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Research Paper / Araştırma Makalesi

Effect of Microwave Heating on Quality Parameters of Hazelnut, Canola and Corn Oils

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ABSTRACT

This study was conducted to determine the effect of microwave heating on the turbidity, free fatty acids (FFA), peroxide values (PV), conjugated dienes (K_{232}) and trienes (K_{270}) and oxidative induction times (OIT) of hazelnut, canola and corn oils. The OIT values were determined via differential scanning calorimeter (DSC). Microwave heating was applied to oil samples for 3, 5, 10, 15, 20 and 30 min. Untreated oil samples were also analysed. The FFA, PV, K_{232}, and K_{270} values of all oil samples increased with an increase in microwave heating time while a decrease in the OIT values was detected. Physico-chemical parameters as well as thermal measurements were effective in detecting the oxidative changes occurring in oils during microwave heating. No changes in oil turbidity during microwave heating were determined. Results indicated that oxidation changes occurred in all oil samples. Although there was an increase in the PV and FFA values of the oils, these values still remained within the legal limits required for oils.

Keywords: Microwave heating, Hazelnut oil, Canola oil, Corn oil, Oxidation

Mikrodalga Isıtmanın Fındık, Kanola ve Mısır Yağı Kalite Parametreleri Üzerindeki Etkisi

ÖZ

Bu çalışma, mikrodalga ısıtmanın fındık, kanola ve mısır yağlarının türbidite, serbest yağ asitliği (FFA), peroksit değeri (PV), konjüge dienler (K_{232}) ve trienler (K_{270}) ve oksidatif indüksiyon süresine (OIT) olan etkisini değerlendirmek amacıyla yapılmıştır. OIT değerleri diferansiyel taramalı kalorimetre (DSC) ile belirlenmiştir. Mikrodalga ısıtma her bir yağa, 3, 5, 10, 15, 20 ve 30 dakika süreyle uygulanmıştır. Herhangi bir mikrodalga ısıtmaya maruz kalmayan yağ örnekleri de analiz edilmiştir. Tüm yağ örneklerinin FFA, PV, K_{232}, K_{270} değerleri mikrodalga ısıtma süresine bağlı olarak artış göstermiş, buna karşın, OIT değerlerinde düşüş saptanmıştır. Fiziko-kimyasal parametreler kadar DSC sonuçlarının da, yağlarda mikrodalga ısıtmaya bağlı olarak gerçekleşen oksidatif değişimlerin belirlenmesinde etkili olduğu bulunmuştur. Mikrodalga ısıtmanın yağların türbidite değerlerini etkilemediği saptanmıştır. Sonuçlar, mikrodalga ısıtmanın araştırılan yağlarda oksidatif değişikliğe sebep olduğunu göstermiştir. PV ve FFA değerlerinde artış gözlenmesine rağmen, bu değerler yasal limitler dahilinde tespit edilmiştir.

Anahtar Kelimeler: Mikrodalga ısıtma, Fındık yağı, Kanola yağı, Mısır yağı, Oksidasyon

INTRODUCTION

During the last decades, applications of microwave heating have been continually of interest both at households as well as in food industry for cooking, thawing, dehydration, baking, blanching, pasteurization, sterilization, roasting, frying, etc. [1-7]. When compared with conventional cooking, microwave heating has several indispensable advantages such ease of application, energy and time saving capacity, thus leading to reduction of production costs [6, 8, 9]. Therefore, it is expected that microwave heating usage will continue to widen its applications. On the other hand, the way of microwave heating rises the concerns towards any deteriorations of food products subjected to this application.

In literature, there are a number of studies dealing with the effects of microwave applications on the quality of food products and oil oxidation is the main point of investigation, since oxidation is one of the major problems for edible oils and oil containing food products [4, 6, 8, 10]. Oil oxidation process consists of series of chain reactions defined as initiation, propagation and termination. The oil oxidation process is commonly affected by temperature, presence of oxygen, free fatty acids, metal ions, antioxidants and degree of unsaturation. Primary and secondary products occur during oxidation. The primary oxidation products are named as hydroperoxides and give information about oil oxidation. The secondary oxidation products such as carbonyl compounds, unsaturated aldehydes, non-volatile aldehydes and alcohols are responsible for the rancid odour and flavours. Oxidation may lead to deterioration of oils and oil-containing foods leading to losses in quality and nutritional value [4, 6, 8, 10, 11].

Albi et al. [1] investigated microwave and conventional heating effects on the physical and chemical parameters of oils and fats. Viera and Regitano-d'Arce [10] reported thermal oxidation of canola oil during microwave heating. Yoshida et al. [2] studied the effects of microwave treatment on oxidative stability of peanut oil. Hassanein et al. [3] showed that changes in oil composition of sunflower, soybean and peanut oils during microwave heating occurred. Dostalova et al. [12] monitored the oxidative changes of sunflower, rapeseed, peanut oils and lard during microwave cooking. Chiavaro et al. [13] examined the chemical and thermal parameters of different vegetable oils subjected to microwave heating. Similarly, the changes in the physico-chemical and thermal behaviour of fat blended with hydrogenated palm kernel oil and butter was investigated [14]. Furthermore, the oxidative changes of different vegetable oils due to microwave applications were recorded both by physico-chemical and thermal analyses [6].

The goal of this study was to determine the effects of microwave treatment on the oxidative stability of three vegetable oils with different fatty acid compositions: canola, corn and hazelnut oils.

MATERIALS and METHODS

Materials

Canola, corn and hazelnut oils, produced in 2015 season, were purchased from a local market. All of the chemicals used for the analyses were of analytical grade and purchased from Sigma-Aldrich or Merck.

Microwave Heating Treatment

Oil samples (100 g) were filled into beaker-glasses and then heated for 0, 3, 5, 10, 15, 20 and 30 min in microwave oven (Cendix, 2450 MHz, 1200 W). The microwave treatment was done in duplicates. After microwave treatment, oil samples were poured into amber-glass bottles and the bottles were closed under N_2 gas flow. The treated samples were stored in deep-freezer until analysis.

Physico-Chemical Measurements

The free fatty acids content (FFA), peroxide value (PV), iodine (IV), K_{232} and K_{270} values and refractive indices (RI) of the samples were measured according to AOCS Official methods (Ca 5a-40), (Cd 8-53), (Da 15-48), (Ch 5-91) and (Cc 7-25), respectively [15]. The turbidity values of the oil samples were determined by using Micro T100 Lab Turbidimeter (HF Scientific Inc., USA) according to the instructions of the instrument.

Thermal Measurements

Oxidative induction time (OIT) values of the oil samples were determined with differential scanning calorimeter (DSC- 4000, Perkin Elmer). Approximately, 10-12 mg oil samples were weighed into aluminium pans. The pans were heated from 30°C to 150°C under N_2 gas flow rate 20 mL/min and after that the samples were held at that temperature for 1 min under N_2 gas flow rate 50 mL/min. Then, the gas was switched to O_2 flow rate 50 mL/min at isothermal conditions for determination of the OIT values of the samples [16]. Oxidative induction time was calculated from the thermograms by using DSC software. A sample of OIT thermogram is given in Figure 1.

Statistical Analysis

The microwave heating treatment was done twice and all analyses were done in triplicate. The results were presented as means with standard deviation values. Comparison of the results was accomplished by applying the analysis of variance (ANOVA) test, with Tukey's test. Statistical analyses were carried out with Minitab v.16.1.1 software [17].

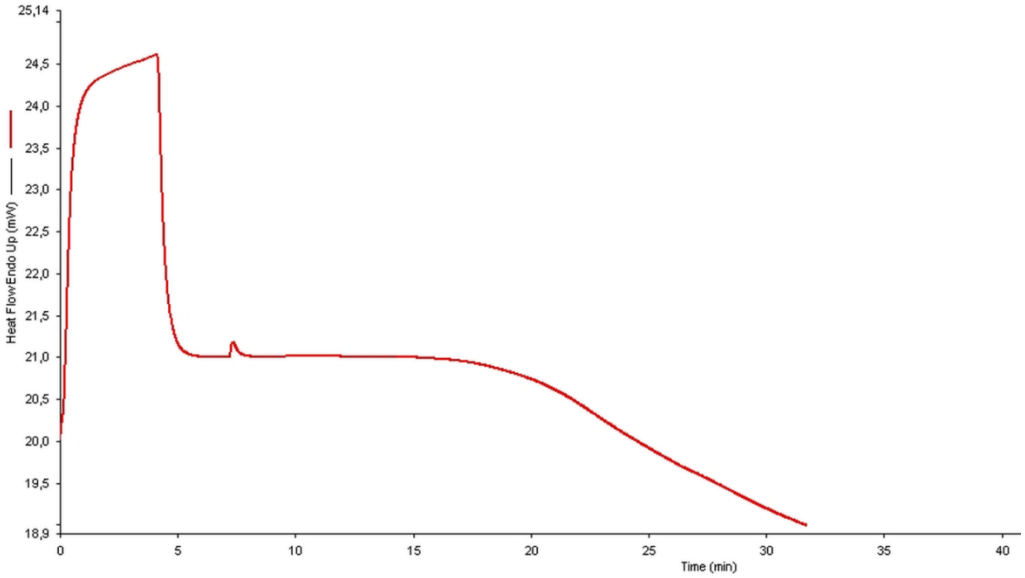

Figure 1. Sample OIT thermogram

RESULTS and DISCUSSION

The physico-chemical properties of untreated oil samples are presented in Table 1. All samples exhibited similar refractive index and turbidity values ($p>0.05$). On the other hand there were statistically significant differences for the iodine values, free fatty acids content, peroxide values, K_{232} and K_{270} values and oxidative induction time values of the investigated oil samples ($p<0.05$).

Table 1. Physico-chemical features of untreated oil samples

Oils	RI	Turbidity (NTU)	IV	FFA (%)	PV (meqgO_2/kg)	K_{232}	K_{270}	OIT (min)
Canola	1.4700±0.01	0.19±0.03	115.94±0.02b*	0.34±0.01a	3.27±0.16a	7.39±0.04b	0.85±0.22b	18.45±0.26a
Corn	1.4710±0.01	0.14±0.05	131.97±1.45a	0.22±0.01b	3.06±0.18b	11.01±0.01a	3.92±0.02a	13.22±0.01b
Hazelnut	1.4673±0.01	0.20±0.05	92.97±2.26c	0.22±0.01b	0.05±0.01c	4.88±0.04c	0.47±0.04c	11.94±0.01c

RI; Refractive index, IV: Iodine value, FFA; Free fatty acid, PV; Peroxide value, OIT; Oxidative induction time. *Different small letters show differences among the oil samples in the same column

The effect of microwave heating on the turbidity values of the oils is given in Figure 2. After 15 minutes of exposure to microwave heating corn oil exhibited an increase in the turbidity level, then its turbidity decreased (Fig. 2). Although there was an increase in the turbidity level of canola oil, visibly there were no sharp changes in the appearance of all oil samples, revealing that there was no obvious effect of microwave heating on oil turbidity.

The free fatty acid (FFA) content is related with the formation of off-flavours in oils and fats, since it represents the level of hydrolysis in vegetable oils. Thus, when the FFA increases, the level of hydrolysis due to deterioration also increases [18]. The change of FFA during microwave heating of the oil samples is given in Figure 3. Overall, the FFA contents of all investigated samples increased after 30 min microwave heating (Fig. 3). Similar increase in the FFA content of canola oil was reported by Vieira and Regitano-d'Arce [10] after 36 min microwave heating. Significant increase in FFA of safflower oil and rapeseed oil after 5 min exposure to microwave heating was indicated by Pop [19]. On the other hand, Dostalova et al. [12] stated that the increase in FFA was negligible for sunflower, rapeseed, peanut oils and lard after 40 min microwave heating. On the contrary, Hassanein et al. [3] reported gradual significant increase in FFA of sunflower, soybean and peanut oils during 18 min microwave heating and concluded that this increase was mainly because of the splitting of ester linkages of triglycerides due to heating.

The peroxide value (PV) of oils shows the amount of peroxides produced as a result of oil oxidation and is regarded as a useful parameter for measuring the level of primary oxidation [18, 19]. Thus, the PVs of the hazelnut, canola and corn oils subjected to microwave heating were measured in this study. As can be seen from Figure 4, for all samples there was an increase in the PVs at the end of 30 minutes of exposure to microwave heating, although there were also drops at different times for the different oil samples. Hassanein et al. [3] reported that there was gradual increase in PVs of sunflower, soybean and peanut oils during 18 min. microwave heating. On the other hand, in a number of studies, increase and decrease in PVs during microwave heating were reported for canola oil [10]; pork lard, sunflower, zero-erucic rapeseed peanut and high-oleic peanut oils [12]; sunflower, soybean, rapeseed and corn oils [8]; peanut, sunflower and canola oils [13]; corn oil [9]; blended fat (hydrogenated

palm kernel oil and butter) [14]; safflower and rapeseed oils [20] and tiger nut oil [7]. Javidipour et al. [6] detected that after 9 minutes of microwave heating a sharp decrease in PVs of refined hazelnut, soybean, sunflower and virgin olive oils. According to Dostalova et al. [12] and Lukesova et al. [8], the different level of unsaturated fatty acids and the degree of their oxidation is the reason for the variability of the PVs during microwave heating exposure, since PV is a measure of primary oxidation products. After a drop in the PV is observed, the oxidation reactions continue to next phases and thus new compounds are formed.

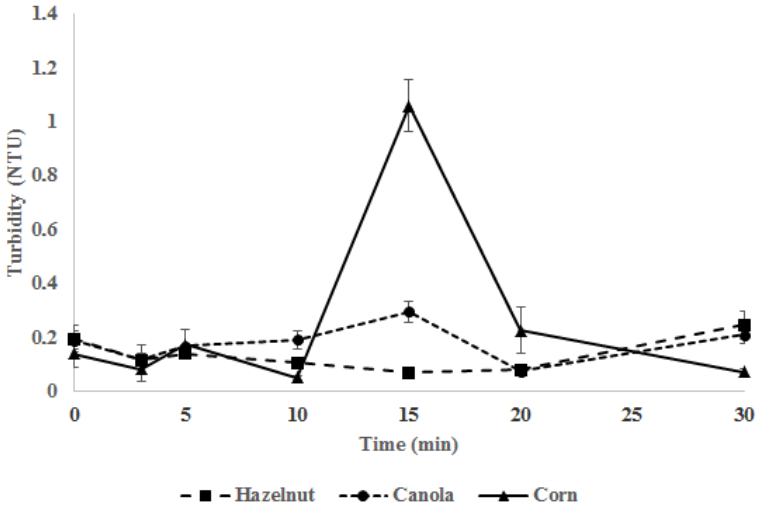

Figure 2. Turbidity values of the microwave treated oil samples

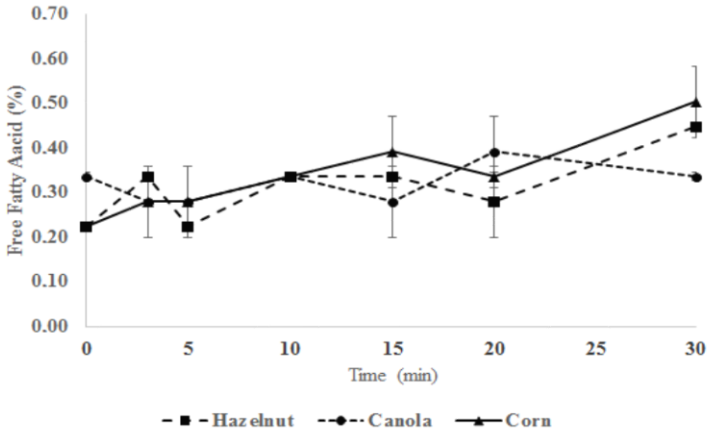

Figure 3. Free fatty acid values of the microwave treated oil samples

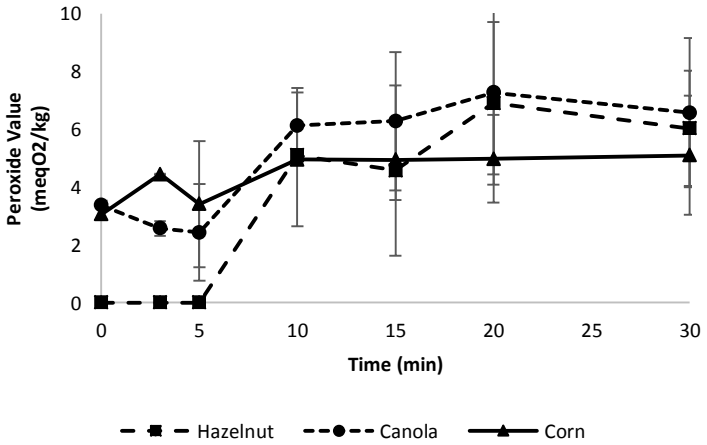

Figure 4. Peroxide values of the microwave treated oil samples

Absorbance values at 232 and 270 nm are found to be good indicators of the formation of secondary oxidation products, since absorbance at 232 nm represents the conjugated dienes, while absorbance at 270 – the conjugated trienes [18]. Thus, in the present study, the K_{232} and K_{270} values of the oil samples were monitored during microwave heating and the results were presented in Figure 5 and Figure 6, respectively. For all samples, both K_{232} and K_{270} increased with microwave heating, showing that secondary oxidation products were formed during microwave heating of hazelnut, canola and corn oils (Fig. 5 and Fig. 6). Similarly, Albi et al. [1] found out that K_{232} and K_{270} of virgin olive, olive, sunflower, high oleic sunflower oils and lard increased after microwave cooking and were higher when compared to conventional heating and suggested that this increase was mainly due to the fact that during microwave heating, the formation of trienes and unsaturated ketones or aldehydes was higher because of the internal friction of the molecules. Lukesova et al. [8] reported that conjugated dienes and trienes gradually increased in rapeseed, sunflower, soybean and corn oils exposed to microwave heating for 30 min. Kiralan and Kiralan [21] investigated the effect of microwave heating on the quality of black cumin and hazelnut oils and found out that there was an increase in the K_{232} and K_{270} values after 8 min. exposure to microwave heating. Similar increase for the K_{232} and K_{270} values of tiger nut oil after 15 min. microwave heating was reported by Sobhani et al. [7].

Besides evaluation of oil oxidation with the afore-mentioned physico-chemical parameters, nowadays, differential scanning calorimetry (DSC) appears as reliable method since it is time-saving and no chemicals that might be toxic for both laboratory staff and environment are required [16]. In a number of studies, when assessing the oxidative deterioration of oils, a good correlation was proved between the thermal properties measured with DSC and the standard chemical oxidative parameters, such as PV and FFA content [13, 14]. In the present study, the OIT values of the oil samples were measured at different intervals after microwave heating for 30 min. The results are presented in Figure 7. For all oil samples there was a profound decrease in the OIT values with microwave heating, implying the oxidative deterioration due to microwave treatment.

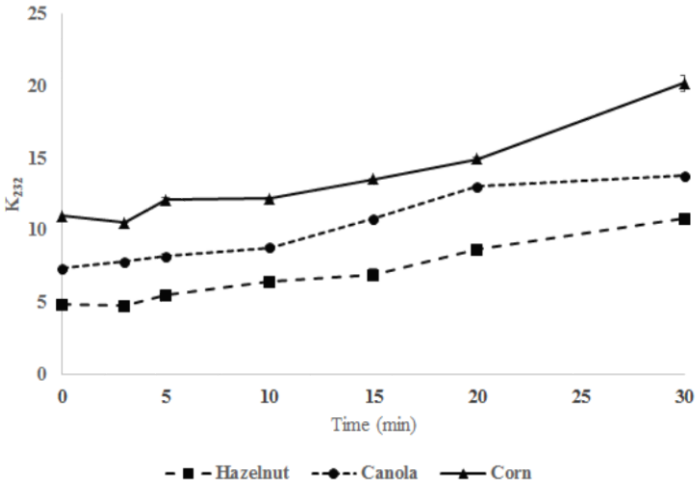

Figure 5. K_{232} values of the microwave treated oil samples

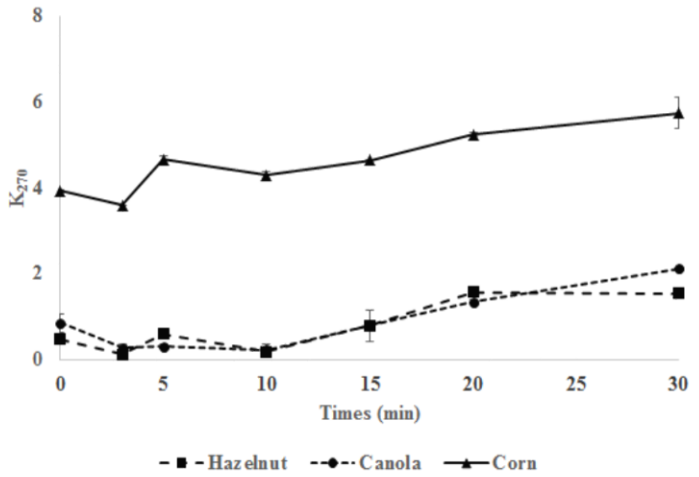

Figure 6. K_{270} values of the microwave treated oil samples

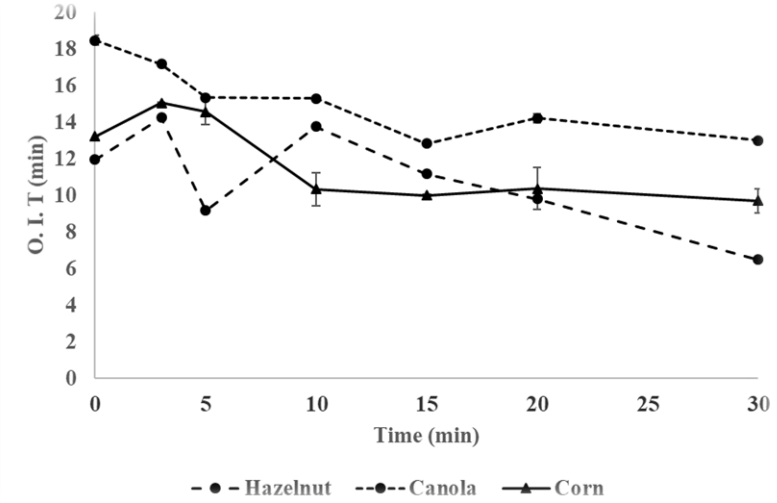

Figure 7. Oxidative induction times of the microwave treated oil samples

CONCLUSIONS

In the present study, the effect of microwave heating from 0 to 30 min. on the quality of hazelnut, canola and corn oils was investigated by monitoring the turbidity, free fatty acid content, peroxide values, K_{232} and K_{270} values, as well as oxidative induction time of the samples. The results revealed that in all of the oil samples oxidative changes occurred, with the extent of oxidation being different for the specified oils since their fatty acids content was different from each other. Furthermore, the results suggested that both primary and secondary oxidative products were formed during microwave heating of the oil samples. It was also proved that measurement of oxidation induction time via differential scanning calorimetry was effective in evaluating the extent of oil oxidation, showing that oil oxidation may be determined without using chemicals and causing less hazards and risks to laboratory staff. Detailed evaluation of the chemical changes of vegetable oils during microwave cooking might be suggested for further research studies.

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