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Damage caused by mechanical harvesting of olive fruit on the chemical and dielectric properties of extracted extra virgin olive oil

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ABSTRACT

In this study, in order to investigate the effect of mechanical impact during olive fruit harvesting on the quality of the extracted oil, the effect of two factors, the type of finger-hammer at two levels and the ripeness of the olive fruit at three levels, was investigated. The statistical method used for this was a factorial experiment in a randomized complete block design, and the comparison of means was performed based on Duncan's multiple range test at the 5% level. An impact harvesting device, on whose axis of rotation was installed a different type of finger-hammer made of neoprene and ethylene propylene rubber (EPR), was used to harvest three types of oil, yellow and fish olive fruits at three stages: immature, semi-ripe and ripe. The qualitative characteristics of olive oil, including acidity, peroxide, sterol compounds, fatty acid composition and total phenol of the extracted olive oil, were investigated. Dielectric properties related to chemical characteristics were also measured. The phase and amplitude oscillation voltage changes were obtained using the dielectric spectroscopic technique and the output data were evaluated by artificial neural network (ANN) and support vector machine (SVM). Analysis of the means as well as the examination of quality indicators showed that although the extracted oil of the samples was extra virgin olive oil (EVOO), the quality of the olive oil samples extracted by EPR was higher than that of neoprene.

1- Introduction

more than half of the produced olives belong to Spain, Greece and Italy. Also, the production of extra virgin oil in the world was more than 3500 kg, which shows the importance of olive oil in the food industry chain (FAO, 2020).

The healthy properties of olive oil compared to other oils, increase the tendency of consumers to use this product day by day. Olive oil contains a large amount of unsaturated fatty acids (70-80%), oleic acid (55-75%), linoleic acid (6-12%) and biophenolic compounds [1]. The chemical properties of olive oil depend on the olive cultivar (cv), climatic characteristics as well as ripeness stage of the olive. Also, mechanical damage caused by the harvesting and post-harvest process affect the quality of olive oil [2]. Many researchers and engineers carried out some research to reduce mechanical damage in the olive harvest process [3, 4, 5]. Despite the fact using vibration harvester leads to less damage to olives, some farmers prefer to use impactor harvester (IH). Although the IH increases the mechanical damages, this device is proper and useful for small scale orchards. On the one hand, the mechanical damage caused by the impact of the IH head with the olive leads to bruising, which reduces the customer's trend to purchase this product. On the other hand, this mechanical damage affects some qualification factors of extra virgin olive oil (EVOO) such as acidity and peroxide value, palmitic acid, oleic acid as well as unsaturated fatty acids [6].

Non-destructive methods for determining the quality of olive oil have attracted the attention of researchers. The quality of olive oil can be achieved using the Ultrasonic [7], Near-infrared spectroscopy [7], image processing [8] Fluorescence Spectroscopy [9] methods. Also, dielectric spectroscopy is a non-destructive method with acceptable accuracy. Due to the different chemical properties of the various EVOO, the dielectric properties change. Oleic acid is one of the quality factors of olive oil. As the oleic acid increases, the dielectric content decreases [10]. Furthermore,
by decreasing or increasing other quality factors of olive oil, the dielectric rate is converged [11]. Therefore, the non-destructive method of dielectric spectroscopy can be used to assess the quality of olive oil. The aim of this study is to concentrate on two issues. (i): to assess the effect of IH head made of Ethylene Propylene Rubber (EPR) compared Neoprene on the chemical characteristics of extracted EVOO. (ii): Measurement the dielectric properties of extracted EVOO as a quality factor. For this reason, a low frequency portable capacitive sensor was used to obtain the phase shift and gain voltages. Also, in order to analysis the data, two methods of artificial neural network (ANN)and support vector machine (SVM) were used.

2-Material and methods

2.1. Sample preparation and physical-mechanical properties

Three types of Oily, Yellow and Fishemi have different physical-chemical properties and widely consume in Mediterranean regions. Also, the physical, mechanical and chemical characteristic of olives during the ripening period change. Therefore, olive samples were harvested in three different ripening stage include: unripe (early October), semi-ripe (early November) and ripe (late November). Determining the appropriate IH head to achieve qualified olive and EVOO depends on their physical and mechanical properties during the ripening period. On the other word, using determination of mechanical characteristics of olive during ripening stages, the material of the IH can be determined in such a way that the least mechanical damage is achieved. Physical properties include size, volume, density and moisture. To obtain the dimensions of olives, a digital caliper (accuracy of 0.001) was used. Also, the moisture of the samples was specified by the method proposed by Boukhiar [12] and fluid displacement method was used to obtain the density of olive [13]. The most important mechanical properties of agriculture products include fracture force, fracture energy, modulus of elasticity and bio yield stress point [14]. To obtain the mentioned factors, stress-strain test was carried out (Santam, STM20 device). Five intact samples of each cultivar and ripe level were selected. Loading was performed on the samples using the flat plate method. The maximum accuracy of mechanical properties for viscoelastic material can obtained at a loading rate of 5-15 mm/min (ASABE). Therefore, the loading rate of 5 mm/min and frequency of 10 Hz using load cell of 50 N were applied.

In this research, two types of IH machines with different harvester head material (EPR and Neoprene) were used. Considering to pre-tests harvesting by IH, a speed of 300 rpm had acceptable yield for harvesting the olive. In addition, this velocity lead to minimum damage. Samples were harvested in one day with the equal weather conditions. Then, the samples were transported to laboratory to oil extraction process.

2.2. Process of EVOO extraction

Olive oil extraction was carried out using the Oliomio GOLDFrance machine. The olive samples were washed and the leaves were separated [15]. The samples were transferred to the malaxor of the machine for 30 minutes at a temperature of 27 ° C. Then, the crushed samples were centrifuged at 5000-6000 rpm. Finally, after the filtration process by a separator, the EVOO samples were packed in dark glass containers and stored at 4 ° C.

2.3. Quality indices of extracted olive oil

2.3.1. Acidity and peroxide value

In order to obtain acidity and peroxide value, the Kiritsakis [16] Method was used. For this purpose, 5 g of the olive oil sample was mixed with 50 ml of neutral and hot ethanol and titrated with phenolphthalein. Also, to obtain the amount of peroxide, 30 ml of acetic acid + isooctane solution (ratio of 3 to 1) was prepared and added to 5 g of olive oil sample. Then, 0.5 ml of saturated potassium iodide (KI) was added to the contents of the container and the container was placed in a dark place for 1 minute. Furthermore, 30 ml of distilled water was added and 1% starch solution was added to the container.

2.3.2. Composition of fatty acids

The samples were prepared as a fatty acid methyl ester derivative and then injected into GC device (model Yung Lin 6500, South Korea). The detector and injector temperature were considered to280 ° C and 260 ° C, respectively. Methylation of fatty acids was performed according to Standard No. 13126-2. In this method, by adding 2 ml of hexane and 200 µl of 2 M methanolic potash, methylated at room temperature and after dehydration with anhydrous sodium sulfate, the methylated sample was injected into the GC machine.

2.3.3. Total phenol

The amount of total phenol was obtained by Veneziani [17] method. Using Folin's reagent, the total phenol content of the samples was determined. To perform the experiment, five ml of Folin's reagent was mixed with 50 ml of distilled water. Then, one ml of the sample was mixed with 1.5 ml of folic acid and placed at room temperature (21±1) for five minutes. Finally, 1.5 ml of sodium carbonate was added to the solution and placed in a dark room for 70 minutes. The absorption process was performed at 765 nm and the concentrations were calculated. Standard curves were obtained with concentrations of 20, 25, 50, 75, 100, 125 and 150 µg.

2.3.4. Sterol compounds

determination of sterol compounds was performed using gas chromatography (GC) and Cercaci et al (2003) method. Specifications of the experiment include SE-54 gas chromatography column, hydrogen carrier gas with a flow rate of 36 cm / s, injection temperature and detector 320 ° C, temperature program of 240 to 255 ° C. By calculating the level below each peak, the amount of sterol compounds was determined [18].

2.4. Dielectric spectroscopy

A low frequency portable dielectric spectroscopic system was used to determine the non-destructive quality of olive oil. The dielectric system consisted of an ATMEGA 32 microcontroller, a direct voltage circuit, a capacitive sensor, a signal generation circuit, serial receivers and transmitters and an LCD display (Figure 1). DAC0800 chip is used to generate the signal. Also, the output frequency (10 kHz to 1 MHz) was controlled using an external resistor and a variable capacitor. AD8307 chip was used to measure dielectric constant (ε′) and loss factor (ε"). The qualification experiment was carried out with three repetitions at room temperature.

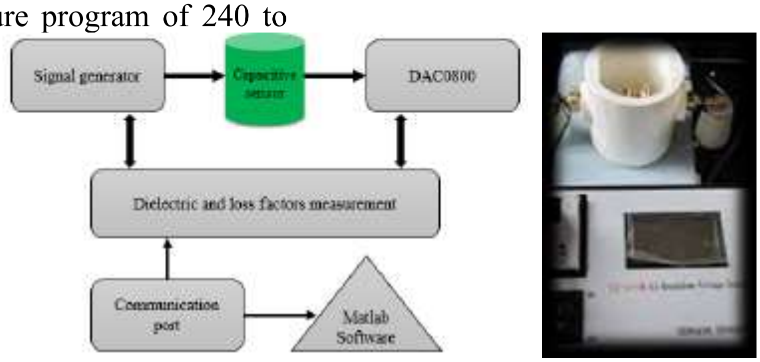


Fig.1. Schematic illustration of the portable dielectric spectroscopy system

At each connection of the capacitive sensor to the computer, two data of ε′ and ε" were acquired (equation.1 and 2). dielectric and loss factors depend on phase shift (Δφ), is the thickness of the sensor (d), speed of voltage(c), frequency of signal (f) and attenuation (ΔA).

$$\varepsilon' = [1 + (\Delta\varphi/360 \times d)(c/f)]^2 \quad (1)$$

$$\varepsilon'' = [(\Delta_A/8.68 \times \pi)(c/f)\sqrt{\varepsilon'} \quad (2)$$

2.5. Artificial neural network (ANN)

The development of artificial intelligence leads to an increase in the accuracy of mathematical models in qualitative studies of food industry products. Various models of ANN including Kohonen self-organizing maps [19], Multi-layer perception and Counter propagation [20] have been developed to analyze the data. In this research, a Multi-layer perception (MLP) model with a back-propagation algorithm were used to design and train neurons. Although the number of hidden layers can have a positive effect on the data results, it enhances the analysis time. Therefore, one hidden layer with 1-10 neurons was considered. Furthermore, gradient descent momentum (GDM) was applied to minimization the error. Input data include voltages of the dielectric and loss coefficients, and the output of the network was the class of EVOO.

2.6. Support Vector Machine (SVM)

The SVM is an efficient system that not only provides acceptable accuracy by minimizing errors but also reduces analysis time [21]. In the SVM regression model, a function with a dependent variable (which is itself a function of several independent variables) is predicted and finally separates the two classes using a linear boundary. Similar to ANN and mathematical systems, SVM has different algorithms. In this research, three kinds of SVM functions consist of the kernel (RBF), polynomial and linear were used. In equations of the kernel-RBF [22] function, the amount of γ can affect the amount of accuracy and error. The γ control the width of the kernel function and represents a great influence on mapping data onto the higher dimensional space. Therefore, three values of 0.01, 0.1 and 1 were considered for the RBF function and the value that provided the maximum accuracy was used. Also, in the polynomial equation [23], the amount of factor C can be effective in maximizing accuracy. Hence, for achieve best result three values of 0.01, 01 and 1 were considered for the polynomial function.

In order to comparison the developed models of ANN and SVM, two statistics criteria of R2 and RMSE was applied (equation 3 and 4). In addition, Matlab 2018.b software was used for design evaluation of ANN and SVM models.

$$\mathrm{RMSE}= \sqrt{\left[\sum_{i=1}^{n}(y_a-y_p)^2/n\right]} \quad (3)$$

$$R^2= \sum_{i=1}^{n} (y_a-y_p)^2/\sum_{i=1}^{n} (y_a-\hat{y}_a)^2 \quad (4)$$

Where ya , yp and $\hat{y}a$ are real value, predicted value and average value, respectively.

3-Results and discussion

In this study, in order to investigate the effect of mechanical harvesting on the quality of extracted olive oil, the effect of two factors, the material of the hammer at two levels (Neoprene and Ethylene Propylene Rubber (EPR)) and the ripeness of the olive fruit at three levels (oil, yellow and fish olives at three stages of immature, semi-ripe and ripe), was investigated. The statistical method used for this was a factorial experiment in a randomized complete block design and the comparison of means was performed based on Duncan's multiple range test at the 5% level. The qualitative characteristics of olive oil, including acidity, peroxide, sterol compounds, fatty acid composition and total phenol of the extracted olive oil, were investigated. Dielectric properties related to chemical characteristics were also measured. The changes in phase and amplitude oscillation voltage were obtained using the dielectric spectroscopy technique and the output data were evaluated by artificial neural network (ANN) and support vector machine (SVM). Analysis of the averages as well as the examination of quality indicators showed that although the olive oil extracted from all samples was extra virgin olive oil (EVOO), the quality of the olive oil samples extracted by EPR was higher than that of neoprene.

3.1. Physical and mechanical characteristics

The physical properties of the samples including volume, mass, moisture, sphericity and density were obtained by performed research of Rashvand [24]. The moisture content of the Yellow cv in the unripe stage was more than the Oily and Fishemi cv. The mechanical properties of each class (with five repetitions) were investigated and reported (Table 1.). In the semi-ripe and ripe levels, the fracture force of Oily cv was more than the Yellow and Fishemi cv. It seems over time, the amount of produced oil in the Oily cv has been more and is also a reason for being more resistant rather than Yellow and Fishemi cv. In the semi-ripe stage, the maximum fracture forces of Oily, Yellow and Fishemi were199.84, 170.24 and 157.49 N, and also in the ripe stage were 132.36, 71.63 and 59.73 N, respectively. The trend of fracture and energy force of samples indicates the resistance of the Oily cv in the semi-ripe and ripe stage was more than the other two species. It seems that the two factors of mass and oil had an effect on the fracture and energy of olive. Also, with the increasing ripeness of the olive fruit and due to the chemical activities inside the olive fruit (olive flesh), the resistance of the olive to deformation decreased. In the unripe stage, the resistance of the Yellow cv was more than the Oily and Fishemi cv and Young's modulus of the Yellow, Oily and Fishemi were 5.81, 5.51 and 5.17 MPa and also bio yield stress of samples were 1.35. 1.32 and 1.1 MPa, respectively. Similar to the report [25], the amount of oil in olive flesh increased the resistance to deformation of the olive fruit.

Table 1. Mechanical properties of samples during the ripening periods

Cultivar ⬇	Parameter ⬇	Fracture Force (N)	Fracture Energy (J)	Bio-yield Stress (MPa)	Young's modulus (MPa)
Oily	U	212.51±38	0.696±0.15	1.32±0.1	5.51±0.2
	S	199.84±27	0.664±0.14	1.24±0.1	3.41±0.1
	R	132.36±21	0.271±0.07	0.39±0.01	1.69±0.05
Yellow	U	241.08±36	0.761±0.13	1.35±0.08	5.81±0.3
	S	170.24± 26	0.546± 0.09	0.79±0.01	2.73±0.1
	R	71.63± 11	0.152± 0.03	0.17±0.02	0.46±0.01
Fishemi	U	182.34± 25	0.592±0.07	1.1±0.05	5.17±0.2
	S	157.49±19	0.499± 0.08	0.49±0.01	2.44±0.09
	R	59.73±10	0.142±0.04	0.09±0.01	0.32±0.02

Note: U, S and R are abbreviation of unripe, semi-ripe and ripe stages, respectively.

3.2. Acidity and Peroxide

The amount of acidity indicates the hydrolysis of triacylglycerols and is affected by the type of cultivar, storage temperature, extraction and processing method of olive oil [26]. The intact olive has lower acidity value and higher quality. In addition, the ripening period of the olive fruit affects the level of acidity. The acidity and peroxide content of the extracted oil samples were investigated with three replications. As the amount of ripening increases, the acidity of the oil increased. (Figure 2-a). The peroxide parameter indicates the degree of oxidation of the lipid system in terms of the amount of produced hydroperoxides. Contrary to the degree of acidity, the amount of peroxides value was decreased with increasing degree of ripening.

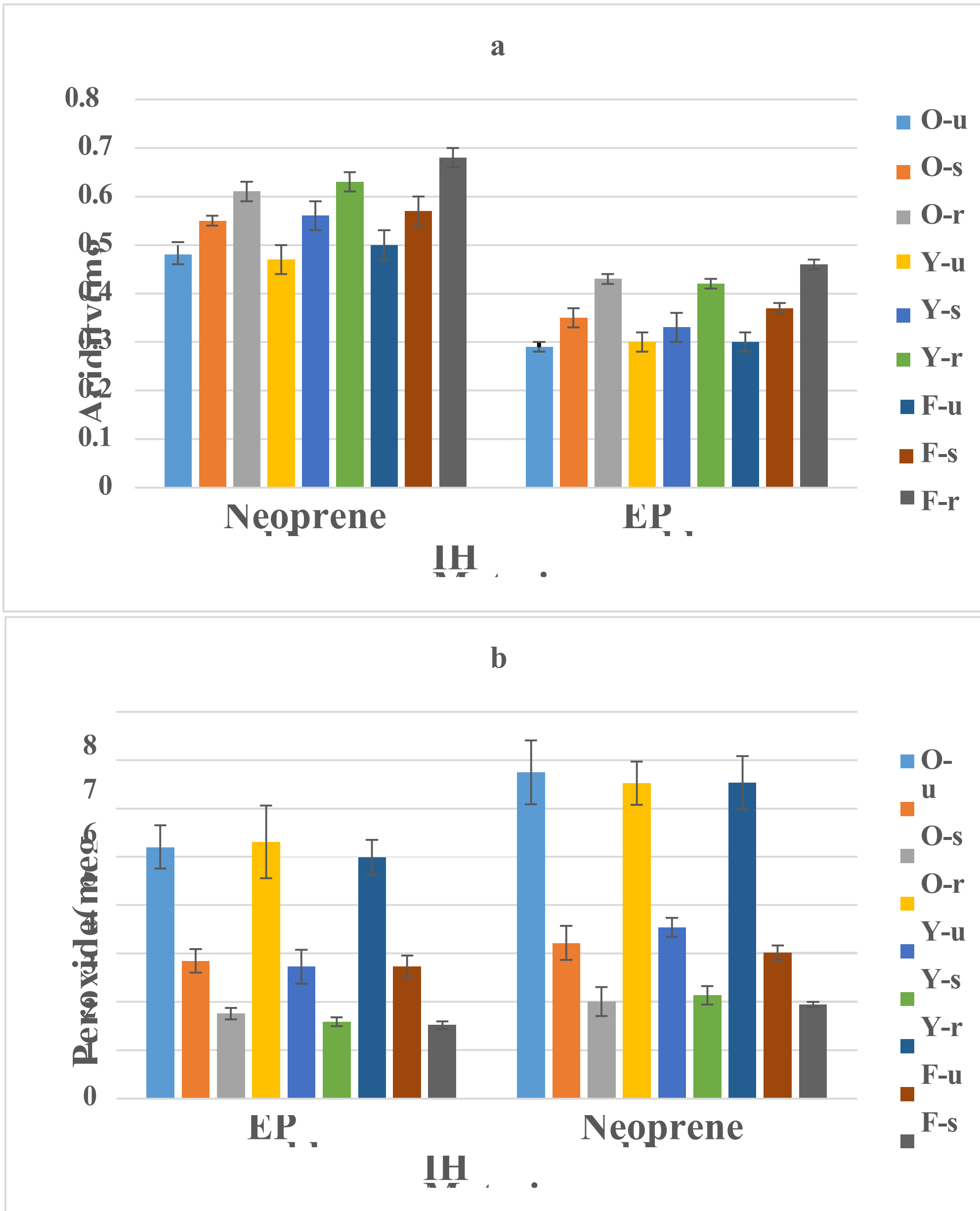


Fig2. The result of acidity and peroxide value of samples

Also, figures 2-a and 2-b show the effect of IH with EPR and neoprene head on acidity and peroxide indices. At all stages of ripening, the acidity and peroxide index of EVOO which harvested by EPR was lower than Neoprene. For example, the lowest acidity of extracted olive oil obtained from EPR and Neoprene was 0.29 and 0.47 mg KOH / g oil, respectively. Furthermore, the maximum amount of olive oil peroxide extracted from EPR and Neoprene were 1.52 and 1.95 meg O^2/kg oil, respectively. Although all samples of extracted olive oil were EVO components, the quality of extracted olive oil from EPR harvest was more than Neoprene.

3.3. Fatty acids component

Table 2 shows the amount of fatty acids of samples extracted by EPR. The amount of palmitic acid decreased with the increasing ripening stage for three types of Oily, Yellow and Fishemi cv. Conversely, stearic acid levels increased with increasing ripening. In addition, the lowest amount of heptademic acid was achieved at unripe stage. The results were consistent with the reports by Razeghi and seifi [27, 28]. On one hand, during the three harvest periods, oleic acid had the highest amount of unsaturated fatty acids. The increasing trend of oleic acid during three harvest periods increased the ratio of oleic acid to linoleic acid. Previous researchers have used this factor as a quality assessment of olive oil [29, 30, 31]. Higher ratio of oleic acid to linoleic acid increases the oxidative resistance of olive oil, which is a desirable feature for EVOO. On the other hand, previous researchers have considered the correlation between the ratio of polyunsaturated fatty acid to monounsaturated fatty acid as a quality factor[29, 31]. Low ratio of the mentioned factor, indicates higher oxidative resistance of the oil, which leads to higher quality olive oil. Extracted olive oil from unripe samples had the highest ratio. In other words, with increasing olive ripeness, the resistance of the extracted olive oil to oxidation decreased. However, the olive fruit at the beginning of the ripening period contains high biophenolic compounds which leads to a decrease in the percentage of oil in the olive.

Table2. Fatty acid composition of EVOO samples during ripe stages- IH with EPR

Cultivar ⬇	Parameter ⬇	C16- Palmitic acid	C17- Heptadic anoic acid	C18- Stearic acid	C18: 1c- Oleic acid	C18: 2c- Linoleic acid	PUFA: Poly Unsaturated Fatty acids	MUFA: Mono Unsaturated Fatty acids	SFA: Saturated Fatty acids
	U	14.88±0.7	0.02±0.01	1.68±0.18	65.79± 2.31	8.22± 0.11	8.36± 0.15	61.37± 1.75	16.37±0.32
Oily	S	14.04±1	0.03±0.01	1.95±0.24	76.42± 2.22	7.98±0.08	7.58± 0.12	67.38± 2.49	16± 0.21
	R	13.68±0.85	0.03±0.01	2.2± 0.2	81.24 ±1.14	7.54±0.05	6.34± 0.08	72.45± 0.95	15.24±0.12
	U	15.56± .92	0.03±0.01	1.58± 0.38	61.24± 1.24	9.32± 0.1	9.24± 0.06	64.28± 2.13	16.85±0.24
Yellow	S	15.24± .55	0.04±0.01	2.47± 0.62	78.24± 2.35	8.56± 0.06	8.75± 0.11	70.85± 0.92	16.15±0.16
	R	15.11±1.2	0.03±0.01	2.28±0.31	82.14± 1.27	8.08± 0.07	7.98± 0.1	78.16± 1.16	15.11±0.09
	U	15.8±1	0.02±0.01	1.85±0.12	62.14±1.25	8.12± 0.12	8.85± 0.06	61.52±2.74	15.95±0.21
Fishemi	S	14.48± .75	0.02±0.01	1.93± 0.1	74.35± 2.39	7.82± 0.1	8.02± 0.12	67.36± 2.2	15.32±0.18
	R	14±0.86	0.03±0.01	2.35± 0.2	81.66± 1.58	7.02± 0.07	7.32± 0.06	69.35± 1.85	14.85±0.21

Note: U, S and R are abbreviation of unripe, semi-ripe and ripe stages, respectively

Table 3 shows the amount of saturated fatty acids extracted by the IH with Neoprene head. Two important factors for comparing the quality of oils extracted from EPR and Neoprene are the ratio of oleic acid to linoleic acid and the ratio of monounsaturated fatty acid to monounsaturated acid. Due to the higher level of oleic acid and the smaller amount of linoleic acid in the EPR olive oil samples, the quality of EVOO oil was higher. For example, the oleic acid content of EPR oil (in unripe, semi-ripe and ripe olive oils samples) were 65.79 ± 2.31%, 76.42 ± 2.22%, 81.24 ± 1.14% and linoleic acid were 8.22 ± 0.11% 7.98 ± 0.08 7% and 54 ± 0.05%, respectively. While the amount of oleic acid of olive oil extracted from the extraction of olive oil by Neoprene (in unripe, semi-ripe and ripe olive oils samples) were 60.14 ± 3.24

%,68.47 ± 5.26%, 78.19 ± 2.45 and the amount of leonic acid were 13.24 ± 0.24 %, 12.22 ± 0.31%, 11.85 ± 0.15. Also, the smaller ratio of unsaturated polyunsaturated fatty acid to monounsaturated fatty acid of olive oil extracted with EPR compared to neoprene indicates the higher quality of this EVOO.

Table3. Fatty acid composition of EVOO samples during ripe stages- IH with Neoprene

Cultivar ⬇	Parameter ⬇	C16- Palmitic acid	C17- Heptadic anoic acid	C18- Stearic acid	C18: 1c- Oleic acid	C18:2c- Linoleic acid	PUFA: Poly Unsaturated Fatty acids	MUFA: Mono Unsaturated Fatty acids	SFA: Saturated Fatty acids
Oily	U	18.32±0.45	0.03±0.01	2.29±0.05	60.14±3.24	13.24±0.24	13.38±0.18	51.36±3.52	14.22±0.08
	S	18.04±0.25	0.03±0.01	2.37±0.07	68.47±5.26	12.22±0.31	12.85±0.14	56.78±2.74	13.95±0.12
	R	17±0.34	0.05±0.1	3.22±0.03	78.19±2.45	11.85±0.15	12.04±0.13	61.08±5.32	13.55±0.09
Yellow	U	20.6±0.16	0.04±0.1	2.67±0.01	62.15±4.15	12.96±0.21	14.1±0.17	52.37±4.15	14.89±0.13
	S	19±0.37	0.05±0.1	3.27±0.08	70.08±3.58	12.08±0.17	13.64±0.22	58.31±3.15	14.23±0.1
	R	17.36±0.1	0.06±0.02	3.46±.06	79.32±5.16	11.34±0.11	12.98±0.2	63.28±4.23	13.67±0.13
Fishemi	U	23.36±0.58	0.04±0.1	2.74±0.04	59.21±4.38	13.02±0.13	13.21±0.15	50.16±3.2	13.85±0.08
	S	23.08±1.02	0.04±0.1	2.79±0.05	69.32±6.16	12.14±0.19	12.55±0.16	56.34±4.52	13.21±0.11
	R	21.48±0.75	0.05±0.1	2.88±0.3	76.33±5.82	11.4±0.14	11.84±0.12	60.89±2.63	12.83±0.08

Note: U, S and R are abbreviation of unripe, semi-ripe and ripe stages, respectively

3.4. Total Phenol

Measurement of phenolic compounds is considered as an indicator of the oxidative stability of olive oil [32]. The results of this study showed a downward trend during the three harvest periods for olive oil extracted from Oily,Yellow and Fishemi cv. Due to the higher content of phenolic compounds of EVOO samples by EPR which harvested in the unripe stage (Oily: 26.49, Yellow: 30.48, Fishemi: 31.5 mg GAE/kg) compared to Neoprene (Oily: 26.48, Yellow: 29.48, Fishemi: 28.47mg GAE/kg) , had more oxidative stability. The findings of the phenolic compounds of this study and its effect on the quality of olive oil were consistent with the reports of Morrone and Squeo [33, 34].

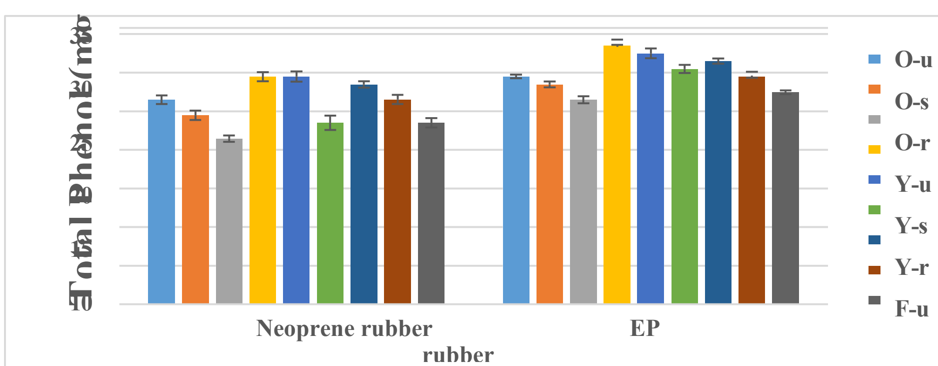


Fig.3. Total phenol of EVOO samples

3.5. Sterol component

The important types of sterols of olive oil include beta-sitosterol, delta-5 sterol, campesterol and stigmasterol [35]. The highest and lowest sterol compositions in different harvest periods were beta-sitosterol and cholesterol, respectively (table.4). Decreasing trends of Cholesterol levels were similar to performed research by Lammi [36]. The ratio of campesterol to stigmasterol has been introduced as a qualitative parameter in olive oil to determine the best olive harvest time [37]. When this index is at its highest, it is the best time to harvest olives. The ratio of campesterol to stigmasterol of EVOO samples of EPR was more than EVOO of Neoprene. For instance, when olive samples were harvested by the EPR machine, the levels of campesterol (in the unripe stage) of Oily, Yellow and Fishemi cv were 3.96, 3.64, 3.82% and also the stigmasterol levels were 0.54%, 0.55% and 0.59%, respectively. While the levels of cholesterol of Oily, Yellow and Fishemi in the immature stage (when harvested by Neoprene head) were 3.42%, 3.22%, 3.53% and the level of stigmasterol were 0.65%, 0.63 % and 0.68%, respectively. Delta-5 Sterol has antioxidant properties due to its Delta-8 and 24 side chains at high temperatures. Therefore, this compound can protect olive oil against oxidation [7]. In this study, delta 5 sterol levels increased with increasing ripening, which was consistent with the findings of Xu [38]. Conversely, beta-sitosterol levels declined during ripening.

Table4. Sterol composition of EVOO during ripening periods (EPR and Neoprene head)

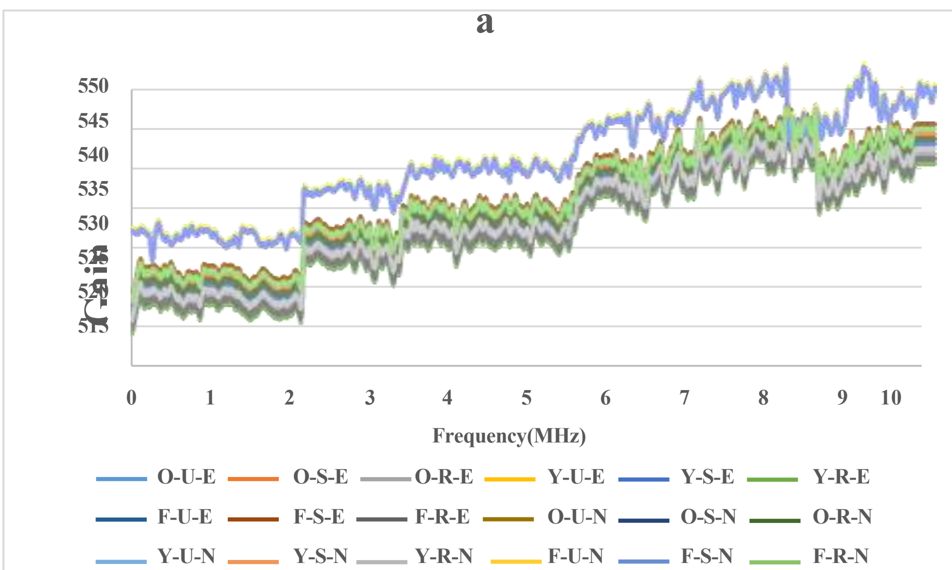
		EPR						
Cultivar ↓	Parameter ↓	Cholesterol	Campe sterol	Stigma sterol	beta- Sito sterol	Delta5-sterol	Delta2 4- stigma stadien	Delta7-sterol
Oily	U	0.03±0.01	3.96±0.09	0.54±0.04	81.37±4.58	4.65±0.08	0.39±0.02	0.12±0.01
	S	0.02±0.01	3.67±0.06	0.5±0.01	75.28±5.81	6.81±0.09	0.51±0.01	0.29±0.01
	R	0.02± 0.01	3.08± 0.09	0.43±0.02	70.09±6.13	7.96±0.15	0.78±0.04	0.43±0.03
Yellow	U	0.04± 0.01	3.64± 0.11	0.55±0.01	83.49±4.16	3.92±0.31	0.34±0.01	0.07±0.01
	S	0.03±0.01	3.26±0.08	0.49±0.03	78.57±3.8	5.77±0.09	0.46±0.01	0.19±0.01
	R	0.03±0.01	3±0.09	0.43±0.05	72.29±6.08	6.94±0.27	0.68±0.02	0.27±0.01
Fishemi	U	0.02±0.01	3.82±0.23	0.59±0.02	80.09±5.16	5.53±0.31	0.36±0.01	0.09±0.01
	S	0.02±0.01	3.31±0.16	0.53±0.01	75.33±4.13	6.82±0.26	0.47±0.02	0.19±0.01
	R	0.02±0.01	2.98±0.14	0.48±0.03	70.16±4.82	8.17±0.42	0.55±0.01	0.38±0.02

		Neoprene						
Cultivar ↓	Parameter ↓	Cholesterol	Campe sterol	Stigma sterol	beta- Sito sterol	Delta5-sterol	Delta2 4- stigma stadien	Delta7- Stigma sentinel
Oily	U	0.04±0.01	3.42±0.09	0.65±0.05	85.37±2.36	2.86±0.03	0.26±0.01	0.41±0.01
	S	0.04±0.01	3.18±0.05	0.61±0.02	81.16±4.82	5.16±0.03	0.38±0.03	0.38±0.01

	R	0.03±0.01	2.95±0.04	0.57±0.01	76.38±5.16	7.14±0.08	0.59±0.03	0.35±0.01
Yellow	U	0.05±0.02	3.22±0.1	0.63±0.02	82.33±2.52	3.06±0.02	0.29±0.01	0.42±0.01
	S	0.03±0.01	2.98±0.05	0.56±0.01	76.45±3.13	5.88±0.15	0.46±0.02	0.36±0.01
	R	0.03±0.01	2.67±0.07	0.5±0.01	71.22±4.92	7.23±0.29	0.65±0.04	0.3±0.01
Fishemi	U	0.03±0.01	3.53±0.13	0.68±0.03	85±5.61	3.45±0.08	0.25±0.01	0.4±0.01
	S	0.02±0.01	3.09±0.27	0.6±0.04	80.09±4.3	5.98±0.09	0.39±0.01	0.35±0.01
	R	0.02±0.01	2.81±0.01	0.54±0.02	74.61±2.85	7.31±0.34	0.48±0.01	0.31±0.01

3.6. Dielectric measurement

In this study, phase shift and gain voltages were used to investigate the dielectric properties of oil samples. Figures 4-a and 4-b show the gain phase shift voltages of all classes, respectively. The maximum and minimum phase shift coefficients were 950.83 mV (cv: Oily, ripening stage: unripe, IH head: Neoprene) and 942.43 mV (cv: Yellow, ripening stage: ripe, IH head: EPR). Frequency parameter, sample moisture, temperature, and chemical composition change the dielectric coefficient [39]. Oleic acid is one of the chemical parameters that affects the gain and phase shift voltages. The findings of this study regarding the effect of oleic acid on the phase shift and gain coefficient were consistent with the findings of Lizhi and Others [9, 17, 37,40]. With increasing oleic acid, the phase shift coefficient and gain decreased.



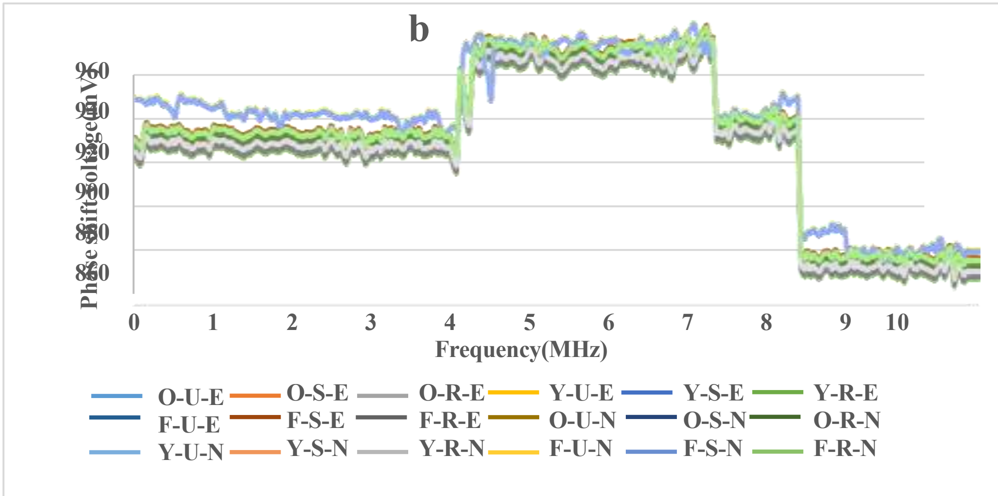
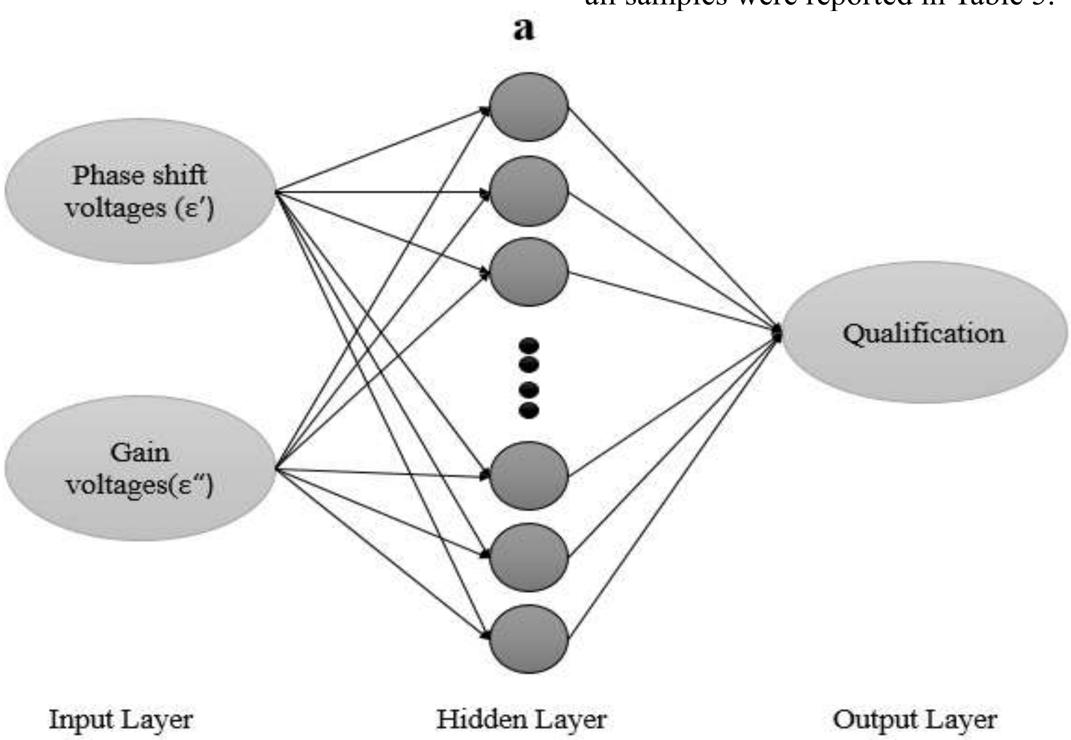


Fig.4. results of gain and phase shift voltages of all EVOO samples (O: Oily, F: Fishemi, Y: Yellow, U: unripe, S: semi ripe, R: ripe, E: EPR, N :Neoprene)

3.7 ANN and SVM

In order to develop the regression model, artificial neural networks with a hidden layer and 20 neurons were used (Figure 5-a). Network models with different neurons were trained and tested. Figure 5-b shows the results of ANN for the o-u-e class. The best and weakest network topologies were 1-18-8 (R: 0.88, RMSE: 0.09) and 1-3-8 (R: 0.71, RMSE: 0.25), respectively. All samples were tested and trained with different networks and the best results for all samples were reported in Table 5.



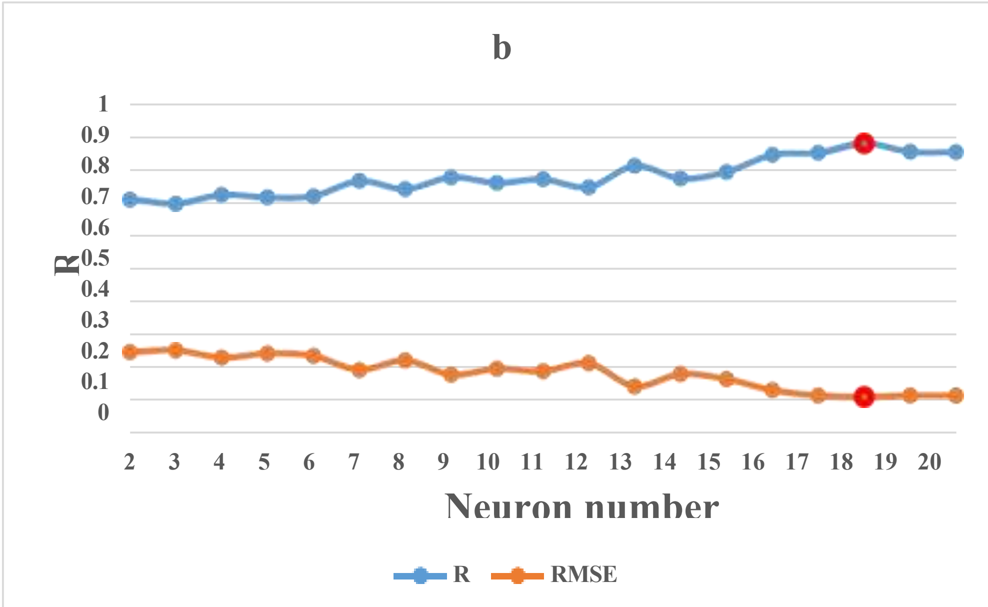


Fig5. The statistical result of different topology of ANN for o-u-e sample

The SVM was used with three different linear, RBF and polynomial algorithms. For the SVM model, in the pre-tests, the and C=0.1 provided the highest accuracy. Therefore, for quality assessment of all classes, γ and C= 0.1 were used and reported (Table 5). For all samples, the best and weakest models were linear, RBF, and poly-nominal, respectively. For example, for the o-u-e sample, the R and RMSE of linear-SVM were 83.52 and 13.31and also the R and RSME of polynomial-SVM were 71.33 and 23.51%, respectively. The findings of comparing the polynomial and linear SVM model were consistent with the findings of Marchal and Karami [41, 42].

Table.5. The best results of ANN, SVM- Polynomial, SVM-RBF and SVM-Linear

Sample	Model							
	ANN		SVM- Polynomial		SVM-RBF		SVM-Linear	
	R	RMSE	R	RMSE	R	RMSE	R	RMSE
O-U-E	90.08	7.81	71.33	23.51	79.57	17.02	83.52	13.31
O-S-E	88.03	9.07	69.11	25.81	77.16	19.67	81.64	14.99
O-R-E	88.09	10.2	66.87	27.83	76.27	20.91	80.31	16.36
Y-U-E	89.02	8.62	70.13	24.53	78.35	18.32	82.59	13.97
Y-S-E	87.34	10.39	66.07	29.12	74.22	21.96	79.57	17.93
Y-R-E	88.72	10.04	68.12	26.91	76.63	20.24	80.92	15.73
F-U-E	86.47	10.6	64.27	30.08	73.62	23.42	78.69	19.42
F-S-E	88.69	9.01	69.64	24.84	77.81	18.67	82.71	14.34
F-R-E	87.67	10.29	66.51	28.63	75.82	21.27	80.08	16.86
O-U-N	86.76	10.53	65.18	29.89	73.82	22.96	79.22	18.83
O-S- N	89.15	8.31	70.16	23.99	78.85	17.85	83.12	13.76
O-R- N	89.72	8.12	71.19	23.76	79.28	17.27	83.49	13.46
Y-U- N	88.36	10.16	67.36	27.42	76.55	20.67	80.68	16.07

Y-S- N	88.92	9.09	68.59	26.37	76.81	19.89	81.26	15.46
Y-R- N	87.62	10.36	66.27	28.89	74.27	21.68	79.76	17.47
F-U- N	86.28	11.34	63.45	30.57	76.37	23.81	78.34	20.07
F-S- N	88.36	9.03	69.27	25.36	77.52	18.94	81.91	14.86
F-R- N	87.11	10.45	65.67	29.57	74.19	22.53	79.28	18.36

Table 5 shows the results of ANN, linear, RBF and polynomial SVM for all samples. The ANN had more accuracy and less error compared to SVM models for all quality determination of all samples. The maximum and minimum errors obtained by the ANN were 11.34 (f-u-n) and 7.81 (o-u-e), respectively. Compared to SVM polynomial, the maximum and minimum errors were 30.57 and 23.76, respectively. The comparison of ANN and SVM models was consistent with the findings of Soltani et al. They used two SVM models with three different Landa and C levels to determine the quality of sesame oil using the spectroscopic dielectric technique. Based on the results of SVM, not only the Landa and C-optimal values of 0.1 were considered but also the accuracy of the RBF model was higher than the polynomial model. In addition, the ANN error was lower than SVM models . In another study, two models of ANN and SVM (RBF, polynomial and normalized polynomial) were used to detect the quality of olive oil by a capacitive sensor. Although the polynomial accuracy was higher than RBF, the ANN error value was lower than all SVM models [9].

4-Conclusion

The mechanical damage caused by the collision of the olive harvester with the olives affects the quality of the extracted olive oil. Changes in the structure and material of the olive impact harvester head increased the quality of the olive oil. By obtaining the mechanical properties of three types of olives in different ripening stages, the material of the IH head was considered in such a way that when the olive is impacted in harvest process, the olive has the least bruising. This bruise caused by mechanical damage affected the chemical properties of the extracted olive oil. The acidity and peroxide index of EVOO samples of EPR were lower than Neoprene. Also, the amount of oleic acid of EVOO samples of EPR was high compared to Neoprene and low linoleic acid. Conversely, the ratio of polyunsaturated fatty acid to monounsaturated fatty acid of olive oil harvested with EPR was smaller than Neoprene. In addition, the ratio of campesterol to stigmasterol in the EVOO of EPR head was higher than Neoprene. As a result, the quality of the extracted olive oil of the samples harvested with the EPR head was better than that of the samples harvested with the Neoprene head.

The dielectric coefficient changed by changing the chemical properties of olive oil. With increasing oleic acid, the phase shift and gain coefficient decreased. Also, ANN, linear, RBF and polynomial SVM were used to evaluate the quality of shift and gain phase coefficient data. The best and weakest results of the analysis were related to artificial neural network models, linear-, RBF-SVM and polynomial-SVM, respectively. Although EPR was used in this study to increase the quality of the extracted olive oil, it is suggested that other materials with different mechanical properties being used to fabricate the IH head and its effect on extracted olive oil be investigated. In addition, other effective factors such as the speed of the IH head should be considered.

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Data Available

The authors confirm that the data supporting the findings of this study are available within the article.

CONFLICT OF INTEREST

The authors have declared no conflicts of interest in this article. Also,

ETHICAL APPROVAL

This study does not involve any human or animal testing.

5-References

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چکیده

در این پژوهش به منظور بررسی تأثیر ضربه برآمده از برخورد مکانیکی در برداشت میوه زیتون بر کیفیت روغن استحصال شده، اثر دو فاکتور جنس انگشتی ضربه‌زن در دو سطح و رسیدگی میوه زیتون در سه سطح مورد بررسی قرار گرفت. روش آماری مورد استفاده برای این امر آزمایش فاکتوریل در قالب طرح بلوک‌های کامل تصادفی بوده و مقایسه میانگین‌ها بر اساس آزمون چند دامنه‌ای دانکن در سطح ۵ درصد انجام گرفت. یک دستگاه برداشت ضربه‌ای که بر روی محور دوران آن در هر نوبت یک نوع انگشتی ضربه‌زن از جنس متفاوت نئوپرن (Neoprene) و اتیلن پروپیلن رابر (EPR) نصب گردید، برای برداشت سه نوع میوه زیتون روغنی، زرد و فیشمی در سه مرحله نارس، نیمه رسیده و رسیده استفاده شد. ویژگی‌های کیفی روغن زیتون شامل مقدار اسیدیته، پراکسید، ترکیبات استرولی، ترکیب اسیدهای چرب و فنل کل رcوغن زیتون استخراج شده، بررسی گردید. همچنین خواص دی‌الکتریک مربوط به ویژگی‌های شیمیایی اندازه‌گیری شد. تغییرات ولتاژ نوسان فاز و دامنه با استفاده از تکنیک دی‌الکتریک طیف‌سنجی به‌دست آمد و داده‌های خروجی توسط شبکه عصبی مصنوعی (ANN) و ماشین بردار پشتیبان (SVM) مورد ارزیابی قرار گرفت. تحلیل میانگین‌ها و نیز بررسی شاخص‌های کیفی نشان داد، گرچه روغن استحصالی نمونه‌ها، روغن زیتون فوق بکر (EVOO) بود اما کیفیت نمونه‌های روغن زیتون برداشت شده توسط EPR بالاتر از نئوپرن بود.