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Influence of Thermal Processing and Ultrasound-Assisted Extraction on the Bioactive Properties and Fatty Acid Composition of Rapeseed (*Brassica napus* L.)

Mehmet Musa Özcan[1*], Nurhan Uslu[1], Haiam O. Elkatry[2], Abdelrahman R. Ahmed[2*]

[1]Selcuk University, Department of Food Engineering, Faculty of Agriculture, 42031 Konya, Turkey

[2]Food and Nutrition Science Department, Agricultural Science and Food, King Faisal University, Al Ahsa 31982, Saudi Arabia

[*]Corresponding authors. E-mail: mozcan@selcuk.edu.tr; arahmed@kfu.edu.sa

ABSTRACT

Rapeseed (*Brassica napus* L.) is an important oilseed crop widely used for edible oil production and functional food ingredients due to its favorable lipid profile and bioactive compounds. Processing methods such as roasting and ultrasound (sonication) can significantly influence its nutritional and phytochemical composition. The oil contents of unroasted and roasted rapeseeds were defined between 13.45 (10 min) and 20.92% (60 min) to 16.61 (30 min) and 21.33% (roasted seed control), respectively. Total phenolic quantities of unroasted and roasted rapeseeds sonicated at different times changed to be between 23.78 (30 min) and 46.88 (unroasted seed control) to 25.44 (30 min) and 42.43 mg GAE/100g (60 min), respectively. Catechin quantities of rapeseeds sonicated changed between 26.02 (raw control) and 43.13 (60 min) to 18.53 (30 min) and 43.97 mg/100g (roasted control), respectively. Oleic acid quantities of the oils varied between 61.80% (unroasted seed control) and 62.18% (30 min) to 61.65 (60 min) and 62.01% (roasted seed control), respectively. While the total phenol, total flavonoid amounts and antioxidant capacities of unroasted rapeseed seeds were highest in the control sample while the lowest values for these parameters were generally observed at 30 min of sonication.

Keywords: rapeseed, oil, sonication, roasting, bioactive compounds, fatty acids.

INTRODUCTION

Rapeseed (*Brassica napus* L.) is known worldwide as a good source of oil and protein for food and industrial applications (Wanasundara et al., 2016; Raboanatahiry et al., 2021). Rapeseed polyphenols, a globally important oil-bearing crop containing a wide variety of bioactive components thought to be the most typical of polyphenolic compounds, encompass different structural variants and are thought to have many bioactive functions beneficial to human health (Ye and Liu, 2023). It is also used in animal feed and biodiesel production due to its high yield and high oil content per unit area (Khanal and Shah, 2021). Rapeseed (*Brassica napus* L.) plays an important role as a source of edible oil in the world food trade and ranks third after oil palm and soybean. As a result of breeding studies, seed glucosinolates and low erucic acid content and are widely accepted due to their distinct advantages as they have fat-soluble nutritional elements compared to other oil types (Rekas et al., 2017; Chew, 2020). Rapeseed with lower glucosinolate and erucic acid content has been bred to produce canola oil or rapeseed oil with low erucic acid on the market (So and Duncan, 2021). Considering the fatty acid profile of triacylglycerol lipids of rapeseed oil, it is reported to be a good vegetable oil for human consumption and a protein source for the feed industry (Lee et al., 2018; Öztürk et al., 2022). Rapeseed also contains minor levels of free sinapic acid, ferulic acid, vanillic acid or syringic acid (Siger et al., 2013). Rapeseed is recognized as an important oilseed crop due to its high nutritional value and the presence of bioactive compounds, including unsaturated fatty acids, phenolic compounds, and natural antioxidants. The application of ultrasound-assisted extraction and sonication technologies has recently gained attention as an efficient approach to enhance the release and preservation of valuable compounds from plant matrices. Ultrasound treatment can promote mass transfer through acoustic

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cavitation, which improves cell disruption and facilitates the extraction of phenolic constituents and antioxidant compounds (Chemat et al., 2017). Previous studies have demonstrated that sonication may influence the fatty acid profile of vegetable oils by improving extraction efficiency while maintaining the stability of polyunsaturated fatty acids, which are highly susceptible to oxidative degradation (Pingret et al., 2013). In addition, ultrasound-assisted processes have been reported to increase the recovery of phenolic compounds, resulting in enhanced antioxidant capacity of oil extracts due to the improved availability of bioactive molecules (Toma et al., 2001). However, excessive ultrasound intensity or prolonged treatment may induce oxidative changes by generating reactive oxygen species, potentially affecting lipid stability and antioxidant activity (Soria and Villamiel, 2010). Therefore, optimizing sonication conditions is essential to maximize the extraction of beneficial compounds from rapeseed while preserving its nutritional quality and oxidative stability. The most important features of sonication-assisted extractions include shortening the extraction time, reducing solvent consumption and improving the quality of the extract (Corona-Jiménez et al., 2016). The aim of current study was to reveale the effect of sonication times on changes in total phenolic, total flavonoid content, antioxidant capacities, fatty acids and phenolic compound composition of rapeseed extracts obtained with ultrasound-assisted extraction system were investigated.

MATERIAL AND METHODS

Material

After cleaning the foreign materials such as leaves, stems, soil and foreign seeds of rapeseed harvested from Konya (Çumra) district of Turkey, the separated seeds were dried at room temperature. The dried rapeseeds were ground for analysis.

Methods

Roasting process

Cleaned rapeseeds were roasted at 180^{o}C for 10 minutes in an oven with a continuous mixer system. There are two separate control groups in the study, one of which is the raw seed and the other is the roasted seed control group. Both seeds were considered as separate control groups when subjected to sonication.

Moisture content

The moisture amounts of rapeseed samples were esablished by the KERN & SOHN GmbH infrared moisture analyser.

Oil content

Ground rapeseeds were weighed in filter paper and mixed with petroleum ether in an Erlenmeyer flask. Some samples were sonicated in an ultrasonic bath for 10, 30, or 60 minutes. Total oil content of both sonicated and control samples was then extracted using a Soxhlet system with petroleum ether at 50°C for 5 hours. Finally, the solvent was evaporated, and the remaining residue was measured as crude oil.

Extraction procedure

In the transfer of rapeseed carried out according to the method reported by Jakopic et al. (2011).

Total phenolic content

Total phenolic quantities of rapeseed extracts were defined using the Folin-Ciocalteu according to the study proposed by Yoo et al. (2004).

Total flavonoid quantity

Total flavonoid contents of roasted and unroasted sonicated rapeseed were determined according to the study of Hogan et al. (2009).

Antioxidant activity

DPPH free radical scavenging activity

The antioxidantactivities of raw and sonicated rapeseed extracts were defined using DPPH (1,1-diphenyl-2-picrylhydrazyl) according to the study proposed by Lee et al. (1998).

Ferric reducing antioxidant power (FRAP)

Antioxidant activities of raw and sonicated rapeseed extracts were characterized using FRAP reagent based on the methodproposed by Mudenuti et al. (2021).

Determination of phenolic compounds

HPLC (Shimadzu) montaged with a PDA detector and an Inertsil ODS-3 (5 µm; 4.6 x 250 mm) column was used for analysis and chromatographic separation of phenolic constituents of raw and sonicated rapeseed extracts was characterized. The peaks were taken at 280 using a PDA detector.

Fatty acid composition

A gas chromatography (Shimadzu GC-2010) equipped with flame-ionization detector (FID) and capillary column column (Tecnocroma TR-CN100, 60m x 0.25mm, film thickness: 0.20µm) was used for analysis of fatty acid methyl esters of rapeseed oils esterified according to ISO-5509 (1978) method.

Statistical Analyses

Variance analysis was applied to the analysis results obtained with three replications. Results were described as mean±standard deviation (MSTAT C) of independent sonications times and roasting process.

RESULTS AND DISCUSSION

The oil contents, bioactive properties of unroasted and roasted rapeseeds

The oil contents, bioactive compounds and antioxidant capacity values of unroasted and roasted rapeseeds sonicated at different times (10, 30 and 60 minutes) are proposed in Table 1. The oil contents and bioactive properties of rapeseeds were affected by sonication times.

Table 1. Some chemical and bioactive properties of unroasted and roasted rapeseeds sonicated at different times

	Sonication time	Total oil content (%)	Total phenolic content (mg/100 g)	Total flavonoid content (mg/100g)	Antioxidant activity (mmol/kg, DPPH)	Antioxidant activity (mg/100g, FRAP)
Unroasted	Control	22.20 ± 0.05*a	46.88 ± 0.76a	73.95 ± 0.59a	1.66 ± 0.01a	126.51 ± 0.95a
	10 min	13.45 ± 0.04d**	25.35 ± 0.09c	48.64 ± 0.23c	1.10 ± 0.01c	57.94 ± 2.92c
	30 min	19.00 ± 0.05c	23.78 ± 0.11d	45.89 ± 0.13d	1.02 ± 0.03cd	54.71 ± 1.40d
	60 min	20.92 ± 0.02b	34.13 ± 0.29b	61.04 ± 0.94b	1.46 ± 0.02b	85.44 ± 0.34b
Roasted	Control	21.33 ± 0.06a	38.61 ± 0.25b	62.37 ± 0.73b	1.54 ± 0.02b	99.31 ± 4.89b
	10 min	18.20 ± 0.03c	28.63 ± 1.27c	50.64 ± 0.35c	1.26 ± 0.01c	64.26 ± 1.80c
	30 min	16.61 ± 0.04d	25.44 ± 0.25d	45.66 ± 0.35d	1.13 ± 0.03d	56.92 ± 1.77d
	60 min	20.92 ± 0.05b	42.43 ± 0.52a	68.03 ± 0.58a	1.60 ± 0.00a	106.52 ± 3.80a

*standard deviation; ** values within each column followed by different letters are significantly different at $P < 0.05$.

The oil quantities of roasted rapeseeds sonicated at different periods were characterized to be between 16.61 (30 min) and 21.33% (control). Total phenolic and flavonoid contents of roasted rapeseeds sonicated at different times were stated between 25.44 (30 min) and 42.43 mg GAE/100g (60 min) to 45.66 (30 min) and 68.03 mg/100g (60 min), respectively. In addition, antioxidant capacities (DPPH and FRAP) values of roasted rapeseeds were depicted to be between 1.13 (30 min) and 1.60 mmol/kg (60 min) to 56.92 (30 min) and 106.52 mg/100g (60 min), respectively. The oil quantities of unroasted rapeseeds sonicated at different times were determined between 13.45 (10 min) and 20.92% (60 min). While total phenolic values of unroasted rapeseeds at different times vary between 23.78 (30 min) and 46.88 mg GAE/100g (control), flavonoid amounts of unroasted rapeseeds at different times were defined to be between 45.89 (30 min) and 73.95 mg/100g (control). Antioxidant capacity (DPPH and FRAP) results of unroasted changed between 1.02 (30 min) and 1.66 (control) to 54.71 (30 min) and 126.51 (control), respectively. The oil quantitiy of the unroasted and roasted rapeseed seed oils decreased with the sonication time compared to the control. The most reduction in unroasted and roasted rapeseed oils was detected at the 10^{th} and 30^{th} minutes of sonication, respectively, when compared to the control. While the total phenol, flavonoid amounts, radical scavengin (DPPH) and antioxidant activity values of unroasted rapeseeds were highest in the

control sample, the values of these parameters were found at the lowest levels at the 30th minute of sonication. The mean ORAC, FRAP and DPPH values for methanol extracts of rapeseed were determined in the range of 4092-12989, 6218-7641 and 6238-7645 μmol Trolox/100 g, respectively (Szydłowska-Czerniak et al., 2010). Total phenolic and antioxidant capacities of rapeseed cake extract were characterized as 33.03 mg/g and 42.64%, respectively (Lee and Lee, 2017). Oil contents of the rapeseed samples varied between 36.9-40.52% (Beyzi et al., 2019). The oil contents of the rapeseed mutant lines were defined to be between 38.14 and 42.04% (Channaoui et al., 2020). Total phenolic and flavonoid quantities of rapeseeds were defined to be between 54.82 and 75.69 mgGAE/100gt o 111.31 and 138.21 mg/100g, respectively (Öztütk et al., 2022). The average DPPH values for methanol rapeseed extracts were found between 6238 to7645 μmol Trolox/100 g (Szydłowska-Czerniak et al., 2010). Szydłowska-Czerniak et al. (2011) defined 756-1324 mg sinapic acid/100 g the total phenolic quantity in rapeseed cultivars. Antioxidant activities of methanolic extracts of rapeseed cultivars were characterized to be between 3194-6346 μmol Trolox/100g (Szydłowska-Czerniak et al., 2011). Antioxidant activity values of rapeseeds were defined to be between 2.84 and 3.30 mmol/kg (Öztürk et al., 2022). The oil quantities of our roasted and unroasted rapeseeds were established to be lower than those of 36 and 37. In addition, our findings regarding total phenol were established to be similar to the values of Öztürk et al. (2022), while the total flavonoid amounts of our roasted and unroasted rapeseed seeds were depicted to be lower. The antioxidant activities of present study were found to be lower than those of Szydłowska-Czerniak et al. (2011). Our findings differ from the results of Siger et al. (2008), Szydłowska-Czerniak et al. (2011) and Chen et al. (2014). These changes may be due to whether the seeds were sonicated or not and the analytical procedures applied. The large and small variations in total phenolic content recorded in rapeseed varieties are mostly due to variety, biological characteristics of the seed, growing conditions, harvest time, genotype and environmental factors.

The phenolic compounds of unroasted and roasted rapeseeds

The phenolic constituents of rapeseeds sonicated at different times are defined in Table 2. The gallic acid amounts of roasted rapeseeds sonicated were characterized to be between 6.37 (60 min) and 8.83 mg/100g (30 min). 3,4-Dihydroxybenzoic acid amounts of roasted rapeseeds were detected between 4.12 (30 min) and 14.31 mg/100g (60 min). Catechin values of roasted apeseeds sonicated were detected between 18.53 (30 min) and 43.97 mg/100g (control), respectively. Caffeic acid quantities of roasted rapeseeds sonicated were found between 0.70 (30 min) and 4.21 mg/100g (control). Rutin quantities of roasted rapeseeds sonicated were defined to be between 0.16 (30 min) and 6.66 mg/100g (control), respectively. Kaempferol values of roasted rapeseeds changed between 5.67 (30 min) and 7.71 mg/100g (control), respectively. The gallic acid amounts of unroasted and roasted rapeseeds sonicated were defined to be between 6.60 (60 min) and 7.75 mg/100g (10 min). Also, while 3,4-dihydroxybenzoic acid values of unroasted rapeseeds changed between 6.06 (10 min) and 13.87 mg/100g (60 min). Catechin quantities of unroasted rapeseeds sonicated were detected between 26.02 (control) and 43.13 (60 min). Caffeic acid quantities of unroasted rapeseeds sonicated changed between 1.60 (30 min) and 5.84 mg/100g (10 min). Also, rutin quantities of unroasted rapeseeds sonicated were defined to be between 5.83 (30 min) and 19.52 mg/100g (10 min). The phenolic compounds of unroasted rapeseeds were monitored to increase at some sonication times compared to the control, while the majority of the phenolic constituents of the roasted rapeseeds decreased with sonication times compared to the control. There was a partial increase in the amounts of these phenolic components at the 60th minute of sonication. The most

important phenolic constituents in rapeseed are reported to be sinapic acid derivatives, erulic acid, o-couma, p-couma, caffeic, phydroxybenzoic, vanillic, gentisic, protocatechuic, syringic and chlorogenic acid, salicylic, cinnamic acids and sinapic acid constitutes 70.2-85.4% of free phenolic acids in oil-free rapeseed (Kozlowska et al., 1983a, b). Differences between the results and literature data may be due to genetic potential, variety, growing conditions and analytical procedures.

Table 2. Phenolic compounds of unroasted and roasted rapeseeds sonicated at different times

Phenolic compounds (mg/100g)	Unroasted			
	Control	10 min	30 min	60 min
Gallic acid	7.52 ± 2.43*b	7.75 ± 1.71a	6.80 ± 1.81c	6.60 ± 1.44d
3,4-Dihydroxybenzoic acid	9.43 ± 4.00b**	6.06 ± 1.49d	7.44 ± 4.95c	13.87 ± 2.72a
Catechin	26.02 ± 8.99d	31.25 ± 5.48c	35.48 ± 34.20b	43.13 ± 3.75a
Caffeic acid	3.55 ± 0.23c	5.84 ± 0.35a	1.60 ± 1.77d	5.59 ± 1.88b
Syringic acid	3.79 ± 1.25b	4.85 ± 1.38a	1.00 ± 0.04d	3.52 ± 3.01c
Rutin	14.86 ± 1.61b	19.52 ± 6.96a	5.83 ± 1.10d	6.63 ± 0.81c
p-Coumaric acid	1.49 ± 0.63c	1.79 ± 0.98b	0.60 ± 0.31d	2.34 ± 0.58a
Ferulic acid	2.81 ± 0.41a	2.04 ± 1.09b	0.52 ± 0.19d	1.48 ± 0.96c
Resveratrol	1.64 ± 0.89a	1.19 ± 0.71b	0.37 ± 0.03d	0.57 ± 0.06c
Quercetin	2.78 ± 1.51b	3.88 ± 0.56a	1.59 ± 0.54c	0.89 ± 1.19d
Cinnamic acid	0.70 ± 0.33a	0.50 ± 0.03b	0.24 ± 0.04d	0.27 ± 0.09c
Kaempferol	1.52 ± 0.53b	1.38 ± 0.17d	1.43 ± 0.56c	2.38 ± 0.93a
Phenolic compounds (mg/100g)	Roasted			
	Control	10 min	30 min	60 min
Gallic acid	7.45 ± 1.78c	8.36 ± 2.34b	8.83 ± 0.07a	6.37 ± 0.76d
3,4-Dihydroxybenzoic acid	10.22 ± 3.78b	7.47 ± 1.04c	4.12 ± 0.05d	14.31 ± 2.52a
Catechin	43.97 ± 5.86a	28.49 ± 0.53b	18.53 ± 2.82d	27.01 ± 3.40c
Caffeic acid	4.21 ± 1.27a	1.91 ± 0.21c	0.70 ± 0.48d	3.80 ± 0.87b
Syringic acid	2.88 ± 0.45a	2.02 ± 0.66b	0.30 ± 0.09d	1.97 ± 0.09c
Rutin	6.66 ± 1.03a	4.29 ± 0.84b	0.16 ± 0.07d	0.47 ± 0.07c
p-Coumaric acid	1.35 ± 0.83a	0.44 ± 0.05c	0.11 ± 0.04d	0.62 ± 0.09b
Ferulic acid	1.33 ± 0.57a	0.67 ± 0.05c	0.02 ± 0.00d	0.75 ± 0.07b
Resveratrol	0.73 ± 0.02a	0.40 ± 0.84b	0.02 ± 0.01d	0.32 ± 0.01c
Quercetin	2.09 ± 0.09a	1.07 ± 0.09b	0.29 ± 0.06d	0.38 ± 0.07c
Cinnamic acid	0.32 ± 0.10b	0.22 ± 0.09c	0.18 ± 0.01d	0.35 ± 0.11a
Kaempferol	7.71 ± 1.65a	6.47 ± 1.46c	5.67 ± 1.42d	6.79 ± 0.37b

*standard deviation; ** values within each row followed by different letters are significantly different at $P < 0.05$.

Fatty acid composition of the oils obtained from sonicated unroasted and roasted rapeseeds

Fatty acid profiles of the oils obtained from unroasted and roasted rapeseeds sonicated at different times are given in Table 3. Oleic acid values of the oils extracted from roasted rapeseeds sonicated at different times varied between 61.65 (60 min) and 62.01% (roasted seed control). Linoleic acid amounts of the oils extracted from roasted rapeseeds were depicted to be between 22.15 (10 min) and 22.45% (60 min). In addition, linolenic acid quantities of the oils exracted from roasted rapeseeds sonicated at different periods were defined to be between 8.84 (10 min) and 9.00% (60 min). Also, palmitic acid contents of the oils extracted roasted rapeseed sonicated at different periods were identified to be between 4.15 (control) and 4.45% (10 and 30 minutes). Oleic acid amounts of the oils of unroasted rapeseeds sonicated at different times varied between 61.80% (unroasted seed control) and 62.18% (30 min). Also, linoleic acid amounts of unroasted rapeseed oils were displayed to be between 22.14 (30 min) and 22.35% (unroasted seed control). Linolenic acid

quantities of the oils of unroasted rapeseeds sonicated at different periods were detected between 8.96 (10 min) and 8.98% (unroasted seed control and 60 min). The linoleic acid values of the rapeseed oils increased at the 30th and 60th minutes of sonication, while the oleic, arachidic and behenic acid amounts were partially decreased. Statistical differences were observed between the amount of fatty acids in rapeseed oils ($p<0.05$). The oil quantities of FJL290 and BAL102 rapeseed genotypes were determined as 43.98% and 43.85%, respectively, and the linoleic, oleic and linolenic acid quantities of the oils of these genotypes were 20.51% and 20.37%, 65.23% and 64.93%, respectively, and were defined as 7.20% and 7.09%, respectively (Joughi et al., 2018). Beyzi et al. (2019) determined 53.95-60.98% oleic 20.42-25.02% linoleic, 8.74-9.56% linolenic and palmitic acid contents between 4.24-6.00% palmitic acids in rapeseed oils. The amounts of fatty acids differed compared to those of Joughi et al. (2018) and Beyzi et al. (2019), and our results were not in good agreement with the literature values. It has been reported that the fatty acid composition of seed oils varies among varieties and environmental conditions are effective (Zanetti et al., 2009).

Table 2. Fatty acid composition of the oils extracted from rapeseeds sonicated at different times

Fatty acids (%)	Unroasted			
	Control	10 min	30 min	60 min
Myristic	0.06 ± 0.00*a	0.05 ± 0.00b	0.05 ± 0.00b	0.05 ± 0.00b
Palmitic	4.25 ± 0.21a**	4.21 ± 0.03ab	4.08 ± 0.00d	4.17 ± 0.08c
Stearic	1.48 ± 0.02a	1.45 ± 0.01b	1.45 ± 0.00b	1.44 ± 0.00bc
Oleic	61.80 ± 0.14d	61.96 ± 0.03c	62.18 ± 0.02a	62.08 ± 0.12b
Linoleic	22.35 ± 0.05a	22.34 ± 0.01ab	22.14 ± 0.03cd	22.18 ± 0.04c
Arachidic	0.54 ± 0.04bc	0.52 ± 0.01d	0.58 ± 0.00a	0.55 ± 0.01b
Linolenic	8.98 ± 0.01a	8.96 ± 0.00c	8.97 ± 0.02bb	8.98 ± 0.00a
Behenic	0.36 ± 0.04c	0.33 ± 0.00d	0.38 ± 0.02a	0.37 ± 0.01b
Erucic	0.20 ± 0.02b	0.16 ± 0.00c	0.21 ± 0.01a	0.20 ± 0.01b
Fatty acids (%)	Roasted (180^{o}C)			
	Control	10 min	30 min	60 min
Myristic	0.05 ± 0.00b	0.06 ± 0.00a	0.06 ± 0.00a	0.06 ± 0.00a
Palmitic	4.15 ± 0.11c	4.45 ± 0.11a	4.45 ± 0.07a	4.37 ± 0.01b
Stearic	1.49 ± 0.01c	1.52 ± 0.01b	1.56 ± 0.01a	1.46 ± 0.00d
Oleic	62.01 ± 0.08a	61.86 ± 0.09bc	61.87 ± 0.02b	61.65 ± 0.00d
Linoleic	22.17 ± 0.04bc	22.15 ± 0.01d	22.19 ± 0.05b	22.45 ± 0.01a
Arachidic	0.58 ± 0.03a	0.55 ± 0.02b	0.53 ± 0.02c	0.52 ± 0.00cd
Linolenic	8.98 ± 0.00b	8.84 ± 0.01cd	8.86 ± 0.01c	9.00 ± 0.02a
Behenic	0.38 ± 0.04a	0.36 ± 0.02b	0.34 ± 0.03c	0.34 ± 0.00c
Erucic	0.20 ± 0.02a	0.19 ± 0.01b	0.18 ± 0.01c	0.19 ± 0.00b

*standard deviation;** values within each row followed by different letters are significantly different at $P < 0.05$.

Principal component analysis (PCA)

Principal component analysis (PCA) was performed to determine the effect of sonication and roasting processes on bioactive compounds and antioxidant activities of rapeseeds and, which are shown in Figure 1. The first principal component (PC1) explained 50.471% of the total variability, while the second principal component (PC2) accounted for 25.880%. Together, the first two components explained 76.351% of the total variance, indicating a strong representation of the dataset. The main variables contributing to PC1 were ferulic acid (0.948), syringic acid (0.881), resveratrol (0.879), cinnamic acid (0.848), and p-coumaric acid (0.809). In contrast, PC2 was mainly associated with 3,4-dihydroxybenzoic acid (0.738) and antioxidant activity measured by DPPH assay (0.713).

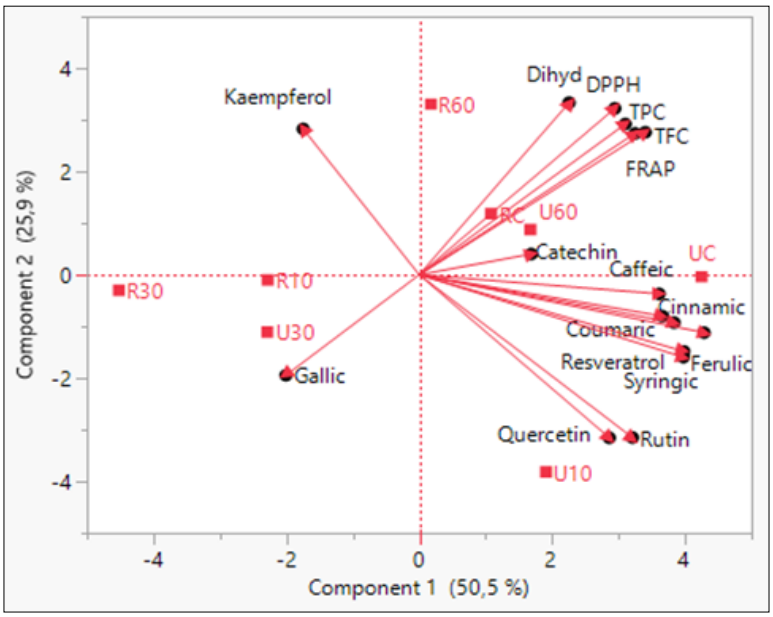

Figure 1. Biplot illustrating the principal component analysis (PCA) of rapeseed samples based on bioactive compounds and antioxidant activity

CONCLUSIONS

Compared to the control group, the oil yields of unroasted and roasted rapeseed decreased with sonication time. The greatest oil reduction in unroasted and roasted rapeseed occurred at the 10 min and 30th minutes of sonication. At the 30 minute of sonication, total phenol, total flavonoid amounts, radical scavenging (DPPH) and antioxidant capacities of unroasted rapeseed decreased significantly compared to the control. In general, the amounts of phenolic constituents of unroasted rapeseed fluctuated depending on the sonication time compared to the control. Regarding fatty acid composition, oleic, behenic, and arachidic acid contents in unroasted rapeseed oil showed partial increases at 30 and 60 minute of sonication, whereas palmitic and linoleic acid contents decreased. In roasted rapeseed oil, linoleic acid content showed partial increases at 30 and 60 minute of sonication.

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