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Effect of different drying methods on the heating under reflux and microwave extraction on techno-functional properties from the *Elaeagnus angustifolia* L., fruit

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Abstract

A microwave heating and extraction process for Russian olive fruit can quickly remove the moisture content and the effect of the functional properties in Russian olive fruit. In this paper, the key parameters for Russian olive fruit to the drying treatments and extraction methods, were performed using microwave-grill- drying at different power (300, 450 and 600 W) and freeze-drying (5 µbar, 68 hours), respectively, and extraction was by microwave at 200 W extracted (EMW) by ethanol and time of extraction is 6 min and second method extraction is a conventional method by heating under reflux (EHUR) extracted by ethanol and time of extraction is 30 min.The Russian olive fruit Freeze dried and extracted by heating under reflux had the highest values of viscosity and total soluble solid (2.37±0.06 and 13.30±0.51 respectively), analyze the drying kinetics and functional properties of *E. angustifolia* (pulp) dehydrated by microwave – grill-drying (MWGD) and freeze-drying (FD) and extracted by microwave at 200W and heating under reflux. Drying times for dehydration by microwave were lower than for freeze- drying. The drying and extraction methods did significantly affect the functional properties of Russian olives fruits ($p \leq 0.05$). In general, Russian olive fruit dehydrated by microwave at 600 W (presented better water and oil absorption properties, solubility and emulsifying properties (220.89±0.60(%), 210.42 ±0.03 (%), 74.49 ±0.09 (%), 26.40±2.90 (%) and 32.12±0.23 (%) respectively) was effective and suiTable for the stabilisation of Russian olive fruit for long term storage, as well as improving some functional properties. The gelling properties of Russian olive powders were very important when dehydrated in microwave at 450, 600 W and extracted by microwave at 200 W (21.42±0.00 (%), and 26.24±0.00 (%) when 2% concentration of Russian olive fruit) ,is employed in food products. This study shows that Russian olive pulp dehydrated and extracted by microwaves has huge potential to be reprocessed and used as food ingredients as sorbent of water and/or oil, solubility, emulsification.

Keywords: Elaeagnus angustifolia L.; drying methods; extraction methods; freeze - drying (FD),microwave-grill-power (MWGD); Extraction in microwave (EMW); extraction by heating under reflux (EHUR); funtional properties.

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1. Introduction

Oleaster (*Elaeagnus angustifolia* L., Russian olive) belongs to *Elaeagnus* L. genus and *Elaeagnaceae* family. *Elaeagnus angustifolia* L. is a kind of shrub or tree with a height of up to 7 m and a capacity to grow under a wide range of environmental conditions [22]. This species shows a broad geographical range, existing widely in Asia and Europe, particularly in Turkey, Caucasia and Central Asia [4].The main *Elaeagnus* species in Algeria, Russian olive (*Elaeagnus angustifolia* L.), commonly called “Jijibe”, grow 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 [21].

Fruits are valuable in terms of health and can be used as natural antioxidants and as natural color [13]. Also, as used in the fields of medicine and pharm acy in Asia and in Europe [17].

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The processes of industrialization of fruits can generate various types of by products such as pieces of pulp depending on the industrial process implemented [20].

These by products, which are commonly discarded as waste, constitute an important source of nutrients for the human body and/or for the food industry [31].

Most of the plant byproducts have high percentages of moisture, which cause difficulties for their manipulation, transport and final disposal, due to the weight and volume they may occupy. The drying allows the stabilization of these biomaterials due to the limitation of the microbial growth and the enzymatic action. In addition, it minimizes physical and chemical changes during storage [33].

This process leads to the preservation of food by reducing its water content through the simultaneous occurrence of heat and mass transfer [39].

Among the most common methods used for the drying of plant tissues are, freeze-drying, dehydration by micro-waves and/or the combination between them and other methods. The choice of method depends on factors such as: the characteristics of the drying equipment, the type of product, the cost of dehydration and the desired quality for the dried product, with fuel consumption and the quality of the final dry products being the most critical considerations for choosing the drying method [30].

In recent years, new microwave extraction techniques have increasingly emerged as an alternative to traditional liquid-solid extraction techniques (heating under reflux, maceration, percolation, leaching, accelerated solvent extraction, etc.) for the preparation of plant origin samples.

Indeed, the latter has certain disadvantages in terms of toxicity by solvents, duration, cost, or environmental pollution.

Nevertheless, the study of the drying and extraction processes could not be discussed in that opportunity. The aim of the present study was to deepen the analysis of the kinetics of the dehydration processes of Russian olive pulp through microwave drying. In addition, a comparison drying methods between freeze- drying and microwave – grill - drying at different power and extraction methods between mheating under reflux and microwave extraction at 200 W in terms of the functional properties was also carried out.

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. Russian olive had an initial moisture content of percentage-wet basis, which was determined by drying in a convective oven (Memmert DO 6836, Germany) at 103±1 °C for 24 h [6]. The fruit was conserved at -20 °C until used. Russian olive was sorted. After that, the total quantity was divided into three batches, one for each process Microwave grill drying (Figure 1) .

2.2.Drying Methods

2.2 .1. Microwave- grill drying

The drying apparatus used consisted of a laboratory microwave grill oven (GE107Y, SAMSUNG Electronics) 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 generation powers 30, 450 and 600W. Drying was performer per cycle (30 S ON / 30 S OFF); each cycle corresponds to the application of microwaves for a given 30-S power and 30-S power off. At the end of each cycle, the products are weighed on a scale of precession model: GL-300. The drying kinetics was thus determined by the evolution of the mass of the products after each cycle.

Drying was run until the moisture content of about 10% w.b. the water was attained; the Mass of the material was recorded continuously during drying with the accuracy ±0.1 g. By the equation below it can be determined the variation of the dry base moisture content (X) versus time (S) [5].

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

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

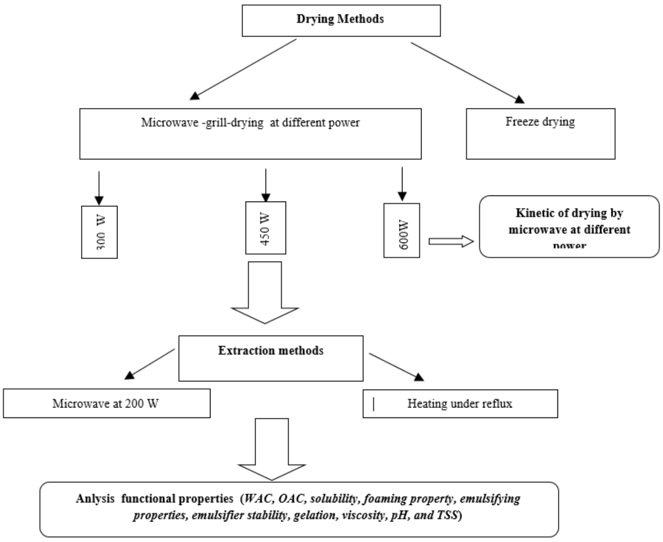

Figure 1. Shows different drying and extraction methods of *Elaeagnus angustifolia* fruit

In the MWGD, 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 every 120 S for 600 W, up to 180 S for 450 W, and up to 270 S for 300 W. The total drying time was determined as the passing time until no discernible weight change for each sample was observed in each MWGD power level.

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.

2.2 .1. Freeze- drying: Freeze-drying was carried out in a laboratory freeze-dryer (4KB TXL–75; Virtis Benchtop K, New York) at a plate temperature, which was adjusted to - 80°C. Sublimation occurred at a pressure of 5 µbar for 68 h. The Freeze Drying process was performed in three independent repetitions. The fruit was conserved at −20 °C until further analysis.

2.3. Extraction processes

2.3.1. Heating Under Reflux: The fresh and dried samples are ground, then 10 g is extracted and placed in a round-bottomed flask and 100 ml of ethanol are also added.

The flask is connected to a reflux condenser and is electrically heated using a Variac controlled flask heater. The extraction is carried out for 30 minutes under conditions of total reflux at the boiling point of the solvent.

*2.3.2. Microwave Extraction:*10-gram samples and ethanol were placed in an extraction flask with a capacity of 1L, then the flask was placed in the microwave. Power (200W) and time (6 minutes (2 min *On* and 2 min *Off*)) were adjusted using the microwave control panel, which is rotating, to have average irradiation. The optimal conditions of microwave were; ethanol concentration 65%, solvent volume 25ml microwave power 250W and extraction time 6.0 min [8].

2.3. Functional properties analyses

2.3.1. Water and oil absorption capacity

Measurements of water and oil absorption capacity are performed according to the method of Phillips et *al*. (1988) [32]. 1g of the dried Russian olive is mixed (m0) in 10 mL of water or oil and the whole was mechanically stirred for 30 min using a stirrer. The mixture was then centrifuged at 2200 g for 30 min in a centrifuge (Model: SIGMA 3K20). The pellet after centrifugation is weighed (mL), but for measuring the water retention capacity, it is first dried at 105 °C in an oven for 8 h (m2).

The water retention capacity (WAC) and oil absorption capacity (OAC) is calculated by the following formulas:

$$\mathrm{WAC}\ (\%) = \frac{\mathrm{m2} - \mathrm{m1}}{\mathrm{m1}} \times 100$$

(WAC) was expressed as g water pound by 100 g materials.

$$\mathrm{OAC}\ (\%) = \frac{\mathrm{m1} - \mathrm{m0}}{\mathrm{m0}} \times 100$$

(OAC) was expressed as g oil pound by 100 g materials.

2.3.2. Solubility properties

0.1 g of the dried Russian olives were placed into a centrifuge tube (known weight) then dissolved with 10mL of 1% acetic acid for 30min, using an incubator shaker operating at 240 rpm and 25°C. The solution was then immersed in a boiling water bath for 10 minutes, cooled to room temperature 25°C and centrifuged at 10.864 g for 10 min.The supernatant was decanted.The undissolved particles were washed in distilled water (25mL) then centrifuged at 10.864 g.

The supernatant was removed and undissolved pellets dried at 60°C for 24 hr. Finally, weighedtheparticlesand determined the percentage solubility [15]. Calculation:

$$\mathrm{solubility}\ (\%) = \frac{\mathrm{iw} - \mathrm{fw}}{\mathrm{iw}} \times 100$$

iw: Initial weight of the sample(g)
fw: Final weight of the sample (g)

2.3.3. Emulsion activity (EA) and emulsion stability (ES)

Emulsifying activity and stability were determined using the method of Neto et *al.* (2001) [29]. Five milliliters portion of dried Russian olive dispersion in water (10 mg·mL^{-1}) was homogenized with 5mL oil for 1min. The emulsions were centrifuged at 1100*g* for 5 min. The heightof emulsified layer and that of the total contents in the tube was measured. The emulsifying activity was calculated as:

$$\mathrm{Emulsifying\ property}\,(\%) = \frac{\mathrm{h1}}{\mathrm{h2}} \times 100$$

h1:height of emulsified layer in the tub (mL)
h2**:**height of the total content in the tube (mL)

Emulsion stability (ES) was measured by recentrifugation followed by heating at 80°C for 30 minutes and subsequently cooled to 15°C.

After centrifugation, the emulsified poured into 50 mL measuring cylinders and stay a few minutes until the emulsified layer was sTable. ES was expressed as the percent of the total volume remaining emulsified after heating.

$$\mathrm{Emulsifying\ stability}\ (\%) = \mathrm{h1}/\mathrm{h2}$$

h1: height of emulsified layer heating (mL)
h2:height of emulsified layer before heating (mL)

2.3.4. Foaming properties

2.3.4.1.Foam capacity (FC) and foam stability (FS)

The method of Coffman and Garcia (1977) [12] is used for the determination of the foaming capacity and stability of dried Russian olive. A weighed amount of flour is dispersed in 100 mL distilled water, after which the suspension was whipped vigorously for 2 min using a Phillips kitchen blender set at speed 2. Volumes were recorded before and after whipping. FC was expressed as the percentage increase involume. After 30 min, the volume of foam was measured and expressed as FS.

$$FC = \frac{Volume\ after\ whipping - Volume\ before\ whipping\ x\ 100}{Volume\ before\ whipping}$$

$$FS = \frac{Foam\ volume\ after\ time\ (t) x\ 100}{Initial\ foam\ volume}$$

2.3.5.Viscosity

The viscosity of fresh and dried Russian olive fruit extracts is measured using a Gemini 150 digital rheometer. Viscosity was displayed in mPa • s .

2.3.6.pH

1 g of the dried Russian olive is homogenized in 3 mL of distilled water. The pH of the solution obtained was determined using a pH-meter (Model: HANNA HI 2210) (AFNOR NF V 50-108) [2].

2.3.7.Total soluble solids (TSS)

TSS Measurement of the refractometric index (°Brix)

Total soluble solids (TSS) were measured with a refractometer (Refracto 30PX). One drop of liquid was extracted from Russian olive fruit with extraction and analyzed. The TSS content is expressed in °Brix (AFNOR NF V 50-109) [2].

2.3.8. Gelation properties

Gelation properties were studied by employing the method of Coffman and Garcia (1977) [12].

Sample suspensions of 2 – 20% were prepared in distilled water. Ten milliliters of each of the prepared dispersions were transferred into a test tube.

The test tubes were heated in a boiling water bath for 1 h, after which they were cooled in a bath of cold water. The test tubes were further cooled at 4°C for 2 hours. The least gelation concentration was taken as the concentration when the sample from an inverted test tube did not fall or slip.

$$\text{Gelation properties} = \frac{h1}{h2} \times 100$$

h1: Height of gélation layer in the tube (mL)
h2: Height of the total content in the tube (mL)

2.4. 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 2018 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 ($p \leq 0.05$).

3 .Results and discussion

3.1. Moisture content

The water content varies between 15.20 and 23.14% by weight of fruit. These results are similar to those of dried fruits such as fig (30.00%), prune (30.92%), cranberry (16.00%) and apricot (30.89%) [9]. This low water content leads to a decrease in water activity, less biochemical and microbiological alterations. These fruits have the advantage of being easy to store, so they can be consumed for several months and therefore used for industrial purposes.

3.2. Drying

3.2.1. Effect of mipcrowave gri ll power Levels on temperature: Temperature variations, drying curves, and drying rate curves about microwave output power levels were shown in Figure 1. The temperatures in Celsius units were measured with thermometer. The drying time decreases significantly and the drying rate increases sharply as the microwave-grill power level increases from 300 W to 450 W, and 600 W, which can be attributed to the fact that the electromagnetic intensity increases simultaneously with the increase in drying power level.

A great deal of heat energy is generated in a rapidly alternating electric field.

The importance of thermal energy production and the increase in the pressure difference at microwave-grill power levels above 600 W, resulting in an increase in the drying rate and final temperature of Russian olives to 60°C below 600 W. This can be explained by a large amount of thermal energy and a higher pressure difference at the power levels of the microwave grill which results in an increase in the drying rate and final temperature of the Russian olive fruits, as shown in Figure 2.

3.2.2. Effect of microwave-grill power levels on drying kinetics: The variations of the water content (X) versus time (S) for three powers of the microwave grill oven are shown in Figure 3.

Overall, we see regularly decreasing curves (Figure 2.), 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).

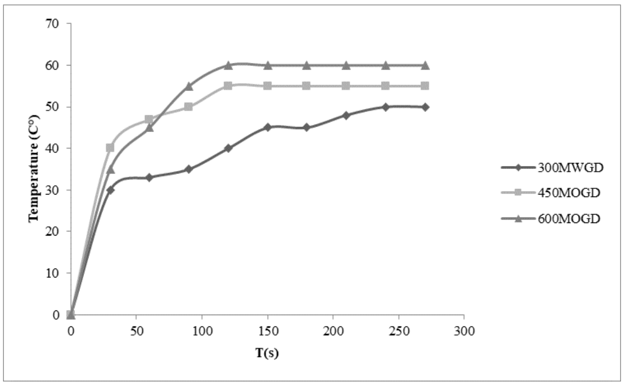

Figure 2. Drying curve of Russian olive fruit a different microwave-grill at different power levels (Temperature vs. drying time).

Obviously, drying time reduced with the increasing microwave-grill drying power levels from 300 W to 450 W and lastly to 600 W. Based on Figure2., 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.

Trade is less and less important as drying takes place because the amount of water remaining in the product is low and difficult to remove.

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 [23].

3.3. Effect of methods drying and extraction on the functional properties of Russian olive pulp

3.3.1. Water and oil absorption capacity: Water and oil absorption capacity are very important in the food system because of their effects on the flavor and texture of foods. As shown in Table1.

WAC (water absorption capacity) were calculated to assess the effect of drying and extraction methods in the Russian olive fruit (Table1). At higher power of microwave and extraction by heating under reflux results in structural damage that hinders water absorption capacity. This structural damage decreases the number and size of accessible capillary paths or pores, the capillary suction and affects water absorption capacity values [18, 28]. The water migration from the outside to the inner regions of the product is influenced by the product microstructure, which depends on the drying and extraction methods .

Water absorption capacity (WAC) of Russian olive fruits obtained in this study ranged between 58 and 222% as presented in Table 1. It is shown in Table 1 that the water absorption capacity (WAC) values increased with microwave power and decreased with increasing of drying and extraction time. The increased drying time (FD) was observed to produce a finer powder that possible to decrease a particle surface area and facilitated less water absorption capacity. However,water absorption capacity (WAC) value of a fresh sample was lower than the extracts samples as shown in Table 1 , that such differences in water absorption capacity (WAC) values be due to the application of different drying and extraction methods.

Drying by microwave-grill at 600 W and whatever the type of extraction (reflux heating and microwave at 200W) the Russian olive fruits is water absorption capacity between (220-222%), presented higher water absorption capacity (Table 1).

On the other hand, the fragile structure of freeze-drying and extracted by heating under reflux samples can explain the lower values of water absortion capacity of these samples when compared others to samples.

Besides, application of drying by microwave - grill and microwave at 200W extraction method showed a tendency to increase the product porosity and caused a more room space in powder to absorb water.

The effect of drying and extraction methods on oil absorption capacity (OAC) of Russian olive fruits is shown in Table 1. The oil absorption capacity values obtained from all treatments were in the ranges of 203- 210 %.

The type and time extraction was observed more controlling oil absorption capacity values than microwave power. The oil absorption capacity values showed a tendency to increase with longer extraction time, while decreased with increasing microwave grill power drying. The longer time extraction process produced a finer powder that might enlarge powder surface area for absorbing more oil.

The oil absorption capacity of a fresh sample was significantly higher than the dried fruits. However, it was concluded that the Russian olive fruit preferred to absorb more water than oil.

Sangnark and Noomhorm, (2003) [36] reported that particle size reduction of dietary fibers has been associated with a lower ability to retain water and a lower oil binding capacity. Lario et *al*, (2004) [24] reported that the high WAC of fiber concentrate could be used as a functional ingredient to avoid syneresis, modification of texture and viscosity and reduce calories of food formulations.

The reduction of water absorption capacity by both treatments could be as a result of hydrothermal treatment which blocked the tissue pores, thereby hindering water slippage and retention.

From Table 1, it can be seen that the oil absorption capacity is inversely proportional to the water absorption capacity. This makes sense. The ability of water and oil retention to respond to the structure of protein and polysaccharide macromolecules.

The interactions between the water and the constituents are established at the level of acid groups and amine groups present in the polysaccharides or at the level of the uncharged polar groups capable of forming hydrogen bonds with water, while the groups that are apolar in character can contribute to the structure of the water in there environment. According to Cloutour (1995) [11], heat treatments such as microwave -grill-drying can alter the polysaccharide and protein content and consequently the water and oil absorption capacity. It is noted that the capacity of water retention is clearly higher than that of the oil. This is explained by the abundance of the hydrophilic groups by adding to the hydrophobic groups, the Russian olive of which is rich in polysaccharides (pectins 1.43% and cellulose 3.92%) and low in lipid (0.55%) [14, 34].

3.3.2. Solubility: Solubility is an important characteristic for powdered ingredients that will be incorporated into dry mixes that must be reconstituted. To satisfy the normality assumption during the statistical analysis. The average solubility values for the Russian olive powder is Table1.

The solubility of the Russian olive produced at different drying and extraction traitement is illustrated in Table1.In general, the solubility of the freeze-dried fruits obtained increased with the rise of drying and extraction time.

As the inlet powers rose from 450 to 600 W and extracted by microwave at 200 W, the solubility increased from 74.49% to 74.65%.

The highest value obtained in freeze dried and extracted by heating under reflux (77.53%) and the lowest level is of powder produced at 600W and extracted by heating under reflux (74.46%).

The large particles were heavier and thus may be easily sunk; whereas the small ones were lighter therefore just floating on the water's surface. Consequently, the latter caused uneven wetting and reconstitution,therefore reducing the solubility of the powder.

In general, Russian olive components such as pectin and sugars are soluble in water, while proteins and lipids are readily soluble in acidic solutions diluted below pH 6 (pH4), which explains the use of Acetic acid in this technique (a 1% acetic solution is equivalent to pH 4).

According to Table 1, the solubility of dried by microwave grill at different powers is accepTable without significant difference (≥ (74%). The solubility of the macromolecules is influenced by several parameters (pH, ionic strength, drying, concentration, temperature, etc.).

Linden and Lorient, (1994) [25] show that the property of solubility has major consequences on other functional properties (Emulsification, gelling...). On the other hand, depending on the results obtained, the microwave grill drying does not have a negative effect; On the other hand, it retains this property. As a result, the other properties will be more or less conserved.

3.3.3. Emulsifying properties and emulsion stability: Table 1 shows the emulsifying capacity and the stability of emulsions Russian olive dried by microwave grill at different powers. Good capacity is observed for all samples (over 17%).

The emulsifying properties in and the emulsion stability of Russian olive samples are presented in Table 1. The emulsifying properties and emulsion stability of the Russian olive fruit were 17.17 and 32.12%, respectively.

It could be observed that the Russian olive fruit subjected to dry by two methods (microwave grill drying at different power and freeze-drying) and extraction by two techniques (extracted by microwave at 200 W and heating under reflux) had better ($P < 0.05$) emulsifying property and emulsion stability the highest value was obtained in microwave-grill-drying at 600 W and extracted by microwave at 200W of Russian olive sample (EP: 32.12% SE: 26.40, respectively).

Drying by microwave grill at different power (300,450 and 600 W) decreased caused significantty ($p<0.05$) decrease in emulsion capacity of Russian olive berry, when compared with the non-dried (control) samples. Drying by microwave grill at different power (300,450 and 600 W) decreased emulsion capacity Russian olive berry. The decrease in emulsifying property may be attributed to protein aggregation as well as surface hydrophobicity and change the characteristics, which affect emulsifying properties in different ways [10].

Emulsion capacity denotes the maximum amount of oil that can be emulsified by protein dispersion. The high emulsion capacity could be as a result of high content of free fatty acid, which leads to increased oil absorption [19].

On the one hand, Russian olive fruit s can exhibit good emulsifying properties under extraction conditions; on the other hand, heating treatment is conducive to the rapid expansion of protein molecules in the oil-water interface, thereby improving the emulsifying activity index and the emulsion stability of proteins [38].

Good emulsifying properties are beneficial for proteins that are to be used as fat emulsifiers in food formulations. It has also been confirmed that the formation of emulsions is due to presence of hydrophilic and hydrophobic protein groups [38].

3.3.4.Foaming capacity and foaming stability: As an important functional property of protein, foaming properties reflect the ability of protein to reduce the surface tension of water and air [7].

The results gathered in Table1 show that non-foam for Russian olive raw and dried by microwave grill at different powers. According to Lorient et *al.* (1988) [26], the formation of foams is based on the presence of proteins in quantity and quality, thus the low Russian olive protein content (0.29%) [1] is insufficient to form sTable foam. The shape, size, concentration, and hydrophobicity of the particles have been identified as the main factors in the formation of foams.

3.3.5. Viscosity: Viscosity is an important role in various applications, such as a gelling agent, thickening agent, emulsifier, stabilizer.

The effects of drying and extraction methods ont he viscosity of Russian olive fruits in a microwave grill dryer and in a freez-drying and extracted by microwave oven at 200W and heating under reflux are shown in Table 1.

The results shown in Table 1 indicate that drying Russian olive fruits in a microwave grill drying at different power can improve the viscosity properties of samples. The highest viscosity was found after using freeze-drying for 68 hours and extracted by heating under reflux (2,37 mPas). The relationship between viscosity and porosity of Russian olive fruit is shown in Table 1.

They found that porous cellulose beads were considered to consist of a three-dimensional skeletal fiber system on which the liquid can be taken up both in the pores between fibers and in the solid fiber matrix itself. Moreover, it was found that the pore size in cellulose beads almost doubled when the beads were swollen in water. For this reason, the microwave -grill- drying at higer power samples with low porosity resulted in a less viscous liquid particle shape of Russian olive fruit

During microwave – grill - drying, heat was generated and water was evaporated rapidlywith the increase in power to outside of the Russian olive fruit. Thus, the Russian olive powders were ruptured and showed arough shape. Hence, the ratio of the surface area to the volume of the granules increased and contributed to the decreased viscosity of the sample.Significant changes in viscosity may be due to the significant impact of the process drying on the biochemical composition Russian olive fruit. As also explained by Simas-Tosin et al (2010) [37], the presence of oligosaccharides with free reducing functions, phenolic compounds and inorganic salts and polysaccharides in the structure of the Russian olive fruit. The effect of drying on the polysaccharide viscosity of Russian olive fruit could be due to the different proportions of soluble materials compared to insoluble materials.

3.3.6. pH: The pH of the fresh Russian olive by two extraction methods fruit was between 5.14 and 5.92 The pH values of the microwave grill drying at different power and freeze-drying samples were slightly higher than the fresh fruit values; however, there were significant differences among treatments.

Generally, the recorded pH is acid in the vicinity of 5; This is explained by the presence of free organic acids in the Russian olive [35] such as malic acid (0.67mg/100g), oxalic acid (0.08mg/100g), ascorbic acid (0,08mg/100g), acetic acid (0.52mg/100g), citric acid (0.59mg/100g), tartaric acid (0.52mg/100g) and formic acid (0.05mg/100g) .

*3.3.7. Total soluble solids (TSS):*The soluble solids content decreased in all of the dried samples exception freeze-drying Russian olive fruit compared to the fresh fruit (the content diminished between 13.20 and 80.18%).

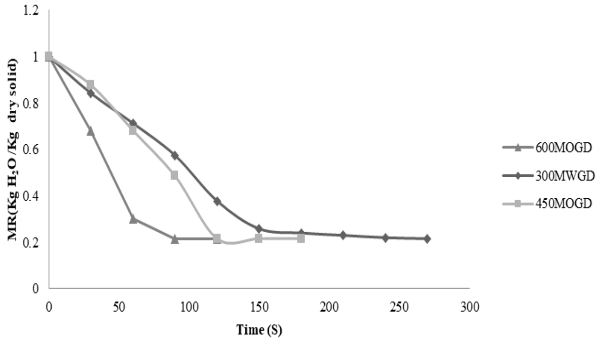

Figure 3. Variation in moisture content X (kg H_2O / kg dry matter) versus time (S) of dried Russian olive in microwave grill at different power.

Significant changes in TSS after microwave drying were obtained due to variation power level. Decreased moisture content in fruits is generally accompanied by an increased percentage of TSS since TSS is the main component of dry matter [27]. Thus, the value of TSS is significant ($P < 0.05$) decreased after drying (Table 1).

According to our results, we found that the temperature and the treatment time had no effect on pH and Brix°.

Table 1. Effect of drying and extraction techniques on the water and oil absorption capacity, solubility, mulsifying capacity, emulsion stability, foaming power, viscosity, pH and total soluble solid of Russian olive

	Water absorption capacity (%)	Oil absorption capacity (%)	Solubility capacity (%)	Emulsifying activity (%)	Emulsifying stability (%)	Foaming capacity (%)	Viscosity (mPa.s)	pH	Total soluble solid [Brix°]
Drying and extraction methods									
ElafrMW									
300GElaMW	97.916±0.02^{f}	205.15±0.05^{d}	76.79±0.07^{b}	17.71±0.00^{d}	20.93±0.42^{h}	0	2.08±0.00^{b}	5.92±0.00^{ab}	10.6±01^{b}
450GElaMW	118.41±0.00^{e}	206.33±0.10^{c}	76.41±0.23^{bc}	18.00±0.00^{c}	21.13±0.15^{g}	0	1.92±0.01^{c}	5.50±0.03^{c}	9.2±0.2^{c}
600GElaMW	217.96±1.33^{b}	210.29±0.20^{ab}	74.54±0.39^{c}	19.36±0.30^{b}	22.09±0.32^{c}	0	1.17±0.02^{ef}	6.01±0.04^{a}	2.4±0.00^{h}
ElaFDMW	220.89±0.60^{a}	210.42±0.03^{a}	74.49±0.09^{b}	26.40±2.90^{a}	32.12±0.23^{a}	0	1.15±0.02^{ef}	6.06±0.01^{a}	2.2±0.01^{i}
	212.10±0.00^{b}	210.04±0.00^{ab}	74.65±0.70^{cd}	19.28±0.00^{b}	22.04±0.56^{d}	0	1.22±0.03^{c}	5.14±0.01^{d}	2.8±0.01^{g}
ElafrHUR									
300GElaHUR	168.18±3.06^{d}	208.16±0.30^{b}	75.47±0.35^{b}	18.68±0.02^{c}	21.61±0.10^{f}	0	1.55±0.05^{c}	5.14±0.01^{d}	5.8±0.06^{d}
450GElaHUR	193.07±0.01^{b}	209.22±0.04^{b}	75.01±0.10^{cd}	19.02±0.01^{b}	21.85±0.06^{e}	0	1.36±0.01^{e}	5.84±0.04^{b}	4.1±0.00^{f}
600GElaHUR	175.50±0.46^{c}	208.47±0.03^{b}	75.34±0.21^{cd}	18.78±0.12^{c}	21.68±0.55^{d}	0	1.49±0.03^{d}	5.98±0.04^{ab}	5.3±0.12^{e}
ElaFDHUR	222.35±2.07^{a}	210.48±0.08^{a}	74.46±0.40^{d}	19.42±0.36^{b}	22.14±0.03^{b}	0	1.11±0.00^{f}	6.05±0.01^{a}	2.1±0.01^{i}
	58.38±0.47^{g}	203.46±0.06^{f}	77.53±0.30^{a}	17.17±0.00^{e}	20.55±0.81^{i}	0	2.37±0.06^{a}	5.88±0.00^{b}	13.3±0.51^{a}

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 2. Effect of drying and extraction techniques on the water and oil absorption capacity, solubility, emulsifying capacity, emulsion stability, foaming power, viscosity, pH and total soluble solid of Russian olive.

	Water absorption capacity (%)	Oil absorption capacity (%)	Solubility capacity (%)	Emulsifying activity (%)	Emulsifying stability (%)	Foaming capacity (%)	Viscosity (mPa.s)	pH	Total soluble solid [Brix°]
Drying and extraction methods									
ElafrMW									
300GElaMW	97.916±0.02^{f}	205.15±0.05^{d}	76.79±0.07^{b}	17.71±0.00^{d}	20.93±0.42^{h}	0	2.08±0.00^{b}	5.92±0.00^{ab}	10.6±01^{b}
450GElaMW	118.41±0.00^{e}	206.33±0.10^{c}	76.41±0.23^{bc}	18.00±0.00^{c}	21.13±0.15^{g}	0	1.92±0.01^{c}	5.50±0.03^{c}	9.2±0.2^{c}
600GElaMW	217.96±1.33^{b}	210.29±0.20^{ab}	74.54±0.39^{c}	19.36±0.30^{b}	22.09±0.32^{c}	0	1.17±0.02^{ef}	6.01±0.04^{a}	2.4±0.00^{h}
ElaFDMW	220.89±0.60^{a}	210.42±0.03^{a}	74.49±0.09^{b}	26.40±2.90^{a}	32.12±0.23^{a}	0	1.15±0.02^{ef}	6.06±0.01^{a}	2.2±0.01^{i}
	212.10±0.00^{b}	210.04±0.00^{ab}	74.65±0.70^{cd}	19.28±0.00^{b}	22.04±0.56^{d}	0	1.22±0.03^{c}	5.14±0.01^{d}	2.8±0.01^{g}
ElafrHUR									
300GElaHUR	168.18±3.06^{d}	208.16±0.30^{b}	75.47±0.35^{b}	18.68±0.02^{c}	21.61±0.10^{f}	0	1.55±0.05^{c}	5.14±0.01^{d}	5.8±0.06^{d}
450GElaHUR	193.07±0.01^{b}	209.22±0.04^{b}	75.01±0.10^{cd}	19.02±0.01^{b}	21.85±0.06^{e}	0	1.36±0.01^{e}	5.84±0.04^{b}	4.1±0.00^{f}
600GElaHUR	175.50±0.46^{c}	208.47±0.03^{b}	75.34±0.21^{cd}	18.78±0.12^{c}	21.68±0.55^{d}	0	1.49±0.03^{d}	5.98±0.04^{ab}	5.3±0.12^{e}
ElaFDHUR	222.35±2.07^{a}	210.48±0.08^{a}	74.46±0.40^{d}	19.42±0.36^{b}	22.14±0.03^{b}	0	1.11±0.00^{f}	6.05±0.01^{a}	2.1±0.01^{i}
	58.38±0.47^{g}	203.46±0.06^{f}	77.53±0.30^{a}	17.17±0.00^{e}	20.55±0.81^{i}	0	2.37±0.06^{a}	5.88±0.00^{b}	13.3±0.51^{a}

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**).

3.3.8. Gelation properties

The effect of drying on extraction methods on gelation capacity of *Elaeagnus angustifolia* fruits was presented in Table 1. Gelation proprties characterizes the tenderness or hardness of cooked fruit when cooling down.

The gelation concentration of Russian olive fruit raw and dried is shown in Table 2. It formed a weak gel at 2 %, strong gel at 16 and 20% and very strong gel.

Table 2 shows that the effect drying and extraction methods on gelation properties value was higher than dried in microwave at 600W and freez-drying and extracted by microwave at 200 W (20% concentration of *E.angustifolia*, 100% gelation). The value of fresh sample was lower than microwave-grill dried fruits at 600W as illustrated in Table 2. This suggested that the use of microwave – grill - drying method could increase the softness of cooked Russian olive fruit.

The Russian olive fruit has concentration of 20 % has least gelation capacity 77.07% of fruit dried in microwave – gril l- power 600 W and extracted by heating under reflux. This study showed that snakegourd Russian olive fruit a higher concentration for gel formation and may find useful applications in food systems such as sausage emulsion, sauces that require thickening and gelling.

The least gelation capacity results for microwave grill at 300 W dried Russian olive is 2%, and microwaved grill at 600 W samples ranged from 12% to 16%. The gel - forming ability is reported to be influenced by the nature of the protein in the sample as well as their interaction during heat treatment [40].

According to Table 2, the gelling power for the Russian olive fruit dried at 300 and 450 W and for the concentrations 16 and 20% are excellent it reaches 100%, these results are explained by the richness of Russian olive in (pectins 1.43% and cellulose 3.92%) [34].

In general, the concentration expresses the percentage of the gelling agents (proteins, polysaccharides, etc.), a proportional increase in the gelling power with the increase of the concentration, the better is the gelating ability of the protein ingredient [3]. Variations in gelling properties may be ascribed to the ratios of different constituents, such as proteins, carbohydrates, and lipids.

Gelation is an aggregation of denatured molecules and protein concentration, especially globulin fraction, and interactions between proteins, carbohydrates and lipids have been reported to be responsible for the gelation capacity of legume and oil seed protein [16].

Gelatinization influences the textural quality when powder of the Russian olive fruit is incorporated into food products such as creams, soups, puddings, pie fillings and many sauces in viscosity.

4. Conclusions

It was determined that the drying techniques had a considerable impact on the Russian olive samples' drying kinetics and functional properties. Microwave drying technique remarkably minimized the drying duration in proportion to freeze techniques.

Moreover, the kinetics of the dehydration of Russian olive fruit shows that microwave drying time is short in supply to other drying methods. This reveals the economic importance of dehydration by microwave of the Russian olive fruit.

In the drying process, power and long exposure times contribute significantly to the decreasing of emulsifying property content present in the Russian olive fruit. At 600W occurs its lowest decreasing.

It was determined that microwave drying took shorter drying time than freeze-drying. In addition, the Russian olive pulp, those that were dehydrated and extracted by microwaves, had better functional properties than those obtained by heating under reflux methods.

The effect microwave–grill-drying at different level (300,450 and 600 W) on the functional properties of Russian olive fruit has a relatively low water absorption capacity compared to Russian olive fruit raw. The higher functional properties of Russian olive fruit dried in a microwave - grill - drying at 600 W is very important.

The best functional properties of the dried Russian olive samples in microwave grill at different power were extracted by the microwave at 200W techniques.

These results allow us to conclude that Russian olive fruit, dehydrated and extracted by microwaves have great potential for use as food ingredients, not only because of their better functional properties, but also because they can be produced in shorter times, which could also generate some economic benefits. These results represented useful information for drying and extraction processes for the production of Russian olive pulp by products.

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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