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# Evaluation of three-phase centrifugal separator machine (Tricanter) for olive oil extraction

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**Abstract:** One of the most important machines in the olive oil extraction line is the horizontal three-phase centrifugal separator machine or Tricanter. The purpose of this paper is to evaluate the machine designed on the basis of Tricanter and to evaluate the quality of extracted olive oil. For this purpose, four different olive cultivars from Gilan Province in Iran were used. In this research the rotational speed of the Tricanter machine was tested at three levels of 2 500, 3 000, and 3 500 rpm and the content of water added to olive paste was used at three levels of 10, 20, and 30% of the paste mass. Peroxide value (PV) and percentage of acidity were measured for oil extracted from all four olive cultivars. The results of the analysis of variance (ANOVA) test showed that rotational speed and the content of added water had an effect on the acidity and PV for all samples of olive cultivars. The measured values showed that the best speed for the Tricanter machine is 3 500 rpm. At this rotational speed, the peroxide and acidity values are lower than the standard values.

**Keywords:** Tricanter machine; rotational speed; content of water added; peroxide value; free fatty acids (acidity)

The olive, scientifically known as *Olea europaea*, belongs to the family Oleaceae and is widely cultivated in Mediterranean climates. The olive tree is one of the few trees that can produce fruit even in non--fertile soils and from it oil of suitable quality can be obtained (Doveri and Baldoni 2017). Olive oil accounts for 2.5% of the world's vegetable oil distribution. Consumption of olive oil is increasing due to its high nutritional value as well as its beneficial effects on the health of consumers around the world (Loumou and Giourga 2003). If the climatic conditions are favourable, about 65 kg of olives can be harvested from each olive tree on average, and about 1 L of oil can be obtained from every 4 kg to 5 kg of fruit (Akbarnia 2007). Olive oil is one of the sources of fat in the diet and due to its high content of unsaturated fats, phenolic compounds and antioxidants it has a very high nutritional value (Bianchi 2003; Landete et al. 2008). Unsaturated fatty acids (oleic acid) increase the level of good cholesterol [high-density lipoprotein (HDL)] and decrease the level of bad cholesterol [low-density lipoprotein (LDL)], thus preventing cholesterol from building up in the arteries and clogging the arteries. The use of olive oil reduces the incidence of cardiovascular diseases and cancer (Owen et al. 2000).

The quality of olive oil depends on various factors such as the type of cultivar, geographical conditions of the place of production, climatic conditions, method of extraction, time and method of harvest (Ferguson et al. 2010). The International Olive Oil Council (IOOC) and the European Economic Community (EEC) have determined the quality of olive oil based

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on parameters including the amount of free fatty acids (FFA), peroxide value (PV), specific extinction coefficients in the ultraviolet region at two wavelengths of 230 nm and 270 nm ($K_{232}$ and $K_{270}$).

In this research, the effects of two parameters of peroxide index and acidity on the quality of olive oil (four different olive cultivars) extracted from a three-phase centrifugal separator machine (Tricanter) have been investigated.

PV indicates the degree of lipid oxidation in terms of the amount of hydroperoxides produced (Raufi and Yousef Zadeh 2015). According to the IOOC standard, the maximum amount of peroxide in olive oils must be 20 meq$O_2$ kg$^{-1}$ (milliequivalents of oxygen per kg of the sample) (International Olive Council 2015). Acidity is the percentage of FFA in olive oil. According to the IOOC standard, the acidity percentage of olive oil must be less than 0.8% (International Olive Council 2015).

Olive fruit has a bony core (endocarp) and a middle layer (mesocarp) (fruit flesh pulp) (Monfreda et al. 2014). The mesocarp layer is edible and rich in fat, which is 65% to 83% of the total mass of olive fruit and the endocarp is 13–30% of its mass. The mass of the fruits varies from 1.3 g to 20 g and the suitable cultivars of olives for oiling have a mass equal to 2 g to 4 g (Malek 2007). The quality of the extracted oil is strongly dependent on the olive paste temperature and the percentage of water in the paste (Akbarnia 2007). Also, the results of Altieri (2010) showed that the best speed difference between the outer shell (cup) and the stator of the examined separator for the best phase separation is 13.3 rpm. Also, the extraction of olive oil by a centrifugation method affects the phenolic compounds in olive oil, thus affecting the taste and residue of the oil (Pastore et al. 2017). One of the important things that play a role in separating the materials inside the machine is the conical part of the cup as well as the length of the cup. As the cup length increases, the centrifugal force finds more time to separate the phases (Vakamalla et al. 2017). Effective conditions in olive paste such as heat, time of olive paste being in contact with air, evaporation and phenolic composition of pure olive oil will have consequences for oil quality. The optimum temperature and time of dough exposure to air were determined by modelling the reaction surface. The optimal temperature and time of exposure of olive pastes to air were cultivar dependent being 30 min at the investigated temperature of 22 °C for Frantoio cultivar (Servili et al. 2003). The results of Ambrosone et al. (2007) showed that the presence of water in olive oil in an emulsion state and even microscopic droplets in the oil caused oxidation. This effect is evaluated by measuring the amount of peroxide in oil samples (Ambrosone et al. 2007). The results of Ranalli et al. (2001) showed that the presence of water in olive oil in an emulsion state and even microscopic droplets in the oil caused oxidation. This effect is shown by measuring the amount of peroxide in oil samples (Ranalli et al. 2001). In another study on total and partial changes in the oxidation components and indices, seven samples of virgin (pure) olive oil were stored under storage conditions for 21 months at room temperature and in the dark. As expected, statistical analysis showed a significant difference in antioxidant content (Gomez et al. 2007).

Zhu and Lee (1999) studied the shell conical part of the centrifugal separator machine and concluded that the conical part increased the tangential velocity and separated the smaller particulate solids. They also performed general experiments on the cone length and their results showed that the cone length had a direct effect on separation performance.

**Horizontal three-phase centrifugal separator machine (Tricanter).** One of the methods for olive oil extraction is centrifugation of olive paste (including fruit flesh, kernels and water) by a Tricanter. By injecting the olive paste into a horizontal press (centrifuge) machine (Tricanter machine) which is spinning at a relatively high speed, the separation of solid and liquid phases in the machine takes place.

This machine consists of two concentric rotating units including a conical outer shell (cup) and a central part (helix) where the speed of the cup is faster than the speed of the helix. The parts of the machine Tricanter are shown and described in Figure 1. Separating materials in this machine is based on rotational speed and centrifugal force. Also on the other hand, because the outer shell is conical, by passing the material through the conical part due to the narrowing of the duct, it causes double pressure on the material and sepa-

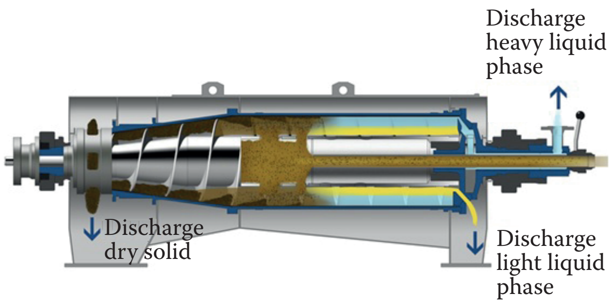


Figure 1. Three-phase separator Tricanter machine

Source: Flottweg Tricanter (2021)

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rates the liquid phase from the solid one. The Tricanter centrifuge is a device that uses centripetal acceleration to continuously separate multiphase flows of particulate solids and a liquid, where the solids have a higher density than the liquid.

Due to the rotation of the material inside the machine, the heavier materials, including solids and pulp (first phase), are thrown around the machine and guided by the spiral in the central part of the machine to the installed output and exit from the outlet.

Medium-density material including interstitial water of grains, pigments and water added to smooth and dilute the dough (second phase) is placed in the middle space of the centrifuge under the layer of heavy materials and is directed to its own outlet and lighter materials. Third phase consists of oil extracted from olive seeds in the centre of the machine, moving towards its corresponding outlet. Therefore, in the Tricanter device, the phases of the material are in the form of three concentric rings, including solids, interstitial water and oil, respectively.

## MATERIAL AND METHODS

**Case study of centrifuge machine.** Figure 2 shows a Tricanter centrifuge machine made to extract olive oil. This machine has been made in the workshop of the Iran Scientific and Industrial Research Organization as a research project. All parts of this machine that are in contact with water and oil were made of stainless steel grade 304 with a capacity of 350 kg $h^{-1}$.

What enters the Tricanter machine is the pulp from the crushed olive fruit with some water (usually hot water). The material (paste) injected into the centrifuge is divided into three phases: solid, liquid (interstitial water, pigments, etc.) and oil under the influence of the centrifugal force from the rotation of the machine and its special shape (conical shape). The low FFA (acidity) and also the low PV in the olive oil indicate the good performance of the Tricanter machine. In order to test the built centrifuge machine, after placing it in the processing line, the olive fruit pits were crushed. This operation was performed by the crushing unit in the processing line. The crushed pits were poured into the mixer and after adding some water (about 30% by weight of the crushed pits) into the mixer, the heater in the mixer was turned on and then all was stirred in the mixer for 20 min (Figure 3).

When the machine is rotating (about 3 500 rpm), the material injected into the machine is divided into three separate phases by centrifugal force. For each phase, outputs are embedded. The solid materials were expelled from the rear wall of the device and the oil from the front of the device (Figure 4).

**Preparation of olive samples and determination of mechanical properties.** To prepare the olive samples, four olive cultivars with the names Manzanilla, Fishmi, Kalamata, and Roghani were collected from the research station of the Ministry of Agriculture in Rudbar, Gilan Province. The olives were then transferred to the Mechanical Properties Laboratory of the Faculty of Agriculture, Campus of Natural Sciences and Natural Resources, University of Tehran. To measure, evaluate and determine the dynamic behaviour of olive samples, Santam SMT-20 material test device (Iran) and 500 N load cell were used during the compression test at a speed of 10 mm $min^{-1}$. The test was performed with 18 samples of each cultivar that were selected completely randomly. Table 1 shows the measured mechanical properties for each olive cultivar.

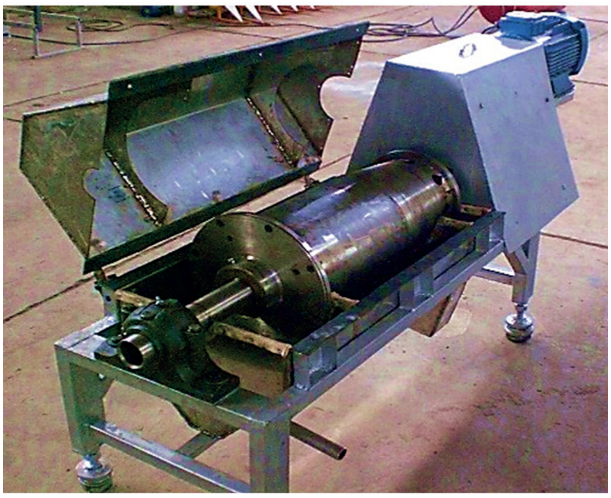

Figure 2. Designed centrifugal Tricanter machine

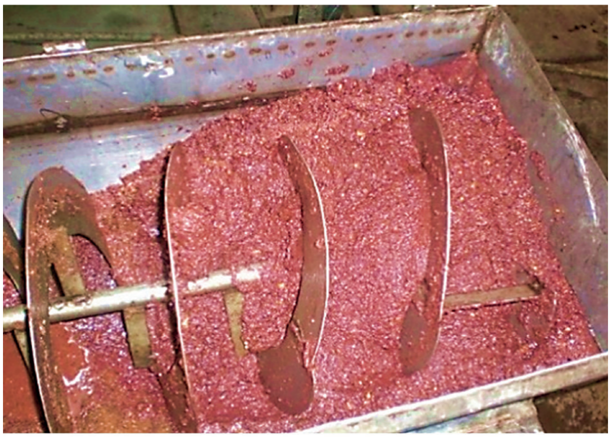

Figure 3. Chopped and crushed olive fruit in a mixer

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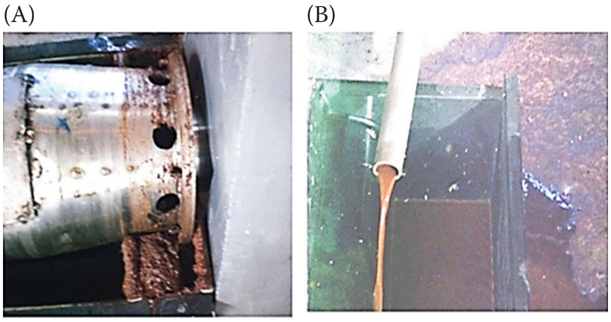


Figure 4. Oil and solids materials removed from the Tricanter machine: (A) solid materials, and (B) olive oil

The rupture force continued until the olive sample between the two jaws of the Santam device was a failure. The force-deformation curve was also plotted by the computer connected to the device until the moment of rupture. Failure energy by calculating the area under the force-deformation curve from the loading point to the rapture point was obtained using Excel 2016 software (Azadbakht et al. 2015). The toughness is equal to the area under the force-deformation curve from the loading point to the rapture point per unit volume of the olive sample (Herák et al.2012). Volume and mass of 4 cultivars Manzanilla, Fishimi, Kalamata and Roghani oil were equivalent to 3.07 $mm^3$ and 3.14 g, 4.15 $mm^3$ and 4.14 g, 3.30 $mm^3$ and 3.38 g, 3.50 $mm^3$ and 3.68 g, respectively.

**Tricanter machine performance test method.** In order to evaluate the performance of the Tricanter machine, an experimental design (randomised complete block design) was performed as follows. In this statistical and experimental design, the rotational speed of the centrifuge at three levels of 2 500, 3 000, and 3 500 rpm was constant, the stirrer temperature was 50 °C, the constant stirring time was 20 min and the content of water added to the dough 10, 20, and 30% of dough weight was considered.

Table 1. Mechanical parameters of four oil samples tested

| Variety | Parameter | Value (average) |
|---|---|---|
| Manzanilla | rupture force (N) | 120.0 |
| | failure energy (J) | 0.300 |
| | toughness (J $mm^{-3}$) | 0.065 |
| Fishmi | rupture force (N) | 108.0 |
| | failure energy (J) | 0.250 |
| | toughness (J $mm^{-3}$) | 0.075 |
| Kalamata | rupture force (N) | 80.0 |
| | failure energy (J) | 0.180 |
| | toughness (J $mm^{-3}$) | 0.060 |
| Roghani | rupture force (N) | 81.5 |
| | failure energy (J) | 0.210 |
| | toughness (J $mm^{-3}$) | 0.050 |

**Measurement of acidity and PV of olive oil.** The amount of acidity and PV in the oil removed from the centrifuge can be considered as a basis for determining the qualitative and quantitative performance of the horizontal rotary pump machine. This means that the low acidity and also the low PV of the olive oil indicate an oil of high quality and thus represent the good performance of the Tricanter machine. PV was measured according to the Commission Regulation of the European Union [Commission Regulation (EEC) No. 2568/91 (1991)]. In this method, 5 g of oil sample was dissolved with 30 mg of chloroform acetic acid solution and 0.5 L of saturated potassium iodide solution was added and PV was determined using sodium hyposulfite. Also, to determine the acidity of olive oil, 10 g of the sample was weighed in Erlenmeyer flask and 50 mL of ethanol solvent was added to it.

The acidity was determined in accordance with the Commission Regulation of the European Union [Commission Regulation (EEC) No. 2568/91 (1991)]. For this purpose, 1 g of olive oil was dissolved in 12.5 mL of chloroform. Then 1 mL of the sample was mixed with 12.5 mL of ethanol. Then 3 drops of 1% phenolphthalein were added and finally titrated with sodium hydroxide 0.1 mol $L^{-1}$. Acidity was calculated in terms of oleic acid by the formula (AOCS 1993):

$$Acidity = \left( \frac{N \times V}{W} \times 28.2 \right) \quad (1)$$

where: $N$ – normality of sodium hydroxide; $V$ – consumption caustic soda volume; $W$ – sample mass.

## RESULTS AND DISCUSSION

**Measured values of PV and acidity.** Table 2 shows the measured peroxide and acidity values for the four olive cultivars. According to the IOOC standard, the maximum PV of olive oils must be 20 $meqO_2$ $kg^{-1}$ also the acidity percentage of olive oil must be less than 0.8%. The measured amounts of peroxide from the oil of all four olive cultivars are lower than the standard value, which indicates the proper performance of the stainless steel machine. But the percentage of acidity measured at 2 500 rpm and 3 000 rpm is higher than the standard value. But at 3 500 rpm the acidity values are lower than the standard value. So it can be the result of the effective and suitable operation of the Tricanter machine at 3 500 rpm.

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Table 2. Peroxide value (PV) and acidity measured for four olive oil cultivars

| Rotational speed (rpm) | Content of water added (%) | Manzanilla | | Fishimi | | Kalamata | | Roghani | |
|---|---|---|---|---|---|---|---|---|---|
| | | peroxide index (meq$O_2$ kg$^{-1}$) | acidity (%) | peroxide index (meq$O_2$ kg$^{-1}$) | acidity (%) | peroxide index (meq$O_2$ kg$^{-1}$) | acidity (%) | peroxide index (meq$O_2$ kg$^{-1}$) | acidity (%) |
| 2 500 | 10 | 8.4 | 1.63 | 7.7 | 1.56 | 8.3 | 1.43 | 7.4 | 1.50 |
| | | 8.6 | 1.68 | 8.0 | 1.64 | 8.7 | 1.41 | 7.9 | 1.52 |
| | | 8.8 | 1.60 | 8.3 | 1.71 | 8.8 | 1.44 | 8.2 | 1.51 |
| | 20 | 8.9 | 1.79 | 8.4 | 1.80 | 8.9 | 1.77 | 8.1 | 1.75 |
| | | 9.1 | 1.88 | 8.8 | 1.85 | 9.1 | 1.78 | 8.6 | 1.80 |
| | | 9.5 | 1.94 | 8.8 | 2.03 | 9.4 | 1.98 | 9.0 | 1.82 |
| | 30 | 9.6 | 2.20 | 9.2 | 2.20 | 9.5 | 2.00 | 8.8 | 1.96 |
| | | 10.1 | 2.49 | 9.4 | 2.27 | 9.8 | 2.12 | 9.2 | 2.14 |
| | | 10.7 | 2.83 | 9.8 | 2.69 | 10.5 | 2.08 | 9.6 | 2.16 |
| 3 000 | 10 | 7.9 | 1.22 | 7.8 | 1.21 | 7.7 | 1.32 | 7.4 | 1.12 |
| | | 8.1 | 1.18 | 7.7 | 1.22 | 7.8 | 1.32 | 7.6 | 1.13 |
| | | 8.0 | 1.20 | 7.9 | 1.19 | 8.2 | 1.35 | 7.8 | 1.10 |
| | 20 | 8.3 | 1.61 | 8.2 | 1.62 | 8.4 | 1.38 | 8.2 | 1.56 |
| | | 8.5 | 1.65 | 8.4 | 1.60 | 8.4 | 1.40 | 8.3 | 1.62 |
| | | 8.2 | 1.64 | 8.5 | 1.65 | 8.7 | 1.38 | 8.3 | 1.53 |
| | 30 | 8.8 | 1.89 | 8.8 | 1.85 | 9.0 | 1.52 | 8.8 | 1.81 |
| | | 9.0 | 2.01 | 8.9 | 1.82 | 8.9 | 1.50 | 8.6 | 1.85 |
| | | 9.1 | 1.92 | 8.9 | 1.83 | 9.0 | 1.51 | 8.5 | 1.79 |
| 3 500 | 10 | 6.7 | 0.67 | 7.0 | 0.55 | 6.8 | 0.43 | 6.2 | 0.53 |
| | | 6.9 | 0.69 | 7.1 | 0.53 | 6.9 | 0.45 | 6.4 | 0.53 |
| | | 7.0 | 0.67 | 7.1 | 0.55 | 7.1 | 0.45 | 6.8 | 0.55 |
| | 20 | 7.3 | 0.72 | 7.4 | 0.62 | 7.2 | 0.52 | 7.0 | 0.62 |
| | | 7.4 | 0.70 | 7.3 | 0.66 | 7.3 | 0.50 | 7.2 | 0.65 |
| | | 7.5 | 0.75 | 7.5 | 0.65 | 7.7 | 0.52 | 7.3 | 0.60 |
| | 30 | 7.6 | 0.79 | 7.6 | 0.72 | 8.3 | 0.68 | 7.4 | 0.77 |
| | | 7.9 | 0.77 | 7.7 | 0.71 | 8.2 | 0.62 | 7.5 | 0.75 |
| | | 8.1 | 0.75 | 8.0 | 0.75 | 7.9 | 0.64 | 7.9 | 0.79 |

Analysis of variance (ANOVA) was used to test four olive cultivars. The results of this analysis are reported as the Fisher *F* ratios. The *F* ratio with the degrees of freedom tests whether between and within variances are significantly different. ANOVA test was performed using Design Expert 21.0.3.0 statistical software. The results of the ANOVA test for all olive samples are as follows.

**Manzanilla cultivar.** According to the results of ANOVA (Table 3) for Manzanilla cultivar in terms of quality traits of olive oil, including PV and acidity, a significant difference was observed between rotational speed and the amount of added water (for both traits). But the interaction effect of rotational speed and added water (for both traits) was not significantly different.

**Fishimi cultivar.** According to the results of ANOVA (Table 4) for Fishimi cultivar in terms of quality traits of olive oil, including PV and acidity, a significant difference was observed between rotational speed and the amount of added water (for both traits). But the interaction effect of rotational speed and excess water (for both traits) was not significantly different.

**Kalamata cultivar.** According to the results of ANOVA (Table 5) for Kalamata cultivar in terms of quality traits of olive oil, including PV and acidity, a significant difference was observed between rotational speed and the

Table 3. Analysis of variance (ANOVA) for the olive oil (Manzanilla cultivar)

| Source of variation | Degrees of freedom | Peroxide | Acidity |
|---|---|---|---|
| Rotational speed | 2 | 157.58** | 25.35** |
| Amount of water added | 2 | 42.19** | 15.79** |
| Rotational speed × amount of water added | 4 | 2.52$^{ns}$ | 0.49$^{ns}$ |
| Error | 16 | 0.025 | 0.033 |

**Significant level at 2%; $^{ns}$not significant

Table 4. Analysis of variance (ANOVA) for the olive oil (Fishimi cultivar)

| Source of variation | Degrees of freedom | Peroxide | Acidity |
|---|---|---|---|
| Rotational speed | 2 | 104.24** | 37.11** |
| Amount of water added | 2 | 51.65** | 21.16** |
| Rotational speed × amount of water added | 4 | 4.02$^{ns}$ | 0.49$^{ns}$ |
| Error | 16 | 0.012 | 0.033 |

**Significant level at 2%; $^{ns}$not significant

Table 5. Analysis of variance (ANOVA) for the olive oil (Kalamata cultivar)

| Source of variation | Degrees of freedom | Peroxide | Acidity |
|---|---|---|---|
| Rotational speed | 2 | 85.33** | 43.47** |
| Amount of water added | 2 | 28.03** | 23.61** |
| Rotational speed × amount of water added | 4 | 0.17$^{ns}$ | 0.24$^{ns}$ |
| Error | 16 | 0.037 | 0.016 |

**Significant level at 2%; $^{ns}$not significant

Table 6. Analysis of variance (ANOVA) for the olive oil (Roghani cultivar)

| Source of variation | Degrees of freedom | Peroxide | Acidity |
|---|---|---|---|
| Rotational speed | 2 | 21.51** | 18.67** |
| Amount of added water | 2 | 18.28* | 10.02** |
| Rotational speed × amount of added water | 4 | 0.96$^{ns}$ | 14.99** |
| Error | 16 | 0.017 | 0.033 |

*, **Significant levels at 5% and 2%, respectively; $^{ns}$not significant

amount of added water (for both traits). But the interaction effect of rotational speed and excess water (for both traits) was not significantly different.

**Roghani cultivar.** According to the results of ANOVA (Table 6) for Roghani cultivar in terms of quality traits of olive oil, including PV and acidity, a significant difference between rotational speed and the amount of added water (for both traits) and also the interaction of rotational velocities and added water (for acidity) were observed to be significant. But the interaction of rotational speed and added water for PV was not significantly different.

## CONCLUSION

One of the methods for olive oil extraction is a centrifugation method using a three-phase centrifugal separator machine (Tricanter). In this study, the centrifugal Tricanter machine for extracting olive oil was investigated. The quality of the olive oil from the separator machine was studied.

To evaluate the performance of the designed centrifugal Tricanter machine (testing the extracted olive oil quality), two parameters of the rotational speed of the Tricanter machine and the amount of water added

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to the olive paste and its effect on the quality of the olive oil (PV and acidity) in four different olive cultivars (Manzanilla, Fishimi, Kalamata and Roghani) an experiment was performed and the results were presented.

According to Tables 3–6, the rotational speed of the Tricanter machine and the content of added water had an effect on the acidity and PV in all samples of olive cultivars. For Manzanilla, Fishimi, and Kalamata cultivars the factors mentioned had no effect on each other. But for Roghani cultivar the interaction of rotational velocities and content of added water affected acidity. The reason for this effect in the oil cultivar is high oleic acid (77.2%) and low linoleic acid (7.3%) in this type of cultivar compared to the other three cultivars (Ehteshamnia and Zahedi 2017).

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