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ORIGINAL PAPER

The Effects of Microwave Frying on Physicochemical Properties of Frying and Sunflower Oils

Maryam Gharachorloo · Mehrdad Ghavami · Maryam Mahdiani · Reza Azizinezhad

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Abstract Deep fat frying is a method of food preparation which has been popular for quite a number of years. During deep frying, the quality of oil and the finished product decreases as the result of heat treatment of the oil exposed to air at high temperature. Application of heat by microwave as an alternative to the conventional method of frying has become popular in recent years. In this research, the effects of microwave frying on the changes in the quality indices of used oil have been investigated. To achieve this, potato slices were fried in both frying and sunflower oils by application of medium power microwave (550 W) for 20 min, three times a day, for five consecutive days, and oils were sampled for analysis. The results obtained from the chemical tests demonstrated that used frying oil had lower polar compounds, a higher induction period, and more saturated fatty acids than sunflower oil. The interesting point observed was that peroxides formed as the result of oxidation chain reactions were not broken down and were built up due to the lower temperature and shorter period of frying. Therefore microwave frying might be considered as a suitable alternative to the conventional frying due to less degradation of the oil and consequently a lower production of artifacts.

Keywords Microwave frying · Frying oil · Sunflower oil · Qualitative evaluation

M. Gharachorloo (✉) · M. Ghavami · M. Mahdiani · R. Azizinezhad
Department of Food Science and Technology, College of Food Science and Technology, Science and Research Branch, Islamic Azad University, P.O. Box 1476714171, Iranzamin Shomali, Sardar Jangal, Poonak, Tehran, Iran
e-mail: gharachorlo_m@yahoo.com

Introduction

Deep frying is a popular way to produce and prepare foods all over the world and fried products such as potato chips are widely used as consumers have a high preference for fried foods owing to their particular taste and texture [1, 2].

During industrial processes, oil is continuously heated at high temperatures in the presence of atmospheric oxygen and moisture. Under such conditions, chemical reactions such as oxidation, polymerization, degradation, and hydrolysis occur and this leads to destructive changes in the oil quality. Moreover, as a result of such changes, oxidized and polymerized compounds are produced that are nutritionally harmful to the consumers' health [1, 3].

The most commonly used oil for frying processes is a commercial frying oil which is formulated by blending palm olein or partially hydrogenated oils with other vegetable oils particularly canola or soybean oil. Sunflower oil might also be an alternative for frying due to its high smoke point and fatty acid composition [4, 5].

Microwave heating is considered as an efficient and ideal method of frying as compared to the conventional method due to the shorter time and the lower temperature of processing. The speed and convenience of a using microwave oven are among other advantages of employing this appliance. These have brought about its widespread application for food preparation in recent decades for domestic use as well as for industrial processes [6, 7]. However, application of this method for frying has not been studied in detail.

Oztop et al. [8] studied the effect of microwave heating when slices of potatoes were fried in sunflower, maize, and hazelnut oils and concluded that potatoes fried using sunflower oil had the lowest amount of absorbed oils. Chu et al. [9] studied the effect of different heat treatments on the quality of shallots and evaluated the oil used. Owing to the lower temperature and shorter duration of microwave heating, as compared to the conventional method, the oil kept a better quality and volatile compounds in the product were preserved better.

Therefore there is a need for further investigation into microwave heating of both frying and sunflower oils, the two most popular media in frying processes. In this research the effects of microwave frying on the changes in the quality indices of used oil have been investigated.

Materials and Methods

Materials

Sunflower oil, the most popular oil in the food industry for frying processes due to a higher smoke point and commercial frying oil, a blend of palm olein and soybean oil containing 0.01% TBHQ were employed as the media for frying processes.

Potatoes were supplied from a Tehran market and all the chemicals used were of analytical grade, purchased from the Merck Chemical Company of Germany.

Methods

Preparation of Potato Slices

Potatoes were peeled, washed, and cut by using a manual operated cutting device into slices. The slices were washed to remove free starch and the surface was blotted with a paper towel before frying.

Microwave Frying

A domestic microwave oven (Panasonic, Model NN-S235WF) with regular power (low, medium, and high) was used in this study.

All the oil samples were simultaneously exposed at a frequency of 2450 Hz. Microwave frying was performed using a glass container containing 2 L of oil. Potato slices (36 g) were placed in the oil and fried at medium power (ca. 550 W) for 20 min with a final oil temperature of 150 °C, which was determined immediately after the frying process.

For each oil, microwave frying was carried out for five successive days, three times every day.

Particles were removed from the oil by filtration after it had cooled down and oil samples were stored in glass jars in the refrigerator for further analysis.

Physical and Chemical Analysis

A series of physical and chemical tests were carried out on the treated oil samples according to the AOCS Official Methods [10] consisting of peroxide value (Method Cd 8-53), free fatty acid content (Method Cd 3d-63), total polar compounds (Method Cd 20-91), and color (Method Cc 13e-92). The fatty acid composition of the fresh and used oils were determined by Gas Chromatography according to the AOAC official method [11] (Method 969/33) employing a Varian Star 3400 gas chromatograph equipped with a DEGS capillary column (30 m × 0.25 mm i.d.) and a flame ionization detector. The injector, column oven, and detector temperatures were 240, 200 and 280 °C, respectively.

The induction period was performed on a Metrohm Rancimat apparatus model 743 at 110 °C with an air flow of 20 L/h.

Statistical Analysis

All the experiments and/or measurements were carried out with two replicate.

The data were statistically analyzed using the Statistical Analysis System software package on replicated test data. Analyses of variance were performed by application of an ANOVA procedure. Significant differences between the means were determined using the Duncan multiple range test.

Results and Discussion

Both oils showed increases in acid values due to hydrolysis of triglyceride because of moisture content and heat treatments and as the concentration of acid increased, further hydrolysis of triglycerides occurred [12]. The results shown in Fig. 1 indicate a steady increase in the acid value of sunflower oil while the increase in acid value of frying oil occurs with some variations and interruptions which might be due to the volatile free fatty acid released as the result of hydrolysis and final evaporation at the frying temperature. Although the increase in the fatty acid concentration might also be due to the formation of low molecular weight acid as the final result of an oxidation process as some researches have explained [13].

Although in both oils, the acid values increased as the frying treatment progressed but the final figures obtained was less than 2.5 which is the oil rejection level for frying oils set by some countries [14]. Mahdiani et al. [15] obtained higher acid value figures for conventional frying than by microwave which might be due to the application of higher temperature in the former than the latter.

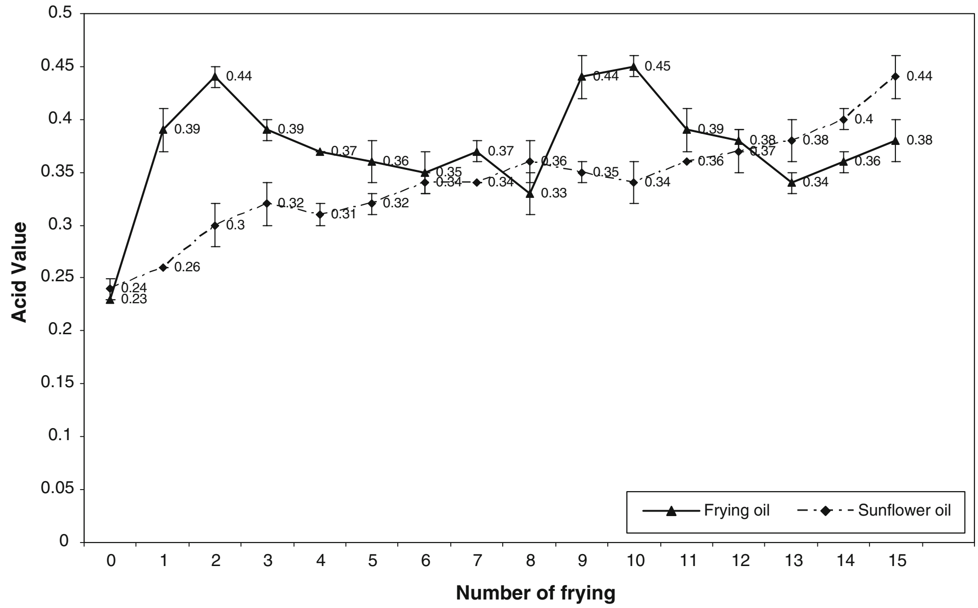

Fig. 1 Acid value of frying and sunflower oils during the period of microwave frying

Figure 2 shows the stability of sunflower and frying oils as the result of microwave frying in term of peroxide values. Peroxides are unstable compounds and disintegrate at frying temperatures into various artifacts namely aldehydes, ketones, alcohols, and acids [16]. Frying oil showed a better stability as compared to sunflower oil because of the higher concentration of saturated fatty acids (Table 1), concentration of natural antioxidants, and the presence of TBHQ in the frying oil. In this work, peroxides were formed in both oils as the oxidation was in progress and the break down of hydroperoxides, which is usually indicated by a sharp decrease in the peroxide value, was not observed. Mahdiani et al. [15] carried out sets of experiments concerned with the conventional method of frying where the results indicated that hydroperoxides due to their instability decompose and break down at elevated temperatures giving rise to wide ranges of artifacts and compounds which might be nutritionally harmful to the health. Experiments carried out by Chu et al. [9] showed that the conventional method of frying produced a higher

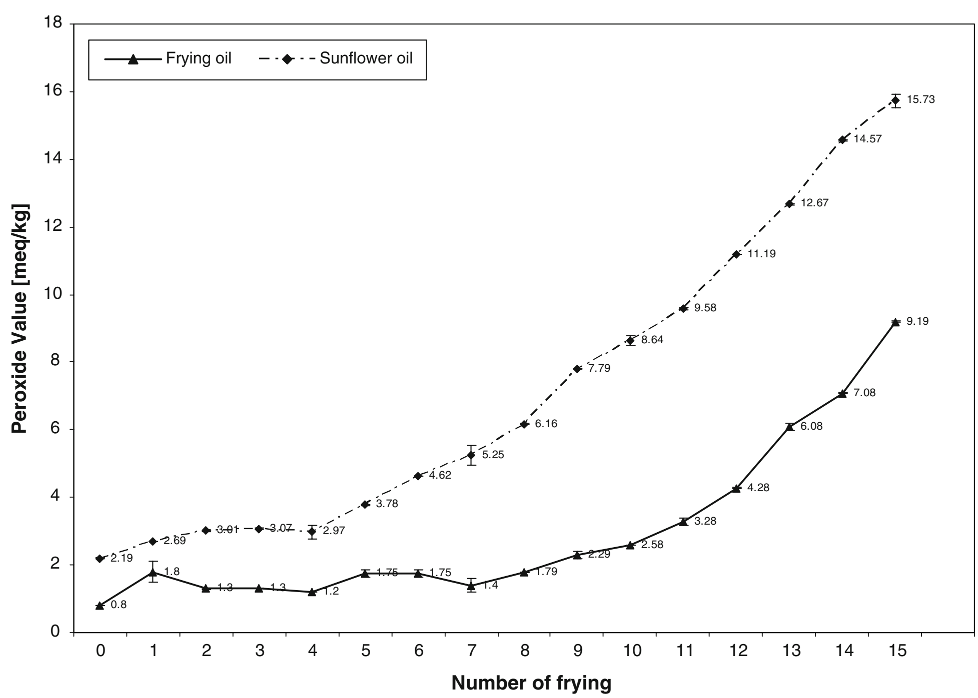

Fig. 2 Peroxide value of frying and sunflower oils during the period of microwave frying

Table 1 Fatty acid composition of different oil samples

Oil samples	C12:0	C14:0	C16:0	C17:0	C18:0	C18:1	C18:2	C18:3
Fatty acid composition (%)[a]								
Sunflower oil (fresh oil)	–	–	5.13 ± 0.01	–	1.64 ± 0.01	28.29 ± 0.03	64.93 ± 0.03	0.01 ± 0.00
Sunflower oil (after 15 period of frying)	–	–	6.97 ± 0.02	–	2.88 ± 0.02	27.79 ± 0.04	62.36 ± 0.04	–
Frying oil (fresh oil)	–	0.43 ± 0.02	32.28 ± 0.04	–	1.46 ± 0.02	50.35 ± 0.01	15.36 ± 0.01	0.12 ± 0.00
Frying oil (after 15 period of frying)	0.34 ± 0.00	0.38 ± 0.01	34.86 ± 0.01	0.20 ± 0.00	3.65 ± 0.01	51.11 ± 0.03	9.38 ± 0.01	0.08 ± 0.01

[a] The values are expressed as means ± standard deviation

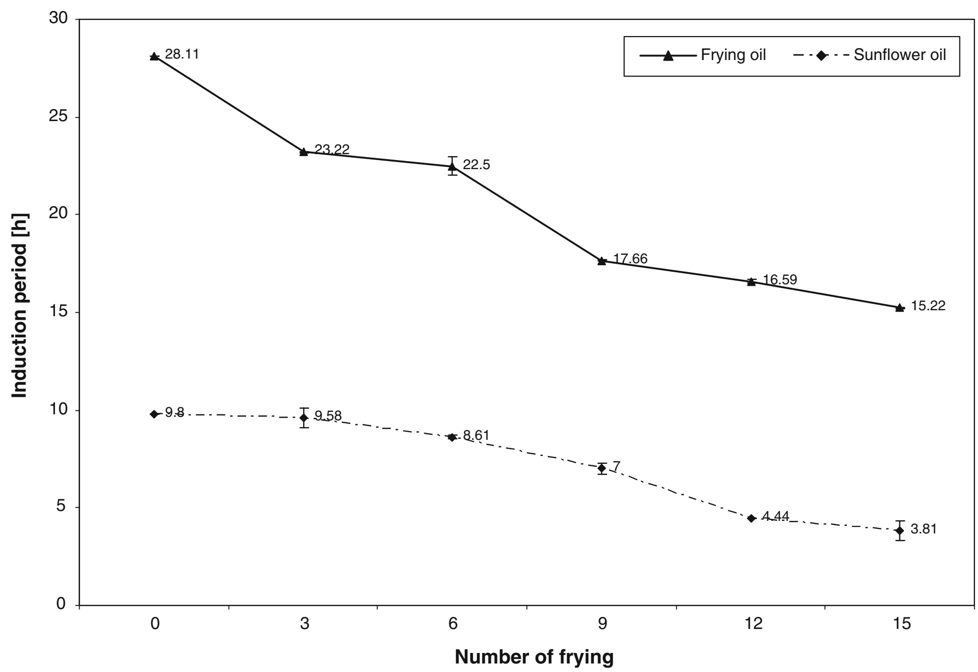

Fig. 3 Induction period of frying and sunflower oils during the period of microwave frying

concentration of hydroperoxide as compared to microwave frying. The formation of peroxides and consequently its decomposition in the oil affects the induction period of the oil.

The induction period, an indication of the oil resistance to oxidation is measured at specified time intervals during the course of frying for both oils (Fig. 3). The frying oil showed a higher resistance to oxidation and both oils had reasonable and acceptable induction periods after 15 periods of heating. The differential effects between the two oils are related to their different fatty acid compositions, presence of TBHQ and possibly the concentration of natural antioxidants present. Here, it is worth pointing out that microwave heating should be regarded as suitable for frying of potatoes due to the better conservation of the frying media as is the case for the two sources employed. However further studies should be carried out to understand the behavior of microwaves on certain nutrients namely vitamins and pigments.

The polar compound content, an indication of hydrolysis and oxidation of triglycerides and formation of free fatty acids, mono, diglycerides as well as other compounds is not only concerned with hydrolysis of triglycerides but is related to saturation and unsaturation of the media as some researches have suggested [17], therefore it has been suggested that polar compounds increase as unsaturation is increased [8]. Here total polar compounds in both oils increased linearly as frying progressed and reached 33.5 and 23.7% for sunflower and frying oils respectively at the end of frying period (Fig. 4). The acceptable standard for polar compounds is below 25% according to some European countries [14]. Sunflower oil indicated an unacceptable range of polar compounds after 15 periods of frying processes, while the frying oil which is a mixture of

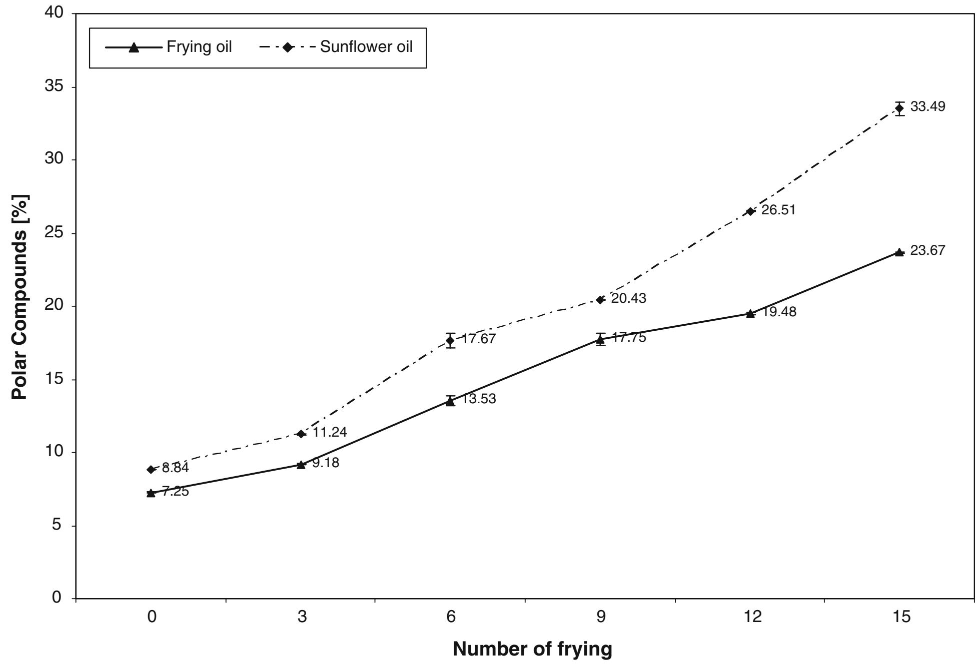

Fig. 4 Polar compounds of frying and sunflower oils during the period of microwave frying

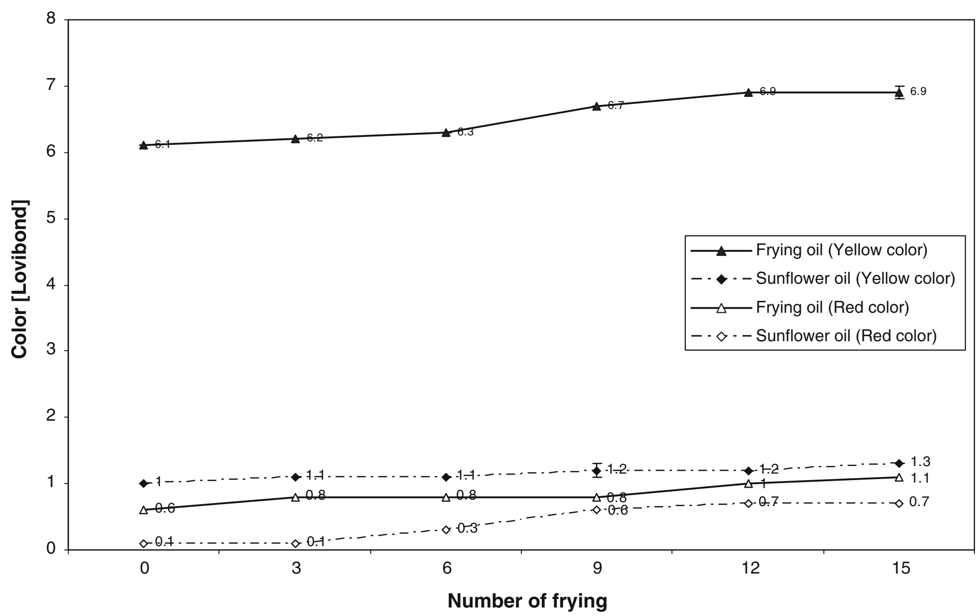

Fig. 5 Color of frying and sunflower oils during the period of microwave frying

palmolein and soybean oils obtained a value below the figure mentioned earlier. Therefore, frying oil had a lower concentration of polar compounds which are partially regarded as the products of hydroperoxide decomposition namely aldehydes, ketones, acids, and alcohols, secondary oxidation products.

Pigments and colors present or produced as the result of microwave heating of both frying and sunflower oils are shown in Fig. 5. The frying oil has a higher concentration of both red and yellow colors than sunflower oil which might be due to the pigment naturally present or color formed as the results of the Maillard reaction or reactions similar to it. By reactions similar to the Maillard reaction, the reactions between amino containing compounds namely traces of some phospholipids and aldehydes is meant, the secondary oxidation products formed as the result of fatty acid oxidation.

Due to the lower heat treatment applied in microwave frying, the rate of oxidation has been kept to a minimum as indicated by the fatty acid composition presented in Table 1, which shows a significant decrease in both linoleic and linolenic acids contributions throughout the frying period ($P < 0.05$). However, the nutritional effects of frying oil which contains a higher concentration of palmitic acid might be a matter to be investigated.

The statistical analysis of the results based on the Duncan multiple range test concerned with the acid value, peroxide value, induction period measurement and polar compounds of both sunflower and frying oils indicated a significant difference.

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