 min (36 hr) of dried fig. On the other side, the drying time when used the air convection drying method was 1200 min (20 hr). These results may be due to a slight mass transfer rate in the vacuum drying method leading to the higher drying time in tested samples as compared with others drying methods used. Giri and Prasad, (2007) reported that the product quality can be better maintained by vacuum drying. However, vacuum drying requires high investment and operating costs and thus is only suitable for high value products such as herbs. As for vacuum drying, it has a poor mass transfer rate and leads to a long drying time (Lewicki, 2006 and Wang *et al*., 2013). Also, Xu *et al*. (2004) reported that the vacuum drying has high operating costs due to the need to maintain vacuum over long periods of drying.

From the obtained results (Table 3 and Fig.3), it could be also illustrated that the shorter drying time of tested samples was obtained when used the air convection assisted by microwave energy (microwave-air convection drying MWAD method), where it was reached about only 90min with the dried fig fruit when used MWAD drying method. On the other side, the MWVD method gave the shorter drying time than air convection drying and vacuum drying methods in tested samples. Where, the drying time was reached to 120 min with dehydrated fig when used MWVD method.

These results may be due to the microwave energy enhanced the moisture transfer rate because a higher energy input to all tested samples and microwave heating effect in the MWAD and MWVD methods made the temperature of the tested samples rise sharply and enhanced the moisture transfer rate. The MW energy generates heat in dielectric materials such as foods and fruits through dipole rotation and/or ionic polarization. The MW energy selectively warm up the areas with high liquid content (Metaxas and Meredith, 1993). In other words, MW heating influences on free moisture inside the product, which causes a vapor pressure gradient that removes moisture from the sample (Schiffmann, 2006).

Hence, for better quality of heat sensitive products such as vegetables and fruits, microwave vacuum drying (MWVC) is applied. This method combines the advantages of microwave and vacuum drying (Giri and Prasad, 2007 and Wang *et al*., 2013).Products dried by the microwave vacuum method produce a more porous and uniform structure as compared to those which have undergone hot air drying (Therdthai and Zhou, 2009; Nahimana and Zhang, 2011). This is due to volumetric pressure developing inside the product from the microwaves and the low boiling point of water under vacuum helping to dry the food at a low temperature (Cui *et al*., 2006). The proses of MWVC are also improving the quality of the dried product, increasing the energy efficiency of the drying processes, enhancing the drying rate (Clary *et al*., 2007; Nahimana and Zhang, 2011and Huang *et al*., 2012) and decreasing the creation of hot spots on the surface of the product (Zhang *et al*., 2007).

The economical evaluation of air convection drying and vacuum drying compared to microwave-air convection and microwave-vacuum drying methods for dried tested fig fruits.

In present study the cost per LE/kg of dried fig product for different drying systems namely: air convection drying (AD), combined microwave-air convection drying (MWAD), vacuum drying (VD) and combined microwave-vacuum drying (MWVD) are shown in Table (4) and Figure (4)

Table 4: Cost estimation for air convection drying (AD) and vacuum drying (VD) compared to microwave-air convection (MWAD) and microwave-vacuum drying (MWVD) methods of dried fig fruits.

Items	AD	MWAD	VD	MWVD
Depreciation.	558 LE/year	63 LE/year	450 LE/year	207 LE/year
Interest on investment.	98.89 LE/year	11.16LE/year	79.75 LE/year	36.68 LE/year
Taxes and insurance.	134.85LE/year	15.22LE/year	108.75 LE/year	50.02LE/year
Maintenance and labor.	186 LE/year	21 LE/year	150 LE/year	69 LE/year
Electricity costs oven Heater Blower/vacuum	 1342.8 E/year 275 LE/year ---	 102 LE/year 120 LE/year 298.8LE/year	 1680 LE/year -- 315.60 LE/year	 120 LE/year -- 315.60 LE/ year
Total costs LE / year	2595.54	631.18	2784.1	798.3
Total production LE / year	0.240	0.1598	0.080	0.144
Total costs LE / ton	10814.75	3949.81	34801.25	5543.75
Total costs LE/ kg	10.8148	3.94981	34.8013	5.543.75

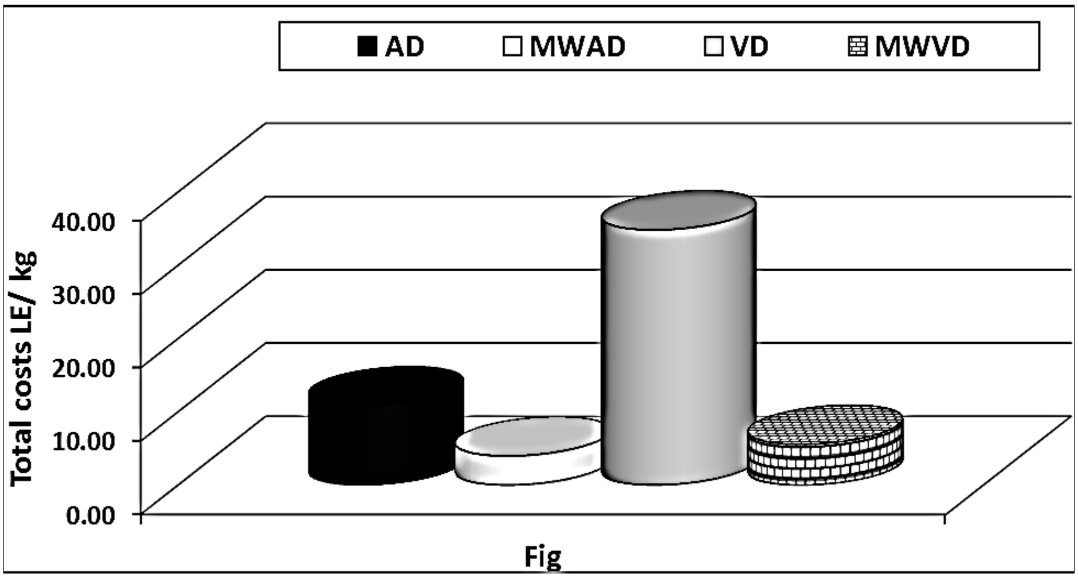

Fig. 4: The production costs LE/Kg for air convection drying (AD) and vacuum drying (VD) compared to microwave-air convection (MWAD) and microwave-vacuum drying (MWVD) methods of dried fig fruits.

The production cost was used in present work for identifying the economic evaluation for convection drying and vacuum drying compared to microwave-air convection drying and microwave-vacuum drying methods utilized for producing dried fig.

With regards to the production cost of one kilogram for dried tested products, the MWAD drying system had much lower cost up to 2.73, 2.63, 3 and 2.05 times as compared with respectively than that obtained by the air convection drying system. This highly affected by fixed and operating costs that directly affected by the drying time. Because the drying time of MWAD dryer is more less than that required for air convection drying method, therefore, the power and operating costs is too much decrease and this interpret the lower values of producing one Kg of fig by using MWAD dryer than that occurred by air convection drying one.

In addition, the calculated production costs of one kilogram of dried products by using microwave-vacuum dryer (MWVD) was found a much lower than that obtained by vacuum dryer system. Whereas it was found to be as 5.543, 5.543, 3.932 and 3.245 LE/Kg by using MWVD, while it was represented about 34.801, 23.200, 15.467 and 15.467 LE/Kg when used the vacuum dryer system (VD) for dried fig, grape, onion and garlic; respectively.

From the same data in Table (4) and Fig. (4), it could be observed that the production cost of one kilogram using MWVD drying system had lower up to 1.95 times than that obtained by the air convection drying system of fig. Meanwhile, it was much lower up to 8.81 times of fig, grape, onion and garlic; respectively when used MWAD system than that obtained by vacuum dryer system (VD).

It is also clear that the difference between the production costs of dried product can be related to the difference of moisture migration mechanism that directly proportional to drying time and method used.

Finally, the microwave energy assisted with the different drying system especially with air convection and vacuum drying system leading to sharply reduce the drying time, and thus lead to a reduction cost of the dried products.

In general, MW-related drying can meet the four major requirements in drying of foods: speed of operation, energy efficiency, cost of operation, and quality of dried products **(Gunasekaran, 1999**). The increased demand for plant-origin foods in fast-dehydrated form has increased interest in MW-assisted dehydration (Zhang and Xu, 2003).

Effect of different drying methods on the quality attributes for investigated fig.

Fruits are truly among nature's great gifts because they provide many nutrients that are essential for the health and maintenance of our bodies. They are commonly consumed fresh, but can also be eaten in a dried state. Almost all dried fruits provide essential nutrients and an array of health protective bioactive ingredients that help to reduce its risk of illness by preventing chronic diseases. Natural products have the potential to be used as therapeutic drugs for humans and livestock species. Such compounds, along with their analogues, can also act as intermediates to produce useful drugs (Makkar *et al*., 2009).

Ficus carica L., a deciduous tree belonging to the Moraceae family, is one of the earliest cultivated fruit trees. In the northern Mediterranean region, fig trees produce one or two crops per year, depending on the cultivar. The first crop is grown from flowers that were initiated in the previous year, and the fruit ripens at the beginning of summer. The second crop (the main one) is produced from flowers that emerge on the current season's shoots, and the fruit ripens in late summer. Therefore, the development of both crops is marked by different weather conditions. Fruits from the two crops can also differ in size and shape (Slatnar *et al*., 2011).

The fig is a delicious, nutritive fruit and has medicinal properties that may reduce the risk of cancer and heart disease. Fig fruit is consumed fresh, dried, preserved, canned, and candied. In the Mediterranean region, it is used for alcohol and wine production and in Europe for a fig-coffee preparation. Fresh and dried figs are especially rich in fiber, trace minerals, antioxidant polyphenols, proteins, sugars, organic acids, and volatile compounds that provide a pleasant characteristic aroma. Dried figs can be stored for 6-8 months (Slavin, 2006; Oliveira *et al*., 2009 and Oliveira *et al*., 2010).

The consumption of fresh figs is increasing as consumers are showing an interest in fresh quality produce of less familiar fruits. In some areas, such as California, most fig cultivars have been selected for drying and the growers have little fresh fruit handling experience (Crisosto *et al*., 2010), but in some northern Mediterranean conditions, which have sometimes less favorable weather conditions for drying, most of the figs are consumed fresh and proper conditions for fruit drying have to be established. Sun-drying can ensure proper preservation of figs. However, with traditional drying methods prior selection of the produce with respect to maturity, size, condition, and state of ripeness does not exist. Moreover, the produce is exposed to direct solar irradiation and as the drying parameters cannot be controlled, the product quality is low. Sun-drying is, therefore, not homogeneous, and the final product is caramelized and crusted. Direct exposure to the sun also destroys the color, vitamins, and oven-dried flavor of the figs (Chimi *et al*., 2008).

Effect of different drying methods on chemical composition of produced dried fig fruit.

The effect of air convection drying (AD) and vacuum drying (VD) methods as compared to the combined microwave-air convection (MWAD) and microwave- vacuum drying (MWVD) methods on chemical composition of tested fig fruit are listed in Table (5).

As shown in the obtained results of Table (5), it could be indicated that the moisture content of tested fig fruit was found to be as 71.59%. Moreover, the fresh fig fruit contained a higher amount of carbohydrates (24.67%), whereas the reducing sugar was the major component in it, which was represented about 85.81% of the total carbohydrates (21.17%), in addition the fresh fig fruit contained an adequate percentage of protein, ash and dietary fibers which were found to be as 1.68, 1.24 and 1.24%; respectively. These results are in accordance with the data obtained by Al-Gendy, (2014); Soni *et al*. (2014) and Ullah *et al*. (2015).

Concerning the effect of different drying methods on the chemical composition of dried fig produced, as illustrated in the obtained data in table (5) it could be exhibited that no significant differences was observed between fig samples dried by AD and VD when compared with the samples dried by the combined MWAD and MWVD in moisture, ash and crude fiber contents. Where the moisture content, ash percentage and crude fiber content were found ranged from 20.30 to 20.98%, from 3.31 to 3.45% and from 3.38 to 3.46% in all tested samples; respectively. The chemical composition of dried fig was also investigated by Russo *et al.* (2010); Al-Gendy, (2014); Soni *et al*. (2014) and Ullah *et al*. (2015). Their results were relatively comparable with the present data.

On the other side, significant differences was found between the dried fig by using AD method and the samples dried by MWAD, and also with the tested samples dried by using VD and MWVD of protein, lipid and total sugars especially reducing sugars. Whereas, the tested samples dried by using AD has the lowest content of the previous components, which were represented about 4.48, 2.0, 63.14 and 56.92% of protein, lipid, total sugars and reducing sugars; respectively. In this concern, noticeable Millard reaction may be occurred in dried fig produced by air-convection drying which involves the binding of reducing sugars to amino acids, eventually leading to loss in protein content and the total sugars especially the reducing sugars.

Table 5: Effect of drying methods (AD and VD as compared with MWAD and MWVD) on chemical composition of produced dried fig fruit (Means± SE)

Chemical composition (%)	Fresh fig		Dried fig fruit by different drying methods							
			AD		MWAD		VD		MWVD	
	WW	DW	WW	DW	WW	DW	WW	DW	WW	DW
Moisture	71.59	-	20.98^{a}±0.08	-	20.87^{a} ±0.24	-	20.30^{a}±0.06	-	20.66^{a}±0.64	-
Protein	1.68	5.90	4.48^{b}±0.11	5.67	4.62^{a}±0.07	5.84	4.57^{a}±0.14	5.73	4.61^{a}±0.05	5.81
Lipids	0.82	2.90	2.00^{b} ±0.05	2.53	2.20^{ab}±0.28	2.78	2.30^{a}±0.121	2.88	2.20^{ab} ±0.07	2.77
Ash	1.24	4.38	3.31^{a}±0.38	4.19	3.45^{a}±0.11	4.36	3.44^{a}±0.23	4.32	3.41^{a} ±0.14	4.30
Total carbohydrates	24.67	86.82	69.23	87.60	68.86	87.02	69.39	87.06	69.12	87.12
Total sugars	23.38	82.33	63.14^{b} ±0.28	79.90	64.27^{a} ±0.23	81.22	64.71^{a} ±0.46	81.19	65.01^{a} ±0.46	81.94
Red. Sugars	21.17	74.53	56.92^{b}±0.16	72.03	58.14^{a}±0.20	73.47	58.52^{a}±0.11	73.42	58.86^{a}±0.28	74.19
Non-red. Sugars	2.21	7.80	6.22^{a}±0.01	7.87	6.13^{a}±0.15	7.75	6.19^{a}±0.03	7.77	6.15^{a}±0.09	7.75
Crude fiber	1.24	4.38	3.41^{a}±0.06	4.31	3.45^{a}±0.03	4.35	3.46^{a}±0.07	4.34	3.38^{a}±0.05	4.26
Other carbohydrates	0.04	0.11	2.68^{a}±0.02	3.39	1.14^{b}±0.01	1.44	1.22^{b}±0.03	1.53	0.73^{c}±0.02	0.92

AD: air-convection drying, VD: vacuum-drying, MWAD: microwave-air convection, MWVD: microwave- vacuum drying, Red. sugar: reducing sugars, Non-red. sugars: Non- reducing sugars, WW: wet weight, WD: dry weight.

Furthermore, no significant differences was observed between the tested samples dried by using MWAD and VD, also with MWVD of the same previous components, whereas the amount of protein, lipid and total sugars especially reducing sugars for dried fig by using MWAD were near with that amount found in dried fig with VD method for the corresponding components. Moreover, the dried fig by using MWVD contained a higher amount of protein, lipid, total sugars and reducing sugars. Similar observation has been reported by Hu *et al*. (2006) they found that the combined drying processes decreased in drying time and mass loads and improved product quality compared with conventional hot-air drying or MW vacuum dehydration alone, when compared the characteristics of hot air, MW vacuum, and the combination of both using Edamame (soybean) as a food material. Also, Therdthai and Zhou, (2009) mentioned that reduction in drying times of mint leaves under microwave vacuum drying was by 85–90% compared to hot air drying.

Effect of different drying methods on physicochemical properties of produced dried fig fruit.

There are many physico-chemical quality characteristics of dried fig produced such as color (O.D. at 340 nm), T.S.S. (%), titratable acidity (T.A. % as citric acid), pH value, rehydration ratio and shrinkage (%), which are played an important role in assessing their quality and palatability as well as the consumer acceptability of this product. As illustrated in the obtained results, it could be noticed that the physicochemical quality characteristics of tested fresh fig such as color (O.D at 340nm), T.S.S (%), titratable acidity (% as citric acid) and pH value were represented about 0.041, 22.41, 0.89 and 5.6; respectively. The present results are in accordance with those previously obtained by Crisosto *et al*. (2010); Pourghayoumia *et al*. (2012); Al-Gendy (2014) and Ullah *et al*. (2015).

Table 6: Effect of drying methods (AD and VD as compared with MWAD and MWVD) on physicochemical properties of produced dried fig fruit (Means± SE).

Physicochemical properties	Fresh fig	Dried fig fruit by different drying methods			
		AD	MWAD	VD	MWVD
Color (O.D)	0.041	0.162^{a}±0.03	0.140^{b}±0.04	0.139^{b}±0.02	0.127^{c}±0.01
T.S.S (%)	22.41	36.60^{a}±2.32	35.73^{a}±1.98	36.78^{a}±3.01	35.87^{a}±3.23
T.A.% (as citric acid)	0.89	0.72^{a}±0.09	0.78^{a}±0.07	0.70^{a}±0.05	0.65^{b}±0.06
pH value	5.6	4.56^{b}±0.59	4.85^{a}±1.21	4.53^{b}±0.82	4.23^{c}±0.76
Rehydration ratio	-	1.89^{c}±0.16	2.26^{b}±0.54	1.97^{c}±0.09	2.82^{a}±0.28
Shrinkage (%)	-	43.81^{a}±0.02	39.14^{b}±0.02	39.92^{b}±0.02	37.15^{c}±0.02

AD: air-convection drying, VD: vacuum-drying, MWAD: microwave-air convection, MWVD: microwave-vacuum drying, T.S.S: Total soluble solid, TA: Titratable acidity

The effect of AD and VD drying methods as compared with the combined MWAD and MWVD drying methods on physicochemical properties of produced dried fig fruit are recorded in Table (6). From these data, it could be concluded that no significant differences in T.S.S (%) was observed between the fig samples dried by AD or VD and MWAD or MWVD drying methods, whereas the T.S.S was found ranged from 35.73 to 36.78% in all dried samples by using different drying methods. These results are in agreement with the data obtained by Pourghayoumia *et al*. (2012) they reported that the TSS (%) was ranged from 36.12 to 44.10% in dried figs.

Color is one of the most important factors for quality characteristics of dried products especially, the products which contain a considerable amount of total sugars in particular reducing sugars which have the ability to interact with amino acids (non-enzymatic browning reaction). This reaction produces brown colored compound. Hence reduction of the brown color development can be used as an index of good quality dried figs. As showing in the obtained data's in Table (6), it could be observed that the dried figs by using air convection drying method (AD) was the higher value of color index (0.162) than those obtained in the other fig samples which dried by using the other drying methods. On the other hand, when used the microwave with air convection dryer (combined MW-AD), the light brown color was significant reduced in dried fig samples (0.140) as compared with the dried samples by AD. Furthermore, no significant difference was observed among fig samples dried by VD (0.139) and the tested samples dried by MWAD (0.140). Moreover, the best treatment was observed in the samples dried by using MWVD, which recorded the lowest value of color optical density (0.127) when compared with the other treatments. From the previously discussion, it could be concluded that when combined the microwave with either air convection drying or vacuum drying methods resulted in significant reduce in the drying time, which could be enhancement of the quality criteria of the final dried products.

From the same Table (6), it could be also observed that the titratable acidity (%) as citric acid in fig samples dried by using AD and VD was 0.72 and 0.70%; respectively. On the other side, the fig samples dried by MWAD had the highest percentage of titratable acidity, which recorded about 0.78%, on contrary the lowest percentage of titratable acidity (0.65%) was found in the dried samples by MWVD. Titratable acidity in dried figs was also mentioned by Crisosto *et al*. (2010); Naikwadi *et al*. (2010) and Al-Gendy (2014).

Concerning the pH value in fig samples dried by different drying methods, as illustrated in Table (6), it could be indicated that the same behavior as titratable acidity was observed in pH value of dried fig samples, whereas fig samples dried by using AD and VD was 4.56 and 4.53; respectively. On the other hand, the fig samples dried by MWAD had the highest value of pH, which represented about 4.85, on contrary the lowest value of pH (4.23) was found in the dried samples by MWVD. These results are in accordance with the data obtained by Piga *et al*. (2004) they found that the pH value was 5.67 in fresh fig fruit, but it was ranged between 4.87–5.04 in dried figs.

Rehydration is influenced by several factors, grouped as intrinsic factors (product chemical composition, pre-drying treatment, drying techniques and conditions, post-drying procedure, etc.) and extrinsic factors (composition of immersion media, temperature, hydrodynamic conditions) (Rastogi *et al*., 2004). It is more desirable for the rehydration process to be as fast as possible in order to retain suitable structural and chemical characteristics and acquire better quality-reconstituted products (flavor, texture and nutritional quality) (Sanjuan *et al*., 2001). The knowledge of the rehydration kinetics of dried products is important to optimize processes from a quality viewpoint since rehydration is a key quality aspect for those dried products that have to be reconstituted before their consumption (Garcia-Pascual *et al*., 2006).

Rehydration ratio is widely used as a quality evaluation method after drying. In fact, it is a complex process and indicates the chemical and physical changes caused by drying procedures. As illustrated in the former Table, it could be exhibited that the lower rehydration ratio was found in the fig samples dried by AD, which was recorded 1.89. In addition, the fig sample dried by MWAD was higher in rehydration ratio (2.26) than those obtained in the fig samples dried by VD (1.97). Furthermore, the highest value of rehydration ratio was found in the fig samples dried by MWVD. Lower rehydration ratio of air-convection dried-figs can be evidence for product shrinkage caused by severe heating and for prolonged drying resulting in irreversible physical and chemical changes. On the other side, the shorter drying time in MWAD and MWVD caused the best of rehydration ratio, especially in MWVD.

Food drying leads to micro-structural alterations of the products and consequently may affect macroscopic characteristics such as shrinkage (Mayor and Sereno, 2004). Shrinkage is the reduction in size of a product (macroscopic phenomenon), which for many vegetables is a consequence of the reduction of its cellular dimensions (microscopic phenomena) (Krokida and Maroulis, 1997). This phenomenon may cause a negative impression on consumers and can be considered a food quality problem.

As illustrated in the obtained data in the same Table, it could be observed that the shrinkage ratio in the fig samples dried by AD was higher than that found in the similar samples dried by the other drying methods, which was represented about 43.81%, on the other side the fig samples dried by MWVD had the lower shrinkage ratio when compared with the other tested samples dried by the other drying methods, whereas found to be as 37.15%. Furthermore, shrinkage ratio of the fig samples dried by MWAD was slightly decreasing (39.14%) when compared with the samples dried by VD (39.92%). This observation in fig samples dried by AD may be due to the long drying time may causes an increased in shrinkage ratio as compared the samples dried by VD or MWAD and MWVD. These results are in accordance with the data obtained by Abbasi *et al*. (2011) they reported that Shrinkage is increased with increasing drying time. In addition, at the same sampling time, the samples undergoing drying at higher temperatures suffer more shrinkage than those undergoing drying at lower temperatures. This is because the drying temperature directly affects the product shrinkage (or deformation);

larger moisture gradients within the samples develop in higher drying temperatures and these larger gradients lead to increased internal stresses, which in turn lead to larger degrees of shrinkage.

Finally, the fig samples dried by using MWAD and MWVD were the best in the most of physicochemical quality properties such as color, rehydration ratio and shrinkage rate when compared with the similar samples dried by AD which drying at the long time. On the other hand, the fig samples dried by using VD also had the highest values for quality criteria which were the same approximate the corresponding properties of the fig samples dried by using MWAD, but this drying method (VD) require high investment and operating costs, also it has a poor mass transfer rate and leads to a long drying time (Lewicki, 2006 and Wang *et al*., 2013). This problem in the vacuum drying has been overcome by using a microwave which provides a higher drying rate than AD and VD.

Effect of different drying methods on antioxidant compounds of produced dried fig fruit.

The effect of AD and VD methods as compared with combined MWAD and MWVD methods on antioxidant compounds (such as *L*-ascorbic acid, total phenolic and flavonoids compounds) of produced dried figs are listed in Table (7).

Fresh fig was known to be contained an adequate amount of antioxidants and thus, it's necessary to research known it a drying method used led to the excessive retention of antioxidant compounds that attain high nutritive and healthy effect of fig products. All tested antioxidants (*L*-ascorbic acid, total phenolic and flavonoids compounds) were significantly reduced by all drying methods used, when related to their original level in fresh fig fruit.

Table 7: Effect of drying methods (AD and VD as compared with MWAD and MWVD) on antioxidant compounds of produced dried fig fruit (Means± SE) on dry weight basis.

Antioxidant compounds (mg/100g DM)	Fresh fig	Dried fig fruit by different drying methods			
		AD	MWAD	VD	MWVD
L-Ascorbic acid	11.50	1.12^{d} ±0.03	4.24^{b} ±0.02	2.69^{c} ±0.02	5.50^{a} ±0.11
Total phenolic compounds	254.13	218.32^{c} ±21.31	237.25^{b} ±16.02	235.86^{b} ±25.14	245.11^{a} ±19.08
Total flavonoids	81.52	58.89^{c} ±9.21	63.34^{b} ±6.02	61.12^{b} ±7.21	73.26^{a} ±10.69

AD: air-convection drying, VD: vacuum-drying, MWAD: microwave-air convection, MWVD: microwave- vacuum drying,

On the other hand, the maximum loss of *L*-ascorbic acid (90.26%) was observed in dried fig produced by AD method, which was higher than the corresponding loss of *L*-ascorbic acid for dried fig produced by MWAD method, which was 63.13%. Also, the same behavior was observed with the samples dried by using VD and MWVD, whereas the loss of *L*-ascorbic acid in dried fig produced by VD method was 76.61%, but it represented about only 52.17% in MWVD. From these results it could be noticed that, when used the microwave system in both AD and VD methods led to improve the quality criteria of the final products. In this concern it was observed. more retention of *L*-ascorbic acid in dried figs by using combined MWAD and MWVD, especially with MWVD drying methods than that obtained by using AD and VD drying methods. The present results are in agreement with the data obtained by Naikwadi *et al*. (2010) and Al-Gendy (2014).

Phenolic compounds are an important constituent of fruit quality because of their contribution to the taste, color and nutritional properties of fruit. Phenolic acids and flavonoids have an even stronger antioxidant activity for instance, ascorbic acid. Besides antioxidant effects, phenolic compounds possess a wide spectrum of biochemical properties and can also have a beneficial effect in preventing the development of diseases like cancer and cardiovascular diseases (Lattanzio, 2003).

As shown in the same results (Table 7), it could be also noticed that the total phenolic compounds was the higher content found in fresh fig fruit (on dry weight basis) when compared with that found in dried figs by using all drying methods, whereas it was represented about 254.13 mg/100g DM in fresh fig fruit, but it was found ranged between 218.32 to 245.11 mg/100g DM in figs dried using all drying methods. These results are in accordance with the data obtained by Nakilcioğlu and Hışıl (2013) which they reported that the amount of polyphenol is higher in fresh figs compared to dried ones.

On the other hand, the dried fig by using MWVD method had the higher amount (245.11 mg/100g DM) than that found in other drying methods of total phenolic compounds, followed by the dried samples using MWAD (237.23 mg/100g DM), which nearly the dried samples by using VD method (235.86 mg/100g DM), while the lowest amount of total phenolic compounds (218.32 mg/100g DM) was found in dried fig by using AD method. This observation is similar to that mentioned by Marinova *et al*. (2005); Pourghayoumia *et al*. (2012); Martínez-García *et al*. (2013); Miletić *et al*. (2014) and Tawfik and Alhejy (2014).

With regard the changes of total flavonoids in dried fig samples as affected by drying methods (Table 7), the MWVD drying process caused, in general, a highly retention of total flavonoids in dried fig samples at a wide rates depending upon the drying time, followed by MWAD drying process as compared to the AD and VD drying methods; whereas, the MWVD drying process caused a highly considerable retention of total flavonoids at ratio of 89.86%, while the fig samples dried by AD have process retained 72.24% of total flavonoids. On the other side, the MWAD drying method caused a higher retention of total flavonoids (77.70%) in dried fig samples, than those obtained by VD (74.98%) and AD (72.24%) drying methods. These results are in accordance with those previously obtained by Marinova *et al*. (2005) and Pourghayoumia *et al*. (2012).

Effect of different drying methods on antioxidant activity of produced dried fig fruit.

The 2,2,-diphenyl-1-picrylhydrazyl radical is a stable free radical and accepts an electron or hydrogen radical to become a stable molecule. The free radical scavenging activity of the fig samples was analyzed using DPPH assay. The antioxidant assay was based on the measurement of the loss of DPPH color by the change of absorbance at 517 nm caused by the reaction of DPPH with the tested sample. *Also* using DPPH method, the result of the analysis of antioxidant activity was determined as ascorbic acid equivalent antioxidant capacity (AEAC) (Ishiwata *et al*., 2004).

The antioxidant potential of fig samples extract was determined against ascorbic acid as percent inhibition of DPPH free radicals. Radical-scavenging activities of fresh and dried figs fruit are shown in Table 8. From the obtained data it could be observed that the antioxidant activity value of fresh fig was 80.92 µ ascorbic acid equivalent/g sample DPPH as (37.94%) inhibition of DPPH free radicals. The present results are in accordance with the data obtained by Ishiwata *et al*. (2004) and Ouchemoukh *et al*. (2012).

Table 8: Effect of drying methods (AD and VD as compared with MWAD and MWVD) on total antioxidant capacity (TAC) of produced dried fig fruit (Means± SE).

Fig samples	The free radical scavenging activity of fig samples	
	% inhibition of DPPH	DPPH (µAsEq/1g DM)
Fresh figs fruit	37.94	80.92
Samples dried by AD	34.81^{c} ±0.84	75.83^{c} ±0.61
Samples dried by MWAD	36.38^{b} ±0.47	78.83^{b} ±0.57
Samples dried by VD	35.60^{b} ±0.39	78.07^{b} ±0.72
Samples dried by MWVD	37.69^{a} ±0.91	80.49^{a} ±0.83

AD: air-convection drying, VD: vacuum-drying, MWAD: microwave-air convection, MWVD: microwave-vacuum drying, µAsEq/1g DM: µ ascorbic acid equivalent/g sample

The effect of AD and VD as compared with MWAD and MWVD drying methods on the antioxidant activity of tested fig samples are presented in Table (8). From the obtained data, the dried figs by using MWVD exhibited the highest scavenging capacity against DPPH than the other samples dried by the other drying methods, which recorded 80.49 µ ascorbic acid equivalent/g sample (µAsEq/1g DM) DPPH as (37.69 %) inhibition of DPPH free radicals, followed be the dried figs by MWAD, which represented about 78.83 µAsEq/1g DM (36.38 % inhibition of DPPH). On the other hand, the dried figs by AD had the lowest antioxidant activity values, whereas it was recorded 75.83 µAsEq/1g DM as 34.81% inhibition of DPPH free radicals. Furthermore, the dried figs by VD were higher DPPH radical-scavenging activity (35.60%) than those obtained in the dried samples by AD (34.81%). These results may be due to the antioxidant compounds such as phenolic and flavonoid compounds found in the tested samples after drying by the different drying methods as shown previous in table 6. Our data suggests correlation between the amount of phenolic and flavonoid compounds with the value of the reaction of DPPH with the tested sample*s*. This implies that phenolic compounds in figs fruit might contribute to their radical scavenging activity.

From the same data in Table (8), it could be also observed that the ability to quench the DPPH radical of both the fig samples dried by AD and VD was lower (34.81 and 35.60 %; respectively) than that exhibited in the fresh figs sample (37.94%). On the other hand, the fig samples dried by MWAD and MWVD were exhibited nearly scavenging capacity against DPPH especially the samples dried by MWVD when compared with the fresh figs sample.

In this concern, it could be noticed that there was strong correlations with the phenolic and flavonoid content of tested fig samples contributed significantly to the antioxidant capacities of dried figs as affected by different drying methods.

From the above discussion, it could be concluded that the combined microwave system with either air convection or vacuum drying methods leading to improve the quality criteria of the final products when compared with the dried samples by using air convection or vacuum drying, in this concern the samples dried by MWVD and MWAD methods exhibited more ability to quench the DPPH radical obviously than those found in the samples dried by AD or VD methods**.**

Effect of different drying methods on the organoleptic quality properties of produced dried fig fruit.

The organoleptic properties of dried fig samples were generally the final guide of the quality from the consumer's point of view. Thus, it was beneficial to make a comparative sensory evaluation for dried fig by using different drying methods (AD and VD as compared with MWAD and MWVD). All samples were evaluated sensorial by ten panelists for mentioned attributes according to given scores (10 degrees for each attribute) and the mean values of scores were statistically analyzed ($p < 0.05$).

The effect of drying methods on sensory quality properties of fig samples such as color, taste, odor, texture and overall acceptability after drying was investigated. The obtained results are statistically analyzed and recorded in Table (9).

Table 9: Effect of drying methods (AD and VD as compared with MWAD and MWVD) on sensory quality properties of produced dried fig fruit (Means± SE).

Sensory quality properties	Dried fig fruit by different drying methods			
	AD	MWAD	VD	MWVD
Color	8.15^{c}±0.07	9.50^{a}±0.09	8.55^{b}±0.30	9.40^{a}±0.23
Taste	8.20^{c} ±0.12	9.45^{a}±0.11	8.50^{b} ±0.41	9.25^{a} ±0.15
Odor	8.40^{b} ±0.14	9.10^{a} ±0.19	8.85^{a} ±0.09	9.00^{a} ±0.09
Texture	8.25^{b} ±0.09	9.00^{a} ±0.22	8.80^{a} ±0.21	9.10^{a} ±0.32
Overall acceptability	8.20^{c} ±0.04	9.50^{a} ±0.31	8.60^{b} ±0.17	9.30^{a} ±0.45

AD: air-convection drying, VD: vacuum-drying, MWAD: microwave-air convection, MWVD: microwave-vacuum drying,

As shown in the obtained results (Table 9), it could be exhibited that there are no significant differences in sensory numerical judging scores for the most of tested organoleptic characteristics such as color and taste between the fig samples dried by MWAD and MWVD. On the other side, significant difference was observed among the fig samples dried by MWAD or MWVD and the fig samples dried by AD or VD in both color and taste properties. Moreover, also significant difference was noticed in both color and taste properties between the fig samples dried by using VD and AD. Where the fig samples dried by MWAD was represented about the highest scores 9.50 and 9.45 for both color and odor properties; respectively. In addition, the fig samples dried by MWVD recorded nearly scores to that obtained with the fig samples dried by MWAD, which recorded 9.40 and 9.25 in the corresponding properties. Meanwhile, the lowest score for color and odor properties (8.15 and 8.20; respectively) was observed in the fig samples dried by AD.

From the same data in the former table, it could be observed that the same trend was also observed in sensory judging score of the overall acceptability in the fig samples dried by the different drying methods, whereas no significant differences were found among fig samples dried by MWAD with MWVD in overall acceptable property, which was recorded 9.50 and 9.30 in the fig samples dried by MWAD and MWVD; respectively. On the other hand, there was significant difference was observed in the overall acceptability of the fig samples dried by MWAD or MWVD compared samples dried by AD or VD, also there was significant difference was exhibited in the fig samples dried by VD and the samples dried by AD in the corresponding property, where these dried samples (AD) recorded the lowest score in the overall acceptability.

Concerning the odor and texture, which are considered of the most important indicator of sensory quality of fig samples dried by AD and VD when compared with the combined MWAD and MWVD, as illustrated in Table (9), it could be indicated that there was no significant difference between the fig samples dried by MWAD, MWVD and VD in odor and texture properties. On the other side, there was significant difference was observed with the fig samples dried by MWAD, MWVD or VD and the fig samples dried by AD in both odor and texture properties. Where, the highest score of odor property (9.10) was observed in the fig samples dried by MWAD, while the higher score of texture property (9.10) was noticed in the fig samples dried by MWVD. On contrary, the fig samples dried by AD had the lowest scores of both odor and texture properties, which recorded 8.40 and 8.25; respectively.

Finally, it could be showed that the fig samples dried by using both MWAD and MWVD exhibited good sensory properties and better acceptability when compared with the samples dried by AD and VD, especially with AD. These results may be due to the short drying time used in both MWAD and MWVD drying methods as compared with the traditional drying methods (AD and VD) leading to enhancement in the quality criteria of the final products.

In general, MWVD, MWAD methods can meet the four major requirements in drying of foods: speed of operation, energy efficiency, cost of operation, and quality of dried products**.** The increased demand for plant-origin foods in fast-dehydrated form has increased interest in MW-assisted dehydration (Zhang and Xu, 2003).

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