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Effect of Combined Microwave-grilled Drying on antioxidant properties of Russian Olive (*Elaeagnus augustifolia* L.,) Berries

Soussene Boudraa

[1]*Food Science Laboratory (LSA), Department of Food Engineering, Veterinary and Agriculture Institute, University HadjLakhdarBatna, Algeria.*

Abstract

The aim of this study is to investigate the effect of microwave-grill drying (MWGD) at three power levels (300, 450 and 600 Watts) on kinetics and antioxidant properties of berry Russian olive extracts were qualitatively and quantitatively determined by using HPLC analysis and antioxidant activity through different in vitro tests (Diphenylpicrylhydrazyl Assay (DPPH), the ferric reducing antioxidant power (FRAP) and the oxygen radical absorbance capacity (ORAC) of *E.angustifolia* L. were determined. The total polyphenols of fresh fruit Russian olive (420.57mg GAE.100 g^{-1}) are higher compared to the fruits dried (137.5mg GAE.100 g^{-1}) in the microwave-grill with a power at 300 W. The presence of vanillic acid, procyanidin, p-coumaric, and quercetin was responsible for high bioactivity of MWGD at 450W in Russian olive fruit dried .At high powers superior to 450 W, drying negatively influences the polyphenols of Russian olive. Microwave-grill dried at 300 W Russian olive had a higher content of ascorbic acid, and β-carotene. Results of the present study confirmed that microwave-grill drying at 450 Watts is the best method of retention of antioxidant properties of fresh fruit of *E.angustifolia* L. It was found that the Russian olive fruit contains relatively high amounts of antioxidant.However; thermal- and oxidation-induced degradation of thermolabile polyphenols was responsible for the loss of antioxidant activity. This work demonstrates that Russian olive (indigenous cultivars) can be a good source of different nutrients for the local population and showed that *E. angustifolia* developed from microwave-grill-drying fruit able to preserve the polyphenols and hence contribute to excellent antioxidant capacity. Incorporation of unfermented *E. angustifolia* in the diet can be a good source of natural antioxidant.

Keywords: *E.angustifolia* L., Russian olive, Power, HPLC, Microwave-grill-drying (MWGD), Antioxidant properties.

1. Introduction

Russian olive *(Elaeagnus angustifolia* L.) is a tree, and its fruit grows in various climatic and environmental conditions. It is also known as Russian olive, and native to western and central Asia, from southern Russia and Kazakhstan to the Mediterranean environment, Turkey and Iran [2]. Fruits are valuable in terms of health and can be used as natural antioxidants [14], and for their natural color. Also as used in the fields of medicine and pharmacy and in Asia and in Europe is certified [15]. There are no toxic substances in oleaster fruits.

The main *Elaeagnus* species in Algeria, Russian olive (*Elaeagnus angustifolia* L.), commonly called "Jijibe", grows spontaneously and it is located mainly in the highlands. It was introduced and planted in the regions of Djelfa, Biskra, Relizane, Mascara and South Tennes and Cherchell [16].

Drying is the oldest and most popular preservation method for food and agricultural products. The fundamental concept of drying is to trim down moisture of products to a level, which will stop microbiological growth and keep the product's nutritive value and bioactive compounds in considerably higher levels [10, 21].

Corresponding authors: b_sawsen82@yahoo.fr / soussene.boudraa@univ-batna.dz

Several drying methods have been developed in order to preserve different kinds of food materials because of myriad environmental, energy efficiency and economic concerns. Besides, all methods have something in common; the heat is applied by conduction, convection, radiation.

In order to prevent quality damage due to long drying time, microwave grill drying has been introduced. Microwave heating is a sort of dielectric heating, which uses electromagnetic radiation in the frequency ranging from 300 MHz to 300 GHz. According to *Changrue (2006)* [10], the decrement of drying time due to volumetric heating of dielectric material increase the use of the microwave as a source of thermal energy.

The "best" drying method for a food product is determined by quality requirements, raw material characteristics, and economic factors. Since it is necessary that dried products be not only convenient and economical but also nutritious, basic research is needed on nutritional qualities and their relationships to processing of dried foods. Information from subjective and objective tests should be used to determine the relationship between nutrients and drying method utilized.

To process Russian olive berry in to powder, a value added ingredient, moisture must be removed by drying, which can be done using drying method by Combined Microwave - grilled Drying at different power. These methods are different with respect to cost, processing time, heat application, waves,and production rate.

The objectives of this research were to compare the effects drying method by Combined Microwave - Grilled Drying at Three power levels including: low – 300 W (MWGD300, medium – 450 W (MWGD400) and high – 600 W (MWGD600), on the nutritional characteristics of compounds phenolics and antioxidant activity as assayed by ORAC and DPPH and FRAP) on for the quality of Russian olive fruit.

The studies on the drying characteristics of Russian olive berries are scarce, and there are not enough studies on the effects of drying method . This study represents the first systematic analysis of the Effect of Combined Microwave-Grilled Drying at three different power levels (300, 450 and 600 Watts) on the antioxidant properties of Russian olive fruits.

To extend the shelf life of the *E.angustifolia* fruit, the fruit could be conserved through a drying method using modern technology, such as MW radiation, which would guarantee the quality of the final product.

Therefore, this study aimed to evaluate the drying of the *E.angustifolia* fruit using grill circulation and MW radiation at different power in preservetion of the antioxidants properties of the *E.angustifolia* pulp. In addition, the drying kinetics.

2.Material and methods

2.1.Fruit collections

Healthy mature Russian olive (*Elaeagnus angustifolia* L.,*)* fruits were harvested between October - November (2018) in North - West Algeria. The fruits were harvested in the field when ripe, their degree of ripeness having been visually based on their size and colour and the authenticity of the material was verified by one of the authors and later confirmed by a botanist. The initial moisture of Russian olive berry content is percentage-dry basis, which was determined by drying in a convection oven (Memmert DO 6836, Germany) at 103±1 °C for 24 h [1]. All the samples were stored at - 20°C until further analyses.

2.2. Drying Methods

Microwave- grill drying (MWGD): The drying apparatus used consisted of a laboratory Microwave-grill drying was performed in household equipment (model Perfect, GE107Y, SAMSUNG Electronics, Seocho, Seoul, South Korea) used option microwave + grill with at different power, with technical features of 230 V, 50 Hz with a frequency of 2,450 MHz. The dimension of the microwave cavity was 335 mm × 330 mm × 195 mm. Drying trials were carried out at different microwave-grill generation powers 300, 450 and 600W. Drying was performed per cycle (30 sec ON / 30 sec OFF); each cycle corresponds to the application of microwaves-grill drying for a given 30-sec power and 30-sec power off. At the end of each cycle, the products are weighed on a scale of precesion model: (GL-300, G-Tech-International-Co-ltd, South Korea). The drying kinetics was thus determined by the evolution of the mass of the products after each cycle.

Drying was done until the moisture content of about 10 % dry basis. The Mass of the material was recorded continuously during drying with anaccuracy of ±0.1 g. By the equation belowit can be determined the variation of the dry base moisture content (X) versus time (Sec).

$$X = \frac{Ww - Wd}{Wd}$$

X: Moisture content on a dry basis (kg H_2O/ kg dry matter);
Ww: Weight of the sample on a dry basis (g);
Wd: Weight of dry matter of the sample (g);

In the MW, Russian olive was placed inside the MWGD oven. For all the power levels studied, samples (5 ± 0.5 g) were taken from the MWGD oven. The microwave-grill- drying time of Russian olive fruit was 270 s at 300 W, whereas it was only 180 s and 120 s with the microwave-grill power level ascending to 450 W and 600 W. Results show that microwave-grill drying can be an effective and potential ways to upgrade Russian olive fruit for its further utilization.

Given the heterogeneity of the microwave heating, we realized the average of ten repetitions for each power.

The Drying process was performed in three independent repetitions. The fruit was kept at −20 °C and ready for further analysis.

2.3.Proximate analysis identification of polyphenols by HPLC

The identification of polyphenols on *Elaeagnus angistifolia* L., was determined by Analysis of phenolic compoundsChromatographic analysis was Agilent Series 1200 HPLC equipped with a vacuum degasser, a quaternary pump, a thermostatted autosampler and a DAD detector, connected to an HP ChemStation software.

2.4.Sample extraction

The extraction of all types of tea was based on the method by Poessel (1983) [25]. 200 mg of fruits dried by microwave-grill-drying at different power were extracted with methanol (≥ 99.9%), using a magnetic stirrer, for 6 h (50°C, 250 rpm). The extract was diluted at 50% in methanol and then centrifuged at 15,000 rpm for 20 min.

The supernatant was filtered through a 0.45 µm PTFE syringe filters for analyses. Free phenolic acids and flavonoids profiles of extracts Russian olive were determined using an analytical HPLC Agilent 1200 series instrument equipped with a UV-Vis diode array detector (DAD). Analytical separation was carried out on a reversed phase column Gravity (L= 250, d = 4.6 mm, particle size 5 microns, Macherey 00351179, Nagel, Germany) and pre-column CC8/4 Nucleodur C18 in gradient system (eluent A = water/formic acid, 95:5, v/v; eluentB= acetonitrile/water/formic acid, 80: 15:5, v/v/v) [18, 26].

The eluent gradient used was as follows: 0-19 min, 3-4% B;19-30 min, 4% B; 30-31 min, 4-6% B; 31-38 min, 6-14% B; 38-50 min, 14% B; 50-55 min, 14-30% B; 55-65 min, 30-35% B;65-68 min, 35-50% B; 68-70 min, 50-80% B;70-75 min, 80% B; 75-80 min, 80-3% B; 80-90 min 3%. The injection volume was 10 µL with the flow rate of 1 $mL.min^{-1}$. The compounds were identified by comparing with standards of each compound using the retention time and UV spectra as well as by running the samples after the addition of pure standards. Flavan-3-ol monomers (as sum of Epigallocatechin, Epicatechin and Catechin), Vanilic acid and B2 Procyanidin were monitored and quantified at 280 nm, Vanillin,Ferulic acid,Sinapic acid,Rutin and chlorogenic acid at 320 nm, p-Coumaric and quercitrin at 360 nm. Identification was achieved by comparison of the retention time and the UV–vis spectra with those of corresponding standards. Tentatively identified phenolic acids and flavonoids were quantified with a calibration curve obtained with the corresponding standards. Results were expressed as micrograms of polyphenols per mL (mg. $100g^{-1}$ dm).

2.5.Determination of total phenols content

The total phenols contents (TPC) of Russian olives were determined by using the Folin–Ciocalteu method by Singleton and al. (1965) [30]. Briefly, 300 µL of the sample was diluted of Russian olive juice in the ratio of 1:100 with methanol: water (6:4) which was mixed with 1.5 mL of 10 fold-diluted of Folin–Ciocalteu reagent and 1.2 mL of 7.5 % sodium carbonate. The mixture was allowed to stand for 90 min at room temperature before the absorbance was measured by a Safas UV–Visible spectrophotometer at 760 nm. Gallic acid was used as a standard.

The results were expressed as mg Gallic acid equivalent in a 100 g of fruit extract (mg GAE/100 g dm of fruits).

2.6.Determination of total flavonoids content

An aliquot (1.5 mL) of each extract was added to an equal volume of a solution of 2% $AlCl_3$, $6H_2O$ (2 g in 100 mL of methanol) and thoroughly mixed. The mixture was vigorously shaken and the absorbance was read at 367.5 nm after 10 min of incubation. Results were expressed in mg quercetin/L of dry weight [4].

2.7.Determination of total flavanols content

The total flavanols content of the Russian olives samples were estimated using a modified p-dimethylaminocinnamaldehyde (DMACA) method by Arnous and al. (2000) [3]. The concentration of flavanols was calculated from a calibration curve, using catechin as standard solutions (2, 4, 8, 10, 12 mg $.L^{-1}$). Russian olives extracts (1 mL) were introduced into a test tube and 5 mL DMACA solution (0.1 % in 1 N HCL in MeOH) was added. The mixture was vortexed and allowed to react at room temperature for 10 min. Following this, the absorbance at 640 nm was read using a Spectrophotometer UV MC2 SAFAS. The results were expressed as milligrams of catechin equivalents per 100 g ± SD dry Russian olive components for the triplicate extracts.

2.8.Determination of anthocyanidins

The anthocyanidins were determined by using the pH-differential official method [22]. The extracts (20 µL) were mixed with 180 µL of the pH1.0 and 4.5 buffers and absorbance was measured at 520 and 700nm by a Spectrophotometer UV MC2 SAFAS. The anthocyanidins were expressed as cyanidin-3-glucoside.

2.9.Determination of proanthocyanidins

Modified vanillin assay of [12, 27] was adopted for examination of the proanthocyanidins contents. Briefly, 1 mL of methanolic solution of condensed tannins, 5 mL of freshly prepared 0.5% vanillin solution in methanol containing 4% concentrated HCl (sample) or 5 mL of 4% concentrated HCL in methanol (blank) are added and mixed well.

The absorbance of the sample or the blank is then read at 500 nm, after 20 min standing at 30 °C. The condensed tannins are expressed as milligrams of catechin equivalents per 100 g of samples.

2.10.Determination of ascorbic acid

Ascorbic acid was estimated following the method of Keller and Schwager (1977) [17]. In brief, 0.5g of dried fruit sample was homogenized with 20 mL of extracting solution (5g oxalic acid 0.75 g EDTA in 1000 mL of distilled water). It was centrifuged for 15 min at 6,000xg : 8,000 rpm and the supernatant collected. The supernatant (1 mL) was added to 2,6-dichlorophenolindophenol (DCPIP) (5 mL of 20 µg/mL), the solution turned pink. The optical density of the mixture was taken at 520 nm (E_s). After taking the optical density (OD) of the mixture, one drop of ascorbic acid was added to bleach the pink color and again the OD was taken at the same wavelength (E_t). The OD of DCPIP solution was also taken at 520 nm (E_o). The standard curve was prepared by using different concentrations of ascorbic acid by following the same method.

2.11. Determination of β-Carotene

Total β-carotene was determined to use the method described by Speek and al. (1988) [31]. The method is based on saponification of the sample, followed by organic extraction where after total β-carotene in the extract is determined to use spectrophotometry.

2.12.Determination of α-tocopherol

The α-tocopherol content in the extracts was calculated from the regression equation of the standard curve. The content was determined spectrophotometrically according to the method of Kivçak and Akay (2005) [19].

2.13.Determination of antioxidant capacity

ORAC Assay: The oxygen radical absorbance capacity (ORAC) procedure used Spectrofluorometer Jenway model 6270. Analyses were conducted in phosphate buffer pH 7.4 at 37 °C. Peroxyl radical was generated using 2,2' – azobis - (2 – amidino - propane) dihydrochloride which was prepared fresh for each run. The fluorescein was used as substrate. Fluorescence conditions were as follows: excitation at 485 nm and emission at 535 nm. The standard curve was linear between 0 and 100 µM Trolox. Results were expressed as µM TE/g dry matter [28].

DPPH assay: The antioxidant capacity of the fruit was studied through the evaluation of the free radical-scavenging effect on the 1,1-diphenyl-2-picrylhydrazine (DPPH) radical. The determination was based on the method proposed by Brand-

Williams et al. (1995) [6]. Briefly, 100 µL of juice was diluted in the ratio of 1:100 with methanol: water (6:4) was mixed with 2 mL of 0.1 mM DPPH in methanol. The mixtures were incubated in the dark for 30 min. The absorbance of the resulting solution was measured at 517 nm by a spectrophotometer UV MC2 SAFAS.

FRAP Assay: Total antioxidant capacity is measured by Ferric Reducing Antioxidant Power (FRAP) assay of Benzie and Strain (1996) [5]. FRAP assay uses antioxidants as reductants in a redox-linked colorimetric method, employing an easily reduced oxidant system present in stoichiometric excess. Briefly, 40 µL of diluted juice in the ratio of 1:20 with methanol: water (6:4) sample was mixed with 0.2 mL of distilled water and 1.8 mL of FRAP reagent. After incubation at 37 °C for 10 min, the absorbance of the mixture was measured by a UV–Vis spectrophotometer at 593 nm. FRAP reagent should be pre-warmed at 37 °C and should always be freshly prepared by mixing 2.5 mL of a 10 mM 2,4,6-tri-(1-pyridyl)-5-triazine solution in 40 mM HCl with 2.5 mL of 20 mM $FeCl_3$, $6H_2O$ and 25 mL of 0.3 M acetate buffer pH 3.6. A calibration curve was prepared, using an aqueous solution of ferrous sulfate$FeSO_4$, $7H_2O$ (200, 400, 600, 800 and 1000 µM/L). FRAP values were expressed on a dry weight basis as µM of Fe^{2+}/g.

2.14. Statistical analysis

The experimental data were expressed as means ± standard deviations. All determinations were carried out in triplicates. A statistical analysis of the results was performed using the 2009 XLStat software. An equal average hypothesis was tested by analysis of variance (ANOVA). The medium was significantly different when compared with the method of Newman-Keuls ($p \leq 0.05$). The correlation between the different assays was evaluated by a multiple correlations test using Pearson coefficients.

3.Results and discussion

3.1.Moisture

The moisture content in Russian olive fruit fresh was 19,17±3,97% dry basis. These results were similar to fresh fruits, such as cranberry (16.00 %) and were lower than other fruits, such as fig (30.00 %), prune (30.92 %), and apricot (30.89 %) [8].

This low water content results in the low water activity and low of biochemical and microbiological chemical alterations.These fruits have the advantage of being easily preserved, so they can be consumed for several months and thus be used for industrial purposes.

3.2. Drying Kinetics

The variations of the water content (X) versus time (s) for three powers of the microwave grill ovenis shown in Figure 1.

Overall we see regularly decreasing curves (Figure 1), this is due to the high evaporation of water free of all samples.The drying time is reduced with increasing power and energy delivered by the microwave grill. The power of 600 W showed the shortest time (120 s).

Obviously, drying time reduced with the increasing microwave drying power levels from 300 W to 450 W and lastly to 600 W. Based on Fig.1, the time required to reduce the moisture content of the Russian olive stem from 1 kg H_2O/kg dry solid to 0.2 kg H_2O/kg dry solid varied between 120 s to 270 s subjected to the microwave grill power level.

In the beginning, the water content is important, which results in an acceleration of evaporation of water under the heating of the samples by the microwave rays and convection.

The observed drastic or sudden drying curve at the initial stages of microwave drying may be triggered by the opening of the sample's structure physically which allowing rapid vaporization and passage of water molecules [20].

3.3.Phenolic profile of fresh and dried Russian olive fruits

The HPLC chromatogram of the phenolic compound for the fresh and drying Russian olive sample are shown in Figures 2, 3, 4 and 5. Thirteen compounds were successfully identified based on their Rt (Table 1).

The concentrations of Catechin, Epicatechin, Vanillic acid, B2 Procyanidin, Epigallocatechin, Catechin gallate, Chlorogenic acid Vanillic, Ferulic acid, Sinapic acid, Rutin, Quercetin, and p-Coumaric are shown in Table 1. The fruit were affected by microwave grill drying at different power (300, 450 and 600 W) (Table 1).

Table 1. HPLC analysis of main phenolics in the ***Elaeagnus angustifolia*** fruit fresh and microwave –grill drying at different powers (300,450 and 600 W)

N Peak	T_R (min)	λ (nm)	Identity	Concentrations (mg /100 g dm)			
				Elaeagnus angustifolia (Fresh)	***Elaeagnus angustifolia*** (MWGD at 300 W)	***Elaeagnus angustifolia*** (MWGD at 450 W)	***Elaeagnus angustifolia*** (MWGD at 600 W)
1	20,40	280	Catechin	0±000^{d}	2.77±0.30^{c}	4±0.50^{b}	70.57±6.00^{a}
2	20,98	280	Vanilic acid	193.29±10.50^{a}	29.18±0.09^{c}	78.16±3.20^{b}	0±0.00^{d}
3	35,08	280	B2 Procyanidin	0±0.00^{b}	10.78±0.00^{a}	11.19±0.31^{a}	0±0.00^{b}
4	40.57	280	Epicatechin	0±0.00^{d}	5.16±0.00^{a}	4.7±0.05^{b}	2.5±0.00c
5	51.95	280	Epigallocatechin	0±0.00^{c}	9.77±0.00^{a}	0.15±0.01^{b}	0±0.00^{c}
6	54.32	280	Catechingallate	24.46±0.44^{a}	8.58±0.13^{b}	0±0.00^{c}	0±0.00^{c}
7	30.20	320	Chlorogenic acid	0±0.00^{b}	1.52±0.01^{a}	0±0.00^{b}	0±0.00^{b}
8	41 .61	320	Vanillin	0.67±0.10^{a}	0.4±0.02^{b}	0.16±0.00^{c}	0.15±0.01^{c}
9	51.52	320	Ferulic acid	22.4±0.01^{a}	8.15±0.03^{b}	8.1±0.04^{c}	8.06±0.01^{c}
10	54.66	320	Sinapic acid	26,42±0,01^{a}	9,61±0,00^{b}	0±0,00^{c}	0±0,00^{c}
11	56.68	320	Rutin	0±0.00^{c}	21.53±0.18^{a}	9.5±0.00^{b}	9.44±0.02^{c}
12	43.52	360	p-Coumaric	18.3±2.00^{a}	0±0.00^{c}	6.67±0.50^{b}	6.28±0.09^{b}
13	57.14	360	Quercetin	0.32±0.06^{a}	0.11±0.02^{b}	0.10±0.00^{b}	0.12±0.01^{b}
Total				**285.86^{a}**	**107.56^{c}**	**121.73^{b}**	**97.12^{d}**

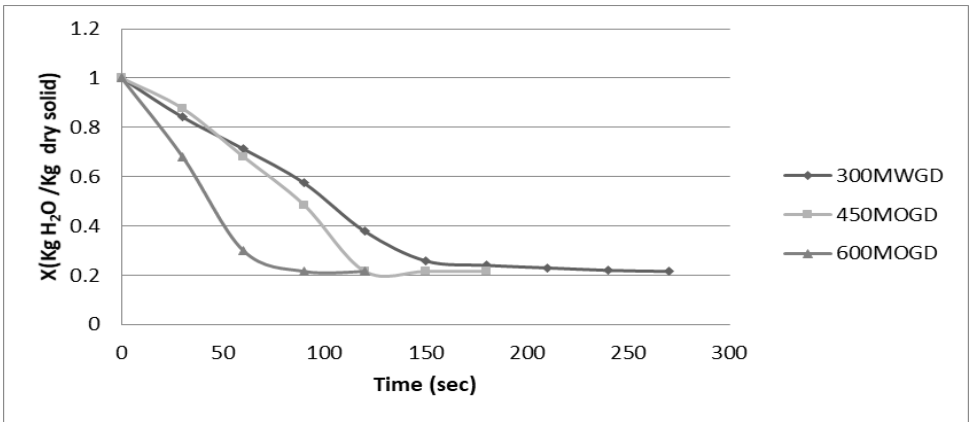
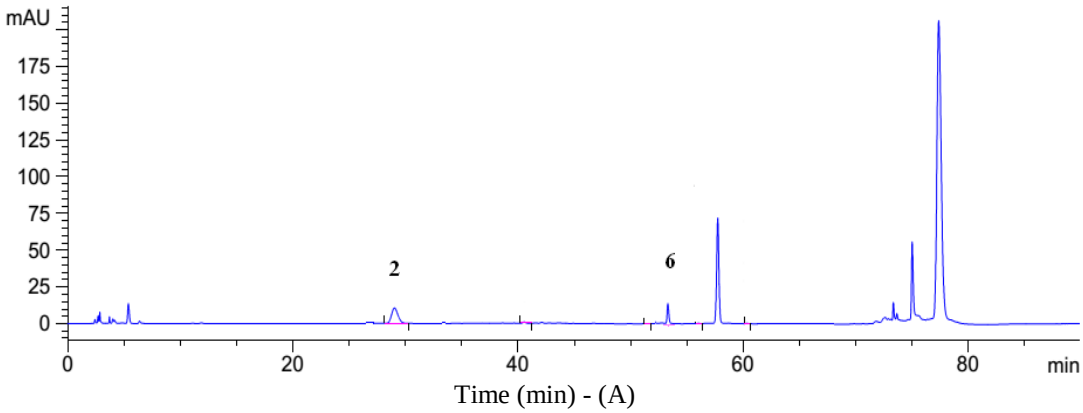


Figure 1. Variation in moisture content X (kg H_2O / kg dry matter) versus time (sec) of dried Russian olive in microwave grill at different power



Time (min) - (A)

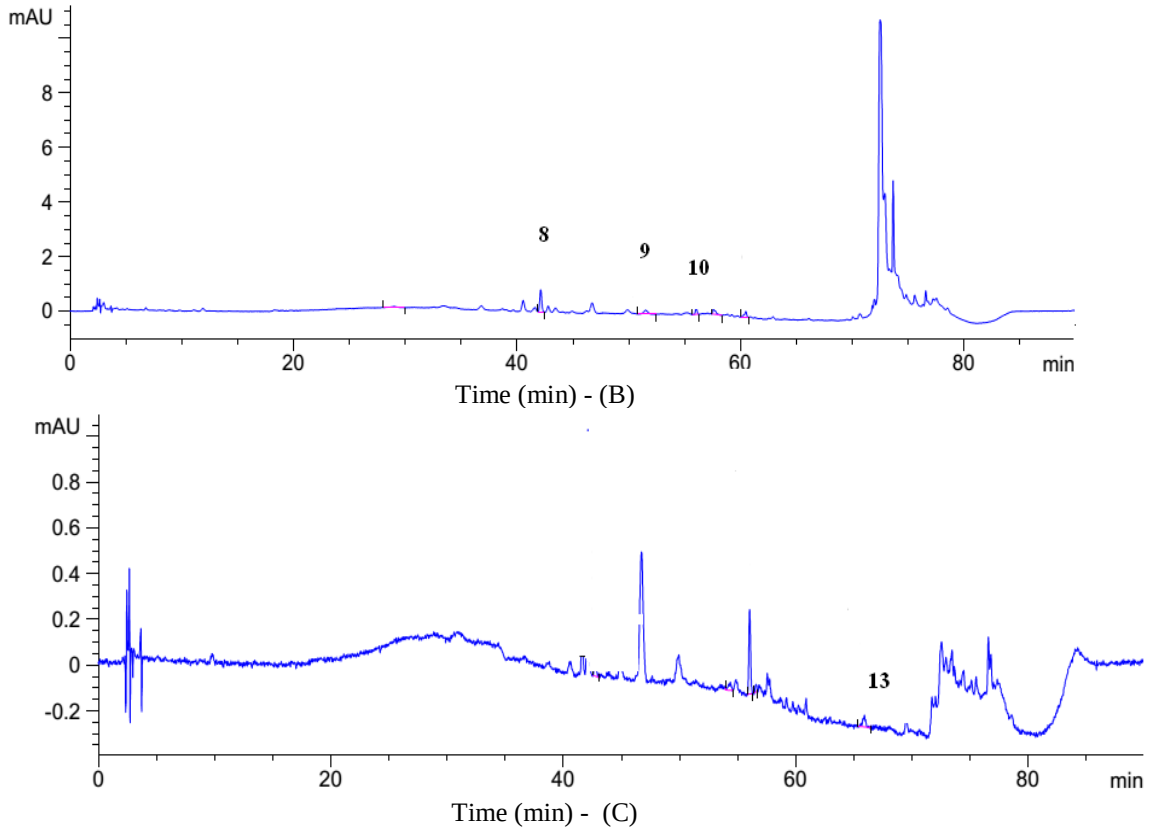
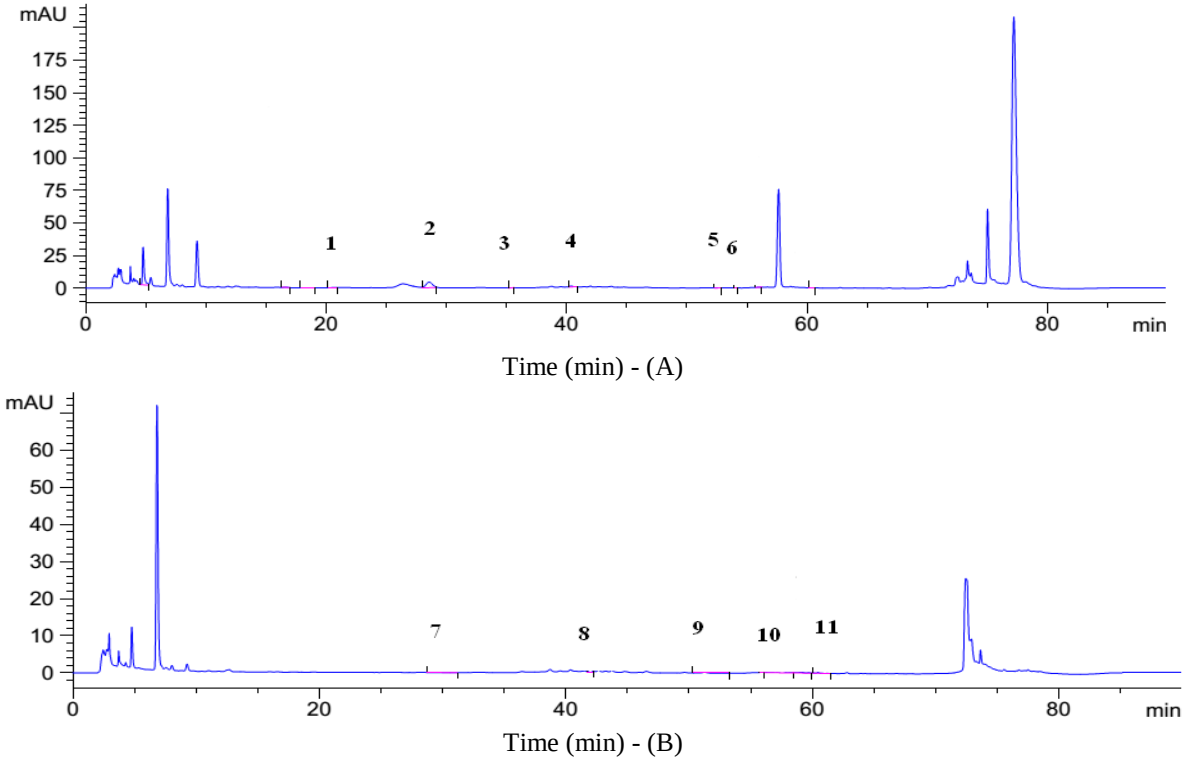
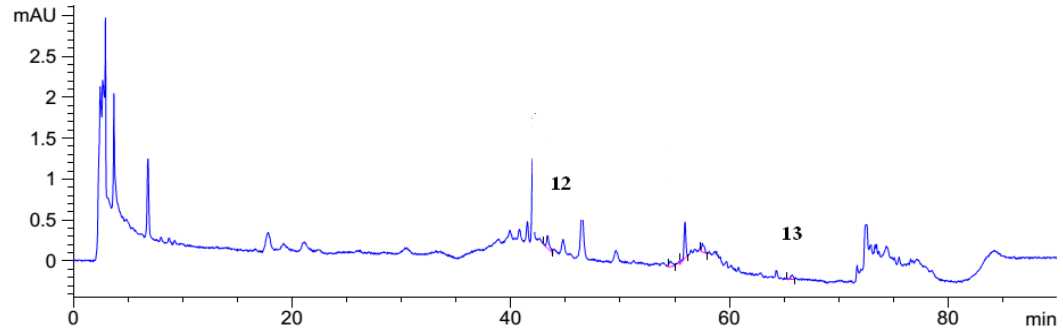


Figure 2. HPLC-DAD chromatograms of fruit Russian olive fresh (A) 280 nm, (B) 320 nm and (C) 360 nm.
2 -Vanilic acid(T_R=20,98 min); 6 - Catechin gallate (T_R=54.32 min); 8 - Vanillin(T_R=41.61 min); 9 - Ferulic acid (T_R=54.66 min), 10 - Sinapic acid (T_R=54.66 min); 13 - Quercetin(T_R=57.14 min)

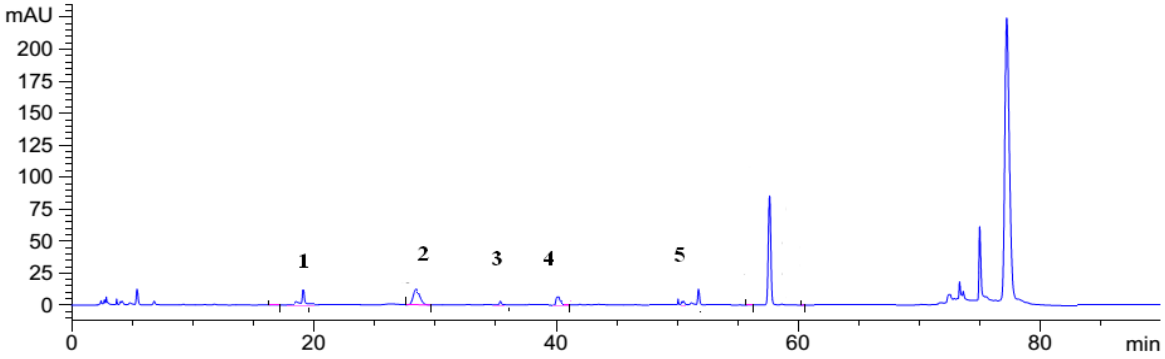




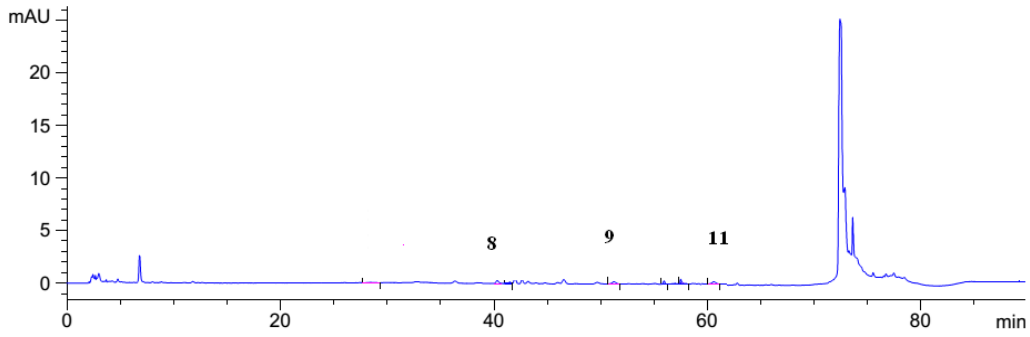
Time (min) - (C)

Figure 3. HPLC-DAD chromatograms of fruit Russian olive dried in microwave grill oven at 300 W (A) 280 nm, (B) 320 nm and (C) 360 nm.

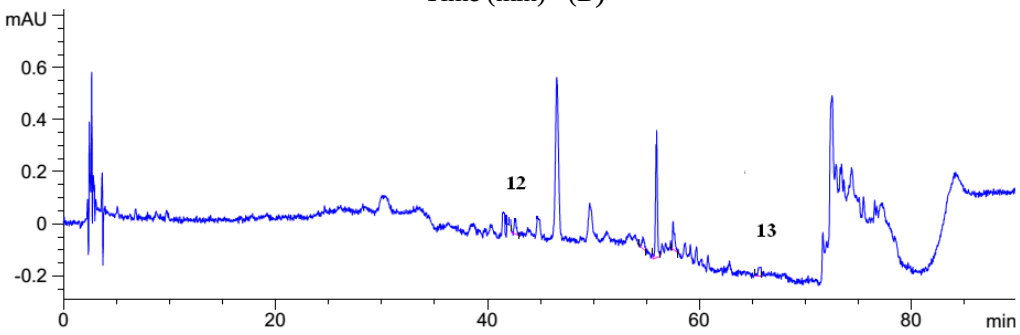
1 - Catechin (T_R=20,40 min); 2 - Vanilic acid (T_R=20,98 min); 3 - B2 Procyanidin (T_R=35,08 min); 4 - Epicatechin(T_R=40.57 min); 5 - Epigallo catechin (T_R=51.95 min); 8 - Vanillin (T_R=41.61 min); 9 - Ferulic acid (T_R=51.52 min); 11 - Rutin (T_R=56.68 min); 12 - p-Coumaric(T_R=43.52 min); 13 - Quercetin(T_R=57.14 min) .



Time (min) - (A)



Time (min) - (B)



Time (min) - (C)

Figure 4. HPLC-DAD chromatograms of fruit Russian olivedried in microwave grill drying oven at 450 W (A) 280 nm, (B) 320 nm and (C) 360 nm.

1 - Catechin (T_R=20,40 min); 2 -Vanilic acid (T_R=20,98 min); 3 - B2 Procyanidin (T_R=35,08 min); 4 – Epicatechin (TR=40.57 min); 5 - Epigallo catechin (T_R=51.95 min); 8 - Vanillin(T_R=41.61 min); 9 - Ferulic acid (T_R=51.52 min); 10 - Sinapic acid (T_R=54.66 min); 11 – Rutin (T_R=56.68 min); 12 - p-Coumaric (T_R=43.52 min);13 - Quercetin(T_R=57.14 min).

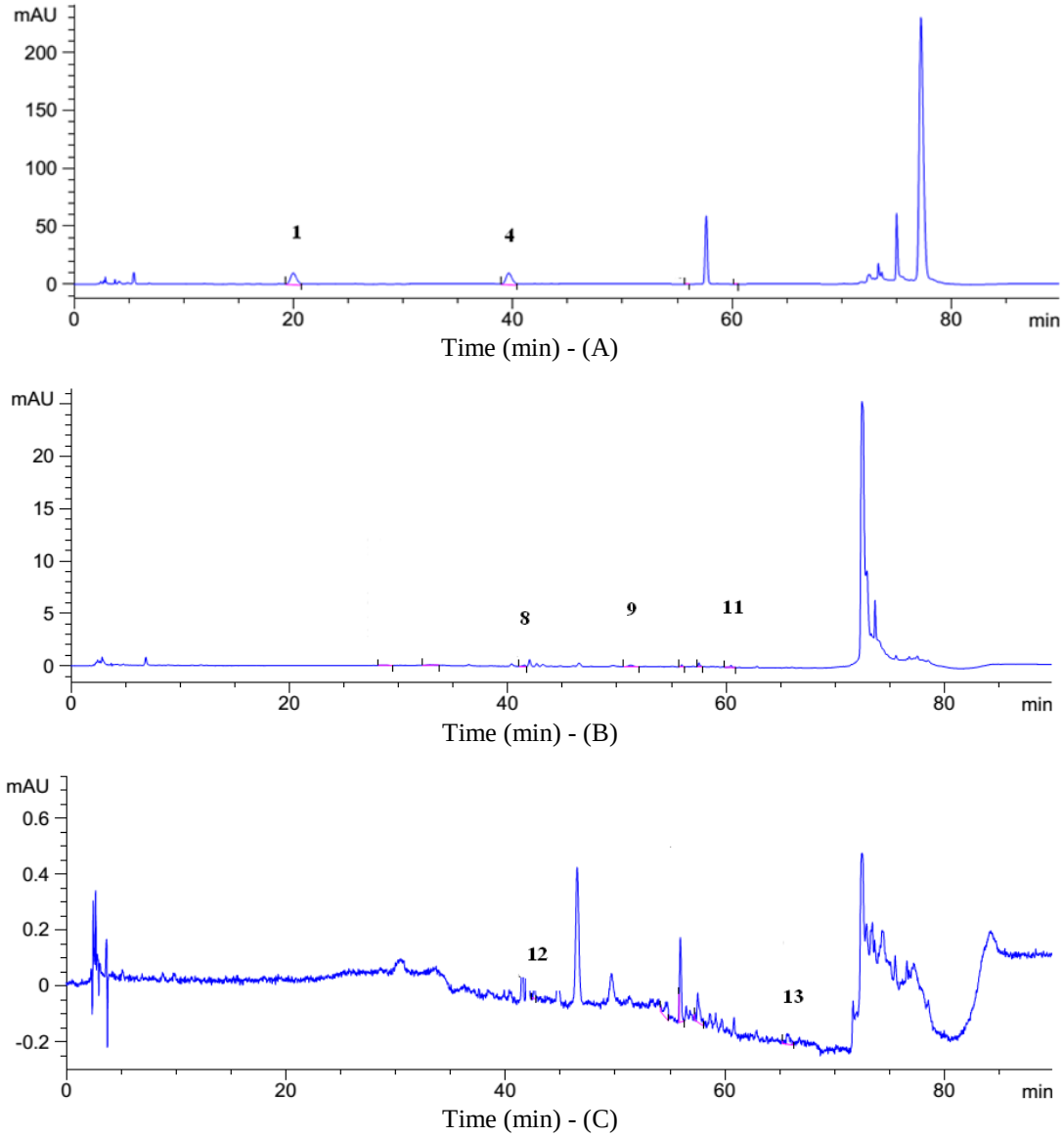


Figure 5. HPLC-DAD chromatograms of fruit Russian olive dried in microwave grill oven at 6000 W (A) 280 nm, (B) 320 nm and (C) 360 nm.

1 - Catechin (T_R=20,40 min); 4 - Epicatechin (T_R=40.57 min); 8 - Vanillin(T_R=41 .61 min); 9 - Ferulic acid

The decreases recorded in the amount of acid Vanillic, Ferulic acid, Sinapic acid and Quercetin in three power of the drying method are found to be statistically insignificant. The highest amount of catechin, epicatechin, Procyanidin, Epigallocatechin, Chlorogenic acid and Rutin were found in fruit dried by microwave grill drying at 300 with 2 .77±0,30; 5.16±0,00; 10.78±0,00; 9.77±1,00; 1.52±0,01; 21.53±0,18 and 0.11±0,02 mg/100 g dm respectively, and lowest value was determined in the fresh sample with 0 mg/100 g dm.

Statistically significant differences in all amounts of were observed in the fresh and dried samplein microwave grill drying at different power (300, 450 and 600 W). However, Total phenols content of the dried sample in microwave grill drying at different powers was lower than that of the fresh sample. While the lowest amount of Total phenols content was found in microwave grill drying at 600W (97.12 mg/100 g dm), loss of Total phenols content was higher Total in microwave grill drying at 450 W (121.73 mg/100g dm).

However, chlorogenic acid concentration in microwave grill drying at 300W dried fruit was considerably higher than that of the fresh sample.

The most significant changes were observed in the content of vanillic acid, the most abundant phenolic compounds present in Russian olive fruit. In Russian olive fruits dried using microwave grill drying, the content of vanillic acid was 139.29, 29.18, and 0 mg/100 g dm at 300, 450 and 600 W microwave power, respectively. Depending on the intensity of drying conditions, the content of rutin was decreased between 15.09 and 100%.

Quercetin concentration in microwave grill drying at different power found to be no statistically significant differences. Mohd Zainol et al. (2009) [23] pointed out that losses in r quercetin, the concentration of ***Centella Asiatica*** after vacuum-oven and air-oven drying could be as a result of temperature and time used in the drying techniques.

The variation in the quercetin content with microwave grill dring at 300 W was lower than that of rutin at 99.49%. The Quercetin with microwave power could be attributed to the degradation of polymeric polyphenols such as chlorogenic acid and rutin into the fraction of simple phenols that attenuated the effect of thermal degradation. Similar variation in the content of monomeric and polymeric flavonoids was observed in MWGD of sour cherries fruits [32].

This effect is conducive to better in vivo bioactivity of Russian olive fruit because the absorption of polymeric polyphenols such as chlorogenic acid and rutin in the gastrointestinal tract is poorer than simpler phenolics such as quercetin [32]. In addition to radical scavenging activity, these phenolic acids play important role in the prevention of inflammatory diseases and cancer and the improvement of vascular function, lipid metabolism, and carbohydrate metabolism [33]. Therefore, maximum preservation of bioactive compounds is of utmost importance during the drying process as degradation of these compounds is dependent on drying time, condition, and intensity.

Lowering the microwave grill drying power to the level at 450 W an even higher reduction in the content of individual value. It has been observed that the high porosity of dehydrated products promotes greater contact of the material with oxygen, which makes the released antioxidants more prone to oxidative damage [24]. Carrying out drying at 450 W increased the required drying time by 33.33 % compared to that at 300 W, which increased the exposure to oxygen and oxidative enzymes.

3.4. Proximate Compositions of Russian olive

Total phenols content: The overall phenolic content (TPC) of the fresh material and microwave preserved Russian olives are shown in Table 2. The entire phenolic content will be decreased as the microwave power is increased. Entire phenolic contents for fresh Russians olives fruits are 420.57mg GAE per 100 g (Dry weight) sample. It was shown that the deterioration of entire phenolic considerably varied/changed, as per the parched a pproach at different MWG powers (300 – 600 W).

It was acclaimed that extracts of preserved pulp invariably display a reduced combination of entire phenolic than those from fresh/new fruits. This deficit of phenolic when parching may be due to the growth condition. Precisely, the temperatures and the duration used [34]. We noted a boost in TPC of MWG dried Russians olives along with increased MWGD power levels (300–600 W). He interpreted that this was attributed to MWGD energy resulting in disruption of cellular components, developing in a greater discharge of polyphenols from the pattern. Plenty of analysts have established that TPC in assorted plant species has erratic development under various drying processes [9, 13].

Henceforth, individuals can reach the outcome that the drying operation develops in high or low levels of TPC determined by the type of plant elements. The location phenolic compounds available in the cell, as the power of the microwave oven, is enlarged, the entire phenolic content of the dried/scorched Russian olive is compressed. The amount of TPC determined in different dried samples was shown in Table 2.

Total flavonoids content: The entire flavonoids content of Russian olives powders adapted by two drying methods amounting from 52 to 143 mg Eq/L dm (Table 2). Then the increase in microwave output power not considerably heightened the entire flavonoids contents of dried Russians olives. The development of the indicated compounds at huge temperatures might be due to the accessibility of precursors of these molecules by non-enzymatic inter-conversion among molecules [29].

Microwave grill drying at 300 W seems to be very interesting to improve and to preserve the highest flavonoids contents respectively. Consequently, the antioxidant activity of these flavonoids compound could be improved and preserved.

Drying processes led to lower the loss of flavonoids in fresh Russian olive than that of total polyphenols and anthocyanidins. This phenomenon could be attributed to the stronger heat stability of flavonoids compared with anthocyanidins and other polyphenols.

Total flavan-3-ols content: Flavan-3-ols seemSsto be more stable with the microwave treatment and its contents in the microwave- grill-dried at 600 W were higher than in the dry fruits.

Flavonoids, especially the flavan-3-ols are more thermostable [7]. Therefore, they can be added to food products, representing a valuable resource. They may act as a functional ingredient or nutraceutical to terminate free radical chain reactions in biological systems and therefore may play an important role in alleviating risk in the development of chronic diseases.

Total anthocyanidins: The total anthocyanidins concentration for Russians olives berries, microwave-grill-dried berries, was determined to inspect the development of drying techniques above the retention of these phenolic pigments. The results of total anthocyanidins contents in the samples are shown in Table 2.

Russians olives berries contain the top most anthocyanidin content of 1.40 mg of cyanidin-3-glucoside/100 g dry mater in fruit fresh and microwave grill dried at 300 W show the poorest anthocyanidin retention (0.22 ± 0.00 mg of cyanidin-3-glucoside/100 g dry fruit) among the samples.

Microwave grill dried at 600 W showed the highest potential for retaining anthocyanidins content in the samples tested in comparison to the other powers. Drying at higher powers levels can lead to higher anthocyanidins because these pigments are not heat-sensitive and are stable during thermal treatment.

Proanthocyanidins: The proanthocyanidins content was 74.2 mg CE/100g dm in the fresh sample and was significantly higher ($p < 0.05$) in the microwave grill drying at 450 W (Table 2).

Comparing the dried plant samples, the microwave-grill-dried ones at 300 W had slightly higher total condensed proanthocyanidins content than a microwave- grill-dried ones at 600 W. Microwave grill dried samples at 600 W is a good method to preserve large molecular weight condensed tannins.

The total tannin contents of dried Russian olive just after drying were higher. This increase in total tannins in dried only might have been due to the desactivation of the enzyme polyphenol oxidase which might have converted tannins into other products.

Ascorbic acid : The ascorbic acid content of the fresh and dried Russian olive at various microwave-powers grill drying (presented in Table 2). The ascorbic acid content significantly decreased from an initial mean value of 7.03 mg/100 g dry matter of the Russian olive to the least value of 3.39 mg/100 g dry matter after microwave grill drying at 300 W. The best ascorbic acid values in the Microwave grill drying at 300 W a value 8.73 mg/100 g dm. The lower result was found at power 450 W with a value of 3.87 mg/100g dm. The lowest ascorbic acid value was 3.39 mg/100 g dm at 600 W.

This phenomenon showed that microwave drying of Russian olive using higher microwave power level willlead to greater vitamin C degradation and affected the quality of microwave-dried Russian olive. This was due to the high thermal energy released has damaged the heat-labile vitamin C compound. Hence, higher microwave power level resulted in greater vitamin C degradation.

β-Carotene: To analyze the effect of the microwave on the β-carotene content, the dried Russian olive content was related to that of the fresh/raw ones (Table 2). Provitamin A is sensitive to heat, light and prolonged processing. The β-Carotene levels of the dried Russian olive are much ($p < 0.05$) raised from an original value of 3.83mg/100g dry matter to an utmost value of 8.73 mg/100g dry matter after microwave grill is 300W. It has been described that in Russian olive, β-carotene content degradation relies up on abundant aspects including processing temperature.

The β-carotene is thermolabile pigments and that microwave heating induces a decrease in their content, causing higher damages in carotenoids content.

Whether these observations are more dependent on the heat exposure time or the temperatures achieved within the process is an interesting issue that deserves more study.

β-Carotene is the most crucial provitamin A, primarily due to its popularity in plant foods consumed/use up by humans, and it's β-Carotene has the highest activity. Nonetheless, when taken as an independent additive, it may bear damaging effects. Thus, microwave drying at 300 W of Russian olive fruit is thefinest source of β-carotene**.**

a-Tocopherol: The results of the α-tocopherol analysis reported in Table 2. The range for α-tocopherol content is from 2 mg/100 g dm in fresh/raw Russian olives to 1.04 mg/100 g dm in the totally dried microwave grill at 300 W preserved samples. A limited measure of α-tocopherol was observed in the fresh/raw fruits, as well as the microwave grill drying Russian olives samples.

The above development mostly leads to the limited evaporation of water during the defrosting and heating of fruits, which has the effect of concentrating constituents in fresh mass and increasing dry weight (Table 2). Nonetheless, it should combine in such a way that the products underwent only one heat treatment in water. Despite α-tocopherols are fat soluble, they are inclined to thermal treatment/remedy in water and losses because of ascending chemical extractability of lipid molecules. This deterioration is further more accelerated by the presence of oxygen and exposure to light during processing.

3.5. Antioxidant capacity

Different researchers have employed different approaches to quantitatively determine the activity of antioxidants in Russian olive fruit. The antioxidant actions of the fresh/raw and dehydrated Russian olive, the ORAC, DPPH and FRAP approach was employed. The extreme antioxidant movement monitored for the microwave-grill-drying at 450W drying samples**.**

ORAC assay: The mean ORAC in raw Russian olive was 77.87 μmol TE/g dm sample. The mean ORAC values of Russians olives pomace using dissimilar drying techniques are shown in Table. The highest mean ORAC value of 23.98 μM TE/g(Dry basis) was observed in microwave-grill-dryer at 450 W and the lowest in the microwave grill dryer at 600 Watts sample (Table 3).

The microwave-grill-dryer at 450 W showed significantly higher ORAC values as compared to the other powers used.

DPPH assay: The outcome of DPPH valuation is given in Table 3. It was noted that a dose-response relationship was established in the DPPH radical scavenging activity; the movement increases as the concentration increases, the extracts were found to be fewer effective in the radical scavenging evaluation. The high DPPH scavenging action of MWG can be related due to the existence of a higher amount of TPP, which could have been discharged due to the interruption of the cell wall, from the insoluble section of the Russian olives or the development of novel compounds having a dominant donating ability [11].

Table 2. Effect of microwave grill drying on polyphenols, flavonoids, flavan-3-ols, anthocyanidins, proanthocyanidins, acid ascorbic,β-Carotene and α-Tocopherol of Russian olive

***Fruit Elaeagnus angustifolia* L** ., (Russian olive)								
Drying Methods	**Polyphenols (mg GAE /100g dm)**	**Flavonoids (mg EQ/L dm)**	**Flavan-3-ols (mg catechin/ g extract dm)**	**Anthocyanidins (mg of cyanidin-3-glucoside / 100 g extract dm)**	**Proanthocyanidins (mg catechin equivalents per 100 g extract dm)**	**Acid ascorbic (mg.100 g^{-1}dm)**	**β-Carotene (mg.100 g^{-1}dm)**	**α-Tocopherol (mg.100 g^{-1}dm)**
Fresh	420.57±0.002^{a}	143.25±12.6^{a}	0.84±0.00^{a}	1.4±0.00^{a}	7.25±5.00^{c}	7.03±0.06^{b}	3.83±0.00^{b}	2.00±0.00^{a}
Microwave grill drying								
300W	116.25±0.003^{c}	72.76±2.88^{b}	0.062±0J00^{d}	0J22±0.06^{d}	129±2.06^{b}	8.73±1.32^{a}	4.21±0.01^{b}	1.05±0.027^{c}
450W	137.5±0.010^{b}	57.81±2.33^{c}	0.75±0.01^{c}	0.67±0.01^{c}	66±0.04^{d}	3.87±0.42^{c}	2.04±0.00^{c}	1.04±0.037^{d}
600W	110.75±0.004^{d}	52.03±2.43^{d}	0.82±0.00^{b}	0.92±0.03^{b}	181.5±0.06^{a}	3.39±0.10^{d}	0.61±0.01^{d}	1.25±0.42^{b}

a, b, c, d: In each column, means followed by a different letter are significantly different at the threshold of P<0.05 (**Method of Newman and Keuls**).

Table 3. Effect of microwave grill drying on the antioxidant activities of dried Russian olive was using ORAC. DPPH assays and FRAP.

Fruit Russian olive (Elaeagnus angustifolia L.)			
Drying methods	**ORAC (µM TE/g dm)**	**DPPH (µg TE / g dm)**	**FRAP (µM of Fe(II)/g dm)**
Fresh	77.87±1.91[a]	291.15±57.00[c]	604.3±3.10[a]
Microwave grill drying			
300W	19.27±0.31[c]	728.4±2.01[a]	533.17±0.10[c]
450W	23.98±1.00[b]	699.97±3.98[b]	566.31±1.18[b]
600W	17.82±0.03[d]	178.67±44.51[d]	501.22±1.10[d]

a, b, c, d: In each column, means followed by a different letter are significantly different at the threshold of P <0.05 (**Method of Newman and Keuls**).

Table 4. Pearson correlation coefficients for microwave-grill-drying at different power in the antioxidant capacity DPPH test.FRAP test and ORAC test.TPC, and TFC.

Pearson's	Cofficient	DPPH			FRAP			ORAC			TPC			TFC		
	(R^2)	300MWGD	450MWGD	600MWGD	300MWGD	450MWGD	600MWGD	300MWGD	450MWGD	600MWGD	300MWGD	450MWGD	600MWGD	300MWGD	450MWGD	600MWGD
DPPH	**300MWGD**	**1,000**	**1.000**	**1.000**	0.993	**1.000**	**1.000**	**0.999**	**1.000**	0.783	0.049	0.234	0.012	**1.000**	**1.000**	**1.000**
	450MWGD	**1.000**	**1.000**	**1.000**	**1.000**	0.992	**1.000**	**0.999**	**1.000**	0.676	0.050	0.252	0.013	**1.000**	**1.000**	**1.000**
	600MWGD	**1.000**	**1.000**	**1.000**	**1.000**	0.992	**1.000**	**0.999**	**1.000**	0.900	0.043	0.240	0.013	**1.000**	**1.000**	**1.000**
FRAP	**300MWGD**	0.993	0.992	0.992	**1.000**	**1.000**	0.993	**0.996**	0.993	0 .883	0.018	0.332	0.001	0.992	0.992	0.992
	450MWGD	**1.000**	**1.000**	**1.000**	0.993	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	0.047	0.257	0.012	**1.000**	**1.000**	**1.000**
	600MWGD	**1.000**	**1.000**	**1.000**	**1.000**	0.993	**1.000**	**1.000**	**1.000**	0.990	0.047	0.251	0.011	**1.000**	**1.000**	**1.000**
ORAC	**300MWGD**	**0.999**	**0.999**	**0.999**	**1.000**	**0.996**	**1.000**	**1.000**	**1.000**	0.895	0.039	0.275	0.007	**0.999**	**0.999**	**0.999**
	450MWGD	**1.000**	**1.000**	**1.000**	0.993	**1.000**	**1.000**	**1.000**	**1.00**	0.999	0.047	0.571	0.011	**1.000**	**1.000**	**1.000**
	600MWGD	0.896	0.894	0.893	0.897	0.942	0.898	0.910	0.898	**1.000**	0.011	0.258	0.047	0.895	0.895	0.895
TCP	**300MWGD**	0.049	0.050	0.051	0.047	0.018	0.047	0.039	0.047	0.032	**1.000**	0.5357	0.988	0.049	0.049	0.049
	450MWGD	0.234	0.252	0.250	0.256	0.332	0.257	0.215	0.258	0.245	0.535	**1.000**	0.645	0.253	0.253	0.253
	600MWGD	0.012	0.013	0.013	0.012	0.001	0.011	0.007	0.011	0.004	0.988	0.645	**1.000**	0.012	0.012	0.012
TCF	**300MWGD**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	0.992	**0.999**	**1.000**	**0.784**	0.049	0.253	0.012	**1.000**	**1.000**	**1.000**
	450MWGD	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	0.992	**0.999**	**1.000**	0.850	0.049	0.253	0.012	**1.000**	**1.000**	**1.000**
	600MWGD	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	0.992	**0.999**	**1.000**	0.967	0.049	0.253	0.012	**1.000**	**1.000**	**1.000**

The ability to the reduction in synthetically generated radical DPPH in fresh fruits was 291.15 µg Trolox/g dm, and it was higher in samples dehydrated by other drying methods by MWG dryer at 450 W (699.97µg Trolox/g dm).

Microwave grill drying involves volumetric heating whereas the berries ingest the microwave energy precisely and change/adapt it to heat internally. This process improves the color attribute and reduces the loss of anthocyanins and polyphenols due to the high temperature and brief period of drying time.

FRAP assay: The FRAP of Russian olives extracts is shown in Table 3. The top most FRAP was detected in a microwave-grill drier at 450 W (566.31 µM of Fe (II)/g dm) and the lowest observed in MWGD at 600 W extracts (501.22 µM of Fe (II)/g dm) In this study, compelling changes ($p < 0.05$) was noticed

This capability of the Russian olive fruit extracts to minimize ferric ions was employing the FRAP (Ferric ion reducing the ability of plasma) analysis developed by Benzie and Strain (1996) [5].

For the FRAP analysis, we noticed additional dissimilarity amidst fresh and dried specimen. A greater FRAP value was achieved by the microwave grill drying at 450W. It was noted that Russian olive fruits were dried out by the microwave grill drying method which consists of higher antioxidant movement and lesser power.

This conduct might be due to two factors:

i. it is noted that polyphenols in a transitional period of oxidation have a higher antioxidant ability when compared to the initial period, even though it's brief.
ii. high-temperature stabilization operations might start the formation of a fresh blend with greater antioxidant activity.

This is actually the condition of the Maillard reaction, which constitutes different products which are the Maillard reaction products.

3.6.Correlation of TPC, TFC, ORAC, DPPH, and FRAP Tests

In order to correlate these methods, a regression model using the Pearson test was used (Table 4). The correlation coefficient between TPC, TFC and the antioxidant capacity of the Russian olive fruit dried by microwave-grill at different power (300,450 and 600 W) (i.e.,the better DPPH/TPC) were R^2= 0.525 for microwave-grill-dried at 450 W and DPPH/TFC) were betwen 1 for microwave-grill-drying at all power. Similarly, the coefficients (R^2) of FRAP/TPC were 0.257 for microwave-grill-dried at 450 W and FRAP /TFC) were betwen (0.992-1) for microwave-grill-drying at all power. And there were strong correlations between ORAC, TPC and TFC of Russian olive fruit dried in microwave-grill at 450 W (R^2 = 0.895 and 1, respectively).

However, the correlation study of TPC with DPPH values of Russian olive fruit dried at 450 W showed moderate correlation (R^2 = 0.252) which TPC with FRAP and ORAC values of Russian showed moderate correlation (R^2=0.332, 0.258, respectively). The high correlation was TFC/DDPH,TFC/FRAP and TFC/ORA observed in Russian olive berry dried in microwave-grill at 450 W (R^2=1, R^2=0.992 and R^2=1).

The results of this correlation coefficient at different processings indicates that change in antioxidant activity when we applied of different power levels of microwave-grill drying (450 W) can be associated with change in phenolic composition of the Russian olive fruit dried , although a decrease (microwave-grill-dried at 600W) in correlation (R^2) was also observed which may be due to degradation of polyphenols due to thermal treatment which caused antioxidation effect.

5. Conclusions

This study highlights the potential application of MWGD at different powers (*300, 450 and 600 Watts*) as a viable method for processing Russian olive to produce a high-quality product with high antioxidant content and activity. During the MWGD, direct generation ofheat in the sample by absorption of energy by water molecules accelerated the dehydration process. MWGD at 450 W had a positive impact on total phenolic, aswell as content vanillic acid, procyanidin, p-coumaric, and quercetin due to the degradation of the bound polyphenolic complexes into fractions of free phenolics.

However, processing conditions for MWGD at 300 W have to be suitable for the better stability of released polyphenols, as drying at either higher or lower microwavegrill power aggravated loss of polyphenols. MWGD at 450 W was the best drying process with TPCby HPLC 121,73 g /100 g dm, DPPH 699.97 µg TE/g dm, ORAC 23.98 µmol TE/g dm and FRAP 566.31 µmolTE/g dm.

The polyphenols drying bymicrowave grill at 450 W of Russian olives would be a good source for either the development of functional food or future applications in food processing, cosmetic or nutraceutical industries.

High amounts of carotenoids (4.21 mg/100 g dm), ascorbic acid (8.73 mg/100 g dm) and antioxidant potential were recorded in fresh fruit of Russian olive, can be recommended preserving these phytoconstituents and antioxidants potential, with a minor loss of constituents in dehydrated fruits of Russian olive place of MWGD at 300 W.

Microwave dried Russian olive with applied 450 W had higher levels of antioxidant activity than other Russian olive dried at other microwave drying powers and with the rest of the drying methods. Thus, this fruit could be considered as an important source of biologically active components with high antioxidant activity to assess the requirements of today's consumers, who are very interested in the potential role of functional or nutraceutical foods.

Compliance with Ethics Requirements. Authors declare that they respect the journal's ethics requirements. Authors declare that they have no conflict of interest and all procedures involving human or animal subjects (if exist) respect the specific regulation and standards.

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