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EFFECT OF MICROWAVE AND OVEN ROASTING METHODS ON BIOACTIVE COMPONENTS AND ANTIOXIDANT CAPACITY OF OKRA SEED OIL

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ABSTRACT

In this study, okra seeds were roasted in an oven (60-90°C) and a microwave (600-800 W), and the oils were extracted by pressing. Changes in oil samples due to roasting were investigated using a range of quality parameters. The peroxide value (1.853-1.530 meq O_2/kg) and Vitamin A levels (0.022-0.005 mg/kg) in the samples decreased, while the Vitamin K1 level remained unchanged. Some samples showed a decrease, while Vitamin E levels, total phenolic content, and antioxidant capacity generally increased (P<0.05). Palmitic acid (29.27-29.55%), stearic acid (3.91-3.95%), oleic acid (19.56-19.61%), and linoleic acid (39.96-40.13%) were identified as the primary fatty acids in the samples. The study found that oven-roasted samples contain higher levels of Vitamin E and phenolics, which enhance oxidative stability. Therefore, it can be concluded that the oven is more advantageous than the microwave.

Key words: Okra seed oil, phenolics, roasting, vitamins

MİKRODALGA VE FIRINDA KAVURMA YÖNTEMLERİNİN BAMYA TOHUMU YAĞININ BİYOAKTİF BİLEŞENLERİ VE ANTİOKSİDATİF KAPASİTESİ ÜZERİNE ETKİSİ

ÖZ

Bu çalışmada, bamya tohumlarına fırın (60-90°C) ve mikrodalga (600-800 W) ortamında kavurma işlemi uygulandı, ardından presleme yöntemi ile yağları ekstrakte edildi. Kavurma işleminin yağ örneklerinde oluşturduğu değişiklikler, çeşitli kalite parametreleri kullanılarak incelendi. Örneklerdeki peroksit değeri (1.853-1.530 meq O_2/kg) ve Vitamin A miktarı (0.022-0.005 mg/kg) azalırken, Vitamin K1 ise değişmedi. Bazı örneklerde azalma olmasına rağmen, genellikle Vitamin E miktarı, toplam fenolik içerik ve antioksidan kapasite düzeyi arttı (P<0.05). Yağ örneklerinde palmitik (%29.27-29.55), stearik (%3.91-3.95), oleik (%19.56-19.61) ve linoleik asit (%39.96-40.13) birincil yağ asitleri olarak tespit edildi. Çalışma sonunda fırında kavurma uygulanan örneklerdeki Vitamin E ve fenolik madde içeriğinin daha yüksek olduğu görüldü. Bu durumun oksidatif stabilite üzerinde olumlu etki oluşturmasından dolayı, fırının mikrodalgaya göre daha avantajlı olduğu söylenebilir.

Anahtar kelimeler: Bamya tohumu yağı, fenolikler, kavurma, vitaminler

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INTRODUCTION

Okra (*Abelmoschus esculentus*) is a vegetable in the Malvaceae family, grown in tropical and subtropical regions worldwide (Akinoso et al., 2023). It is commercially cultivated in countries such as India, Japan, Türkiye Iran, West Africa, Bangladesh, Afghanistan, Pakistan, Malaysia, Thailand, and Brazil. This economically significant vegetable has a wide range of uses (Gemede et al., 2015). The leaves, buds, flowers, pods, and seeds of the okra plant are all utilised for various purposes. In particular, the fruits, which are green seed pods, are popular ingredients in salads, soups, and stews (Ndunguru & Rajabu, 2004; Yonas et al., 2014). Additionally, some studies have indicated that roasted and finely ground okra seeds can serve as an additive in Turkish coffee (Adetuyi & Ibrahim, 2014).

Okra is a highly nutritious vegetable rich in sugar, protein, dietary fibre, unsaturated fatty acids, vitamin C, phenolic compounds (such as flavonol derivatives and oligomeric catechins), folates, and minerals like iron, zinc, manganese, and calcium. Additionally, okra serves as a valuable raw material for drug production, as it contains compounds such as quercetin and sterols, which have significant medicinal value (Petropoulos et al., 2018; Yao et al., 2021; Guo et al., 2024). Research indicates that okra seed oil is rich in oleic acid (23-34%), linoleic acid (29-38%) and palmitic acid (28-30%). It has been reported to have antioxidant properties and to have positive effects on the liver and gastric mucosa (Xiong et al., 2022).

The primary purpose of heat treatment in oil extraction is to lower the viscosity of the oil present in plant materials, facilitating easier extraction. This process leads to increased overall oil yield and improvements in colour, flavour, and aroma. However, it is essential to note that the chemical structure and composition of the oil, including phenolic compounds, also change with the temperature applied during heat treatment (Ahmed et al., 2024). Recent studies have reported that microwave roasting is harmless and more innovative than conventional roasting. In this method, plant material is roasted or heated by the interaction of an electromagnetic field with the food ingredients (Yoshida et al., 2001; Anjum et al., 2006).

Due to the growing population, there is an increasing interest in alternative vegetable oils. As a result, research on vegetable oil raw materials has become essential. Although okra is primarily cultivated as a vegetable today, its seeds contain an average oil content of 20-40%. This suggests that okra could be a promising raw material for oil production (Gemede et al., 2015). In this study, microwave and oven roasting techniques were applied to okra seeds. Then, changes in vitamin and total phenolic content, fatty acid composition, and antioxidant capacity of oils were examined.

MATERIAL AND METHODS

Material

In this study, okra (*Abelmoschus esculentus*) seeds obtained from a local farmer in May 2025 were used (Amasya, Türkiye).

Acetic acid, chloroform, hexane, methanol, potassium iodide and starch were obtained from Isolab (Germany). DPPH (2.2-diphenyl-1-picrylhydrazyl) was obtained from Sigma (St. Louis, MO). Other chemicals were obtained from Merck (Germany).

The process of roasting okra seeds and extracting oils

600 g of seeds were weighed for each sample group and passed through the shredder (Blender, Bosch, Germany). Then, according to similar studies, the samples were roasted at different levels in the oven and the microwave (Ghafoor et al., 2019; Ahmed et al., 2024). The samples were separated into five groups.

- OSC: No heat treatment or roasting was applied (Control Group).
- OS60: Roasting was applied in the oven (AFC340B Arçelik, Türkiye) at 60℃ for 30 minutes.
- OS90: Roasting was applied in the oven at 90℃ for 30 minutes.
- OS600: Roasting was applied in the microwave oven (GE83X Samsung, South Korea) at 600 W for 5 minutes.
- OS800: Roasting was applied in the microwave oven at 800 W for 5 minutes.

Afterwards, the oils were extracted from the seeds using a press machine (Padar, Türkiye). This device was an electric press equipped with temperature control. The roasted seeds released their oils under pressure created between a cylinder and a rotating screw. No external heat source was used during the process, and the extraction was completed without damaging the oil's structure. The exit temperatures of the oils were 25-30℃ during pressing. The oils were filled into dark glass bottles and analysed immediately.

Determination of peroxide value (PV)

The PV (meq O_2/kg oil) of oil samples was determined using the AOCS (1997) method. All analyses were performed in triplicate (n=3).

Determination of fatty acid composition

For fatty acid composition, the ISO 12966-2 (2017) method was used for the preparation of fatty acid methyl esters, and the ISO 12966-4 method was used for chromatographic conditions. The analysis was performed with a gas chromatograph (GC, Agilent 6890N, USA) equipped with a flame ionisation detector (FID) and a HP-88 column (i.d. = 0.25 mm, length = 60 m, film thickness = 0.2 μm, USA). The injector and FID temperatures were set at 270°C and 290°C, respectively. The oven temperature was kept at 165°C for 30 minutes, then increased by 10°C per minute and held at 190°C for 20 minutes. Helium (16.4 psi) was used as the carrier gas. Injection volume, split flow and split ratio were 0.2 μL, 0.4 mL/min, and 1/70, respectively. At the end of the analysis, fatty acid ratios were determined as percentages. All analyses were performed in triplicate (n=3).

Determination of Vitamin A, Vitamin E, and Vitamin K1 content

The extraction method developed by Guo et al. (2024) was modified to determine the Vitamin A, Vitamin E, and Vitamin K1 content.

Extraction of samples

1 g of the samples was placed in a centrifuge tube and dissolved in 5 mL of methanol. The samples were vortexed, and then put in an ultrasonic bath for 15 minutes. The mixture was centrifuged (Hitachi Himac CT15RE, Japan) at 4100 rpm for 10 minutes; the supernatant was filtered through a 0.45 μm filter (Merck Millipore Millex-HV, Germany) and transferred to vials.

Chromatographic conditions for Vitamin A and Vitamin E

High-performance liquid chromatography (HPLC, Shimadzu LC-2030C 3D Plus, Japan) with a photodiode array detector (PDA, 190-800 nm) was used for analysis. EC 250/4.6 Nucleodur C18 Gravity, 5 μm analytical column and methanol:water (98:2) as mobile phase were used for chromatographic separation. The analysis was carried out under isocratic conditions (flow rate 1 mL/min, column temperature 35°C, injection volume 20 μL). The peak areas of Vitamin A and Vitamin E were determined at 325 nm and 290 nm, respectively.

Chromatographic conditions for Vitamin K1

Ultra-performance liquid chromatography (UPLC, Dionex Ultimate 3000, USA) with a UV-VIS detector was used for analysis. Dionex RSLC 120 C18 2.1x150 mm analytical column was used for chromatographic separation. The analysis was performed under isocratic conditions (flow rate 0.7 mL/min, column temperature 35°C, injection volume 20 μL) using a methanol:water (98:2) mobile phase. The peak area of Vitamin K1 was determined at 248 nm. All analyses were performed in triplicate (n=3).

Determination of total phenolic content

The Folin-Ciocalteu method was used to determine the total phenolic content in the samples (Naczk & Shahidi, 2004; Guo et al., 2024). Gallic acid was used as a standard in the analysis. The solutions were prepared at concentrations of 5-50 mg/L to create the calibration graph. The correct equation was obtained by least-squares fitting. Absorbance values of samples and standards were measured at 750 nm. The results were expressed as mg gallic acid/100 g sample. All analyses were performed in triplicate (n=3).

Antioxidant capacity assay

The DPPH free radical scavenging method was used to determine antioxidant capacity (Brand-Williams et al., 1995). Accordingly, 100 μL of sample and 3.9 mL of DPPH solution (0.051 mM) were mixed and then incubated at room temperature for 30 minutes. Afterwards, the change in absorbance values was measured at 517 nm, and results were expressed as μmole Trolox/g sample. All analyses were performed in triplicate (n=3).

Statistical analysis

Analyses were performed in triplicate, and results were expressed as mean ± standard deviation (SD). SPSS (version 22, SPSS Inc., USA) program was used to analyse the results. The obtained data were examined using a one-way analysis of variance. The Duncan test was used to determine the significance of differences between mean values (significance level of 0.05).

RESULTS AND DISCUSSION

Peroxide values of the samples

The amount of peroxide and hydroperoxide released during

the oxidation of oils is measured by the PV. This measurement is an important quality criterion, particularly for vegetable oils (Zhang et al., 2010). PVs of the samples are given in Table 1. The difference between the sample values was statistically significant (P<0.05). The study showed that PVs decreased with the roasting processes applied to the samples. Specifically, the lowest values were observed in OS90 and OS800, 1.530 and 1.575 meq O2/kg, respectively. The decrease in PV value may be due to reduced oxygen requirements for peroxide formation in the environment during the roasting process. Under certain environmental conditions, the decomposition and reduction of peroxides increase the formation of secondary oxidation products, such as aldehydes and ketones (Çelebi et al., 2021). Similarly, Chammem et al. (2015) reported a significant reduction in peroxide values after heat treatment of soybean and sunflower oils.

Vitamin content of the samples

Fat-soluble vitamins are crucial for the proper functioning of the body. Vitamin A is essential for the resynthesis of rhodopsin molecules, which enable us to see in low-light conditions. It is also critical for epithelial integrity and the immune response. Vitamin K is known as the coagulation vitamin because of its vital role in blood clotting. Although the body does not fully absorb it, this heat-stable vitamin is synthesised by bacteria in the large intestine (Akçay & Alkan, 2021). Vitamin E (tocopherol) protects sensitive substances in the body from oxidation and helps reduce lipid peroxidation. Research indicates that tocopherol prevents the formation of free radicals and thereby combats oxidative stress, which causes cellular damage (Rodríguez et al., 2021). Vitamin content of the samples is given in Table 1. The roasting processes applied did not affect Vitamin K1 levels, which remained below 0.03 mg/kg (P>0.05). Vitamin A levels in the samples consistently decreased with oven roasting (P<0.05), with the most significant decrease observed with microwave roasting (OS800, 0.005 mg/kg). In contrast, Vitamin E levels generally increased (P<0.05). This situation can be explained by the roasting methods and conditions, which can either increase or reduce the transfer of minor substances, such as vitamins and phenolics, from the seed to the oil. The oil's bioactive content and antioxidant capacity may change by the end of the processes. Additionally, the oil's susceptibility to heat is an essential factor influencing these differences (Durmaz & Gökmen, 2011).

Total phenolic content of the samples

The oxidative stability of vegetable oils occurs from the natural antioxidants, such as phenolic compounds, that they contain. Additionally, the molecular structures of these phenolic compounds contribute to their antioxidant activity (Liu et al., 2022). The total phenolic content of the samples is given in Table 1. Depending on the roasting process and method, an overall increase in values was observed, which was statistically significant (P<0.05). When the data were analysed, the highest value was found in OS800, 0.331 mg gallic acid/100 g. However, as with the Vitamin E results, some values showed both increases and decreases. As previously explained, this is due to roasting methods and conditions that can affect the release of minor substances from the seed into the oil (Durmaz & Gökmen, 2011). Similarly, in a study using the roasting process, the total phenolic content of sunflower oil increased (Ahmed et al., 2024). Another study investigated the total phenolic content of okra seed oil and found it superior to that of walnut and peanut oils (Guo et al., 2024).

Fatty acid compositions of the samples

Vegetable oils generally contain a wide variety and high proportion of unsaturated fatty acids. This characteristic is an important factor in determining their oxidation stability. Fatty acid compositions of the samples are given in Table 2. Palmitic acid (29.27-29.55%), stearic acid (3.91-3.95%), oleic acid (19.56-19.61%), and linoleic acid (39.96-40.13%) were identified as the primary fatty acids in the samples. The samples also showed that the proportion of polyunsaturated fatty acids was higher than that of monounsaturated and saturated fatty acids. Despite the procedures used in the study, no significant change in fatty acid levels was observed in the samples. High temperatures and similar factors significantly affect the fatty acid composition of vegetable oils. Processes such as frying or roasting tend to increase saturated fatty acids while decreasing unsaturated fatty acids. The reason this change was not observed in the study may be the moderate oven-roasting temperature applied to the samples and the fact that microwaving is less harmful. Similarly, a study of okra seed oil examined the fatty acid composition of the samples. The primary fatty acids in both the roasted and unroasted samples were identified as linoleic acid (25.57-31.03%), oleic acid (16.18-27.92%), palmitic acid (6.85-19.83%), and stearic acid (3.00-5.31%) (Akinoso et al., 2023).

Antioxidant capacity of the samples

DPPH free radical scavenging activity is widely used to assess the antioxidant capacity of foods due to its practicality and ease of use. In this method, the colour change caused by the

antioxidant's reduction of the DPPH radical is measured at 517 nm (Çelebi, 2025). The antioxidant capacity of the samples is given in Table 1. Depending on the roasting processes applied, the samples' antioxidant capacity generally increased (P<0.05). The concentrations of phenolic compounds and Vitamin E, which have antioxidant properties and have been transferred from the seed into the oil, may have significantly influenced this change. When the results are examined, it can be seen that the highest values were obtained with oven roasting (1.202-1.206 µmole Trolox/g). In a similar study, the effects of different roasting methods on the bioactive properties and phenolic compounds of pomegranate seeds and oil were examined. It has been observed that the antioxidant activity of whole seeds increased with both conventional and microwave roasting (Özcan et al., 2021).

Table 1. PV, bioactive components, and antioxidant capacity of the samples

	PV (meq O_2/kg)	**Vitamin A (mg/kg)**	**Vitamin K_1 (mg/kg)**	**Vitamin E (mg/kg)**	**Total phenolic content (mg/100 g)**	**Antioxidant capacity (µmole Trolox/g)**
OSC	1.853±0.006^{d}	0.022±0.002^{c}	<0.03	29.371±0.806^{b}	0.282±0.005^{a}	0.980±0.001^{b}
OS60	1.710±0.030^{c}	0.020±0.000^{bc}	<0.03	38.535±0.556^{c}	0.325±0.000^{d}	1.206±0.001^{c}
OS90	1.530±0.020^{a}	0.018±0.003^{b}	<0.03	43.123±1.082^{d}	0.318±0.003^{c}	1.202±0.002^{d}
OS600	1.605±0.015^{b}	0.022±0.002^{c}	<0.03	30.421±0.569^{b}	0.301±0.004^{b}	1.102±0.000^{c}
OS800	1.575±0.005^{b}	0.005±0.000^{a}	<0.03	25.824±0.738^{a}	0.331±0.000^{c}	0.719±0.003^{a}

Values followed by different lowercase (a–e) letters show significant difference for each column (P<0.05)

Table 2. Fatty acid compositions (%) of the samples

	OSC	**OS60**	**OS90**	**OS600**	**OS800**
Myristic Acid (C14:0)	0.28±0.01	0.28±0.01	0.28±0.01	0.28±0.01	0.28±0.01
Palmitic Acid (C16:0)	29.30±2.05	29.28±2.05	29.27±2.05	29.55±2.07	29.35±2.05
Palmitoleic Acid (C16:1)	0.56±0.12	0.56±0.12	0.56±0.12	0.58±0.13	0.56±0.12
Margaric Acid (C17:0)	0.16±0.03	0.16±0.03	0.16±0.03	0.16±0.03	0.16±0.03
Heptadesenoseic Acid (C17:1)	0.33±0.01	0.33±0.01	0.33±0.01	0.33±0.01	0.34±0.01
Stearic Acid (C18:0)	3.95±0.17	3.93±0.17	3.93±0.17	3.91±0.17	3.93±0.17
Elaidic Acid (C18:1t)	0.17±0.01	0.18±0.01	0.18±0.01	0.17±0.01	0.18±0.01
Oleic Acid (C18:1c)	19.56±1.99	19.57±2.00	19.56±2.00	19.58±2.00	19.61±2.00
Linoleic Acid (C18:2)	39.96±1.76	40.06±1.76	40.13±1.77	39.96±1.76	40.08±1.76
Arachidic Acid (C20:0)	0.49±0.01	0.49±0.01	0.49±0.01	0.49±0.01	0.48±0.01
α-Linolenic Acid (C18:3n3)	0.19±0.01	0.19±0.01	0.19±0.01	0.19±0.01	0.20±0.01
Eicosenoic Acid (C20:1)	0.08±0.01	0.07±0.01	0.07±0.01	0.07±0.01	0.07±0.01

Table 2. Continued

Docosadienoic Acid (C22:2)	1.08±0.01	1.05±0.01	1.04±0.01	1.01±0.01	1.02±0.01
Lignoceric Acid (C24:0)	1.95±0.32	1.95±0.32	1.92±0.31	1.89±0.31	1.90±0.31
SFA	36.23±2.03	36.19±2.03	36.15±2.02	36.38±2.04	36.20±2.03
MUFA	20.71±2.11	20.73±2.11	20.72±2.11	20.75±2.12	20.79±2.12
PUFA	42.99±6.84	43.01±6.84	43.07±6.85	42.80±6.81	42.96±6.83

SFA: Saturated Fatty Acids, MUFA: Monounsaturated Fatty Acids, PUFA: Polyunsaturated Fatty Acids

CONCLUSION

As the population grows, demand for alternative vegetable oils has increased. Therefore, research into vegetable oil raw materials and production techniques has become essential. Heat treatment applied to oilseed material increases oil yield. In addition, oil obtained by mechanical extraction has superior colour, flavour, and aroma compared to oil obtained by solvent extraction. Therefore, mechanical extraction was preferred in this study, and the oil's quality parameters were examined across different roasting techniques. The PV and Vitamin A levels in the samples decreased, while the Vitamin K1 level remained unchanged. Some samples showed a decrease, while Vitamin E levels, total phenolic content, and antioxidant capacity generally increased ($P<0.05$). Neither roasting method affected the fatty acid composition. Although the literature suggests that the microwave method is harmless and more innovative, the study found that oven roasting was more effective for okra seed oil (Yoshida et al., 2001; Anjum et al., 2006). The increase in the concentration of minor substances (such as vitamins and phenolics) resulting from oven roasting and its effect on antioxidant capacity were clearly observed in the samples.

DATA AVAILABILITY STATEMENT

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

CONFLICT OF INTEREST STATEMENT

The author has declared no conflicts of interest.

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