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Effects of roasting and enzyme pretreatments on yield and quality of cold-pressed poppy seed oils

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Abstract: The aim of this study was to compare the effects of roasting and enzyme pretreatments on the yield and quality of cold-pressed oils obtained from 3 poppy seed varieties (Ofis 3 (blue), Ofis 4 (yellow), Ofis 8 (white)). The oil recovery range was 21.89%–38.36% with cold pressing. The oily cakes (meal) contained 42–168 g/kg oil and 113–166.3 g/kg moisture after the cold pressing. Physicochemical and quality tests were conducted to evaluate and compare the efficacy of the pretreatments. Furthermore, fatty acid, sterol, and tocopherol compositions were determined. Oil recovery was enhanced by enzyme treatment in Ofis 3 (28.31%) and Ofis 8 (38.36%), while roasting enhanced oil yield in Ofis 4 (29.36%) samples. On the other hand, enzyme treatment caused some problems, like increases in free acidity and peroxide value. The other physicochemical properties and minor components of the oils were not significantly affected by the pretreatments. Furthermore, it was determined that the oily cakes can be a good source of protein. This study proved that higher quality poppy seed oil can be produced with acceptable yield by applying the cold pressing technique coupled with a preroasting process.

Key words: Cold pressing, enzyme, oil quality, oil yield, poppy seed, roasting

1. Introduction

Poppy (*Papaver somniferum* L.) is an annual plant belonging to the family Papaveraceae, including over 100 genera. It grows in regions with hot summers and midlevel rains. Poppy has been cultivated in the Eastern Mediterranean region; in the archaeological findings of Sumer and Assyria, poppy drawings can be seen. The cultivation of poppy has long been in practice in Turkey and India. It was indicated that poppy has been cultivated in Turkey since Hittite times (Yayçep, 2005; TGB, 2011). Legal poppy cultivation is allowed under the rules of the United Nations, the main producer countries being Turkey, India, Australia, France, Spain, and Hungary. In these countries, approximately 100,000 ha is annually used for poppy production. Around 51% of the area used worldwide for poppy cultivation is in Turkey. On the other hand, Turkey provides only 17% of the legal morphine production from poppy (TGB, 2011).

According to Kapoor (1995), neither poppy seed nor poppy seed oil contains alkaloids. Hence, both can be used safely as human food. Poppy seeds contain around 45%–54% oil and 20%–30% protein. Poppy seeds are usually used in bakery products for flavoring and decorative purposes. Poppy seed oil is used as an edible cooking oil locally in Turkey, and is also used in the production of paints, coatings, and cosmetics. The remaining cake or meal is a valuable feedstuff for dairy cattle (Kapoor, 1995; Azcan et al., 2004). In a previous study, the oils from 8 different poppy varieties were Soxhlet-extracted and analyzed (Erinç et al., 2009). The main fatty acids were linoleic acid, oleic acid, and palmitic acid. Gamma-tocopherol and alpha-tocopherol were also measured. The total mean sterol concentration of the oil samples was 2916.20 ppm. The main sterols were β-sitosterol, campesterol, and Δ5-avenasterol. In another study, seed oil content and fatty acid compositions of 18 cultivated Turkish poppy varieties were analyzed (Rahimi et al., 2011). The oil content of the samples ranged from 35.38% to 47.95%, with linoleic acid, oleic acid, and palmitic acid as the main fatty acids quantified.

The poppy oil literature lacks information about the effects of different oil processing techniques on the oil and meal yield and quality; this study would be an important starting point for such studies. Furthermore, cold press oil production is a technique preferred for edible oils of unique quality under environmentally friendly processing conditions. Hence, the objectives of this study were to evaluate the effects of roasting and enzyme treatment against a control group, as preprocesses applied before cold pressing oil extraction technique, on the oil yield and

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quality in 3 different poppy seed varieties. In addition, some properties of the cold press oily cakes (meal) were measured in order to evaluate the quality of the resulting byproducts. Therefore, possible industrial applications to produce optimum quality edible poppy seed oil by cold pressing technique can be developed.

2. Materials and methods

2.1. Materials

In this study, 3 different poppy seed varieties registered by the Turkish Grain Board (Turkish abbreviation: TMO) were used. The poppy seeds of Ofis 8 (white) produced in Ulubey/Uşak, Ofis 4 (yellow) produced in Şuhut/Afyonkarahisar, and Ofis 3 (blue) produced in Ulubey/Uşak were collected from local growers. All seeds were cultivated in the 2011 harvest season and were dried and cleaned of foreign materials. The seeds were stored in a cool and dry storage area in cotton cloth bags (25 kg) during the study. Ferzim hemicellulase (60,000 U/g, optimal activity at 55–65 °C and 4.0–6.5 pH) and Alphamalt BK Quick protease (12 U/g, optimal activity at 40–65 °C and 4.5–6.0 pH) were bought from local chemical suppliers. All other chemicals and standards were of analytical grade and purchased either from Merck (Germany) or Sigma-Aldrich (USA).

2.2. Analyses of the poppy seeds

The moisture content (%) of the samples was measured with an OHAUS MB45 moisture analyzer (Switzerland) at 107 °C with 1 g sample for a 30-min drying program, while water activity of the seeds was determined with an AQUA Lab 4TE instrument (Decagon Devices, USA) at room temperature according to the manual. The total amount of fat in the seeds was measured by the Soxhlet technique according to the AOAC 920.39 method (AOAC, 2002). The total ash of the seeds was measured by the AOCS Ba 5a-49 technique and crude protein was evaluated by applying the Kjeldahl technique of AOCS Aa 5-38 (AOCS, 1984). Additionally, seed color was measured with a Minolta CR300 colorimeter (Japan). A digital caliper (CD-15CP, Mitutoyo Ltd., UK) was used to measure seed size. Hundreds of seeds were counted and weighed 3 times per each variety to determine 1000 seeds' average weight.

2.3. Preparation of the poppy seeds for cold pressing

Each poppy seed variety was portioned as 2 control, 2 roasting, and 2 enzyme treatment groups so that there would be 2 equal portions for each treatment group for every variety. Thus, cold pressing was applied in duplicate. Before cold pressing, the pretreatments were completed for every portion in each treatment group and variety. All poppy seeds were tempered to 12% moisture prior to cold pressing with the lab scale cold press machine (Koçmaksan ESM 3710, Turkey). In this way, the moisture contents were constantly measured during the treatment techniques and all treatment groups were set to 12% moisture content by water conditioning prior to cold pressing. Water conditioning of the seeds was done by placing the seeds in plastic bottles, spraying the calculated amount of water onto the seeds, hermetically covering the bottles, and storing the samples at room temperature for 24 h. The amount of water required for conditioning was calculated with the following formula: $W = [(A / B) \times C] - C$, where W indicates the amount of added water, A the dry matter content of the seeds (%), B the required dry matter content (%) of the seeds, and C the amount of the seeds (g).

Roasting of the poppy seeds was carried out in a Luxell Lx3530 type oven (Kumtel, Turkey; 1450 W) at 150 °C for 30 min. Selection of roasting temperature and duration were based on literature suggestions (Şimşek, 2009) and our preexperiments. The seeds were placed in metal plates with a height of 2 cm. When the temperature in the middle point of the seed batch reached 150 °C, it was mixed up every 10 min for constant heat transfer. At the end of 30 min of roasting, the seeds were left to cool to room temperature and then the moisture levels were measured. Water conditioning was applied to set the moisture content.

Enzyme treatments of the poppy seeds were performed by incubation with enzyme solutions. The conditions for the enzyme treatment were based on preliminary work in the laboratory. For this purpose, 2.5 g of hemicellulase (60 U/g seed) was dissolved in 500 mL of 0.1 M Na_2PO_4 + 0.1 M citric acid buffer solution (6.0 pH). Due to the very small size of the poppy seeds, the enzyme solution was mixed with the seeds (2.5 kg) without crushing, and the mixture was incubated at 60 °C for 3 h in an incubator. Then 2.5 g of protease (0.012 U/g seed) was dissolved in 100 mL of the same buffer, added to the seed slurry, and incubated for an additional 1 h. After incubation, the enzymes were inactivated by heating the seeds up to 100 °C and leaving the mixtures for 2 h at the same temperature. During the heat treatment, water vaporized; however, roasting did not occur. Meanwhile, the seed moisture levels were monitored and when moisture decreased down to 12%, the batches were cooled down to room temperature.

2.4. Cold pressing of the poppy seeds

Cold pressing was performed with a laboratory scale (12 kg seed/h capacity) cold press machine (Koçmaksan ESM 3710) that is a single head expeller type (kms10) with a 1.5-kW powered engine and 0.6 kW of heating resistance. The 10-mm exit die, 20-rpm screw rotation speed, and 40 °C exit temperature were selected for all oil productions as constant parameters. When oil (liquid phase) and oily cakes (solid phase) were collected and weighed, the oily phase was filtered immediately through a 40-µm screen to separate suspended materials. They were then placed into

amber-colored and capped glasses, flushed with nitrogen, and kept in a fridge until analysis. The sediment levels (%) of the oil samples were measured. For this purpose, 5 mL of oil was filtered through Whatman 41 filter paper that was previously weighed and at the end of filtration the filter paper was washed twice with 10 mL of hexane and dried at 70 °C for 1 h. It was then washed 3 times with 15 mL of diethyl ether and dried at room temperature overnight. Finally the filter paper was weighed, and the oil sediment levels were calculated by the following formula: level of sediment (%) = (A – B) / C × 100, where A is the final and B is the initial weight of the filter paper, and C is the amount of oil filtered.

Because of the fact that the meal produced in cold pressing systems contains higher amounts of oil than that obtained from industrial hot presses, the term "oily cake" is preferred. The oily cakes obtained through cold pressing were in the form of rods of 10–20 cm. Immediately after cold pressing, the resulting oily cakes were crushed with a Warring blender (7011S, Warring Laboratory, USA), placed into zipped refrigerator bags, labeled, and frozen at –20 °C until analysis.

2.5. Analyses of the poppy seed oily cakes

The moisture content (%) of the cakes was measured with an OHAUS MB45 moisture analyzer (1 g sample, 107 °C, and 30 min), while fat content was measured by a Soxhlet apparatus according to AOAC 920.39, crude protein according to AOCS Aa 5-38, and total ash according to AOCS Ba 5a-49 (AOCS, 1984; AOAC, 2002).

2.6. Physical analyses of the poppy seed oils

The density of the oil samples was measured according to AOCS method Cc 10c-95 and refractive indices were determined with an Abbe 5 (Bellingham-Stanley, UK) refractometer at 20 °C (AOCS, 1984). Oil viscosity was measured with a Brookfield viscometer (model DV-II + Pro with Rheocalc software, Brookfield Eng., USA) using an LV-SC4-18 spindle and a special sample holder. The viscosity values were determined as centipoises (cP) at 20 °C with 30 rpm shear rate applied. The turbidity values were measured at 20 °C using a Hach 2100-AN Turbidimeter (USA), while the instrumental color values (L, a*, b*) of the samples were measured with a Minolta Colorimeter CR-200 (Minolta Camera Co.). The temperature of oil samples was set to 20 °C in a water bath, and immediately after taking out the samples, they were read with the instruments in the laboratory at the ambient temperature.

2.7. Chemical analyses of the poppy seed oils

The free fatty acid (FFA) and peroxide values of the oil samples were determined according to AOCS methods Ca 5a-40 and Cd 8-53, respectively (AOCS, 1984). Similarly, iodine numbers and saponification numbers were evaluated by following AOCS methods Cd 1-25 and Tl 1a-64, and the amounts of unsaponifiable matter were measured by ISO 3596 method (AOCS, 1984; TSE, 2002). The total phenolic compounds were extracted from the oil samples twice by a water:methanol (60:40 v/v) mixture, and the total phenolic contents of the extracts were determined by the Folin–Ciocalteu technique according to Papoti and Tsimidou (2009) with an Agilent 8453 UV-Vis spectrophotometer (Germany). The total phenolic contents were calculated as mg gallic acid equivalents per 100 g oil. The antioxidant capacities of the oil samples were evaluated in the same phenolic extracts and were expressed as Trolox equivalent antioxidant capacity (TEAC) (mmol Trolox equivalents per g oil) (Re et al., 1999).

2.8. Component analyses of the poppy seed oils

The tocopherol compositions of the samples were analyzed in accordance with the following ISO 9936 method by an HPLC system (Shimadzu, Japan) equipped with an LC-20AT pump system, 5 µm LiCrosorb Si60, 250 × 4.6 mm i.d. column (Hichrom, UK), and Shimadzu RT-10A-XL florescent detector (ISO, 2006). The mobile phase was 3.6% (v/v) THF in n-heptane with 1 mL min^{-1} flow rate at 25 °C constant column temperature. Excitation at 270 nm and emission at 310 nm were used and quantification was done with external standards of α-, γ-, and β-tocopherols.

The sterol compositions of the oil samples were measured by ISO 12228 method (TSE, 1999). The samples were prepared and injected by an autosampler into a PerkinElmer Auto System XL gas chromatograph equipped with an FID and an HP-5 (30 m × 0.32 mm × 0.25 µm) column. Hydrogen was used as the carrier gas at a flow rate of 30 cm^3/s with a 1:50 injector split and injection volume was 0.2 µL. The injector and the detector temperatures were 280 and 300 °C, respectively. The column oven temperature program was set as follows: initial temperature was 240 °C for 0.5 min, it increased at 5 °C min^{-1} to 255 °C and was held for 4 min, then it increased at 5 °C min^{-1} to 310 °C and was held for 30 min. GC control, data collection, and integration were performed by Total Chrom Navigator version 6.3.1. The phytosterols were characterized by comparison of their retention times (relative to 5α-cholestane) with those of commercially available standards.

The quantification of fatty acid methyl esters was done using a gas chromatograph (Finnigan Trace Ultra, Italy) equipped with an HP 88 capillary column (100 m × 0.25 mm i.d. with 0.2 µm film thickness; Agilent Technologies, Inc., USA). The qualification of the fatty acids was performed with a mass spectrophotometer (Finnigan Trace DSQ, USA) at 200 °C direct capillary interface temperature, 70 eV ionization energy level, 50–500 amu mass range with 500 amu s^{-1} scanning rate. A 37-component FAME mixture (C4-C24, Supelco, USA) and CLA standards (Nu-Check, USA) were used for fatty acid determination.

2.9. Statistical analysis

All physical, chemical, and instrumental analyses in this study were performed twice for all varieties and treatment groups. The comparison of the treatments and poppy seed varieties was accomplished by 2-way ANOVA and Tukey's tests. Nonmetric multidimensional scaling (MDS) was used to observe the cumulative relativeness of the data by poppy varieties and treatments. MDS maps were calculated over Z-score standardized values. All statistical analyses were done by using Minitab 16.1.1 and SPSS package programs.

3. Results and discussion

3.1. General properties of the poppy seeds

The physical and chemical properties of the 3 poppy seed varieties are shown in Table 1. There are statistically significant differences among the seeds.

The highest Soxhlet-extracted oil content (46.3%) was found in the blue seeds (Ofis 3), while white seeds (Ofis 8) contained the lowest amount (36.07%) of oil. In a previous study (Azcan et al., 2004), contrary to our results, the oil contents in yellow seeds were much higher than in blue and white poppy seeds, but the varieties were not stated in that study. Furthermore, in the same study, the mean seed moisture level was reported to be 6.4%. In another study (Erinç et al., 2009), the oil content was highest in Ofis 96 yellow seeds, and lowest in third-class white seeds. Rahimi et al. (2011) analyzed 18 poppy seed varieties grown in Turkey and found that the highest amount of oil was in Afyon95 yellow seed (47.95%), and the lowest was in TMO2 gray seed (35.38%). The results of our study are in accordance with the literature. Different ranges might be due to variety, region of cultivation, and climatic factors. The protein content was higher in the Ofis 8 sample. Although there were some statistical differences among the water activity and moisture and ash contents of the seeds, the differences were not large. Özcan and Atalay (2006) reported some of the physical and chemical properties of 7 different poppy seed varieties. Thousand-seed weight values were between 0.290 and 0.429 g, moisture contents were 3.39%–4.76%, amounts of crude protein were 11.94%–13.58%, crude ash amounts were 4.92%–6.25%, crude fiber values were 22.63%–30.08%, HCl-insoluble ash measurements were 0.72%–1.685%, crude oil quantities were 32.43%–45.52%, and crude energy values were 6367–6740.5 kcal/100 g. The protein contents of the poppy seed varieties analyzed in our study were not in good agreement with this study. This might be due to the different analysis techniques used. On the other hand, Azcan et al. (2004) reported total protein contents in yellow, white, and blue seeds as 21.8%, 21.9%, and 22.7%, respectively, and these findings are relatively closer to our results. To the best of our knowledge, no study reporting the instrumental color values of poppy seeds is present in the literature. The color components of luminosity (L value) (L = 0 black, L = 100 white), a* values (+a* = red, –a* = green), and b* values (+b* = yellow, –b* = blue) of the seed samples measured according to the CIE system (Pomeranz and Meloan, 1994) are reported in Table 1. Bajpai et al. (1999) reported poppy seed size between 0.5 and 1.3 mm, and this range is similar to the findings in our study.

3.2. Oil yield and sediment contents of the poppy seeds

The amounts of oil obtained from the 3 poppy seed varieties with the treatments applied before cold pressing and the oil sediments measured in the oil samples (%) are presented in Table 2.

Table 1. Proximate analysis and seed characteristics of 3 poppy seed varieties.

Property	Ofis 3 (blue)	Ofis 4 (yellow)	Ofis 8 (white)
Oil (g/kg) (P = 0.013)	463.01 ± 1.60 [A]	389.12 ± 1.17 [B]	360.7 ± 0.50 [C]
Moisture (g/kg) (P = 0.000)	64.01 ± 1.20 [A]	53.05 ± 0.20 [B]	54.20 ± 0.50 [B]
Ash (g/kg) (P = 0.001)	62.05 ± 0.50 [A]	56.17 ± 0.10 [B]	61 ± 0.40 [A]
Protein (g/kg) (P = 0.020)	193.20 ± 1.40 [C]	201.24 ± 3.10 [B]	214.01 ± 2.70 [A]
Water activity (a_w) (P = 0.001)	0.6031 ± 0.0025 [A]	0.5775 ± 0.0007 [C]	0.5946 ± 0.0035 [B]
Color L (P = 0.001)	44.98 ± 0.49 [C]	47.61 ± 0.07 [B]	64.28 ± 0.51 [A]
a* (P = 0.000)	2.97 ± 0.17 [C]	7.80 ± 0.10 [A]	4.04 ± 0.14 [B]
b* (P = 0.004)	–3.44 ± 0.18 [C]	11.94 ± 0.33 [B]	14.36 ± 0.20 [A]
Seed size (mm) (P = 0.038)	1.71 ± 0.29 [B]	1.16 ± 0.16 [C]	2.22 ± 0.30 [A]
1000-seed weight (g) (P = 0.000)	0.36 ± 0.06 [B]	0.33 ± 0.05 [C]	0.38 ± 0.01 [A]

[A, B]Means followed by the same letter in the same row are not significantly different (P > 0.05).

Table 2. The oil yield and sediment contents of the poppy seed oils after cold pressing.

Property	Treatment	Ofis 3 (blue)	Ofis 4 (yellow)	Ofis 8 (white)
Oil yield (%)	Control	21.89 ± 6.89 ^{B}	27.85 ± 5.76 ^{A}	28.44 ± 4.03 ^{B}
	Roasted	22.18 ± 0.28 ^{B}	29.36 ± 2.62 ^{A}	24.33 ± 7.42 ^{B}
	Enzyme	28.31 ± 1.70 ^{A}	27.82 ± 1.77 ^{B}	38.36 ± 0.58 ^{A}
Oil sediment (%)	Control	1.92 ± 0.08 ^{A}	1.17 ± 0.31 ^{A}	2.19 ± 0.82 ^{A}
	Roasted	1.91 ± 0.07 ^{A}	1.53 ± 0.37 ^{A}	1.33 ± 0.81 ^{A}
	Enzyme	1.89 ± 0.42 ^{A}	1.35 ± 0.18 ^{A}	1.68 ± 0.37 ^{A}

$^{A, B}$Means followed by the same letter in the same row are not significantly different (P > 0.05).

While the effects of seed variety (P = 0.083) and treatment (P = 0.066) were significant, their interactions (P = 0.230) were not statistically significant for the amount of crude oil recovered by cold pressing. Compared to solvent-extracted oil content (36.07%–46.30%) shown in Table 1, the oil recovery rates (21.89%–38.36%) were much lower in all treatments by cold pressing (Table 2). The enzyme treatment in Ofis 3 and Ofis 8 samples, and roasting in Ofis 4 samples, yielded more oil than the control, indicating some limited positive effects of the treatments on the oil yield in cold pressing. Hence, these pretreatments can be suggested for application prior to cold pressing, but the quality parameters of the resulting oils must also be evaluated. Soto et al. (2007) showed that application of Olivex and Celluclast enzymes to borage seeds before cold pressing enhanced oil yield significantly and did not affect oil quality. Erinç et al. (2009) reported that the Soxhlet-extracted oil contents of 8 poppy varieties ranged from 483 g/kg to 527 g/kg. In another study, the solvent-extracted oil contents of different poppy varieties were between 35% and 48% (Rahimi et al., 2011). As can be seen from these results, the oil yield obtained through solvent extraction is distinctly higher than that of cold pressing. On the other hand, cold-pressed oil can be utilized without refining, and hence most of the minor components remain in the oil. Furthermore, the oil retained in the oily cake can be readily extracted with a solvent, if desired. It might be suggested from our experiments that oil yield in cold pressing can be enhanced by increasing press heat and decreasing seed moisture content or by prolonged enzyme incubation, but the resulting oil becomes dark, burned, and sensorially unacceptable. Hence, if cold-pressed oil will be utilized without a refining process as virgin oil, the oil yield might be increased through optimization of processing conditions to a limited degree.

The effects of seed variety, treatments, and their interactions on the oil sediment content (%) were not statistically significant (P = 0.159, P = 0.808, and P = 0.492, respectively). The oil sediment measurements give an idea about any residual microparticles present in the oil after filtration. The values ranged between 1.17% and 2.19%, which is usually evaluated as a small rate and can be reduced by filtration or centrifugation. Such amounts of sediment did not create any visual turbidity problems in the samples. As in virgin olive oil production, natural decantation in stainless steel storage tanks can be easily applied to reduce any turbidity problems.

3.3. Analyses of the poppy seed oily cakes

Some properties of the oily cakes of the poppy seed varieties analyzed within this study are given in Table 3.

The moisture contents ranged between 113.4 and 166.3 g/kg. Although seed moisture level was adjusted to 12% by water conditioning before cold pressing, the oily cakes had higher moisture levels. This result might be due to the proportional change after oil exclusion. While the effect of treatment (P = 0.021) on cake moisture was significant, the effects of seed variety (P = 0.352) and variety–treatment (P = 0.978) interactions were not statistically significant. The crude protein contents of the cakes, measured by the Kjeldahl technique, were determined to vary between 210 and 280 g/kg, so there is a proportional increase in the protein amount of cakes compared to that of the seeds. Similarly, the effects of seed variety, treatment, and their interactions were unimportant on cake protein level. On the other hand, seed variety and treatment interactions (P = 0.005) significantly affected the remaining oil content of the samples, while variety and treatment were not significant alone. After cold pressing, there was 42–170 g/kg oil remaining in the cakes. The total ash contents of the cakes ranged between 51 and 99 g/kg. The Turkish Standard TS 319 named "Poppy seed meal (cake)" provides some values about expeller- and solvent-extracted poppy seed cakes (TSE, 2003). The standard indicates that poppy seed cakes should contain 30%–35% protein, 17% crude cellulose, 3%–6% oil, 9% ash, 1% foreign matter, and 12% moisture. Since a cold pressing system was used in this

Table 3. Proximate analyses of the poppy oily cakes (meals) after cold pressing.

Property	Treatment	Ofis 3 (blue)	Ofis 4 (yellow)	Ofis 8 (white)
Moisture (g/kg)	Control	113.40 ± 31.70	125.70 ± 4.80	144.50 ± 13.20
	Roasted	142.20 ± 10.30	126.10 ± 15.20	134.12 ± 5.70
	Enzyme	166.30 ± 31.30	159.10 ± 8.30	164.10 ± 13.40
Protein (g/kg) (N × 6.25)	Control	250.00 ± 10.01	225.00 ± 7.00	245.00 ± 21.20
	Roasted	235.00 ± 35.00	250.00 ± 10.10	255.10 ± 21.20
	Enzyme	210.00 ± 28.30	280.00 ± 10.10	265.00 ± 7.00
Oil (g/kg)	Control	60.10 ± 7.70 ^{Bb}	155.20 ± 34.10 ^{Aa}	148.30 ± 10.00 ^{Aa}
	Roasted	108.20 ± 1.14 ^{Aab}	138.60 ± 30.20 ^{Aa}	132.70 ± 13.00 ^{Aa}
	Enzyme	168.60 ± 34.80 ^{Aa}	42.10 ± 6.50 ^{Bb}	100.3 ± 31.60 ^{ABa}
Ash (g/kg)	Control	94.01 ± 4.20 ^{Aa}	51.50 ± 8.50 ^{Bb}	90.50 ± 9.50 ^{Aa}
	Roasted	77.50 ± 18.50 ^{Aa}	82.50 ± 2.50 ^{Aab}	87.00 ± 4.00 ^{Aa}
	Enzyme	83.00 ± 10.50 ^{Aa}	99.50 ± 7.00 ^{Aa}	76.50 ± 13.40 ^{Aa}

$^{A, B}$Means followed by the same letter in the same row are not significantly different (P > 0.05).
$^{a, b}$Means followed by the same letter in the same column are not significantly different (P > 0.05).

study, the values are different. Although the oil recovery rate is lower in cold pressing systems, the produced oil is solvent-free, of high quality, and edible. Moreover, oily cakes from cold pressing can be valuable feedstock and can be utilized for human food production, since they are free of solvents and chemicals.

3.4. Physicochemical characteristics of the poppy seed oils

Some physicochemical analyses were applied to the poppy seed oil samples produced in this study and the results are shown in Table 4.

The refractive indices of the samples ranged between 1.4748 and 1.4764, and there were no significant differences among the varieties and treatments. A similar trend was evident for the viscosity (42.8–44.3 cP) and specific gravity (0.91947–0.92072 g/cm^3) values. The turbidity of the samples presented a rather larger variation (1–181 NTU) and significant differences. The highest turbidity values were observed in the control groups and Ofis 8 samples, though roasting and enzyme treatment were found to reduce turbidity significantly. Hence, it can be claimed that to produce more clear cold-pressed edible oil, roasting can be a valuable pretreatment application. There were no important differences among the L and b* color components of the samples, while the a* values exhibited treatment-dependent variation. Azcan et al. (2004) reported that the mean refractive index was 1.4709 and mean specific gravity was 0.940 g/cm^3 for poppy seed oil. These values and those measured in this study are in accordance. There was no report in the literature for viscosity, turbidity, and color values to compare, so our study provides simple but important data for poppy seed oil characteristics.

The FFA levels of the oil samples ranged from 1.3% to 6.9% and there was no statistically significant difference between varieties (P = 0.285), treatments (P = 0.173), and their interactions (P = 0.997). Although roasting reduced the FFA level a little, enzyme treatment caused some minor increases compared to the control. In general, the FFA level should not exceed 3% in virgin oils. Otherwise, neutralization is required to reduce the acidity because acidic oils are sensorially unacceptable due to sour taste and burning sensation (Kayahan and Tekin, 2006). Cold pressing can yield edible and very high quality oil, though seed roasting seems to be a prerequisite treatment for both better yield and higher quality. Enzyme treatment can enhance oil yield (Table 2) but oil quality is reduced, possibly due to the lipolytic activity present as impurities in the enzymes used, or due to oil hydrolysis that developed during incubation of seeds in an aqueous enzyme solution. Therefore, it can be suggested that enzyme treatment would be better if the oil is going to be neutralized before consumption. The peroxide values of the samples ranged from 0.68 to 2.98 mEq O_2/kg oil. The values were dependent on variety (P = 0.017) and treatment (P = 0.029), but were not dependent to variety–treatment interactions (P = 0.149). The peroxide values were also significantly higher in enzyme-treated samples than in the roasted and control groups. It is quite possible that during the incubation period in the enzyme solution, air-based oxidation may have taken place. Here again, if higher yield is the aim of enzyme treatment, neutralization may

Table 4. The physicochemical properties of the poppy seed oils.

Property	Treatment	Ofis 3 (blue)	Ofis 4 (yellow)	Ofis 8 (white)
Refractive index (20 °C)	Control	1.475 ± 0.001	1.475 ± 0.002	1.475 ± 0.001
	Roasted	1.475 ± 0.005	1.476 ± 0.001	1.475 ± 0.002
	Enzyme	1.475 ± 0.002	1.474 ± 0.001	1.476 ± 0.001
Viscosity (20 °C, cP)	Control	43.20 ± 0.10	43.10 ± 0.80	43.8 ± 1.10
	Roasted	43.90 ± 0.30	44.30 ± 0.70	43.3 ± 0.20
	Enzyme	42.80 ± 0.30	43.60 ± 0.60	43.2 ± 0.40
Specific gravity (20 °C, g/cm^3)	Control	0.9202 ± 0.0064	0.9205 ± 0.0003	0.9194 ± 0.0007
	Roasted	0.9201 ± 0.0009	0.9200 ± 0.0001	0.9198 ± 0.0009
	Enzyme	0.9207 ± 0.0019	0.9203 ± 0.0005	0.9202 ± 0.0004
Turbidity (20 °C, NTU)	Control	43.00 ± 0.00 ^{Ca}	168.00 ± 1.00 ^{Ba}	181.50 ± 1.50 ^{Aa}
	Roasted	1.00 ± 0.00 ^{Ab}	1.50 ± 0.50 ^{Ab}	1.00 ± 0.00 ^{Ab}
	Enzyme	1.00 ± 0.00 ^{Ab}	1.25 ± 0.50 ^{Ab}	3.50 ± 0.50 ^{Ab}
Color L	Control	54.09 ± 0.05	52.42 ± 1.02	52.53 ± 0.92
	Roasted	54.05 ± 0.23	54.02 ± 0.37	53.31 ± 0.35
	Enzyme	53.64 ± 0.19	54.68 ± 0.05	52.08 ± 0.92
a*	Control	0.63 ± 0.09 ^{Aa}	1.32 ± 0.40 ^{Aa}	1.87 ± 0.02 ^{Ab}
	Roasted	0.31 ± 0.24 ^{Aa}	0.09 ± 0.05 ^{Aa}	1.28 ± 0.01 ^{Ab}
	Enzyme	1.29 ± 0.41 ^{Ba}	0.24 ± 0.19 ^{Ba}	3.31 ± 0.83 ^{Aa}
b*	Control	4.59 ± 0.03	1.75 ± 1.48	3.65 ± 1.28
	Roasted	4.84 ± 0.03	4.87 ± 0.17	4.73 ± 0.20
	Enzyme	4.76 ± 0.55	4.54 ± 0.04	3.27 ± 0.99
Free fatty acid (% linoleic acid)	Control	4.01 ± 1.50	3.40 ± 0.90	6.40 ± 1.72
	Roasted	1.50 ± 0.10	1.30 ± 0.10	3.20 ± 0.31
	Enzyme	4.10 ± 2.30	4.50 ± 3.40	6.90 ± 3.50
Peroxide value (mEq O_2/kg oil)	Control	0.68 ± 0.44	0.95 ± 0.24	1.37 ± 0.28
	Roasted	0.82 ± 0.11	0.84 ± 0.11	1.29 ± 0.06
	Enzyme	1.82 ± 0.39	0.72 ± 0.23	2.98 ± 0.78
Iodine number (g/100 g oil)	Control	132.50 ± 5.0	133.50 ± 15	137.01 ± 20
	Roasted	141.10 ± 60	135.01 ± 10	135.05 ± 40
	Enzyme	134.10 ± 10	137.50 ± 25	138.50 ± 45
Saponification number (mg KOH/g oil)	Control	178.61 ± 5.28	179.31 ± 3.98	184.28 ± 0.05
	Roasted	186.33 ± 1.99	183.49 ± 0.59	187.63 ± 3.50
	Enzyme	183.77 ± 1.11	185.79 ± 0.87	182.79 ± 2.12
Unsaponifiable matter (%)	Control	1.02 ± 0.02 ^{Aa}	0.91 ± 0.08 ^{Aa}	0.67 ± 0.05 ^{Bb}
	Roasted	0.65 ± 0.04 ^{Bb}	0.85 ± 0.05 ^{Aab}	0.79 ± 0.11 ^{ABab}
	Enzyme	0.84 ± 0.01 ^{ABab}	0.69 ± 0.01 ^{Bb}	0.89 ± 0.03 ^{Aa}
Total phenolics (mg GA/100 g oil)	Control	2.63 ± 0.28 ^{Aa}	1.69 ± 0.05 ^{Ab}	1.33 ± 0.16 ^{Ab}
	Roasted	2.48 ± 0.49 ^{Aa}	3.47 ± 0.28 ^{Ab}	2.42 ± 0.14 ^{Aab}
	Enzyme	1.01 ± 0.74 ^{Ca}	7.59 ± 0.81 ^{Aa}	4.28 ± 0.76 ^{Ba}
TEAC (mmol Trolox/g oil)	Control	31.23 ± 3.20	22.61 ± 1.75	30.37 ± 0.54
	Roasted	23.25 ± 3.58	20.26 ± 1.56	27.14 ± 2.06
	Enzyme	32.03 ± 2.14	26.62 ± 3.10	43.90 ± 15.3

$^{A, B}$Means followed by the same letter in the same row are not significantly different (P > 0.05).
$^{a, b}$Means followed by the same letter in the same column are not significantly different (P > 0.05).

be required. Depending on the purpose of cold pressing, a decision of whether or not to apply enzyme treatment could be made. The iodine numbers of the samples varied between 132.50 and 141.00 g/100 g oil, and none of the factors were found to be statistically significant. A similar case was evident for the saponification numbers of the samples (178.61–187.63). Unsaponifiable matter contents were between 0.65% and 1.02%, and only the effect of variety and treatment interaction was statistically significant (P = 0.002). Firestone (1999) reported iodine numbers of 132–146, saponification numbers of 188–196, and unsaponifiable matter content of 0.4%–1.2% for poppy seed oil. The findings of our study are in good agreement with the literature. On the other hand, Azcan et al. (2004) reported a mean saponification number of 234, unsaponifiable matter content of 1.03%, and a peroxide value of 39 for Turkish poppy seed oil samples. As can be seen from Table 4, the reported peroxide value is very high compared to our findings, because freshness level of the seeds as well as the oil storage conditions can be different. The total phenolic contents and antioxidant capacities (TEAC) of the samples were in the ranges of 1.01 to 7.59 mg GA/100 g oil and 20.26 to 43.91 mmol Trolox/g oil, respectively. The phenolic contents were significantly affected by variety (P = 0.001), treatment (P = 0.001), and their interactions (P = 0.000), whereas the differences in the TEAC values were not statistically significant. No report about the total phenolic content and antioxidant capacity of poppy seed oils is present in literature. Another cold-pressed oil, namely virgin olive oil, is a good example for data about these parameters. Öğütçü and Yılmaz (2009) reported that total phenolics of 30–208 mg GA/kg oil and TEAC values of 0.60–5.61 Trolox Eq/kg oil were present in olive oils. Hence, our study provides the first data on these parameters for cold-pressed poppy seed oils.

3.5. Compositional characteristics of the poppy seed oils

The tocopherol composition of the oil samples is presented in Table 5.

The levels of γ-tocopherol were affected by both variety (P = 0.001) and treatment (P = 0.034), but not by their interactions (P = 0.694). Contrarily, α-tocopherol levels were affected by variety (P = 0.001), treatment (P = 0.027), and their interactions (P = 0.042). Erinç et al. (2009) reported g-tocopherol levels of 195.37–280.85 ppm and α-tocopherol levels of 21.99–45.83 ppm in poppy seed oil samples. Another study (Bozan and Temelli, 2008) reported total tocopherol content as 11.0 mg/100 g poppy seed oil, and the findings of our study are in agreement with the literature. In general, it can be observed from Table 5 that enzyme treatment can reduce tocopherol content by a small amount.

The sterol compositions of the samples were also analyzed and the results are given in Table 6.

It was observed that most of the sterol components were affected by both seed variety and treatment type. From Table 6, it is obvious that neither enzyme treatment nor roasting influenced sterol composition in a definite pattern. Of course there were some changes compared to the control group, but it is difficult to conclude that treatment had a definite negative or positive effect on the sterol compositions of the samples. Erinç et al. (2009) reported a mean total sterol content of 2916.20 ppm in 8 different seed varieties, with main sterol components being β-sitosterol (663.91–3244.39 ppm), campesterol (228.5–736.50 ppm), and Δ5-avenasterol (103.90–425.02 ppm). In another source, the sterol composition of poppy seed oil was given as: β-sitosterol 68%, campesterol 22%, stigmasterol 3%, and either Δ5- or Δ7-avenasterol 2% (Firestone, 1999). In general, the sterol data of our study are similar to the reported data in the literature. It can be

Table 5. The tocopherol composition of the poppy seed oils.

Tocopherol	Treatment	Ofis 3 (blue)	Ofis 4 (yellow)	Ofis 8 (white)
Alpha-tocopherol (mg/kg)	Control	22.90 ± 0.20	33.5 ± 2.40	22.80 ± 1.30
	Roasted	24.50 ± 0.40	33.90 ± 4.60	19.70 ± 0.50
	Enzyme	20.90 ± 2.20	26.90 ± 4.30	13.20 ± 3.20
Gamma-tocopherol (mg/kg)	Control	279.00 ± 18.40 Aa	247.80 ± 5.70 Aa	249.8 ± 11.30 Aa
	Roasted	278.50 ± 5.10 Aa	241.40 ± 15.60 Aa	227.40 ± 9.40 Aa
	Enzyme	267.40 ± 12.40 Aa	246.10 ± 9.60 Aa	156.10 ± 23.90 Bb
Total tocopherol (mg/kg)	Control	301.90 ± 25.80	281.20 ± 11.40	272.60 ± 14.20
	Roasted	302.90 ± 1.30	275.20 ± 28.40	247.10 ± 12.60
	Enzyme	288.30 ± 20.70	272.90 ± 19.60	169.20 ± 38.30

[A, B]Means followed by the same letter in the same row are not significantly different (P > 0.05).
[a, b]Means followed by the same letter in the same column are not significantly different (P > 0.05).

Table 6. The sterol composition of the poppy seed oils.

Sterol (ppm)	Treatment	Ofis 3 (blue)	Ofis 4 (yellow)	Ofis 8 (white)
Cholesterol	Control	1.28 ± 0.05 ^{Bb}	3.50 ± 0.04 ^{Aa}	4.02 ± 0.25 ^{Aa}
	Roasted	3.06 ± 1.15 ^{ABab}	1.44 ± 0.26 ^{Bb}	4.46 ± 0.85 ^{Aa}
	Enzyme	3.44 ± 0.21 ^{Aa}	3.22 ± 0.17 ^{Aab}	2.65 ± 0.01 ^{Aa}
Brassicasterol	Control	1.81 ± 0.38	nd	nd
	Roasted	nd	2.61 ± 0.32	nd
	Enzyme	nd	nd	nd
24-Methylene cholesterol	Control	35.14 ± 0.97 ^{Bb}	59.82 ± 2.73 ^{Aa}	55.68 ± 0.21 ^{Aa}
	Roasted	42.31 ± 0.34 ^{Aab}	30.77 ± 2.28 ^{Bb}	35.78 ± 2.96 ^{ABc}
	Enzyme	45.61 ± 2.57 ^{Ba}	63.42 ± 0.64 ^{Aa}	48.31 ± 0.34 ^{Bb}
Campesterol	Control	280.79 ± 2.78 ^{Bc}	469.67 ± 2.06 ^{Aa}	466.7 ± 10.7 ^{Aa}
	Roasted	403.02 ± 1.03 ^{Ba}	266.21 ± 0.43 ^{Cc}	428.58 ± 6.41 ^{Ab}
	Enzyme	381.19 ± 0.87 ^{Bb}	449.99 ± 3.12 ^{Ab}	432.32 ± 0.11 ^{Ab}
Stigmasterol	Control	44.29 ± 0.75 ^{Bc}	63.88 ± 0.29 ^{Aa}	65.93 ± 1.72 ^{Aa}
	Roasted	54.24 ± 1.99 ^{Ab}	39.60 ± 0.16 ^{Bc}	52.51 ± 0.43 ^{Ac}
	Enzyme	56.96 ± 0.21 ^{Aa}	58.75 ± 0.52 ^{Ab}	59.36 ± 0.08 ^{Ab}
Delta-7 campesterol	Control	3.62 ± 1.31 ^{Bb}	14.61 ± 0.51 ^{Aa}	11.49 ± 2.42 ^{Aa}
	Roasted	3.77 ± 3.77 ^{ABb}	1.77 ± 0.05 ^{Bb}	10.01 ± 0.150 ^{Aa}
	Enzyme	12.37 ± 2.25 ^{Aa}	15.73 ± 0.22 ^{Aa}	9.51 ± 0.01 ^{Aa}
Delta-5,23 stigmastadienol	Control	1.90 ± 1.90	12.68 ± 1.09	nd
	Roasted	nd	nd	nd
	Enzyme	9.13 ± 1.64	15.26 ± 0.22	nd
Clerosterol	Control	23.48 ± 0.51 ^{Ba}	21.73 ± 0.04 ^{Ba}	27.67 ± 1.88 ^{Aa}
	Roasted	22.98 ± 0.34 ^{Aa}	14.20 ± 0.30 ^{Bb}	23.44 ± 0.18 ^{Ab}
	Enzyme	23.57 ± 1.06 ^{Aa}	20.53 ± 0.02 ^{Ba}	23.93 ± 0.01 ^{Ab}
Beta-sitosterol	Control	920.70 ± 12.20 ^{Cc}	1221.80 ± 13.10 ^{Ba}	1554.70 ± 50.55 ^{Aa}
	Roasted	1321.90 ± 16.80 ^{Aa}	697.88 ± 6.99 ^{Bb}	1385.80 ± 15.40 ^{Ab}
	Enzyme	1217.70 ± 11.40 ^{Bb}	1142.70 ± 26.80 ^{Ba}	1363.40 ± 0.10 ^{Ab}
Delta-5 avenasterol	Control	114.24 ± 1.47 ^{Bb}	245.86 ± 1.19 ^{Aa}	266.27 ± 9.93 ^{Aa}
	Roasted	240.58 ± 4.57 ^{Aa}	80.45 ± 0.23 ^{Bb}	245.14 ± 3.50 ^{Aa}
	Enzyme	220.2 ± 13.60 ^{Aa}	236.73 ± 4.25 ^{Aa}	243.64 ± 0.25 ^{Aa}
Delta-5,24 stigmastadienol	Control	0.83 ± 0.06 ^{Bb}	12.80 ± 0.34 ^{Aa}	13.89 ± 0.67 ^{Aa}
	Roasted	11.69 ± 2.35 ^{Aa}	1.64 ± 0.08 ^{Bb}	14.55 ± 0.16 ^{Aa}
	Enzyme	12.47 ± 0.38 ^{Aa}	13.60 ± 0.33 ^{Aa}	13.05 ± 0.20 ^{Aa}
Delta-7 stigmastenol	Control	1.19 ± 0.07	nd	nd
	Roasted	nd	nd	nd
	Enzyme	nd	nd	nd
Delta-7 avenasterol	Control	2.06 ± 0.12 ^{Bb}	16.32 ± 1.00 ^{Aa}	15.28 ± 0.88 ^{Aa}
	Roasted	15.82 ± 0.13 ^{Aa}	2.97 ± 0.44 ^{Bb}	16.27 ± 0.26 ^{Aa}
	Enzyme	13.65 ± 2.38 ^{Aa}	16.96 ± 0.36 ^{Aa}	16.22 ± 0.48 ^{Aa}
Total sterols	Control	1431.30 ± 21.60 ^{Cb}	2142.60 ± 17.70 ^{Ba}	2481.60 ± 78.80 ^{Aa}
	Roasted	2119.40 ± 3.80 ^{Aa}	1139.50 ± 9.50 ^{Bb}	2216.50 ± 22.40 ^{Ab}
	Enzyme	1996.30 ± 12.20 ^{Ba}	2036.90 ± 35.10 ^{Ba}	2212.40 ± 0.20 ^{Ab}

$^{A, B}$Means followed by the same letter in the same row are not significantly different (P > 0.05).
$^{a, b}$Means followed by the same letter in the same column are not significantly different (P > 0.05). nd : not dedected.

claimed that enzyme treatment and roasting had no effects on the sterol compositions of the poppy seed oil samples.

Table 7 includes the fatty acid compositions of the samples. Generally, the levels of the detected 5 major fatty acids in the oil samples were not found to be dependent on the seed variety and the treatments or their interactions.

Moreover, the amount of each individual fatty acid seemed to be unaffected by either enzyme treatment or roasting. The fatty acid compositions of the samples were very similar to those reported in the literature. Bozan and Temelli (2008) reported major fatty acids of poppy seed oil as 73% linoleic, 10% palmitic, and 13% oleic acids. Azcan et al. (2004) reported GC/MS-analyzed fatty acid composition of poppy seed oil as stearic acid of 2.5%–3.2%, linolenic acid of 0.4%–0.6%, palmitic acid of 10%–13%, oleic acid of 16.1%–24.7%, and linoleic acid of 56.4%–69.2%. Additionally, it was indicated that a major fatty acid, linoleic acid, was highest (69.2%) in white seeds and lowest (56.4%) in blue seeds (Azcan et al., 2004). Another study reported that the fatty acid composition of poppy seed oil was as follows: 12.20% palmitic, 0.27% palmitoleic, 2.30% stearic, 22.19% oleic, 59.87% linoleic, 1.30% linolenic, 0.67% arachidonic, 0.16% gadoleic, and 0.29% erucic acid (Ryan et al., 2007). All these studies and our findings indicate that poppy seed oil is rich in linoleic acid, and because it includes some oleic and palmitic acid, it can be classified as a balanced nutritious edible oil.

The relationship among the seed varieties and treatment types by the measured parameters can be visualized simultaneously by MDS, which provides a closeness map on dimensions. In this statistical technique, the validity of the map is defined by the stress value; if the stress value is under 0.025, this is classified as very good, 0.025–0.05 as good, 0.05–0.1 as acceptable, and 0.1–0.20 as poor validity. The closeness of the 15 measured parameters within each variety to the treatments (control, roasting, and enzyme treatment) is presented in Figure 1a. The groups were very well separated, with a stress value of 0.00618. In fact, the control samples are completely separated from the other 2 groups, but also located far from each other. Contrarily, roasted and enzyme-treated samples are well separated but very closely located within the groups. These results once again indicate that the applied pretreatments caused some measurable differences among the samples. By a similar approach, the distribution of only seed varieties by the 15 measured parameters is shown in Figure 1b. Obviously Ofis 8 (white seed) is definitely separated from the other 2 varieties. The parameters of Ofis 3 (blue) and Ofis 4 (yellow) seeds also form 2 definite separate groups, but closer to each other. Hence, this map indicates that some differences in the measured parameters are also dependent on the seed varieties.

Cold pressing is a versatile, easy-to-operate, cheap, and high-quality oil production system. Enzyme treatment and roasting of oil seeds can improve oil yield, but enzyme treatment in particular may cause some problems, like hydrolysis and oxidation in oil quality due to the longer

Table 7. Fatty acid composition of the poppy seed oils.

Fatty Acid (%)	Treatment	Ofis 3 (blue)	Ofis 4 (yellow)	Ofis 8 (white)
Palmitic acid (C16:0)	Control	9.51 ± 0.08	8.70 ± 0.09	8.90 ± 0.13
	Roasted	9.40 ±0.05	8.70 ± 0.03	8.80 ± 0.01
	Enzyme	9.40 ± 0.02	8.70 ± 0.00	8.70 ± 0.12
Stearic acid (C18:0)	Control	2.30 ± 0.03	2.50 ± 0.03	2.30 ± 0.08
	Roasted	2.20 ± 0.01	2.60 ± 0.01	2.20 ± 0.01
	Enzyme	2.20 ± 0.01	2.50 ± 0.00	2.30 ± 0.13
Oleic acid (C18:1)	Control	13.60 ± 0.01	14.30 ± 0.05	13.60 ± 0.43
	Roasted	13.50 ± 0.05	14.30 ± 0.06	13.20 ± 0.01
	Enzyme	13.60 ± 0.06	14.70 ± 0.00	13.70 ± 0.57
Linoleic acid (C18:2)	Control	74.20 ± 0.10	73.90 ± 0.17	74.50 ± 0.70
	Roasted	74.21 ± 0.06	73.10 ± 0.31	75.20 ± 0.01
	Enzyme	74.15 ± 0.07	73.50 ± 0.01	74.70 ± 0.55
Gamma-linolenic acid (C18:3)	Control	0.50 ± 0.01	0.50 ± 0.01	0.60 ± 0.00
	Roasted	0.50 ± 0.00	0.60 ± 0.01	0.60 ± 0.01
	Enzyme	0.50 ± 0.01	0.60 ± 0.00	0.60 ± 0.04

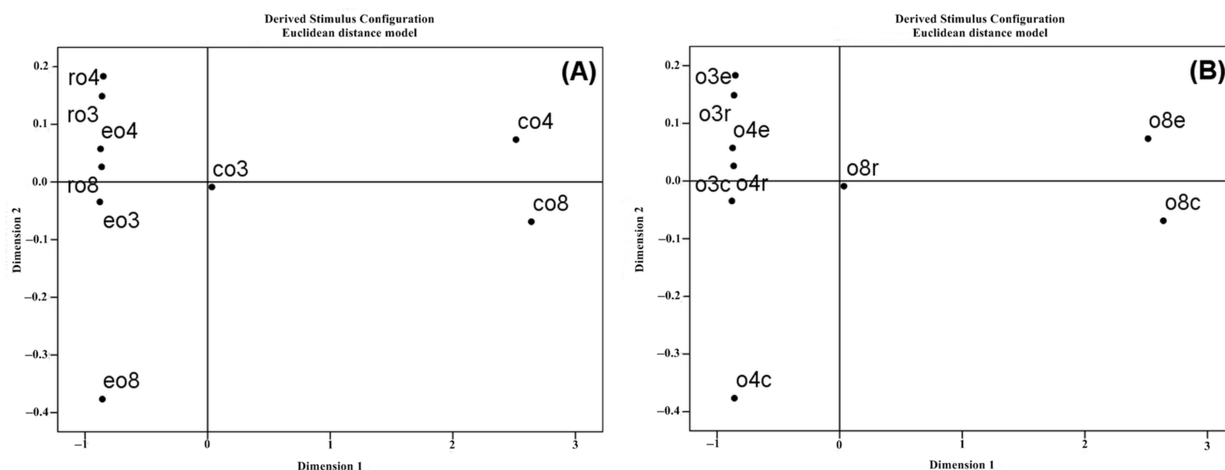

Figure 1. Employment of statistical multidimensional scaling to determine cumulative relativeness among poppy seed varieties (stress: 0.00618, RSQ: 0.99992) (a), and pretreatments (stress: 0.00618, RSQ: 0.99992) (b), prior to cold pressing oil processing. Abbreviations: co8: control Ofis 8, co3: control Ofis 3, co4: control Ofis 4, ro8: roasted Ofis 8, ro3: roasted Ofis 3, ro4: roasted Ofis 4, eo8: enzyme Ofis 8, eo3: enzyme Ofis 3, eo4: enzyme Ofis 4.

incubation period, that may lead to deteriorative reactions. In addition, the oily cake obtained after cold pressing was free of solvents and could be directly used as feedstock or even processed as human food or food additives. The fatty acid, tocopherol and sterol compositions, total phenolics, and antioxidant capacity values of the poppy seed oil samples have proved again that cold-pressed poppy seed oil is a safe, edible oil with high quality and nutritious value. It can be concluded that high-quality edible poppy seed oils can be produced by cold pressing coupled with a preroasting process.

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