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Variations of vitamins (A, C and E) and MDA in apricots dried in IR and microwave

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Abstract

In this study, variations of vitamins (A, C and E) and malondialdehyde (MDA) with moisture removals were investigated in apricot samples in different ripeness namely ''near-ripe'' and ''ripe'' apricots that were dried in infrared and microwaves driers. For two drying systems, the values of vitamins (A and E) and MDA in the ripe apricot were observed to be higher than those in the near-ripe apricot samples at all moisture removals. The values of vitamins (A, C and E) and MDA in apricot samples dried in the microwave drier were found to be larger than those in apricot samples dried in infrared. Infrared and microwave driers were compared one another in terms of less losses of vitamins and MDA, rate of drying and preservation of original color of apricot. It was concluded that microwave drier is more effective than IR drier in terms of less losses of vitamins, rate of drying and preservation of original color of apricots.

Keywords: Apricot; Drying; Antioxidant vitamins and MDA

1. Introduction

Apricot trees can grow over the five continents of the world and production level exceeds 2 millions tons. Australia, France, Hungary, Iran, Israel, Italy, Morocco, Spain, Tunisia, Turkey can be regarded as important apricot producer countries. While some of countries such as Hungary, Morocco, Tunisia and Israel are important fresh apricot exporters, the others such as Australia, Iran and Turkey are major and famous dried apricot producers and exporters. Dried apricots which are in extensive demand in several parts of the world, i.e., USA, UK, Germany, Australia, etc., occupy an important place in the world trade.

Apricot culture mostly depends on the climate conditions, soil compositions and the variety that is chosen. The yield, fruit quality and early ripening are affected by these factors. Apricot is an important foodstuff due to its minerals and other nutrients. Today we know that it is rich by some minerals such as potassium, and some organics such as β-carotene. It is also known that its nutrient values depend on its variety and where it has grown.

Since variety of apricot is important parameter on the levels of nutrient and mineral contents, some kinds of apricots are especially suitable for drying to give a high calorific values, vitamin and mineral-rich products. Pala, Açkurt, Löker, and Saygı (1994) reported that protein, oil, carbohydrate, moisture, ash, cellulose and total acid change with apricot varieties.

Among preservation methods, drying process is the most commonly used preservation method. The conventional method of drying or open-air sun drying has been used since the beginning of human life in the world to dry grains, plants and other agricultural products as a means of preservation. In most of developing countries the dried fruits and vegetables continue to be sun dried in the open without technical aids. However, it has been reported that large-scale production limits in use of open-air natural drying process that has the following

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disadvantages: (i) it requires both a large amount of space and long drying time; (ii) the crop becomes damaged because of hostile weather conditions; (iii) contamination of crop from foreign materials; (iv) the crop is subject to insect infestation; and (v) the crop is susceptible to readsorption of moisture if it is left on the ground during periods of no sun which reduces its quality.

In recent years considerable investigations have been done on drying of grains, plants and other agricultural products. Simal, Berna, Mulet, and Rosselló (1993) proposed a method for determination of heat transfer coefficient for the first falling period of potato cubes. In their study heat and mass transfer were considered as coupled phenomena. It was claimed that the obtained heat transfer coefficient is in good agreement with previous studies. The heat transfer coefficient is influenced by parameters such as thermal fluid velocity, the physical properties of fluid, the temperature difference between the fluid and the target material, and the characteristics of the physical system under consideration (Singh & Heldman, 1984).

Rough rice was dried using far infrared by Afzal and Abe (1997). In their study thin layer drying data were obtained for 30 °C inlet air temperature at three radiation intensities, inlet air velocities and initial moisture levels. In their study effects of radiation intensity and inlet air velocity on far infrared of rough rice were investigated to propose a model for that drying process.

Tolaba, Aguerre, and Suárez (1997) performed drying of cereal grain and solved diffusion equation with variable diffusivity. In that study the thin layer drying of rough rice, maize and sorghum at several temperatures was investigated. They numerically solved diffusion equation for spherical shape of grain. An analytical expression for the dependence of the diffusion coefficient with moisture content was obtained based on considerations of the energy needed to dissociate water molecules from their sites and of resistance to diffusion.

Moisture diffusion during soaking of Kisan maize in water at temperatures ranging from 30 to 90 °C was studied by Verma and Prasad (1999). They indicated that the relationship between moisture diffusivity and reciprocal of absolute temperature followed the Arrhenius type equation.

Goyal and Tiwari (1997) studied on the drying of agricultural products in a cabinet drier in which the reverse flat plate collector used as a heating medium of air. In their study the thermal performance of proposed drier was analyzed by solving the various energy balance equations. They also tried to optimize the vent area of drier for speedy flow of humid air from the drying chamber to atmosphere.

In order to obtain an efficient and higher rate of drying either present drying techniques have to be improved or new drying techniques have to be developed by investigators. Among three modes of heat transfer, conduction and convection have been extensively studied. Irradiative transfer by far the quickest mode has received less practical application in agriculture. Efforts have been made to determine the drying characteristics of important crops in electromagnetic energy spectrum (John & Otten, 1989; Nindo & Beki, 1994; Shivare, Raghavan, & Bosisio, 1994).

In the electromagnetic spectrum, the microwave radiation region is located between infrared radiation and radio waves. Microwaves have wavelengths of 1 mm–1 m, corresponding to frequencies between 0.3 and 300 GHz. Telecommunication and microwave radar equipment occupy many of the band frequencies in this region. In general, in order to avoid interference, the wavelength at which industrial and domestic microwave apparatus intended for heating operates is regulated to 12.2 cm, corresponding to a frequency of (2.245 ± 0.05) GHz, but other frequency allocations do exist.

As with all electromagnetic radiation, microwave radiation can be divided into an electric field component and magnetic field component. The former component is responsible for dielectric heating, which is effected via two major mechanism namely dipolar polarization and conduction. In dipolar polarization mechanism, one of the interactions of the electric field component with matrix is called the dipolar polarization mechanism. For a substance to generate heat when irradiated with microwave it must posses a dipole moment, as has a water molecule. On the other hand, in conduction mechanism, in the sample the ions will move through the solution under the influence of an electric field, resulting in expenditure of energy due to an increased collision rate, converting kinetic energy to heat. The conductivity mechanism is a much stronger interaction than the dipolar mechanism with regard to the heat generating capacity (Lidström, Tierney, Wathey, & Westman, 2001).

In general, the quality of a foodstuff is determined by its contents of vitamins, minerals and calorific values that can be affected by drying process conditions and moisture contents. Some vitamins are quite important in human health. For instance, vitamins A, C, E and element Se are some of the major non-enzymatic antioxidants in the body (Halliwell, 1994; Laila et al., 1991). Vitamins A, C and E have a protective effect against lung, bladder and prostate cancers. Reactive oxygen species have been implicated as mediators of tissue damage in patients with prostate cancer (Kolonel, Hinds, Nomura, Hankin, & Lee, 1985). Vitamins are organic compounds which must be taken into the body and they are cofactors for many enzymes. In addition, vitamins A, E and C have antioxidant roles against oxidative damage (Stryer, 1995). Because of their antioxidant properties, ascorbic acid, carotenoids, and vitamin E are currently the object of much attention due to possible links to prevention of certain types of cancer (Krinsky, 1989; Ziegler, 1989), cardiovascular disease (Kritchevsky, 1992), atherosclerosis (Mezzetti et al., 1995), and delay of the aging process (Packer, 1996). Ascorbate acts in oxidation reduction reactions with metal ions associated with metalo-enzymes and as a free radical scavenger in animal and plant tissues (Foyer, 1993, chap. 2). Carotenoids with nine or more

conjugated double bonds are quenchers of reactive oxygen species and function as antioxidants at low oxygen pressure (Bendich, 1989). Also, they may protect tissues against free radical damage and peroxidation (Machlin & Bendich, 1987). Although some studies (Hennekens et al., 1996; Omenn et al., 1996) revealed uncertainty regarding the nutritional benefit and physiological roles of the antioxidant nutrients, current recommendation for public is to increase consumption of fruits and vegetables and consume a variety of foods (ADA, 1996).

The body maintains pools of the antioxidant vitamins, such as vitamin E, vitamin C, and β-carotene, the vitamin A precursor. This first defense system tries to handle all free radicals, but if the oxidative stress is far greater than the capacity of the system, the second line of defense (vitamins) may come into play. Vitamins scavenge and quench free radicals, but are oxidized and inactivated in the process. Each of these antioxidant nutrients has specific activities, and they often work synergistically to enhance the overall antioxidant capacity of the body (Sies & Stan, 1998).

Up to today, changes in vitamins (A, C and E) and malondialdehyde (MDA) values in apricots as a function of type of drying systems have not been examined to determine which type of drier gives the better results in terms of time required to dry apricots, preservation of original color of a product, less loss in vitamins and MDA values. Furthermore, the different drying systems in the drying of apricots have not been compared with one another in terms of variations in values of vitamins and MDA and effectiveness of drier. Therefore, the purpose here was to determine less loss in vitamins (A, C and E) and MDA values as a function of dehydration at the same rates in the different drying systems. It was also aimed to choose the effective drying system in terms of the velocity of drying, the preservation of original colors of apricot samples and less losses of vitamins (A, C and E) and MDA values.

In this study, infrared and microwave driers were used for drying of apricots samples. The results here indicated that the highest values of vitamins (A, C and E) and MDA values were obtained from the microwave drier comparing to those obtained from IR drier. Moreover, the speed of drying and the preservation of color in the microwave drier were found to be better than those in the infrared drier.

2. Drying of apricot in microwave and infrared

2.1. Infrared drier

As expressed early, one of the radiator used in this study, transmit electromagnetic radiation in the range medium to shortwave infrared radiation (wavelengths between 2 and 3.5 μm), was used as drying equipment. The technical data of infrared drier and moisture analyzer equipment (METTLER LJ16, Switzerland) is as following:

Frequency: 50 Hz–60 Hz	Graduation: 5 °C
Power consumption max: 470 VA	Time switch (range): 0–240 min
Temperature range: 50–160 °C	Reproducibility (sample = 1 g): 0.2%
Reproducibility of the temperature: 1%	Resolution of balance: 1 mg

Apricots were split up to remove its pits and after removing of pits, apricot samples were placed in the infrared drier in a way that inside of apricot was opened to its ambience. Infrared drier was regulated to a temperature of 80 °C and apricots were dried at that temperature. Moisture removals of samples were observed by the balance mounted on the drier. Apricot samples at the different moisture contents (loss in the initial mass of sample as a percentage) of 20%, 30%, 40%, 50% and 60% were taken out from the drier to analyze it in terms of vitamins (A, C and E) and MDA.

2.2. Microwave

Similarly, after removing of pits, weight of apricot sample was initially measured and sample was placed in microwave as in infrared drier. Microwave used for drying operations in this study has the wavelength of 12.2 cm, corresponding to a frequency of 2.450 ± 0.05 GHz (Goldstar MH-1075 MD). Moisture removals of apricot samples were tracked by measuring of sample weight during drying process. Apricot samples were taken out from the microwave at moisture contents of (loss of its initial weight as a percentage) of 20%, 30%, 40%, 50% and 60% to determine values of vitamins (A, C and E) and MDA.

3. Vitamins and MDA analysis

In order to determine amounts of vitamins A, C and E, and MDA in the apricot samples with different moisture contents, sample of 1 g for vitamin C and MDA and that of 1 g for vitamins A and E were taken from homogenized each apricot sample.

To determine vitamins A and E, 4 ml of ethanol were added into the above homogenates that were vortexed and centrifuged (Mistral #2000) at 4500 rpm for 5 min at 4 °C. The supernatant was also filtered through a Whatman No. 1 paper, and then the 0.15 ml *n*-hexane was added into the obtained solution that was mixed. Vitamins A and E were extracted twice in the hexane phase and the collected extract was dried under a stream of liquid nitrogen. Dried extract was dissolved in 0.2 ml methanol for HPLC. Injections were made in duplicate for each sample. Vitamins A, E were quantitated by utilizing absorption spectra of 326 and 296 nm, respectively. In this process, methanol:acetonitril:chloroform (47:42:11, v/v) mixture was used as mobile phase at flow rate of 1 ml min^{-1} in Techsphere ODS-2 packed (5 μm particle and 80 Å pore size) column

(250 × 4.6 ID) (Catignani, 1983; Miller, Lorr, & Yang, 1984).

The extraction of vitamin C and free MDA were performed according to Cerhata, Bauerova, and Ginter (1994). The supernatant was filtered and the vitamin C level was determined by using the method of Tavazzi, Lazzarino, Di-Pierro, and Giardina (1992) and MDA levels by Karatas, Karatepe, and Baysar (2002). Vitamin C and MDA were determined by using absorption spectra of 246 and 254 nm, respectively.

The Supelcosil LC-18-DB HPLC reversed-phase column (3 μm particle size and 250 × 3.9 ID) was utilized for the detection of vitamin C and MDA levels. While mobile phase (3.7 mM phosphate buffer, pH 4.0) was used 1.0 ml min^{-1} flow rate to vitamin C level, the free MDA level was determined using mobile phase consisting of 30 mM KH_2PO_4 as a buffer, H_3PO_4 with pH 4 and methanol (65–35% v/v) at 1.5 ml min^{-1} flow rate. Each run was repeated three times to check repeatability.

In high-performance liquid chromatography (HPLC) separations were accomplished at room temperature with a Cecil liquid chromatography system (Series 1100) consisting of a sample injection valve (Cotati 7125 CA, USA) with a 20 μl sample loop, an ultra-violet (UV) spectrophotometric detector (Cecil 68174, UK) and an integrator (HP 3395A, China).

The chemicals and reagents used in this work were of analytical grade and purchased from Sigma Chemical Co. All glassware was acid washed and rinsed with doubly distilled deionized water (ddH_2O).

4. Results and discussion

As expressed previously, in this study changes in vitamins (A, C and E) and MDA values as a function of moisture removals for the two different driers were examined by using two apricot samples in different ripeness namely "near-ripe" and "ripe" apricots. The values of vitamins (A, C and E) and MDA as a function of moisture contents were determined for the near-ripe and ripe apricot samples. Vitamins (A and E) and MDA values for the ripe apricot samples were found to be higher than those for the near-ripe apricot samples at all moisture contents in both driers. However, as expected values of vitamin C for the ripe apricot samples were found to be less than those for the near-ripe apricot samples at all moisture contents in both driers.

4.1. Results obtained from infrared drier

Fig. 1 shows that changes in values of vitamin A with standard deviations at each pair of data points for two apricot samples in different ripeness as a function of moisture removals. As can seen in the figure values of vitamin A for both samples in different ripeness increase with decreasing water content of samples. In addition, we can see in the figure that values of vitamin A for the ripe apricot samples are larger than those for the near-ripe apricot samples.

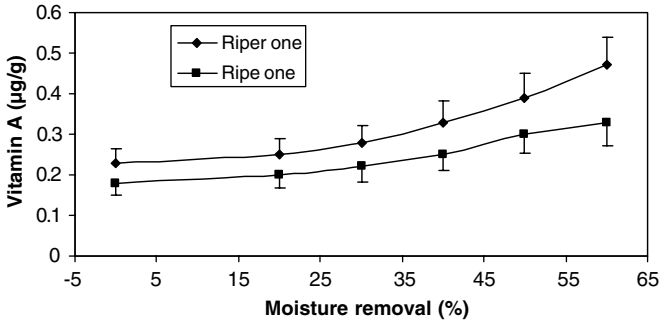

Fig. 1. Variation of vitamin A in apricot with moisture removal in IR drier.

Since vitamin values are defined as mass of vitamin per total mass of sample that decreases with decreasing moisture contents of samples, the values of vitamin A increase with decreasing water contents of samples. Changes in values of vitamin C for both apricot samples in different ripeness as a function of moisture removals are illustrated in Fig. 2. As can be seen in the figure values of vitamin C increase with decreasing water content of apricot samples in different ripeness. We can also see in the figure that values of vitamin C in the sample of near-ripe are larger than those in the sample of ripe one. Fig. 3 was depicted for changes in values of vitamin E as a function of moisture removals for both apricot samples in different ripeness. As can be seen in the figure values of vitamin E for both

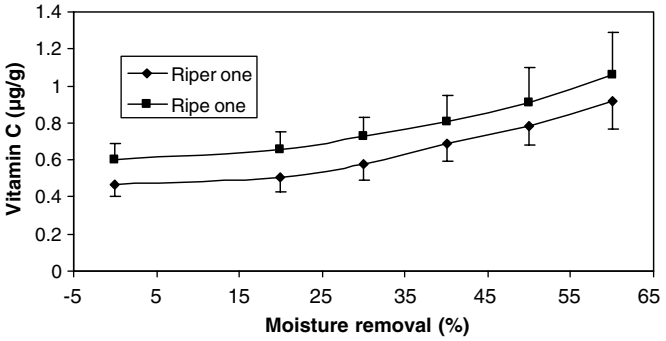

Fig. 2. Variation of vitamin C in apricot with moisture removal in IR drier.

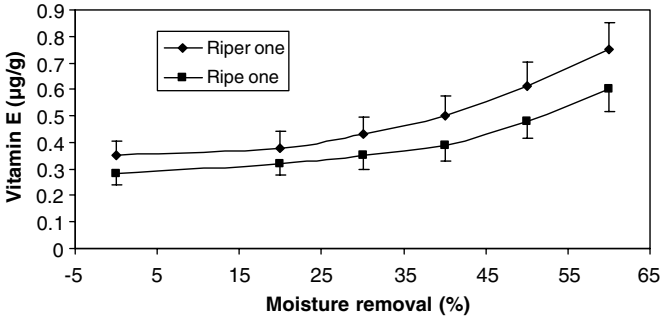

Fig. 3. Variation of vitamin E in apricot with moisture removal in IR drier.

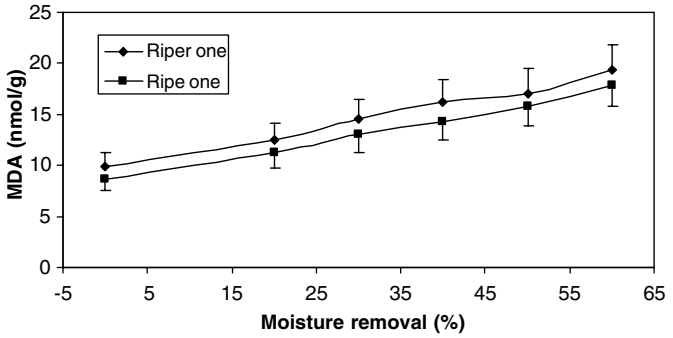

Fig. 4. Variation of malondialdehyde in apricot with moisture removal in IR drier.

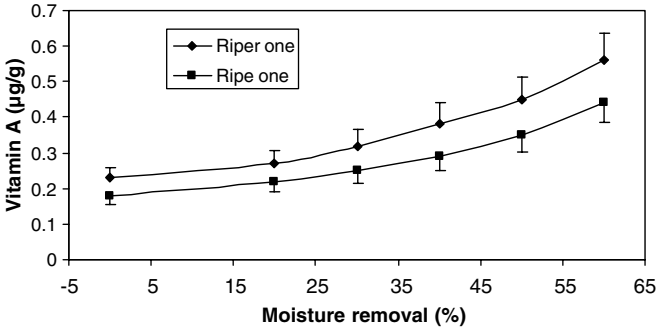

Fig. 5. Variation of vitamin A in apricot with moisture removal in microwave drier.

apricot samples in different ripeness increase with decreasing water contents of samples. Furthermore, values of vitamin E in the ripe apricot sample compared to those in the near-ripe sample are larger. Changes in MDA values in both apricot samples in different ripeness as a function of moisture removals are shown in Fig. 4. As can be seen in the figure values of MDA for both apricot samples in different ripeness increase with decreasing water contents of samples and MDA values of the ripe apricot samples are larger than those of the near-ripe sample at all moisture removals.

The standard deviations at each data point for each vitamin and MDA of each sample are shown in the related figure.

It is expected that vitamins and MDA values proportionally increase with decreasing moisture contents of samples. However, the exact proportionality between vitamins (or MDA) values and moisture removals (see the related figures for each vitamin or MDA) was not observed since the values of vitamins (A, C and E) and MDA depend on ripeness of sample as addressed above and drying process conditions. Therefore, the deviations from the exact proportionality can be resulted from sampling although care was taken to choose apricot samples in the same size and same ripeness. Furthermore, it is known that vitamins and MDA are damaged by the intense and time of heat and radiations. Thus, it may not be observed the exact proportionality between amounts of vitamins and MDA and moisture removals.

Since vitamin values are defined as mass of vitamin per total mass of sample that decreases with decreasing water contents of apricot samples, amount of vitamins (A, C and E) and MDA values increase with decreasing moisture content of apricot samples.

4.2. Results obtained from microwave

For vitamins (A, C and E) and MDA values, trend observed in infrared drier is identical to that in microwave drier but not amounts of quantities. Therefore, the discussion given above is valid for microwave drier. Variation of vitamin A with moisture removals in apricot samples in different ripeness is illustrated in Fig. 5. As can seen in the figure values of vitamin A for both samples in different ripeness increase with decreasing water contents of samples. In addition, we can see in the figure that values of vitamin A for the ripe apricot samples are larger than those for the near-ripe apricot samples. Since vitamin values are defined as mass of vitamin per total mass of sample that decreases with decreasing moisture contents of samples, the values of vitamin A increase with decreasing water contents of samples. Variation of vitamin C is plotted in Fig. 6 against the moisture removals for both apricot samples in different ripeness namely the near-ripe and the ripe. As can be seen in the figure values of vitamin C increase with

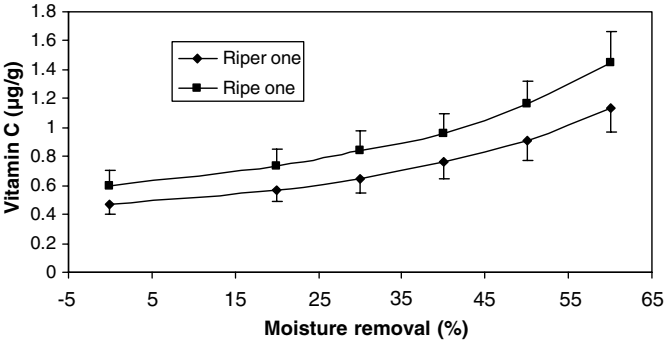

Fig. 6. Variation of vitamin C in apricot with moisture removal in microwave drier.

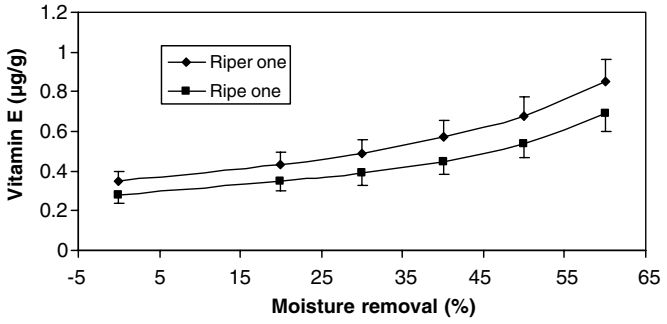

Fig. 7. Variation of vitamin E in apricot with moisture removal in microwave drier.

decreasing water content of apricot samples in different ripeness. We can also see in the figure that values of vitamin C in the sample of near-ripe are larger than those in the sample of ripe one. Fig. 7 was depicted for changes in values of vitamin E as a function of moisture removals for both apricot samples in different ripeness. As can be seen in the figure values of vitamin E for both apricot samples in different ripeness increase with decreasing water contents of samples. Furthermore, values of vitamin E in the ripe apricot sample compared to those in the near-ripe sample are larger. Changes in MDA values in both apricot samples in different ripeness as a function of moisture removals are shown in Fig. 8. As can be seen in the figure values of MDA for both apricot samples in different ripeness increase with decreasing water contents of samples and MDA values of the ripe apricot samples are larger than those of the near-ripe sample at all moisture removals.

Changes in values of vitamin A of apricot samples in identical ripeness as function of moisture removals are illustrated in Fig. 9 for two different driers namely infrared and microwave. As mentioned previously, vitamin values of apricot samples dried from both driers increase with decreasing moisture contents of samples. As can be seen in this figure the values of vitamin A of apricot samples dried in the microwave are higher than those of apricot samples dried in the IR drier. Although here two driers were compared to one another in terms of changes in values of vitamins A of apricot sample, these driers can be compared with each other in terms of other vitamins (C and E) and MDA values. If microwave and infrared driers are compared with one another in terms of vitamin C (compare Fig. 2 with Fig. 6), vitamin E (compare Fig. 3 with Fig. 7) and MDA (compare Fig. 4 with Fig. 8), it will be seen that values of vitamins and MDA of apricot samples dried in microwave are larger than those of apricot samples dried in infrared.

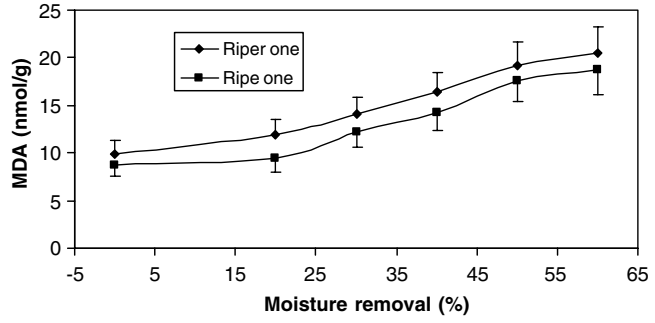

Fig. 8. Variation of molondialdehyde in apricot with moisture removal in microwave drier.

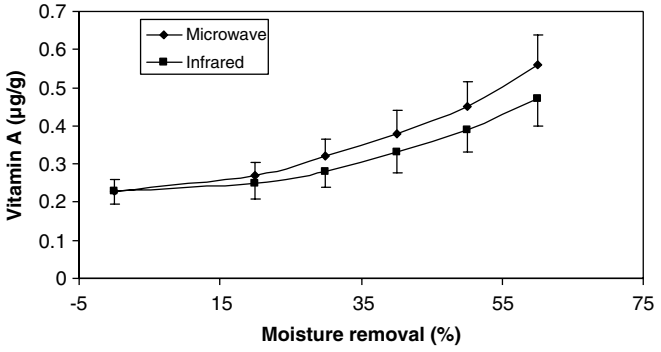

Fig. 9. Comparison of levels of vitamin A in apricot dried in the two different driers.

As stated previously, vitamins and MDA can be damaged by the intense and time of heat and radiation applied in a drier. The drying time in microwave drier comparing to that in IR drier is quite short. While the drying time in microwave drier takes 3–8 min, that in IR drier takes 20–90 min according to removing of moisture in the sample. If microwave and IR driers are compared with one another in terms of color of the product, it will be seen that the better result for color is obtained in the microwave drier. In other words, while browning in color apricot sample is observed in IR, the original color of product is retained in the microwave during the period of drying time.

The waves of infrared radiation are less than those microwave radiation since the microwave radiation region is located between infrared and radio waves. In general, the wavelength at which industrial and domestic microwave apparatus intended for heating operates is regulated to 12.2 cm, corresponding to frequency of 2.450 (±0.05) GHz, but other frequency allocations do exist. Drying of apricots with IR may cause vitamins and MDA values to decrease comparing to microwave drier.

5. Conclusions

Microwave drier for apricot drying is much effective than that in IR in terms of the speed of drying, preservation of original color of apricot samples and less losses of vitamins (A, C and E) and MDA values. It was observed that values of vitamins (A, C and E) and MDA in two apricot samples in different ripeness increase with decreasing moisture contents of samples. The values of vitamin (A and E) and MDA in the ripe apricot samples are larger than those in the near-ripe apricot samples throughout decreasing of moisture contents. However, values of vitamin C in the ripe apricot samples are less than those in the near-ripe apricot samples at all rates of moisture removals. The values of vitamins and MDA of apricot samples dried in microwave were found to be larger than those of samples dried in infrared drier.

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