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RESEARCH ARTICLE

Physicochemical Stability of Cold-Pressed Yellow Poppy Seed Oil from Afyonkarahisar during Repeated Frying

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ABSTRACT

In this study, the physicochemical changes in cold-pressed poppy seed oil used during the frying process were investigated. Cold press yields of poppy seeds at different pressing speeds were calculated, ranging between 32% and 41%. The frying process was carried out using potatoes (180 °C for 3–4 minutes, repeated seven times), and detailed physicochemical analyses were performed on the oil after each frying cycle. The results showed that the free fatty acid content of the poppy seed oil ranged from 0.90% to 0.94% before and after frying. Peroxide values were measured between 0.30 and 0.72 meq O_2/kg, while total polar compounds ranged from 9.3% to 11.8%. Fatty acid composition analysis revealed that among 13 identified fatty acids, palmitic acid (7.58–9.10%) was the most abundant saturated fatty acid, whereas linoleic acid (72.60–74.16%) was predominant among unsaturated fatty acids. Additionally, iodine value, color, saponification number, and unsaponifiable matter content of the poppy seed oil were determined after each frying session. Statistically, it was determined that the peroxide value, iodine value, color, saponification number, total polar compounds, and trans fatty acid values of poppy seed oil changed during the frying process. Overall, the findings indicate that cold-pressed poppy seed oil is suitable for repeated use in frying applications.

Keywords: Cold press, Edible oil, Fatty acid composition, Repeated frying, Yellow poppy seed.

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Afyonkarahisar’dan Soğuk Preslenmiş Sarı Haşhaş Tohumu Yağının Tekrarlanan Kızartma Sırasında Fizikokimyasal Stabilitesi

ÖZ

Bu çalışmada, kızartma işleminde kullanılan soğuk pres haşhaş yağına ait fizikokimyasal değişimler incelenmiştir. Farklı presleme hızlarında elde edilen haşhaş tohumlarının soğuk pres verimleri %32 ile %41 arasında hesaplanmıştır. Kızartma işlemi, patates kullanılarak 180°C sıcaklıkta, 3–4 dakika süreyle ve yedi kez tekrarlanarak uygulanmış; her kızartma döngüsünün ardından haşhaş yağı üzerinde detaylı fizikokimyasal analizler gerçekleştirilmiştir. Analiz sonuçlarına göre, haşhaş yağının kızartma öncesi ve sonrası serbest yağ asitliği %0.90–0.94 aralığında belirlenmiştir. Peroksit sayıları 0.30–0.72 meq O_2/kg, toplam polar madde oranları ise %9.3–11.8 arasında ölçülmüştür. Yağ asidi kompozisyonu incelendiğinde, 13 farklı yağ asidi arasında palmitik asidin (%7.58–9.10) doymuş yağ asitleri içinde en yüksek orana sahip olduğu; linoleik asidin ise (%72.60–74.16) doymamış yağ asitleri içinde baskın bileşen olduğu saptanmıştır. Ayrıca her bir kızartma sonucunda haşhaş yağının iyot sayısı, renk, sabunlaşma sayısı, sabunlaşmayan madde miktarı değerleri belirlenmiştir. İstatistiki açıdan kızartma işlemi sırasında haşhaş yağının peroksit sayısı, iyot sayısı, renk, sabunlaşma sayısı, toplam polar madde, trans yağ asiti değerlerinin değiştiği tespit edilmiştir. Elde edilen bulgular, soğuk pres yöntemiyle elde edilen haşhaş yağının kızartma işleminde birden fazla kez güvenle kullanılabileceğini ortaya koymaktadır.

Anahtar kelimeler: Sarı haşhaş tohumu, Soğuk pres, Tekrarlanan kızartma, Yenilebilir yağ, Yağ Asidi Kompozisyonu.

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INTRODUCTION

The poppy plant (Papaver somniferum L.) is recognized globally as a traditional crop. It is utilized in various forms: its seeds and oil are consumed as food, its capsules are valued for medicinal use due to their alkaloid content, and its residual pulp is used as animal feed. The oil content of poppy seeds varies depending on seed color, with oil levels reaching up to 50% and Indian cultivars, in particular, are known to be rich in oleic and linoleic acids. Poppy seed oil exhibits a great potential for consumption due to its fatty acid profile, where unsaturated fatty acids predominate. Cold-pressed poppy oil is characterized by a nutty aroma and flavor (Özbek et al. 2020), which is ideal for use as salad dressing, cooking oil, or therapeutic applications (Özcan et al. 2006). Poppy seed oil has many beneficial effects on health, such as lowering cholesterol levels in the blood and treating cardiovascular diseases, due to the unsaturated fatty acids, minerals and various phenolic compounds it contains (Şengün et al. 2020).

Poppy seed oil is generally extracted using two main methods: mechanical pressing and solvent extraction. Among these, the cold pressing method is particularly preferred for producing edible poppy seed oil, as it preserves the natural nutritional components and does not require further refining. Oils obtained through this technique are used as raw material in margarine production as well as in salads and meals (Özcan et al. 2006; Dündar Emir et al. 2015).

Deep frying is a widely preferred cooking method for various food products such as potato chips, frozen finger potatoes, tortilla/corn chips, donuts, chicken and fish. In particular, coating products like fish, chicken, and vegetables before frying is commonly employed as a protective measure against the effects of high temperatures (Moreira et al. 1995).

Frying is defined as the process of immersing food in oil at temperatures typically ranging from 150°C to 200°C, allowing it to develop the desired color, texture, and flavor (Farkas et al. 1995). Frying is essentially a heat and mass transfer process between oil, food and the environment. Frying is one of the most frequently used cooking methods because it provides rapid access to the desired sensory properties in food (Moreira et al. 1995). Moreover, the consumption of deep-fried ready-to-eat foods has been steadily increasing, particularly in the West. The characteristic flavor, crust color and crispiness in food are achieved by frying under appropriate conditions (Rossell 2001).

The high temperature involved in the frying process, which is used to improve the flavor and consumability quality of foods; evaporates the water on the surface of the food and also inactivates microorganisms and enzymes, thus high temperature has a protective effect on foods. The active ingredients required for a food to turn into a fried product are; optimum time, type of food, temperature of the oil during frying, frying method, slice thickness of the food, expected change level in terms of taste and quality (Kayahan 2002). However, frying also has nutritional implications. It increases both the trans fatty acid content and the caloric value of the food. Furthermore, the process of slicing the food increases the amount of oil transferred to the food during frying.

In line with this literature, the aim of this study was to obtain poppy seed oil from yellow poppy seeds originating from Afyonkarahisar using the cold pressing method and to determine its usage level by thoroughly examining the changes in the physicochemical stability of the cold-pressed yellow poppy seed oil during repeated potato frying applications.

MATERIALS and METHODS

Material

The yellow poppy seeds used in this study were obtained from a commercial supplier selling in the İhsaniye district (harvested in August 2021) of Afyonkarahisar Province.

Methods

Frying Process

Cold-pressed extraction of yellow poppy seeds was conducted in the laboratory using an oilseed press machine (Karaerler NF 1000, Türkiye), and an oil sample was separated for the control group. Subsequently, frozen potatoes (Inci Quick-Frozen French Fries, Türkiye) (-18°C) sourced from the local market were subjected to repeated frying cycles (8-10 potato slices per batch, repeated 7 times at 180°C for 3-4 min) in a deep fryer (Arzum Cipsco AR272 brand, Türkiye). During the entire frying procedure, the same batch of poppy seed oil was used without renewal or supplementation with fresh oil. After each frying session, the poppy seed oil was collected, stored in dark glass jars, and kept under refrigerated conditions for one day prior to further analyses. The physicochemical changes observed in the poppy seed oil were compared and interpreted with respect to the control group (with respect to the first cold-pressed poppy seed oil).

Performed Analysis

Obtaining Poppy Oil from Yellow Poppy Seeds and Determination of Oil Yield

A Karaerler NF 1000 brand (Türkiye) cold press machine was used to obtain poppy oil from yellow poppy seeds. The cold press machine utilized is a variable speed screw press with a 1.5 kW, 220 Volt motor and has a nominal capacity of 1-30 kg of seed per hour. The operating conditions of the cold press oil machine were determined as 10-15 Hz, which is considered optimal for poppy seed processing. Oil seed samples were processed in 1 kg batches. The average exit temperature of the poppy seed oil during the cold-pressing process was measured as 40°C. The oil and press cake obtained were stored in moisture-free environment and kept under refrigerated conditions (+4-10 °C). Oil yield was calculated as the ratio of the weight of oil obtained at the end of extraction process to the initial weight of seeds. Extraction yield is the amount of oil obtained from 100 kg of oilseed by cold pressing.

Analyses of Poppy Seed Oil Before and After Frying

The free fatty acidity (AOAC method number: 940.28), peroxide value (AOAC method number: 965.33), iodine value (AOAC method number: 993.10), color analysis (Pomeranz and Meloan 1994), saponification value (AOAC method number: 920.160), unsaponifiable substance amount (AOAC method number: 933.08) of poppy seed oil obtained before and after frying were determined following AOAC methods (AOAC 1984; AOAC 1990).

Total Polar Compounds

Polar compounds (PC) in oils can be determined using column chromatography. The column chromatography method allows for the separation of frying oils into their polar and non-polar components. Non-polar fractions are initially eluted from the column using the column solution. The polar compound content is calculated by determining the difference between the sample placed on the column and the non-polar substance fraction collected from the column. In this study, a polar substance measuring device (PCE-FOT 10, Istanbul/Türkiye) was used to determine the polar compound content. This enabled the assessment of how the total polar compound content of poppy seed oil used in frying changed (Çöl 2023).

Fatty Acid Composition

The oil extracted from the yellow poppy seed samples was esterified according to the ISO-5509 (1978) method (ISO-5509 1978). The sample esters were analyzed using a Shimadzu-2025 GC (Kyoto, Japan) gas chromatograph equipped with a flame ionization detector (FID) and a capillary column (RTX-2330 brand) (60 m x 0.25 mm, film thickness: 0.20 µm). Commercial ester mixtures were used as standards to determine retention times (AOAC 1990). Percentages were recorded based on the peak areas.

Statistical Analysis

The results obtained in this study were reported as mean (±) standard deviation and analyzed using the Minitab 21 software, applying one-way analysis of variance (ANOVA) to assess significant differences among groups (Püskülcü and İkiz 1989).

RESULTS

Oil Yield

As presented in Table 1, the yellow poppy seed variety used in this study exhibited an average oil content of 38.47%. When the oil yields (%) of yellow poppy seeds according to different pressing speeds were statistically examined at the level of $p < 0.05$; it was determined that yellow poppy seeds were similar to each other in terms of oil yield according to 13 Hz, 15 Hz, 18 Hz pressing speeds, however, a significant difference was observed at 30 Hz. The most efficient oil yield was achieved at 15 Hz and 100 °C.

Table 1. Oil yield (%) results of yellow poppy seeds according to different pressing speeds.

Yellow Poppy Seeds	Oil Yield (%)
1st Trial (30 Hz)	32.40±1.31[b]
2nd Trial (18 Hz)	39.00±0.78[a]
3rd Trial (15 Hz)	41.40±0.26[a]
4th Trial (13 Hz)	41.10±1.15[a]

* Mean ± standard deviation; Number of replicates for each analysis: 3; Statistical test were made by applying ANOVA; Degree of significance: $p<0.05$; In each column, means with different letters are significantly different.

Free Fatty Acidity

Fatty acids, which are released through enzymatic or chemical hydrolysis of esterified compounds, are considered minor components in edible oils. During frying processes, the presence of water in the environment causes hydrolysis of oils and the free fatty acidity in the oil increases, causing rancidity (Gökalp et al. 2001). As a result of the repeated frying process we performed, the free acidity value of poppy seed oil was found to be 0.90-0.94% as shown in Table 2.

Peroxide Value

As shown in Table 2, the peroxide values of poppy seed oil clearly indicate a significant decline in oil quality as frying cycles progress. Notably, a statistically significant increase in peroxide values was observed during the 6th and 7th frying stages. This elevation signifies a substantial reduction in the oil's oxidative stability and a concentrated accumulation of primary oxidation products at these later stages. Accordingly, even 7 frying processes of yellow poppy seed oil used in frying showed that it is usable in terms of peroxide values (0.30-0.72 meq O_2/kg) as shown in Table 2. These results indicate that yellow poppy seed oil demonstrates considerable oxidative stability and can be considered a heat-resistant oil suitable for frying applications.

Iodine Value

As presented in Table 2, the iodine values of poppy seed oil did not exhibit the anticipated continuous decrease throughout the successive frying cycles. Instead, the values displayed some fluctuation, with even occasional increases observed at certain stages. Although statistical analysis indicated some significant differences between frying stages, these variations were not as pronounced as the clear deterioration trend seen in the peroxide values. The values obtained in this stduy are consistent with the literature research results and the iodine number is in the range of 145.29-148.14 as shown in Table 2 and it has been determined that it is in the category of drying oils.

Color Value

As shown in Table 2, it was determined that the lightness value (L*) increased up to the 6th frying cycle, followed by a slight decrease during the 6th and 7th cycles, it still remained higher than that of the control sample. The redness value (+a*) increased at the end of the 7th frying process compared to the control group. The yellowness value (+b*) increased at the end of the 7th frying process compared to the control group. As a result of this study, the measured color values of poppy seed oil was 31.09-59.89 for the L* value, -0.54/2.38 for the a* value and 7.25-16.14 for the b* value. Based on these findings, it was observed that with increasing frying cycles, the brightness (L*) of the cold-pressed poppy seed oil increased, along with slight increases in both red (a*) and yellow (b*) color values.

Total Polar Compounds

Long-term deep-fat frying and an increased amount of fried product contribute to a rise in total polar compound levels in the frying oil. As shown in Table 2 (9.3-11.8%), when our analysis results were evaluated, it was seen that the total polar compound content of poppy seed oil changed as the number of frying processes increased.

Saponification Number

In the present study, the saponification numbers of poppy seed oils as a result of frying processes are between 206-216 (Table 2).

Unsaponifiable Matter Content

When the unsaponifiable matter content of yellow poppy seed oil were evaluated after frying, it was found to range between 1.20% and 1.71% (Table 2). In line with these results, it was determined that the amount of unsaponifiable matter decreased as the number of frying operations increased in the poppy seed oil obtained by cold extraction method when used for frying.

Fatty Acid Composition

Our research into the fatty acid profile of poppy seed oil identified consistent concentration ranges for its major constituents. Palmitic acid was found to vary between 7.58% and 9.10%, while stearic acid ranged from 2.11% to 2.23%. Oleic acid concentrations were observed between 12.96% and 13.54%. Linoleic acid proved to be the most abundant fatty acid, with its content ranging from 72.60% to 74.16%, and linolenic acid was present in smaller amounts, between 0.10% and 0.61%. These findings, as detailed in Tables 3 and 4, consistently demonstrated that linoleic acid was the dominant fatty acid across all frying stages. Linoleic acid reached its highest detected level after the sixth frying cycle, whereas oleic acid showed its peak concentration after the seventh frying cycle. After repeated frying processes, linoleic acid, which is the most important fatty acid in poppy seed oils, is followed by oleic, palmitic, stearic and linolenic acids in decreasing order.

Figure 1 clearly demonstrates a significant increase in trans fatty acid (TFA) content in poppy seed oil as the number of frying cycles increases. Initially, in its unheated state (control group), the oil exhibits a very low TFA level (0.010) indicating its natural nutritional quality.

However, a sharp rise is observed after the first frying, with TFA content escalating to 0.135%, suggesting substantial structural changes in the oil due to its first exposure to high temperatures. Subsequent frying cycles show a steady and continuous increase in TFA levels, reaching 0.221% by the seventh use.

When yellow poppy seed oil was examined statistically at $p<0.05$; similarities and differences were determined in terms of saturated and unsaturated fatty acids in cold pressed poppy seed oil at each frying degree.

Table 2. Analysis results of yellow poppy seed oil after frying processes

Yellow Poppy Seed Oil	Free Fatty Acidity (%)	Peroxide Value (meq O_2/kg)	Iodine Value	Color Values			Total Polar Matter (%)	Saponification Number	Unsaponifiable Matter Content (%)
				L* Value	a* Value	b* Value			
Pre-Frying – Control Group	0.90±0.02[a]	0.33±0.02[e]	145.61±0.47[c]	31.09±0.17[f]	-0.54±0.23[f]	8.96±0.07[e]	10.50±0.27[b]	206±0.70[d]	1.71±0.18[a]
After 1.st Frying – Poppy Seed Oil	0.91±0.04[a]	0.42±0.02[bcd]	147.47±0.77[ab]	46.78±0.60[bc]	-0.29±0.02[e]	16.14±0.16[a]	11.80±0.94[a]	208±0.95[cd]	1.65±0.35[a]
After 2.nd Frying - Poppy Seed Oil	0.92±0.03[a]	0.40±0.04[cde]	148.05±0.28[a]	44.82±0.93[c]	-0.14±0.02[e]	14.75±0.14[b]	9.40±0.10[bc]	208±0.80[cd]	1.54±0.26[a]
After 3.rd Frying - Poppy Seed Oil	0.90±0.03[a]	0.38±0.03[de]	145.29±0.70[c]	48.91±0.62[b]	0.66±0.02[c]	13.02±0.16[c]	9.60±0.41[bc]	210±1.03[bc]	1.48±0.19[a]
After 4.th Frying - Poppy Seed Oil	0.92±0.03[a]	0.49±0.01[b]	146.02±0.05[bc]	46.12±0.05[c]	0.41±0.01[d]	12.08±0.52[d]	9.40±0.13[bc]	211±0.96[b]	1.36±0.10[a]
After 5.th Frying - Poppy Seed Oil	0.91±0.01[a]	0.48±0.02[bc]	146.47±0.76[abc]	59.89±1.35[a]	0.35±0.01[d]	13.25±0.11[c]	9.50±0.26[bc]	214±1.11[a]	1.30±0.28[a]
After 6.th Frying - Poppy Seed Oil	0.94±0.02[a]	0.72±0.05[a]	148.14±0.22[a]	40.21±0.68[d]	1.54±0.05[b]	14.81±0.05[b]	9.40±0.09[bc]	214±0.99[a]	1.25±0.19[a]
After 7.th Frying - Poppy Seed Oil	0.92±0.01[a]	0.70±0.03[a]	146.60±0.95[abc]	35.11±0.92[e]	2.38±0.03[a]	13.14±0.35[c]	9.30±0.07[c]	216±1.05[a]	1.20±0.23[a]

* Mean ± standard deviation; Number of replicates for each analysis: 3; Statistical test were made by applying ANOVA; Degree of significance: $p<0.05$; In each column, means with different letters are significantly different.

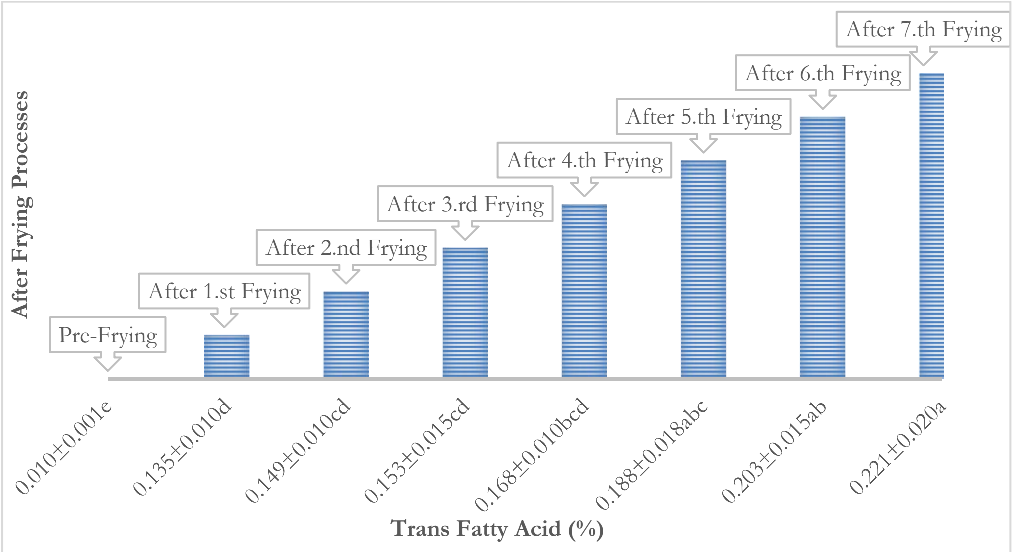

Figure 1: Results of trans fatty acidity of yellow poppy seed oil after frying processes

Table 3. Results of saturated fatty acid composition of yellow poppy seed oil after frying processes

Fatty Acids (%)	Pre-Frying – Control Group	After 1.st Frying - Poppy Seed Oil	After 2.nd Frying - Poppy Seed Oil	After 3.rd Frying - Poppy Seed Oil	After 4.th Frying - Poppy Seed Oil	After 5.th Frying - Poppy Seed Oil	After 6.th Frying - Poppy Seed Oil	After 7.th Frying - Poppy Seed Oil
Myristic Acid	0.04±0.01[a]	0.05±0.02[a]	0.06±0.01[a]	0.05±0.01[a]	0.05±0.02[a]	0.06±0.02[a]	0.05±0.01[a]	0.04±0.01[a]
Palmitic Acid	8.81±0.14[a]	9.02±0.20[a]	8.87±0.41[a]	9.10±0.17[a]	8.93±0.35[a]	7.58±0.48[b]	9.10±0.14[a]	8.53±0.29[a]
Margaric Acid	0.05±0.02[a]	0.05±0.19[a]	0.05±0.22[a]	0.06±0.04[a]	0.05±0.03[a]	0.05±0.03[a]	0.05±0.31[a]	0.05±0.26[a]
Stearic Acid	2.16±0.41[a]	2.11±0.03[a]	2.15±0.25[a]	2.17±0.07[a]	2.18±0.32[a]	2.12±0.23[a]	2.23±0.09[a]	2.23±0.15[a]
Arachidic Acid	0.15±0.04[a]	0.09± 0.02[a]	0.12± 0.01[a]	0.11±0.01[a]	0.10±0.02[a]	0.12±0.02[a]	0.10±0.02[a]	0.11±0.01[a]
Behenic Acid	0.74±0.08[b]	0.06±0.01[c]	0.61±0. 05[b]	0.21±0.04[c]	1.04±0.12[a]	0.18±0.01[c]	1.08±0.06[a]	0.10±0.01[c]
Lignoceric Acid	0.60±0.18[bc]	0.65±0.05[b]	0.50±0.29[bc]	0.42±0.06[c]	0.46±0.32[bc]	0.60±0.21[bc]	0.02±0.01[d]	1.12±0.35[a]
Σ Saturated F.A.	12.55±0.14[a]	12.03±0.89[a]	12.36±0.23[a]	12.12±0.05[a]	12.81±0.20[a]	10.71±0.20[b]	12.63±0.11[a]	12.18±0.65[a]

* Mean ± standard deviation; Number of replicates for each analysis: 3; Statistical test were made by applying ANOVA; Degree of significance: p<0.05; In each column, means with different letters are significantly different.

Table 4. Results of unsaturated fatty acid composition of yellow poppy seed oil after frying processes

Fatty Acids (%)	Pre-Frying -Control Group	After 1.st Frying - Poppy Seed Oil	After 2.nd Frying - Poppy Seed Oil	After 3.rd Frying - Poppy Seed Oil	After 4.th Frying - Poppy Seed Oil	After 5.th Frying - Poppy Seed Oil	After 6.th Frying - Poppy Seed Oil	After 7.th Frying - Poppy Seed Oil
Palmitoleic Acid	0.13±0.02[a]	0.14±0.01[a]	0.14±0.01[a]	0.14±0.06[a]	0.13±0.01[a]	0.14±0.02[a]	0.14±0.03[a]	0.13±0.02[a]
Heptadecanoic Acid	0.04±0.01[a]	0.04±0.01[a]	0.04±0.01[a]	0.04±0.02[a]	0.04±0.01[a]	0.04±0.01[a]	0.04±0.01[a]	0.04±0.01[a]
Oleic acid	12.96±0.20[a]	13.22±0.18[a]	13.37±0.35[a]	13.45±0.09[a]	13.20±0.27[a]	12.98±0.19[a]	13.40±0.21[a]	13.54±0.20[a]
Ecosanoic Acid	0.60±0.12[a]	0.08±0.19[b]	0.06±0.05[b]	0.06±0.05[b]	0.07±0.07[b]	0.10±0.19[b]	0.07±0.02[b]	0.07±0.05[b]
Erucic Acid	nd	nd	nd	nd	nd	nd	nd	nd
Trans Fatty Acidity	0.010±0.001[e]	0.135±0.010[d]	0.149±0.010[cd]	0.153±0.015[cd]	0.168±0.010[bcd]	0.188±0.018[abc]	0.203±0.015[ab]	0.221±0.020[a]
Σ Monounsaturated F.A.	**13.73±0.12[a]**	**13.48±0.24[ab]**	**13.61±0.13[ab]**	**13.69±0.17[ab]**	**13.44±0.06[ab]**	**13.26±0.16[b]**	**13.65±0.20[ab]**	**13.78±0.11[a]**
Linoleic Acid	73.52±0.50[ab]	73.89±0.29[ab]	74.01±0.61[ab]	72.60±0.62[b]	73.11±0.29[ab]	73.45±0.19[ab]	74.16±0.13[a]	73.28±0.55[ab]
Linolenic Acid	0.10±0.04[b]	0.60±0.21[a]	0.60±0.02[a]	0.59±0.05[a]	0.60±0.18[a]	0.60±0.04[a]	0.61±0.06[a]	0.59±0.21[a]
Σ Polyunsaturated F.A.	**73.62±0.67[ab]**	**74.49±0.33[ab]**	**74.61±0.79[ab]**	**73.19±0.15[b]**	**73.71±0.19[ab]**	**74.05±0.50[ab]**	**74.77±0.21[a]**	**73.87±0.96[ab]**
Σ Unsaturated F.A.	**87.35±0.80[a]**	**87.97±0.77[a]**	**88.22±0.19[a]**	**86.88±1.06[a]**	**87.15±0.37[a]**	**87.31±0.37[a]**	**88.42±0.47[a]**	**87.65±0.36[a]**

nd=not detected.

* Mean ± standard deviation; Number of replicates for each analysis: 3; Statistical test were made by applying ANOVA; Degree of significance: $p<0.05$; In each column, means with different letters are significantly differen

DISCUSSION

Literature data indicate that poppy seed oil content ranges between 47-53% in Pakistan, 41.4-49.1% in India and 44-57% in Turkey (Azcan et al. 2004). Studies investigating oil content according to seed color have reported that yellow poppy seeds generally contain higher oil percentages compared to blue and white varieties. Depending on where poppy is grown, its origin and color type, its seeds have different oil content. While 32.3% oil was obtained by applying the extraction method to yellow poppy seeds, 17.6% oil was obtained when solvent extraction was applied to the oil cake obtained as a result of extraction (Azcan et al. 2004).

Kabutey et al. (2023) processed different oilseeds (sesame, pumpkin, flax, camel thorn, hemp, and cumin) using a cold press machine. The researchers noted that oil yield decreased with increasing pressing speed. The studies have reported that among poppy seed varieties, the highest oil content was found in the Ofis 96-yellow variety, while the lowest was observed in the 3rd class-white variety (Erinç et al. 2009)..

In another similar study, while the crude oil ratio was determined as 32.43 - 45.52% in seven poppy seed varieties (Özcan et al. 2006), it was reported that the oil ratio obtained by applying solvent extraction to different poppy seeds was 35-48% (Rahimi et al. 2011). Although cold pressing enables high-quality oil production without the need for refining and avoids the cost of solvents, a considerable amount of oil remains in the press cake. Therefore, the extraction method appropriate for the purpose of production should be preferred. The oil amounts of the yellow poppy seeds used in the study as a result of cold pressing were found to be similar to the data in the literature, but lower than the methods applied with solvent extraction. Nonetheless, the cold-press technique used in this study yielded high-quality poppy seed oil that did not require further refining.

A review of the literature reveals that the free fatty acidity (FFA) of poppy seed oil samples ranges between 1.3% and 6.9%. It was also observed that the roasting process applied to the seed can reduce the acidity to levels between 1.3% and 3.2%, whereas enzymatic treatment may increase it to 4.1%–6.9% (Dündar Emir 2014).

The FFA value determined in our study (0.90-0.94%) is lower than those reported, this free fatty acidity value is lower than those reported in the literature for poppy seed oil and is comparable to the FFA levels typically observed in natural virgin olive oil.

According to the Turkish Food Codex Communiqué on Oils Named After Plants (Communiqué No: 2012/29), the maximum allowable free acidity for cold-pressed and virgin oils is 4 mg KOH/g of oil (TFC 2012). The free acidity can be reduced by applying a neutralization process (Hussain 2023). Although, our primary goal should be to produce edible quality cold-pressed oil without undergoing any refining process. There is no special value in the Turkish Food Codex for poppy seed oil to be used as frying oil, and the values obtained in this study fall within the limit established in the Turkish Food Codex for frying-grade palm oil.

In conclusion, the frying performance of poppy seed oil, in terms of peroxide value, appears acceptable up to a certain limit; however, it undergoes rapid and statistically significant deterioration in quality particularly after the 5th frying stage. Consequently, the suitability of poppy seed oil for prolonged or repeated frying applications becomes limited, leading to a decrease in frying quality, adverse effects on the sensory profile (taste and aroma) of foods, and an increase in potential health risks.

According to the Turkish Food Codex "Communiqué on Oils Named After Plants" (Communiqué No: 2012/29); the maximum permissible peroxide value for cold-pressed and natural oils is 15 meq O_2/kg (TFC 2012). In a study conducted by Keller et al. (2003), vegetable sunflower oil was heated at 50, 105 and 190°C for certain periods of time and the results showed that peroxide values increased proportionally with both temperature and time (Keller et al. 2003). Similarly, Avcı (2015) investigated the chemical changes that occurring in various olive oils (virgin, natural, Riviera and refined) and sunflower oil during the deep-fat frying process (Avcı 2015). In that study, frozen potatoes were fried at 180ºC for 4 minutes and the process was repeated 10 times without the addition of fresh oil. They reported that there was an increase of 11% ration in refined olive oil and 55% ration in sunflower oil in peroxide values from the beginning to the end of frying. These values are significantly higher than those observed in the present study, and the difference can be attributed to the type and oxidative stability of the oils used in frying. In general, the studies conducted in the literature are aimed at revealing the physicochemical properties of different oilseeds (sunflower, corn, canola, and poppy seed oil) and their oils and their use in frying, but no literature has been found on the use of cold pressed poppy seed oil in frying.

Based on this specific characteristic/value, our findings are consistent with the classification of poppy seed oil as a drying oil. This places it in a similar category to other known drying oils, including linseed, walnut, hemp seed, safflower, and castor oils (Caballero et al. 2003). This suggests that the behavior of double bonds in the oil during frying is more complex than a simple linear reduction, implying that other chemical reactions, in addition to oxidation, likely influence the iodine value. While the iodine value of poppy seed oil is generally reported to range between 132 and 146 in the literature, other studies have found the iodine values in the range of 139.6, 133-141, and 122.0-129.5 for various poppy seed oils

(Atalay 2004; Azcan et al. 2004; Chen et al. 2013; Dündar Emir 2014). According to Karaefe (1992), the iodine value of poppy seed oil obtained by cold pressing is approximately 143, whereas oil extracted using solvent methods exhibits lower iodine values, ranging from 127 to 130 (Karaefe 1992). The iodine value is due to the saturated and unsaturated fatty acids found in the triglyceride structure.

In light of these results; it has been determined that there is not much change in terms of iodine value when poppy seed oil obtained by cold pressing is used for frying. In this respect, there is no problem in using it for frying.

Despite the filtering process applied after each frying cycle, the increases observed in the L*, a*, and b* color values are attributed to the residual potato particles remaining in the oil and the chemical reactions of the oil when exposed to heat. When the color values of enzyme pretreated poppy seed oils were examined in the literature, it was found that the a* value was in the range of 0.09-3.31 and the b* value was in the range of 1.75-4.87 (Dündar Emir 2014).

In the study conducted by Abudak (2014) , the color values (L, a, b) of poppy oil were measured for different poppy varieties and it was stated that white poppy oil was lighter (high L), with yellowish tones (high b); black and gray poppy oils were darker (low L), with reddish tones (high a). Kodaman et al., (2019) examined the color properties of cold-pressed poppy oil in paint applications and reported that the oil had yellowish tones and the L value was at a moderate level. These changes in color do not pose any limitation to the use of cold-pressed poppy seed oil for frying purposes.

According to the Regulation on Specific Hygiene Rules for Solid and Liquid Oils Used in Frying, the highest allowed polar matter for solid and liquid oils to be used in frying is 25% (T.C. Presidential Legislation Information System 2012).

Chen et al. (2013) investigated the accumulation of total polar compounds of frying oils used repeatedly for 48 hours and reported that the polar matter content exceeded the regulatory limit of 25% after 23 hours in soybean oil and 25 hours in palm olein oil (Chen et al. 2013). The differences observed in our study are likely attributable to variations in the type of oil used, as well as differences in the nature of the fried products such as their physical state (e.g., frozen) and moisture content. Despite the increase observed during the frying cycles, the final total polar compound (TPC) content (9.3–11.8%) remained well within the maximum limits determined by the Turkish Food Codex (T.C. Presidential Legislation Information System 2012).

Dündar Emir et al. (2015) reported a decrease in some quality parameters (especially oxidative compounds) in poppy seed oil after roasting and enzyme pretreatment. This is due to the inactivation of enzymes during roasting, the loss of some volatile oxidative compounds, and the increased oxidative stability of the oil due to phenolic/tocopherol compounds. In other words, the decrease in total polar compounds were explained by the breakdown or volatilization of some of the degradation products formed by heating.

The saponification number provides insight into the average molecular weight. Oils with more short-chain fatty acids have higher saponification values. Atalay (2004) reported the saponification number of poppy seed oil to be between 199.5 and 206.5; while Kaarefe (1992) reported values between 192 and 198 (Karaefe 1992; Atalay 2004). It is suggested that the increase in saponification value with successive frying cycles may be attributed, at least in part, to the moisture content of the fried product, which could influence hydrolytic reactions occurring during frying.

According to the literature, the unsaponifiable matter content of poppy seed oils was found to be 1.03%, while in other studies has been reported to vary between 0.40-2.40%, 1.00-2.40%, 0.4-1.2% (Atalay 2004; Azcan et al. 2004, Firestone 1999; Norris 1979). In the study conducted by Karaefe (1992), the unsaponifiable matter of the poppy seed oil extracted by pressing was 0.5%, and the unsaponifiable matter of the oil extracted by extraction was 0.2-0.3% (Karaefe 1992).

When the physicochemical properties of yellow poppy seed oil presented in Table 2 were statistically evaluated at a significance level of $p<0.05$, it was determined that each property was similar or different from each other. According to the degree of frying, it was determined that cold pressed poppy seed oil was similar in terms of free fatty acidity at each degree of frying. However, significant differences were observed in peroxide value, iodine value, color parameters, saponification number, unsaponifiable matter content, and total polar compound content as the number of frying cycles increased.

Our findings are consistent with the literature data. When literature studies were examined, it was found that poppy seed oil predominantly contained 73% linoleic acid, 10% palmitic acid and 13% oleic acid; in another study examining 18 poppy seed oils, it was found that it contained 7.96-10.19% palmitic acid, 2-2.5% stearic acid, 13-17% oleic acid, 68-74% linoleic acid and 0.5-0.8% linolenic acid; In another study on poppy seed oils, it was reported that they contained 12.20% palmitic acid, 0.27% palmitoleic acid, 2.30% stearic acid, 22.19% oleic acid, 59.87% linoleic acid, 1.30% linolenic acid, 0.67% arachidonic acid, 0.16% gadoleic acid and 0.29% erucic acid (Bozan and Temelli 2008; Rahimi et al. 2011; Ryan et al. 2007). When the fatty acid analysis of three different poppy seed varieties was made, it was found that they contained 2.5-3.2% stearic acid, 0.4-0.6% linolenic acid, 10-13% palmitic acid, 16.1-24.7% oleic acid and 56.4-69.2% linoleic acid (Azcan et al. 2004).

In the study conducted on different poppy varieties, the dominant fatty acids were found to be linoleic acid (687.6 - 739.2 g/kg), oleic acid (141.3 - 192.8 g/kg) and palmitic acid (76.8 - 92.8 g/kg) (Erinç et al. 2009).

In the study conducted by Atalay (2004), 2.40-4.30% stearic, 12.85-18.70% palmitic, 13.11-24.13% oleic, 52.60-71.50% linoleic, 0.16-0.50% linolenic acid were found in poppy seed oil samples (Atalay 2004). According to Karaefe (1992), poppy seed oil obtained by pressing contains 0.0091% myristic, 8.687% palmitic, 18.75% stearic+oleic, 72.54% linoleic acid, poppy seed oil obtained by extraction contains 0.0373% myristic, 12.90% palmitic, 33.52% stearic+oleic, 53.534% linoleic acid, and both oils obtained by pressing and extraction contain trace amounts of palmitoleic acid. In addition, the lowest fatty acid in poppy seed oil grown in India is 0.4% arachidonic acid, the highest fatty acid is 73% linoleic acid; the highest fatty acid in poppy seed oil grown in Europe is 65% linoleic acid; the lowest fatty acid in poppy seed oil grown in Argentina is 0.1% arachidonic acid, the highest fatty acid is 70.3% linoleic acid; the lowest fatty acid in poppy seed oil grown in England is 0.3% arachidonic acid, the highest fatty acid is 72.6% linoleic acid (Karaefe 1992).

In line with these results; when poppy seed oil obtained by cold extraction method was examined in terms of fatty acid composition in frying, it was determined that there were very small deviations in terms of fatty acid composition as the number of fryings increased, that it was resistant to heat in this respect, and that the fatty acid composition was important in terms of nutrition, especially in terms of unsaturated fatty acids.

This consistent upward trend highlights the progressive degradation of oil quality and the accumulation of harmful trans fats with repeated use. Overall, the data underscore the health risks associated with reusing frying oils, emphasizing the importance of limiting frying cycles to maintain food safety and minimize the intake of trans fatty acids.

It has been determined that the usability level of an oil should be reduced in order not to increase the concentration of substances harmful to human health in the oil depending on the amount of fried product, the amount of water in the environment, the frying temperature and the frying time in frying processes, and that there is a decrease in the ratio of important fatty acids as the oil used is fried too much (Duman 2008).

According to researchers, hydroperoxides formed as a result of lipid peroxidation in heat-treated oils are transferred to foods fried with these oils, and from there, when these foods are consumed, lipid peroxidation products increase in human tissues, and these peroxidation products can cause atherosclerosis (vascular occlusion) in humans (Cohn 2002).

CONCLUSION

In the study was determined that free fatty acidity of poppy oil before and after frying was 0.90-0.94%, peroxide numbers were 0.30-0.72 meq-O_2/kg and total polar compounds were 9.3-11.8%. When fatty acid composition was examined, it was found that palmitic acid (7.58-9.10%) was the highest value in terms of saturated fatty acids among 13 different fatty acids and linoleic acid (72.60-74.16%) in terms of unsaturated fatty acids. In this respect, the data obtained in our research are the first data in the literature in terms of vegetable oil technology, food, nutrition and other branches of science. As a result of the present study, it was determined that cold pressed poppy oils obtained from yellow poppy seeds are consumable and have nutritious properties. Otherwise, when the results obtained are examined, It has been determined that cold-pressed yellow poppy seed oil can be used at least 3 times in frying potatoes for health reasons, specifically concerning its free fatty acid, peroxide value and total polar matter levels. However, it was determined that the cold pressed poppy oil obtained can be used as more than one frying oil, and it is recommended that attention be paid to the content (water, protein content, etc.) of the food group (meat, vegetables, etc.) to be used for frying in the oil regarding the degree and number of uses, and that research be conducted according to different food groups.

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Authors'Contributions: Idea/Concept/Design/Supervision/Consultancy/Data Collection and/or Processing/Analysis and/or Interpretation/Source Scan/Writing of the Article/Critical Review/: SD

Ethical approval: This study is not subject to the permission of HADYEK in accordance with the "Regulation on Working Procedures and Principles of Animal Experiments Ethics Committees" 8 (k). The data, information and documents presented in this article were obtained within the framework of academic and ethical rules."

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