

THE INFLUENCE OF MICROWAVE HEATING AND ANTIOXIDANTS ON THE OXIDATIVE STABILITY OF COLD-PRESSED VEGETABLE OILS*

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Abstract

Lipid oxidation is a significant problem in the production, processing and use of edible oils, which causes significant changes in chemical, sensory and nutritional properties. Therefore, the aim of this research was to examine the influence of microwave heating and antioxidants, natural and synthetic, on the oxidative stability of cold-pressed vegetable oils (rapeseed oil, sesame oil and milk thistle seed oil). Cumin and fennel essential oils were used as natural antioxidants, and propyl gallate (PG) and butylhydroxytoluene (BHT) as synthetic antioxidants. The test was carried out by determining the value of the peroxide value in the tested samples, first through the impact of microwave heating of different intensity at the same sampling time, as well as microwave heating of the same intensity sampled every 5 minutes up to a maximum of 25 minutes. By extending the time of microwave heating at constant power (140 W), the values of peroxide value increased in all tested samples with and without the addition of antioxidants. The biggest changes in the value of the peroxide value were recorded in milk thistle seed and rapeseed oil, and the least in sesame oil. The best protection against oxidative deterioration was seen in BHT in all tested samples, as well as in fennel essential oil in rapeseed oil. With the increase of the power intensity of the device during microwave heating for the duration of 5 minutes, the values of the peroxide value of all tested samples increased, both with and without the addition of antioxidants. Using different powers of microwave heating (140 W, 280 W and 420 W), the best protection against oxidative deterioration of sesame oil was shown by PG, milk thistle seed oil by BHT and PG, and rapeseed oil by fennel essential oil and BHT.

Keywords: *oxidative stability, cold-pressed oils, antioxidants, microwave heating.*

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INTRODUCTION

Cold-pressed vegetable oils are obtained exclusively by mechanical pressing and are consumed directly, without any subsequent refining. They are a group of important food ingredients. Novel specialty seed oils rich in health-promoting factors are in high demand due to consumer interest in disease prevention and health promotion through improved nutrition. These beneficial factors include special fatty acid (FA) compositions such as high content of monounsaturated FA (MUFA) or n-3 FA, tocopherols, carotenoids, and antioxidative phenolic compounds (Parry *et al.*, 2006). Cold pressing of oilseeds enables maximum retention of bioactive compounds, such as essential fatty acids, phenolic and flavonoid substances, tocopherols, tocotrienols, phytosterols, etc. (Radočaj and Dimić, 2013), as well as of the characteristic sensory properties of the oils (Moslavac *et al.*, 2023). Rapeseed oil is a rich source of natural components with an antioxidant effect. It is well-known for its high content of unsaturated fatty acids, especially polyunsaturated fatty acids, which make it of great nutritional value (Shen *et al.*, 2023). Rapeseed oil contains about 65% oleic, 20% linoleic, 9% linolenic and 2% stearic acid (Beyzi *et al.*, 2019). The low content of saturated fatty acids in rapeseed oil has led to it being considered one of the most health-promoting edible oils (Coughlan *et al.*, 2022). Sesame oil, also known as gingelly oil or til oil, is a highly unsaturated edible oil rich in essential fatty acids such as linoleic acid. It is also rich in various bioactive compounds including phytosterols, tocopherols and lignans such as sesamin, sesamol and sesaminol, which are known to play an important role in providing stability against oxidation of oil and contribute to antioxidative activity (Bopitiya and Madhujith, 2013). Oxidative stability of sesame oil is superior to that of other vegetable oils although it contains nearly 85% unsaturated fatty acids (Abou-Gharbia *et al.*, 2000; Lončar *et al.*, 2012; Moslavac and Vuković, 2013; Zahran *et al.*, 2020). It may be added to other oils to enhance oxidative stability such as in the preparation of frying oils (Gunstone, 2004). Milk thistle seed oil is an important byproduct of industrial production of silymarin. It oil has a high concentration of unsaturated fatty acids, especially linoleic and oleic acid, which are beneficial to human health in preventing arteriosclerosis, diabetes, and cancer (Tarasevičiene *et al.*, 2023; Zhang *et al.*, 2020). Milk thistle seed oil has also been documented as a potential natural source of vitamin E, and has often been recommended as a favorable edible oil (Meddeb *et al.*, 2017). Oil oxidation is problematic, reducing the oil quality over the storage period due to the breakdown of essential fatty acids, resulting in increased free fatty acids, resulting in oil rancidity, reducing the nutritional benefits significantly (Coughlan *et al.*, 2022). Oxidative stability is an important indicator of the quality and shelf life of products. Oxidative stability of edible oils is defined as resistance to oxidation during processing, storage, and cooking (Loganathan *et al.*, 2022). Today, many methods are used to determine the oxidative stability of vegetable oils based on accelerated oil oxidation: Schaal Oven test, AOM test and Rancimat test (Shahidi, 2005). Antioxidants are used to prevent oxidation of edible oils and fats. Synthetic antioxidants are cheaper than natural ones, while natural antioxidants are safer than

synthetic ones. Extracts of various plants are used to stabilize oils and fats, as well as essential oils obtained by extracting aromatic, spice and medicinal plants. Microwave heating is a modern and widely used method for food preparation (Dostálová *et al.*, 2005). It represents the conversion of electromagnetic field energy to thermal energy, in materials that possess dielectric properties (Moslavac *et al.*, 2012). Microwave heating of different vegetable oils and fats causes the formation of free radicals that rapidly react with atmospheric oxygen to produce hydroperoxides and secondary oxidation products (Kishimoto, 2019). It was found that the rate of quality deterioration, such as oxidation, depends on the polyunsaturated fatty acid (PUFA) content (Lukešová *et al.*, 2009). In vegetable oils exposed to microwave energy, the higher the amount of PUFA in the oils, the greater was the rate of quality deterioration of the oils. The levels of free fatty acids also increased in vegetable oil heated in microwave oven (Hassanein *et al.*, 2003). In this study, the influence of microwave heating and antioxidants on the oxidative stability of cold-pressed rapeseed, sesame and milk thistle oil was investigated.

MATERIALS AND METHODS

As material for the experimental part of the work, three samples of cold-pressed oils were used, i.e. rapeseed oil, sesame oil and milk thistle seed oil from the Sarajevo Canton market. For the distillation of essential oils, samples of dried fennel and cumin herbs were taken. Butylhydroxytoluene (BHT) and propyl gallate (PG) were used as synthetic antioxidants. The extraction of essential oils was performed by hydrodistillation using an adapted Neo Clevenger apparatus (ISO 8571, 1988, E). To evaluate the sustainability, i.e. the oxidative stability, a sustainability test with microwave heating was carried out. A microwave oven was used for research purposes (Tristar, output intensity 700 W). Natural antioxidants (fennel and cumin essential oils) in a concentration of 0.1% and synthetic antioxidants (BHT-butyhydroxytoluene and PG-propyl gallate) in a concentration of 0.01% have been added to the cold-pressed oils (rapeseed oil, sesame oil and milk thistle seed oil). For each base oil sample, a control sample without added antioxidants was prepared, which was further treated like all samples. The tested samples were treated with microwave heating under the following conditions:

- Á power 140 W for 5, 10, 15, 20 and 25 minutes and
- Á powers of 140 W, 280 W and 420 W for 5 minutes.

During each sampling, the value of the peroxide value (PV) was determined using the method according to ISO 3960 (2017). The Past 3.15 program (Hammer *et al.*, 2001) was used for statistical data processing. To determine a statistically significant difference in the PVs under the influence of the type of added antioxidants, sampling time and different intensity of microwave heating a two-factor analysis of variance was applied. In case of statistically significant differences, Tukey's post-hoc test was used (significance level $\alpha=0.05$).

RESULTS AND DISCUSSION

The results of testing the influence of microwave heating time at a power of 140 W of natural and synthetic antioxidants on the oxidative stability of rapeseed, sesame and milk thistle seed oil are shown in Table 1. A two-factor analysis of variance determined that there is a statistically significant influence of experimental factors (microwave heating time and type of antioxidants) on the PV of the examined oil samples with the addition of different antioxidants ($p < 0.05$). From the results shown in Table 1, it can be seen that with the increase in the time of treatment with microwave heating at a constant power of the device, the PV of the tested oils with and without the addition of antioxidants increase, but with a significantly lower intensity in the case of sesame oil compared to the other two test samples in this work. All applied antioxidants, natural and synthetic, as can be seen in Table 1, stabilized rapeseed and milk thistle seed oil, i.e. protected them from oxidative deterioration, while the PV in all samples with the addition of antioxidants were lower than the values of the control sample. On the other hand, the addition of antioxidants to sesame oil did not lead to a stabilization of the oil, except when BHT was added. Low peroxide values of the control sample of sesame oil during treatment with microwave heating without any additives indicate good stability. The PV of the sesame oil sample with the addition of BHT increased with a lower intensity compared to the control sample up to a value of 0.50 mmol O₂/kg, i.e., the same value as the control sample at the end of the treatment of 25 minutes. BHT and fennel essential oil exhibited the best stabilization of rapeseed oil, i.e. protection against oxidative deterioration. Also, the synthetic antioxidant BHT showed the best protection in milk thistle seed oil. The most intense changes were recorded in the sesame oil sample with the addition of PG. The results of the study by Labrović (2011) are consistent with the results of this work. Namely, the authoress states in her research that increasing the time of treatment of rapeseed and sesame oil with microwave heating decreases the sustainability of the oil, and that the addition of natural antioxidants to the oil leads to a change in stability towards oxidative deterioration. The sample with the addition of pomegranate extract showed the best stability of rapeseed oil, while the mentioned antioxidant was the only one that did not protect sesame oil from spoilage. Pavlović (2014) noted in her research that the viability of rapeseed oil reduced by applying microwave heating at constant power (450 W) with increasing treatment time, as well as stabilization with the addition of natural and synthetic antioxidants. The best protection of rapeseed oil against oxidative deterioration was achieved by the addition of rosemary extract, as well as the addition of the synthetic antioxidant octyl gallate. Examining the oxidative stability of rapeseed oil through microwave heating with increasing treatment duration in the research of Dostálová *et al.* (2005) and Lukešová *et al.* (2009), the PV increased up to a certain point in treatment, after which the value started to decrease. In the research of Nikolov (2018), using the Rancimat method, better oxidative stability of sesame oil was determined, compared to hemp, flax and sunflower oil. Of the applied extracts, the winter savory extract had the least influence on the oxidative stability of the examined vegetable oils. Pelko (2019), in his research shows similar results to the ones in Table 1, i.e. an increase in the PV of cold-pressed milk

thistle seed oil with an extension of the microwave heating time (300 W). Stabilization of milk thistle seed oil was achieved by the addition of rosemary extract, while no further stabilization of the oil was achieved with the combination of the mentioned extract and synergist, citric acid. The synthetic antioxidant tert-butylhydroquinone (TBHQ) showed a significant protection of milk thistle seed oil from oxidative spoilage using the Schaal Oven test at a constant temperature of 63°C, was recorded in the research of Furundžija (2020).

Table 1. The influence of microwave heating time at 140 W power and antioxidants on the oxidative stability of rapeseed, sesame and milk thistle seed oils (expressed as peroxide value mmol O₂/kg)

Sample	Antioxidant	%	Microwave heating time (minutes)					
			0	5	10	15	20	25
Rapeseed oil	-		2.46 ^{Aa} ±0.02	2.72 ^{Aa} ±0.04	3.17 ^{Aa} ±0.07	4.19 ^{Ab} ±0.32	4.46 ^{Ab} ±0.00	5.17 ^{Ac} ±0.38
	PG	0.01	2.46 ^{Aa} ±0.02	2.55 ^{Aa} ±0.24	2.69 ^{Aa} ±0.31	2.94 ^{Ba} ±0.04	3.43 ^{Bb} ±0.06	4.06 ^{Bb} ±0.49
	BHT	0.01	2.46 ^{Aa} ±0.02	2.46 ^{Aa} ±0.02	2.96 ^{Aa} ±0.06	3.06 ^{Ba} ±0.13	3.09 ^{Ba} ±0.26	3.47 ^{Bb} ±0.05
	Cumin essential oil	0.10	2.46 ^{Aa} ±0.02	2.50 ^{Aa} ±0.00	2.70 ^{Aa} ±0.35	3.21 ^{Ba} ±0.34	3.96 ^{Ab} ±0.00	4.19 ^{Bb} ±0.44
	Fennel essential oil	0.10	2.46 ^{Aa} ±0.02	2.72 ^{Aa} ±0.35	3.00 ^{Aa} ±0.00	3.00 ^{Ba} ±0.00	3.00 ^{Ba} ±0.00	3.47 ^{Ba} ±0.05
Sesame oil	-		0.00 ^{Aa} ±0.00	0.00 ^{Aa} ±0.00	0.25 ^{Aa} ±0.35	0.25 ^{Aa} ±0.35	0.50 ^{Aa} ±0.00	0.50 ^{Aa} ±0.00
	PG	0.01	0.00 ^{Aa} ±0.00	0.25 ^{Aa} ±0.35	0.50 ^{Aab} ±0.00	0.98 ^{Bb} ±0.02	0.98 ^{Bb} ±0.02	0.98 ^{Ab} ±0.02
	BHT	0.01	0.00 ^{Aa} ±0.00	0.00 ^{Aa} ±0.00	0.00 ^{Aa} ±0.00	0.17 ^{Aa} ±0.35	0.25 ^{Aa} ±0.00	0.50 ^{Aa} ±0.00
	Cumin essential oil	0.10	0.00 ^{Aa} ±0.00	0.50 ^{Aab} ±0.00	0.50 ^{Aab} ±0.00	0.61 ^{Aab} ±0.15	0.66 ^{Aab} ±0.14	0.74 ^{Ab} ±0.34
	Fennel essential oil	0.10	0.00 ^{Aa} ±0.00	0.50 ^{Aab} ±0.00	0.50 ^{Aab} ±0.00	0.50 ^{Aab} ±0.00	0.50 ^{Aab} ±0.00	0.86 ^{Ab} ±0.17
Milk thistle seed oil	-		3.98 ^{Aa} ±0.03	4.46 ^{Aa} ±0.00	4.75 ^{Ab} ±0.35	4.95 ^{Ab} ±0.00	5.17 ^{Ac} ±0.29	5.47 ^{Ac} ±0.04
	PG	0.01	3.98 ^{Aa} ±0.03	4.04 ^{BAa} ±0.12	4.41 ^{Aa} ±0.06	4.51 ^{BAa} ±0.14	4.87 ^{Ab} ±0.03	5.34 ^{Ab} ±0.07
	BHT	0.01	3.98 ^{Aa} ±0.03	4.23 ^{Aa} ±0.32	4.35 ^{Aa} ±0.03	4.47 ^{BAa} ±0.03	4.62 ^{Bba} ±0.29	4.80 ^{Bba} ±0.14
	Cumin essential oil	0.10	3.98 ^{Aa} ±0.03	4.29 ^{Aa} ±0.05	4.56 ^{Aa} ±0.27	4.78 ^{Ab} ±0.09	5.03 ^{Ac} ±0.14	5.08 ^{Ac} ±0.25
	Fennel essential oil	0.10	3.98 ^{Aa} ±0.03	4.17 ^{Aa} ±0.06	4.43 ^{Aa} ±0.03	4.90 ^{Ab} ±0.11	4.95 ^{Ab} ±0.07	5.23 ^{Ac} ±0.39

*A-B Different capital letters in columns indicate statistically significant differences in peroxide values for antioxidants added to oils

a-c Different lowercase letters in rows indicate statistically significant differences in peroxide values at different microwave heating times

The results of determining the oxidative stability of rapeseed, sesame and milk thistle oils by the effect of different powers of microwave heating at the same time are shown in Table 2.

Table 2. The influence of microwave heating power for 5 minutes and antioxidants on the oxidative stability of rapeseed, sesame and milk thistle seed oils (expressed as peroxide value mmol O₂/kg)

Sample	Antioxidant	%	Microwave heating power		
			140 W	280 W	420 W
Rapeseed oil	-		2.72 ^{Aa} ±0.04	2.94 ^{Aa} ±0.00	3.94 ^{Ab} ±0.03
	PG	0.01	2.55 ^{Aa} ±0.24	3.11 ^{Aa} ±0.20	5.42 ^{Bb} ±0.04
	BHT	0.01	2.46 ^{Aa} ±0.02	3.00 ^{Aa} ±0.00	4.73 ^{Cb} ±0.39
	Cumin essential oil	0.10	2.50 ^{Aa} ±0.00	4.25 ^{Bb} ±0.00	5.50 ^{Bc} ±0.00
	Fennel essential oil	0.10	2.72 ^{Aa} ±0.50	2.85 ^{Aa} ±0.53	4.29 ^{Ac} ±0.11
Sesame oil	-		0.00 ^{Aa} ±0.00	0.74 ^{Aa} ±0.35	1.59 ^{Ab} ±0.17
	PG	0.01	0.25 ^{ABa} ±0.35	0.50 ^{Aa} ±0.00	0.50 ^{Ba} ±0.00
	BHT	0.01	0.50 ^{ABa} ±0.00	0.75 ^{Aa} ±0.01	0.75 ^{Ba} ±0.01
	Cumin essential oil	0.10	0.50 ^{ABa} ±0.00	0.87 ^{Aa} ±0.18	3.19 ^{Cb} ±0.35
	Fennel essential oil	0.10	1.00 ^{Ba} ±0.01	1.00 ^{Aa} ±0.01	2.35 ^{Ab} ±0.18
Milk thistle seed oil	-		4.46 ^{Aa} ±0.00	4.73 ^{Aab} ±0.32	5.45 ^{Ab} ±0.00
	PG	0.01	4.04 ^{Aa} ±0.12	5.20 ^{Ab} ±0.35	6.09 ^{BAc} ±0.13
	BHT	0.01	4.23 ^{Aa} ±0.32	4.93 ^{Aab} ±0.10	5.20 ^{Ab} ±0.28
	Cumin essential oil	0.10	4.29 ^{Aa} ±0.05	5.47 ^{Abc} ±0.04	6.00 ^{BAc} ±0.00
	Fennel essential oil	0.10	4.17 ^{Aa} ±0.06	5.23 ^{Ab} ±0.39	7.30 ^{Cc} ±0.18

*A-C Different capital letters in columns indicate statistically significant differences in peroxide values for antioxidants added to oils

a-c Different lowercase letters in rows indicate statistically significant differences in peroxide values at different microwave heating powers

A two-factor analysis of variance determined that there is a statistically significant influence of experimental factors (microwave heating power and type of antioxidants) on the PV of the examined oil samples with the addition of different antioxidants (p<0.05). The investigation of the influence of the power of microwave heating and the

addition of antioxidants on the oxidative stability of the tested oils resulted in different changes depending on the applied power. By increasing the power of microwave heating, there was an increase in the PV of the tested oils with and without the addition of antioxidants. By applying a microwave heating power of 140 W, the antioxidants used stabilized rapeseed and milk thistle seed oil, while the addition of fennel essential oil to rapeseed oil resulted in the same PV as the control sample (2.72 mmol O₂/kg). The best protection against oxidative deterioration was shown by the synthetic antioxidant BHT in the case of rapeseed oil, or PG in the case of milk thistle oil. Contrary to the above, accelerated oxidative deterioration was recorded with the addition of antioxidants in sesame oil. Microwave heating with a power of 280 W for 5 minutes did not stabilize the tested oils with the addition of antioxidants, except for the addition of fennel essential oil in the case of rapeseed oil and PG in the case of sesame oil. The most intense changes were recorded in the samples of rapeseed and milk thistle seed oil with the addition of caraway essential oil and in the case of sesame oil with the addition of fennel essential oil. By treating the tested oils with microwave heating at 420 W, no stabilization was recorded with the addition of antioxidants, except for sesame oil with the addition of synthetic antioxidants and milk thistle seed oil with the addition of BHT. The most intensive changes were recorded in the samples of rapeseed and sesame oil with the addition of caraway essential oil, and milk thistle seed oil with the addition of fennel essential oil. According to the above, the stabilization of oil with the addition of antioxidants is more difficult to achieve with an increase in the power of microwave heating. Also, in the research of Labrović (2011), it was determined that the application of higher power of microwave heating leads to greater oxidative deterioration of rapeseed and sesame oil. By microwave heating of the mentioned oils with a power of 600 W, a decrease in the PV was observed in relation to the value recorded when the oil was treated at 450 W. The authoress states that the reason for the phenomenon mentioned is most probably due to the high temperatures measured in the treated oils, at which the decomposition of the peroxide and hydroperoxide took place. The stabilization of cold-pressed rapeseed oil through the addition of antioxidants was determined in studies by Moslavac *et al.* (2023) and Bigić (2014). According to the Schaal Oven test of accelerated oil oxidation at 63°C, the PV of rapeseed oil with and without the addition of antioxidants increased with the extension of the treatment time. The best protection of rapeseed oil was achieved with the addition of green tea extract (Moslavac *et al.*, 2023; Bigić, 2014). The conducted research found that increasing the content of natural antioxidants resulted in greater stability of the oil. In the research of Moslavac and Vuković (2013), it was determined that by adding sesame oil (50%) to other types of tested edible vegetable oils, there was an increase in the stability of the oil mixture against oxidative deterioration. The research carried out by Ghosh *et al.*, (2014) recorded an increase in the peroxide value of sesame oil with an increase in the power and length of microwave heating. During microwave heating of the highest power after 10 minutes of treatment, the PV decreased. In a study by Pelko (2019), when the power of microwave heating was increased from 180 W to 300 W, an increase in the PV of samples of cold-pressed milk thistle seed oil with and without the addition of

antioxidants and synergists was recorded. However, by further increasing the power of the device to 450 W and 600 W, there was a decrease in the PV of the mentioned samples. In the research of Tomljenović (2021), an increase in the PV of cold-pressed milk thistle oil with and without antioxidants was recorded using the Schaal Oven test at 63°C with an extension of the heating time. The best protection of milk thistle seed oil from oxidative deterioration is achieved by a combination of the addition of a natural antioxidant and a synergist, i.e. rosemary extract and citric acid.

CONCLUSIONS

The tests carried out showed that it is possible to effectively protect cold-pressed rapeseed and milk thistle seed oil from oxidative spoilage by adding antioxidants during microwave heating, while sesame oil behaved differently. In a comparison of the three tested samples, the highest stability was found in sesame oil, while rapeseed and milk thistle seed oils are more susceptible to oxidative deterioration. By increasing the time of microwave heating at a constant power of the device, an increase in the peroxide value was recorded, and stabilization of the tested oils was achieved with the addition of antioxidants, except for sesame oil. By increasing the power of the microwave heating device, an increase in the peroxide value was recorded at a constant heating time. The stabilization of rapeseed and milk thistle seed oil with the addition of antioxidants was achieved at a power of 140 W, and as the power of the device was increased (280 W and 420 W) it was found that oxidative deterioration was accelerated by the addition of antioxidants.

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UTICAJ MIKROVALNOG ZAGRIJAVANJA I ANTIOKSIDANASA NA OKSIDATIVNU STABILNOST HLADNO PREŠANIH BILJNIH ULJA

Sažetak

Oksidacija lipida je značajan problem u proizvodnji, preradi i korištenju jestivih ulja, što uzrokuje značajne promjene u hemijskim, senzornim i nutritivnim svojstvima. Stoga, cilj ovog istraživanja bio je ispitati uticaj mikrovalnog zagrijavanja i antioksidanasa, prirodnih i sintetskih, na oksidativnu stabilnost i kvalitet hladno prešanih biljnih ulja (ulje repice, susamovo ulje i ulje sikavice). Od prirodnih antioksidanasa korišteni su eterična ulja kima i komorača, a od sintetskih propil galat (PG) i butilhidroksitoluol (BHT). Ispitivanje je provedeno određivanjem vrijednosti peroksidnog broja kod ispitivanih uzoraka djelovanjem različitih snaga mikrovalnog zagrijavanja pri istom vremenu uzorkovanja, kao i kod jedne snage mikrovalnog zagrijavanja pri uzorkovanju svakih 5 minuta do maksimalne od 25 minuta. Produžavanjem vremena mikrovalnog zagrijavanjem pri konstantnog snazi (140 W) vrijednosti peroksidnog broja su rasle kod svih ispitivanih uzoraka bez i sa dodatkom antioksidanasa. Najveće promjene vrijednosti peroksidnog broja zabilježene su kod ulja sikavice i repice, a najmanje kod susamovog ulja. Najbolju zaštitu od oksidativnog kvarenja pokazao je BHT kod svih ispitivanih uzoraka, kao i eterično ulje komorača kod repičinog ulja. Porastom snage uređaja tokom mikrovalnog zagrijavanja pri jednakom trajanju od 5 minuta, rasle su vrijednosti peroksidnog broja svih ispitivanih uzoraka bez i sa dodatkom antioksidanasa. Djelovanjem različitih snaga mikrovalnog zagrijavanja (140 W, 280 W i 420 W) najbolju zaštitu od oksidativnog kvarenja susamovog ulja pokazao je PG, ulja sikavice BHT i PG, te repičinog ulja eterično ulje komorača i BHT.

Ključne riječi: *oksidativna stabilnost, hladno prešana ulja, antioksidansi, mikrovalno zagrijavanje.*