Hindawi
Journal of Food Quality
Volume 2022, Article ID 8296212, 12 pages
https://doi.org/10.1155/2022/8296212

Research Article

Effect of Different Extraction Methods on Quality Characteristics of Rapeseed and Flaxseed Oils

Shuzhen Wang,[1] **Jinying Wang**,[1,2] **Guoxin Dong**,[1] **Xia Chen**,[1] **Shulin Wang**,[1] **Feng Lei**,[1] **Xuebing Su**,[3] **and Qin Bai**[3]

[1]*College of Agriculture and Animal Husbandry, Qinghai University, Xining 810016, China*
[2]*State Key Laboratory of Plateau Ecology and Agriculture, Qinghai University, Xining 810016, China*
[3]*Qinghai Tongda Oil Processing Co. Limited, Haidong 810600, China*

Correspondence should be addressed to Jinying Wang; wangjinying0128@126.com

Received 25 May 2022; Revised 11 August 2022; Accepted 29 August 2022; Published 19 September 2022

Academic Editor: Vita Di Stefano

This study reports the effect of roasted pretreatment combined with screw press, hydraulic press, and Soxhlet extraction methods on various quality indexes of rapeseed and flaxseed oils, including the oil yield, sensory indexes (color, smell, clarity, viscosity, and colligation score), physicochemical properties (acid value, peroxide value, saponification value, moisture and volatiles), major components (fatty acid composition and triglyceride composition), and minor components (volatile compounds, total phenols, and vitamin E contents). The results indicated that the oil yield, sensory indexes, physicochemical properties, fatty acid composition, volatile compounds, total phenol, and vitamin E contents in vegetable oils have been significantly affected by different extraction methods. The yields of rapeseed and flaxseed oils of Soxhlet extraction method were increased by 30.10%–73.90% and 6.30%–54.40%, respectively, compared with other treatment groups. In addition, roasted pretreatment significantly increased the yields of oils by 4.10%–25.00% and 6.70%–23.15%, respectively, compared with the untreated group. The contents of linolenic acid and vitamin E in rapeseed and flaxseed oils extracted from screw press method were higher. In particular, the linolenic acid content of cold-pressed rapeseed oil extracted by screw press increased by 1.50%–23.80% compared with other treatment groups. In addition, the contents of vitamin E in cold-pressed rapeseed oil and flaxseed oil obtained by screw press increased by 1.22%–78.91% and 3.00%–18.80%, respectively. The Soxhlet extraction could improve oil yield and total phenol content, but the quality of the oil was inferior due to high acid values (0.93–3.36 mg KOH/g) and peroxide values (0.70–5.23 meq O_2/kg). Furthermore, the hydraulic press method could extract vegetable oils with excellent sensory scores. The roasted pretreatment gives the rapeseed and flaxseed oils a good smell. The major volatile compounds in rapeseed and flaxseed oils were aldehydes, acids, alcohols, heterocycles, and ketones. Different extraction methods and pretreatment had no significant effect on the compositions and contents of triglycerides. This study provides a basic understanding on the selection of appropriate oil extraction techniques for oil extraction at a large scale.

1. Introduction

Rapeseed is one of the major edible vegetable oil seeds with high oil contents (38%–50%) [1]. Canada and China are the top two producers of rapeseeds worldwide, and rapeseed oil is mainly consumed in China [2]. As the traditional bulk edible oil in China, natural rapeseed oil is rich in omega-3 polyunsaturated fatty acids, and the dominant type is linolenic acid, which represents ~8% of total fatty acids [3]. Rapeseed oil also contains many cardioprotective micronutrients including antioxidant vitamins such as vitamin E [4], polyphenols such as sinapic acid (free phenolic acid), sinapine (esterified form; the most abundant species) [5], and phytosterols [6], which have strong antioxidant, senility-delaying, and antihypercholesterolemic activities [7]. In particular, vitamin E offers protection against oxidative deterioration and maintains the sensory properties of foods [8].

Oilseed flax (*Linum usitatissimum* L.) is one of the most important oil crops in the alpine regions of North and

Northwest China [9]. As an ancient edible vegetable oil, flaxseed oil contains an abundant omega-3 fatty acids and small amounts of other components such as polyphenols and phytosterols. Omega-3 fatty acids have been reported to be associated with a lower risk of cardiovascular disease [10], diabetes [11], and cancer [12].

Oil extraction methods play an important role in vegetable oil yields, qualities, and oxidation stability. There are many technical processes involved in the extraction of oils from the same origin, making the final products different in physicochemical proprieties and nutritional values [13, 14]. In China, there are many traditional extraction methods, such as solvent extraction and mechanical pressing. Screw press is one of the oldest and most popular methods for oil production worldwide [15] because the technique is easy to operate and maintain. However, the method could only partially defat the seeds. Therefore, the resulting press cake must be defatted by percolation with hexane. Another mechanical pressing method is the hydraulic press method, which is also one of the oldest and simplest methods for oil extraction. Although the hydraulic press method results in a lower oil yield than the solvent extraction method, the method gives oil higher quality. One study has reported that oils extracted with the hydraulic press tend to contain a higher content of phytosterols [16]. Solvent extraction is one of the cheapest and most efficient techniques for producing edible oils [17], such as Jojoba oil, soybean oil, palm oil, and jatropha oil. In the solvent extraction method, oil seeds are pretreated (grind) and then placed in a suitable solvent to extract the oil from the solid matrix to the liquid phase. Zanqui et al. [18] showed that the average oil yield of flaxseed oil extracted by the subcritical *n*-propane fluid extraction (SubFE) method was 28%, and it had higher purity and higher oxidation stability.

Because it is difficult to extract all of the oil contents from seeds, particularly by mechanical methods, it can be beneficial to develop a pretreatment method that generates oil with a high yield from oilseeds while maintaining the nutritional and quality characteristics. Researchers have recently studied several pretreatments for improving oil yields, such as roasted, freeze-thaw, microwave irradiation [19] and dielectric [20] and ultrasound-assisted hexane extraction. Roasting is a pretreatment method of oilseeds which can provide significant benefits to seeds used for consumption and oil extraction. This method promotes some desirable or undesirable changes in chemical, physical, and nutritional characteristics [21, 22]. Roasting seeds before oil extraction has been shown to have a significant impact on oil as it helps to generate a distinctive aroma and improve the oxidative stability of the oil due to by-products formed as a result of the Maillard reaction [23].

The main objective of this study is to compare the effects of different extraction methods, including screw press, hydraulic press, and Soxhlet extraction methods, on the quality of rapeseed and flaxseed oils. The major components (fatty acid composition and triglyceride composition) and minor components (volatile components, vitamin E, and total phenol contents) were analyzed to assess the quality of oils. This study provides data for processors to select the extraction methods that result in the optimal oil quality.

2. Materials and Methods

2.1. Samples and Chemicals

2.1.1. Samples. Rapeseeds "Qingza No. 12" and flaxseeds "Dingya No. 18" were collected from the Xining and Guide in Qinghai (harvest date: March 2021). The seeds were stored at 4°C until extraction.

2.1.2. Reagents. Chromatographic-grade *n*-heptane and methanol were purchased from Damao Chemical Reagents Co. (Tianjin, China). Methyl undecanoate, methyl hexadecanoate, methyl stearate, methyl oleate, methyl linoleate, and methyl linolenate were purchased from Sigma Aldrich Trading Co. (Shanghai, China).

2.2. Oil Extraction

2.2.1. Sample Pretreatment. Seeds were cleaned and sieved to remove debris. The whole seeds are roasted in an electromagnetic oven, the roasted temperature is 160°C–180°C, the time is 10 min, and the seeds are constantly turned during the roasting to avoid burning. Untreated seeds were used as controls, which represent the cold application.

2.2.2. Screw Press. Vegetable oil was extracted using an XZ-Z505W horizontal screw press machine (Guangzhou Xuzhong Food Machinery Co., LTD, China). The output of the screw press was 0.36 t/h. Gravity fed samples at the hopper of the screw press, and the oil was collected at the outlet. The temperatures of the screw press were 160°C–180°C. Oil temperature was 40°C. To slow down oil oxidation and remove some impurities, after centrifugation at 2500*g* for 15 min, the oil samples were kept in a 250 mL brown bottle and stored in a refrigerator at 4°C until further analysis.

2.2.3. Hydraulic Press. Oilseed flakes were packed in a cloth sheet and placed in a metallic pressing cylinder. The raw material capacity of the hydraulic press is 3–6 kg. The oilseed flakes inside the metallic cylinder were then preheated at 60°C–70°C. While heating, the metallic cylinder was pressed using an XZ-Z505W hydraulic press machine (Guangzhou Xuzhong Food Machinery Co., LTD, China). At a pressure of 50 MPa for 15 min, oil temperature was 50°C. After that, the oil was centrifuged at 2500*g* for 15 minutes and then stored in a 250 mL brown bottle at 4°C until subsequent analysis.

2.2.4. Soxhlet Extraction. Vegetable oil was extracted from these samples with a SOX406 fat analyzer (Shandong Haineng Scientific Instrument Company, China). In a typical extraction, ground dried seeds (6 g) were packed in a thimble and then extracted with petroleum ether (100 mL). The immersion, washing, and recovery steps were performed at

70°C, and each step lasted for 2, 5, and 1 h, respectively. All the extracted oils were collected, and the residual solvent was removed using a draught drying cabinet. The oil was stored in 250 mL brown bottle at 4°C until further analysis.

2.3. Analytical Methods

2.3.1. Sensory Analysis. Oil sensory analysis was carried out according to Szydłowska-Czerniak et al. [24]. Fifteen professional evaluators were employed to evaluate the color, smell, clarity, viscosity, and colligation score of the samples. The samples were given scores on a 5-point scale ranging from 0 (extremely low) to 5 (extremely high).

2.3.2. Physicochemical Properties. Standard methods of the International Organization for Standardization (ISO) were used to determine the acid value (ISO 660, 2020), peroxide value (ISO 3960, 2017), saponification value (ISO 3657, 2020), and moisture and volatiles contents (ISO 665, 2020).

2.3.3. Fatty Acid Profile. Fatty acid contents were determined according to laboratory-established methods [25].

(1) Sample Preparation. 100 ± 0.1 mg of oil samples, 40 mL of methanol, 1 mL of potassium hydroxide methanol (1 mol/L), and 0.5 mL of methyl undecanoate (10 mg/mL; internal standard solution) were mixed until homogenous, and the mixture solution was then shaken in water bath at 50°C for 60 min until the solution was clear. Then, the ester layer was extracted using *n*-heptane. The FAME solutions were diluted with n-heptane prior to injection into the GC column.

(2) GC-FID Analysis. The prepared samples were autoinjected into a Shimadzu GC-2030 gas chromatograph (Shimadzu, Japan) equipped with a fused silica Wonda Cap WAX column (60 m in length × 250 μm in diameter × 0.25 μm). The injector and detector temperatures were fixed at 250°C. High-purity hydrogen was used as the carrier gas flowing at a flow rate of 1 mL/min. The injection volume was 1 μL, and the injection was carried out at a split ratio of 46 : 1. The column temperatures were programmed as follows: initial oven temperature was set at 100°C and held for 13 min; raised to 180°C at 10°C/min and held for 6 min; raised to 200°C at 1°C/min and held for 20 min; and finally raised to 230°C at 4°C/min and held for 10.5 min.

(3) Qualitative and Quantitative Analysis. Qualitative analysis of fatty acids was carried out based on the retention time of 5 types of fatty acid methyl esters, and quantitative analysis was conducted using the internal standard method.

2.3.4. Triglyceride Profile. Triglyceride contents were determined according to laboratory established methods [26].

(1) Sample Preparation. 1 ± 0.1 g of oil was mixed with the mobile phase (acetonitrile : isopropanol (30 : 70, v/v)) in a 10 mL volumetric flask. After swirling for 1 min until completely mixed, the mixture was filtered through a 0.45 um nylon filter membrane in an injection flask before subjecting to high-performance liquid chromatographic analysis.

(2) HPLC-ELSD Analysis. Triglycerides were analyzed using a LC-20AD high-performance liquid chromatograph (HPLC) (Shimadzu, Tokyo, Japan) equipped with an evaporative light-scattering detector (ELSD) and a C18 column (5.0 μm, 4.6 × 250 mm). The column temperature was set at 40°C, and the detector temperature was set to 30°C. Sample at a volume of 5 μL was injected into the HPLC and then eluted with acetonitrile : isopropanol (30 : 70, v/v) at a flow rate of 0.5 mL/min.

(3) Qualitative and Quantitative Analysis. Based on their ECN partitioning, which occurs in the same order as the number of carbon atoms in ECN (from small to large), each triglyceride was qualitatively analyzed based on the order in which the peak emerged. The area normalization method was used for quantitative analysis.

2.3.5. Volatile Compounds. Volatile compounds were determined by reference to the method of Ojeda-Amador et al. with minor modifications [27].

(1) Solid-Phase Microextraction (SPME). Solid-phase microextraction (SPME) was performed using a 50/30 μm PDMS/DVB/CAR PK3 fiber (Beijing, China). 6 ± 0.1 g of oil was transferred into a 15 mL glass vial, which was then inserted with a microstirring bar. The vial was placed in a magnetic water bath at 80°C and stirred magnetically. After allowing the sample to equilibrate for 20 min, the needle of the SPME device was inserted into the vial, and the fiber was allowed to expose to the headspace of the sample. After 40 min of exposure, the fiber was retracted from the vial headspace and then inserted into the gas chromatograph injector.

(2) GC-MS Analysis. An QP2020 NX series gas chromatograph-mass spectrometer (Shimadzu, Japan) was used to analyze volatile compounds adsorbed on the SPME fiber. The separation was carried on an InertCap-wax column (30 m × 0.25 mm, 0.25 μm). Helium was used as the carrier gas flowing at a flow rate of 1.0 mL/min. The injector was operated at 250°C in a split mode at split ratio of 50 : 1. The SPME fiber was kept in the injector for 5 min. The column was maintained at a temperature of 40°C for 2 min; after that, it was heated to 220°C at a rate of 5°C/min and held for 10 min. The MS conditions were as follows: source temperature, 150°C; transfer line temperature, 260°C; acquisition mode, electron impact (EI 70 eV) at 3 scans per second; and mass range, 235–350 m/z.

(3) Qualitative and Quantitative Analysis. In qualitative analysis, the spectra of the compounds were searched against the NIST 14 standard spectrum library and compared with those of the standard. The area normalization method was used in quantitative analysis.

2.3.6. Total Phenols. Total phenols content was estimated by the Folin-Ciocalteu colorimetric method, based on the procedure of Suri et al. [28], using gallic acid as a standard phenolic compound.

(1) Sample Preparation. Oil sample was weighed to 0.5 ± 0.1 g and then subjected to extraction with 2.5 mL of 70% methanol solution. After 5 min, the sample was ultrasonicated for 5 min, refrigerated for 5 min, and then centrifuged for 5 min at 2500g, and the supernatant was transferred to a 10 mL volumetric flask. The above process was repeated 3 times, and the volume was fixed with 70% methanol solution. In another 10 mL volumetric flask, 1 mL of extraction solution, 1 mL of diluted Folin-Ciocalteu (FC) reagent, and 3 mL of 10% sodium carbonate solution were, respectively, added. Pure water was added for volume measurement and then let stand in darkness for 2 h.

(2) Qualitative and Quantitative Analysis. The absorbance at 765 nm was measured using a UV-1780 spectrophotometer (Shimadzu, Japan). The total phenol content was calculated by the equation obtained from the standard curve of gallic acid, which was: $Y = 0.0799X + 0.0368$ $R^2 = 0.9981$.

2.3.7. Vitamin E. Vitamin E was measured based on Faghim et al.'s method with slight modifications [29].

(1) Sample Preparation. Sample was accurately ($Y = 0.0799X + 0.0368$ $R^2 = 0.9981$) weighed to 1.5 ± 0.1 g and then placed in a 50 mL brown centrifuge tube. After 0.2 mL of 50% potassium hydroxide, 0.6 mL of anhydrous ethanol, and 0.2 mL of 16 g/L pyrogallic acid were added, the tube was shaken for 1 min. Saponification was carried out in a water bath at 80°C for 30 min in darkness. After the reaction was complete, the tube was cooled down to room temperature in cold water. Five milliliters of petroleum ether was added to the saponification reaction solution, and the mixture was vigorously mixed by oscillation for 1 min; after that, it was let stand for 15 min. The petroleum ether layer was transferred into another 50 mL brown centrifuge tube. The extraction step was repeated using 5 mL and 3 mL of petroleum ether. The three extracts were then combined and dried under nitrogen stream at room temperature. The dried sample was redissolved in 0.2 mL of chromatography-grade methanol, filtered through a 0.22 μm membrane, and then immediately subjected to analysis.

(2) HPLC-DAD Analysis. The content of vitamin E in oil samples was analyzed by 1100-VWD HPLC equipped (Agilent, China) with a photodiode array detector, of which the emission wavelength was set at 300 nm. The injection volume was 10 μL. The separation was carried out using a Thermo Scientific Syncronis HPLC column with dimensions of 250 mm × 4.6 mm. The flow rate was set at 1.3 mL/min. Methanol and water at a ratio of 92/8 (v/v) were used as the mobile phase.

(3) Qualitative and Quantitative Analysis. Qualitative analysis was carried out using vitamin E standard, and quantitative analysis was conducted using the standard curve, of which the equation was $Y = 1.3901X + 0.1644$ $R^2 = 0.999$.

2.4. Statistical Analysis. The data was statically analyzed using SPSS 26.0 (IBM, USA). To identify significant differences among the extraction methods, two-way analysis of variance (ANOVA) was performed at 95% significance level ($a = 0.05$). Graphs were prepared using Origin 2018 (OriginLab, USA). All results were expressed as arithmetic means of three independent measurements ± standard deviations (SDs).

3. Results and Discussion

3.1. Oil Extractions. Figure 1 shows the effect of different oil extraction methods on rapeseed and flaxseed oil yield. Figure 1(a) shows that the rapeseed oil yield extraction by the Soxhlet extraction method is the highest, which is 39.10%–40.70%, while the rapeseed oil yields of screw press and hydraulic press method are 24.00%–30.00% and 23.40%–26.20%, respectively. The yield of the hot-pressed treatment group was higher than that of the cold-pressed treatment group, which indicated that roasted pretreatment could increase the rapeseed oil yield. This may be because roasted pretreatment destroys the cellular structure of the seeds, making the oils easier to extract [30]. Different oil extraction methods and pretreatment had significant effects on rapeseed oil yield ($P < 0.05$); the yield of rapeseed oil prepared by the Soxhlet extraction method increased by 30.10%–73.90% compared with other methods. The yield of rapeseed oil in hot-pressed treatment increased by 4.10% to 25.00% compared with that in cold-pressed treatment.

Figure 1(b) shows that the yield of flaxseed oil obtained by different oil extraction methods is Soxhlet extraction (31.88%–34.50%) > screw press (24.36%–30.00%) > hydraulic press (22.34%–23.84%). The Soxhlet extraction method has the highest yield of flaxseed oil, but its application in the food industry is limited due to the presence of organic solvent residue in the oil. In contrast, the yield of flaxseed oil extracted by screw press was 8.07%–34.28% higher than that of hydraulic press, which was more suitable for producing flaxseed oil. Different pretreatments had significant effects on the yield of flaxseed oil, and the yield of cold-pressed flaxseed oil was 6.70%–23.15% lower than that of hot-pressed flaxseed oil.

3.2. Sensory Quality. The sensory quality of rapeseed and flaxseed oils prepared by different oil extraction methods was evaluated based on various indicators including color, smell, clarity, viscosity, and colligation score, and the results are shown in Figure 2. As illustrated in Figure 2(a), the sensory scores of rapeseed oil extracted by hydraulic press were highest, followed by those of oil extracted by screw press and Soxhlet extraction. Additionally, hot-pressed rapeseed oil had a better smell, while cold-pressed oil had better color and clarity.

The sensory quality of flaxseed oil was similar to that of rapeseed oil. In particular, hot-pressed flaxseed oil had a better smell than cold-pressed flaxseed oil. This indicates that using roasting as a pretreatment step for rapeseed oil and flaxseed oil extraction could increase consumer satisfaction. This is consistent with research by Yin et al. [31] which showed that consumers prefer roasted sesame oil to cold-pressed sesame oil. Based on the sensory quality, hydraulic press is the most suitable method for extracting oils from rapeseed and flaxseed.

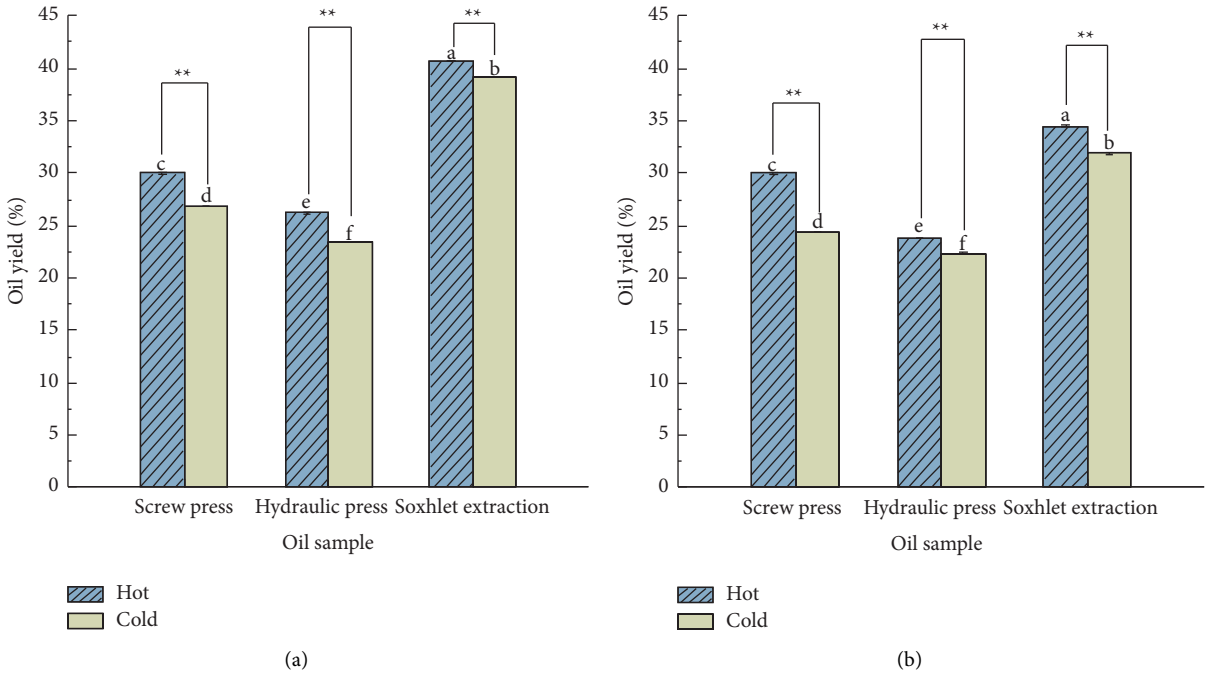

Figure 1: Oil yield of rapeseed and flaxseed oils extracted by different extraction methods. (a) Rapeseed oil and (b) flaxseed oil.

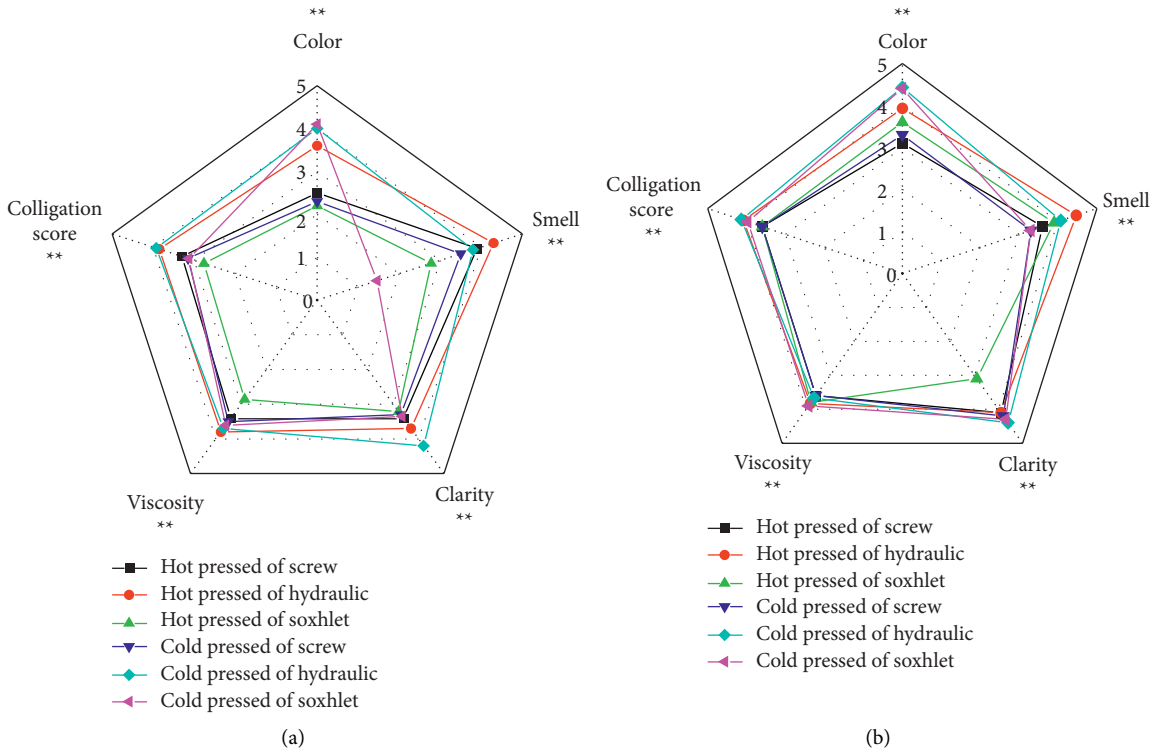

Figure 2: Sensory scores of rapeseed oil and flaxseed oil extracted by different extraction methods. (a) Rapeseed oil and (b) flaxseed oil.

3.3. Physicochemical Properties. The physicochemical properties of oils extracted from oilseeds using different extraction methods are shown in Table 1. Acid values of the extracted rapeseed and flaxseed oils were 0.51–3.36 mg KOH/g and 0.82–1.59 mg KOH/g, respectively, and their peroxide values were between 0.22 and 5.23 meq O_2/kg. The highest acid and moisture values were determined in Soxhlet extraction in hot rapeseed oil. The highest peroxide value was determined in Soxhlet extraction in hot flaxseed oil. In particular, the acid values of hot-pressed rapeseed oil extracted by Soxhlet extraction were 2.11~6.58 times those of other treatments. This might be

Table 1: Physicochemical properties of rapeseed and flaxseed oils.

Oil sample	Extraction	Pretreatment	Acid value (mg KOH/g)	Peroxide value (meq O_2/kg)	Saponification value (mg/g)	Moisture and volatiles (%)
Rapeseed oil	Screw press	Hot	0.70 ± 0.04^{cA}	1.16 ± 0.00^{bA}	194.25 ± 2.04^{cB}	0.05 ± 0.00^{cB}
		Cold	0.56 ± 0.00^{dB}	0.63 ± 0.04^{dB}	195.87 ± 0.75^{bA}	0.09 ± 0.02^{bA}
	Hydraulic press	Hot	0.51 ± 0.01^{eB}	0.52 ± 0.01^{eA}	179.88 ± 1.72^{dB}	0.03 ± 0.00^{cB}
		Cold	0.52 ± 0.06^{eA}	0.46 ± 0.03^{fB}	199.88 ± 1.11^{aA}	0.10 ± 0.00^{bA}
	Soxhlet extraction	Hot	3.36 ± 0.18^{aA}	0.70 ± 0.01^{cB}	173.21 ± 1.69^{fB}	1.54 ± 0.01^{aA}
		Cold	1.38 ± 0.18^{bB}	1.45 ± 0.07^{aA}	178.60 ± 1.17^{eA}	0.06 ± 0.01^{dB}
Flaxseed oil	Screw press	Hot	1.01 ± 0.00^{cB}	0.30 ± 0.00^{dB}	183.23 ± 0.25^{cB}	0.10 ± 0.03^{cB}
		Cold	1.59 ± 0.07^{aA}	0.85 ± 0.04^{cA}	197.51 ± 0.06^{abA}	0.15 ± 0.01^{cA}
	Hydraulic press	Hot	0.95 ± 0.01^{cA}	2.31 ± 0.01^{bA}	183.26 ± 0.04^{cB}	0.06 ± 0.00^{cB}
		Cold	0.82 ± 0.03^{dB}	0.22 ± 0.02^{dB}	199.43 ± 0.63^{aA}	0.14 ± 0.00^{cA}
	Soxhlet extraction	Hot	1.23 ± 0.06^{bA}	5.23 ± 0.25^{aA}	185.16 ± 0.36^{cB}	1.05 ± 0.04^{aA}
		Cold	0.93 ± 0.03^{cB}	0.75 ± 0.01^{cB}	195.28 ± 0.21^{bA}	0.92 ± 0.14^{bB}

Note. Different letters in the same column represent significant differences ($P < 0.05$).

because the oil's water content was too high, which was 1.54%.

Moreover, with the increase of temperature, the hydrolysis reaction of oil accelerated; thus, the acid value increased. The peroxide value of hot-pressed flaxseed oil extracted by Soxhlet extraction was determined to be 5.23 meq O_2/kg, which was an increase of 1.26%–22.77% compared with that of oil in other treatment groups. The rise in the peroxide values of rapeseed and flaxseed oils obtained from the Soxhlet extraction system may be attributed to the solvent used, the applied heat, and the presence of oxygen in the system [32]. Similar results were reported for flaxseed oils. Kulkarni et al. [33] observed that oil extracted by Soxhlet method had the highest peroxide value, whereas the peroxide value of commercial screw press expeller was the lowest. The saponification values of rapeseed and flaxseed oils extracted by different methods were found to be between 173.21 and 199.88 mg/g; these values reflect not only the average molecular weight of the oils but also their purity. The saponification value of hot-pressed rapeseed oil extracted using Soxhlet extraction was the lowest with a value of 173.21 mg/g, and this may be due to the fact that the oil contains some impurities that cannot be saponified.

3.4. Fatty Acid Profile. The fatty acid profiles of rapeseed and flaxseed oils extracted by different methods are presented in Table 2. Five major fatty acids presented in the two types of oils were palmitic acid (C16 : 0), stearic acid (C18 : 0), oleic acid (C18 : 1), linoleic acid (C18 : 2), and linolenic acid (C18 : 3). Oleic acid and linoleic acid (64.20–67.42 g/100 g and 15.01–15.82 g/100 g, respectively) were the most abundant fatty acids found in the rapeseed oils, followed by linolenic acid (7.82–9.68 g/100 g), palmitic acid (3.31–4.75 g/100 g), and stearic acid (2.38–2.89 g/100 g). The contents of oleic acid, linoleic acid, and linolenic acid, which are unsaturated fatty acids (UFA), and palmitic acid and stearic acid, which are saturated fatty acids (SFA), were determined. The contents of saturated and unsaturated fatty acids in rapeseed oil were 5.69–7.64 g/100 g and 87.03–92.75 g/100 g, respectively. The overall fatty acid profile of rapeseed oils presented in this work is similar to that reported previously [34]. In this study, the fatty acid profiles of all the oil samples were nearly indistinguishable, despite the different extraction methods used. However, the statistical analysis showed significant differences between them, particularly the amount of oleic, linolenic, and linoleic acids, which are the major fatty acids in these oils. The content of linolenic acid is higher in screw press in comparison to the hydraulic press and Soxhlet extraction. In particular, the linolenic acid content of cold-pressed rapeseed oil extracted by screw press was determined to be 9.68 g/100 g, which was an increase by 1.50%–23.80% compared with that of oil in other treatment groups. Different pretreatments had no significant effect on the fatty acid composition of rapeseed oil but had a significant effect on its content ($P < 0.05$).

High levels of linolenic acid were detected in flaxseed oils (47.72–51.01 g/100 g), making them a rich source and delivery tool of the essential fatty acid ω-3, followed by oleic acid (24.33–27.02 g/100 g), linoleic acid (13.49–14.48 g/100 g), palmitic acid (5.27–5.97 g/100 g), and stearic acid (4.82–5.16 g/100 g). The total SFA contents were 10.25–10.97 g/100 g, and the total UFA content was 86.57–91.05 g/100 g. The overall fatty acid profile of flaxseed oils was similar to that reported previously [35].

The effects of different extraction methods on the composition and content of fatty acids in flaxseed oil were the same as those in rapeseed oil. The content of linolenic acid in cold-pressed flaxseed oil extracted from a screw press was the highest, 1.10%–6.90% higher than that in other treatment groups. In addition, the linoleic acid content of hot-pressed flaxseed oil extracted by hydraulic press increased by 4.73% to 11.06% compared with other treatment groups. Teixeira et al. [36] also used statistical analysis to show a significant difference ($P < 0.05$) between fatty acid compositions in samples extracted by different extraction methods.

3.5. Triglycerides. The effects of different extraction methods on composition of triacylglycerols in rapeseed and flaxseed oils are shown in Table 3. Some functional properties of oils depend on not only their fatty acid composition but also the distribution of the fatty acids at the three positions of the glycerol backbone. The predominant triglycerides presented

Table 2: Fatty acid profiles of rapeseed and flaxseed oils obtained from different extraction methods.

Oil sample	Extraction methods	Pretreatment	Fatty acids (g/100 g)						
			C16 : 0	C18 : 0	C18 : 1	C18 : 2	C18 : 3	SFA	UFA
Rapeseed oil	Screw press	Hot	3.55 ± 0.06^{cdB}	2.61 ± 0.06^{cB}	67.42 ± 0.03^{aA}	15.80 ± 0.31^{aA}	9.54 ± 0.17^{aB}	6.16 ± 0.12^{dB}	92.75 ± 0.45^{aA}
		Cold	3.66 ± 0.01^{cA}	2.76 ± 0.00^{bA}	67.20 ± 0.07^{aB}	15.68 ± 0.05^{aB}	9.68 ± 0.24^{aA}	6.43 ± 0.01^{cA}	92.56 ± 0.37^{aB}
	Hydraulic press	Hot	4.75 ± 0.04^{aA}	2.89 ± 0.03^{aA}	66.11 ± 0.45^{aA}	15.82 ± 0.09^{aA}	9.12 ± 0.07^{aA}	7.64 ± 0.07^{aA}	91.05 ± 0.43^{aA}
		Cold	4.29 ± 0.00^{bB}	2.87 ± 0.01^{aB}	64.25 ± 0.16^{bB}	15.73 ± 0.18^{aB}	8.24 ± 0.03^{bB}	7.15 ± 0.01^{bB}	88.22 ± 0.37^{bB}
	Soxhlet extraction	Hot	3.31 ± 0.00^{eB}	2.38 ± 0.00^{eB}	64.20 ± 0.00^{bB}	15.01 ± 0.01^{bB}	7.82 ± 0.02^{bB}	5.69 ± 0.00^{eB}	87.03 ± 0.01^{bB}
		Cold	3.47 ± 0.05^{dA}	2.51 ± 0.04^{dA}	66.98 ± 1.12^{aA}	15.79 ± 0.25^{aA}	8.29 ± 0.14^{bA}	5.98 ± 0.09^{dA}	91.05 ± 1.51^{aA}
Flaxseed oil	Screw press	Hot	5.39 ± 0.18^{abB}	4.86 ± 0.15^{bB}	24.33 ± 0.83^{bB}	13.49 ± 0.44^{bB}	50.77 ± 1.66^{aB}	10.25 ± 0.33^{bA}	88.59 ± 2.92^{abB}
		Cold	5.42 ± 0.36^{abA}	4.96 ± 0.33^{aA}	24.53 ± 1.17^{bA}	13.72 ± 0.90^{abA}	51.01 ± 3.25^{aA}	10.39 ± 0.69^{abA}	89.26 ± 5.42^{aA}
	Hydraulic press	Hot	5.27 ± 0.01^{bB}	4.99 ± 0.23^{aB}	25.55 ± 0.05^{aB}	14.48 ± 0.37^{aA}	47.72 ± 0.11^{bB}	10.26 ± 0.11^{abB}	87.75 ± 1.60^{bB}
		Cold	5.40 ± 0.12^{abA}	5.16 ± 0.04^{aA}	27.02 ± 1.34^{abA}	14.09 ± 0.02^{abB}	49.33 ± 1.65^{aA}	10.56 ± 0.04^{abA}	90.44 ± 1.62^{aA}
	Soxhlet extraction	Hot	5.70 ± 0.02^{abB}	4.82 ± 0.00^{bB}	24.63 ± 0.06^{bB}	13.80 ± 0.04^{abB}	48.14 ± 0.96^{abB}	10.52 ± 0.02^{abB}	86.57 ± 0.58^{aA}
		Cold	5.97 ± 0.06^{aA}	5.00 ± 0.12^{aA}	25.80 ± 0.19^{abA}	14.30 ± 0.12^{abA}	50.95 ± 0.68^{aA}	10.97 ± 0.18^{aA}	91.05 ± 1.27^{aB}

Note. Different letters in the same column represent significant differences ($P < 0.05$).

Table 3: Composition of triacylglycerols in rapeseed and flaxseed oils.

Oil sample	Extraction methods	Pretreatment	Triacylglycerols (%)							
			ECN36 LnLnLn	ECN38 LLnLn	ECN40 OLnLn	ECN42 LLL	ECN44 OLL	ECN46 OOL	ECN48 OOO	ECN48 POO
Rapeseed oil	Screw press	Hot	0.46 ± 0.01^{aA}	0.61 ± 0.04^{aA}	2.82 ± 0.08^{aA}	5.48 ± 0.03^{aA}	17.03 ± 1.02^{aA}	21.90 ± 0.42^{aA}	41.93 ± 0.11^{aA}	6.13 ± 0.03^{aA}
		Cold	0.40 ± 0.23^{aA}	0.60 ± 0.02^{aA}	2.48 ± 0.42^{aA}	5.35 ± 0.16^{aA}	18.11 ± 0.23^{aA}	22.54 ± 0.68^{aA}	40.82 ± 1.80^{aA}	6.19 ± 0.06^{aA}
	Hydraulic press	Hot	0.66 ± 0.06^{aA}	1.11 ± 0.52^{aA}	2.99 ± 1.01^{aA}	6.11 ± 0.58^{aA}	18.78 ± 0.50^{aA}	23.02 ± 0.99^{aA}	37.26 ± 2.11^{aA}	5.90 ± 0.24^{aA}
		Cold	0.52 ± 0.08^{aA}	0.95 ± 0.08^{aA}	2.56 ± 0.01^{aA}	6.76 ± 0.01^{aA}	19.16 ± 0.04^{aA}	23.62 ± 0.04^{aA}	39.44 ± 0.06^{aA}	5.82 ± 0.01^{aA}
	Soxhlet extraction	Hot	0.43 ± 0.11^{aA}	0.68 ± 0.10^{aA}	2.67 ± 0.30^{aA}	3.98 ± 1.87^{aA}	18.67 ± 0.50^{aA}	22.28 ± 0.19^{aA}	41.20 ± 0.57^{aA}	6.04 ± 0.78^{aA}
		Cold	0.46 ± 0.07^{aA}	0.63 ± 0.36^{aA}	2.65 ± 0.54^{aA}	5.34 ± 0.10^{aA}	18.09 ± 0.76^{aA}	22.34 ± 0.91^{aA}	41.94 ± 0.56^{aA}	5.43 ± 0.65^{aA}
Flaxseed oil	Screw press	Hot	16.11 ± 0.04^{aA}	8.05 ± 2.14^{aA}	23.18 ± 0.09^{aA}	13.70 ± 0.02^{aA}	17.62 ± 0.08^{aA}	8.28 ± 0.03^{aA}	6.91 ± 0.11^{aA}	2.42 ± 0.09^{aA}
		Cold	16.09 ± 0.06^{aA}	9.53 ± 0.01^{aA}	23.44 ± 0.04^{aA}	13.65 ± 0.06^{aA}	17.74 ± 0.03^{aA}	8.17 ± 0.02^{aA}	6.73 ± 0.06^{aA}	2.34 ± 0.01^{aA}
	Hydraulic press	Hot	15.81 ± 0.27^{aA}	9.40 ± 0.11^{aA}	22.39 ± 1.35^{aA}	13.54 ± 0.01^{aA}	17.64 ± 0.06^{aA}	8.85 ± 0.13^{aA}	7.69 ± 1.18^{aA}	2.59 ± 0.12^{aA}
		Cold	16.05 ± 0.01^{aA}	9.48 ± 0.00^{aA}	23.40 ± 0.04^{aA}	13.62 ± 0.04^{aA}	17.65 ± 0.04^{aA}	8.08 ± 0.41^{aA}	6.61 ± 0.06^{aA}	2.32 ± 0.12^{aA}
	Soxhlet extraction	Hot	14.74 ± 2.08^{aA}	8.86 ± 1.84^{aA}	21.37 ± 2.00^{aA}	13.20 ± 0.05^{aA}	17.82 ± 0.06^{aA}	9.68 ± 1.03^{aA}	6.34 ± 0.54^{aA}	2.64 ± 0.21^{aA}
		Cold	16.16 ± 0.06^{aA}	9.60 ± 0.03^{aA}	23.10 ± 0.00^{aA}	13.66 ± 0.02^{aA}	17.63 ± 0.04^{aA}	8.38 ± 0.02^{aA}	6.96 ± 0.02^{aA}	2.41 ± 0.01^{aA}

Note. Different letters in the same column represent significant differences ($P < 0.05$).

in rapeseed oil included OOO (37.26%–41.94%), OOL (21.90%–23.62%), and OLL (17.03–19.16%). The major fatty acids constituting triglycerides were oleic acid and linoleic acid. This result is in accordance with the GC analysis of total fatty acid content in rapeseed oil, in which the compositions of oleic acid (64.20–67.42 g/100 g) and linoleic acid (15.01–15.82 g/100 g) were highest (Table 2). Different extraction methods had no significant effect ($P > 0.05$) on the compositions and contents of triglycerides. Compared with blank control, the composition and content of triglyceride in rapeseed oil were not significantly affected by roasted pretreatment ($P > 0.05$).

Eight types of triglycerides were found in flaxseed oil: LnLnLn, LLnLn, OLnLn, LLL, OLL, OOL, OOO, and POO. Among all these triglycerides, OLnLn (21.37%–23.44%), OLL (17.62%–17.82%), LnLnLn (14.74%–16.16%), and LLL (13.20%–13.70%) constituted the main body of triglycerides, and the sum of their contents exceeded 71% of total content of triglycerides. This is consistent with the results from fatty acid determination, in which the content of linolenic acid (Ln) was found to be highest (47.72–51.01 g/100 g). Different extraction methods and pretreatment had no significant effect ($P > 0.05$) on the compositions and contents of triglycerides, which was consistent with the results of rapeseed oil.

3.6. Volatile Compounds. The effects of different extraction processes on the volatile components of rapeseed and flaxseed oils are presented in Table 4. A total of 8 volatile compounds, aldehydes, acids, alcohols, heterocycles, alkanes, esters, ketones, and olefins, were identified in the two types of oils. Aldehydes, acids, alcohols, heterocycles, and ketones were the main volatile components identified in rapeseed oils. The contents of alkanes, esters, ketones, and alkenes were lower than those of other volatile compounds. Aldehydes mainly impart the fresh, green, grass, and fatty flavors of oils, while heterocycles play a crucial role in their nutty and roasted flavors. In addition, some alcohols (fruity, coconut) and ketones (floral, fragrant) also contribute to the flavors of oils. Aldehydes are the oxidized products of lipids, mainly linoleic acids and linolenic acids. Aldehydes were found to be the dominant volatile compounds accounting for 1.85%–22.62% of the total amounts of volatiles in the oil samples. Zhong et al. [37] have determined the volatile components in cold-pressed camellia oil and reported the presence of nine saturated aldehydes, from valeraldehyde to nonanoic acid, in the oil. The volatile components of rapeseed oils were significantly affected by different extraction methods. In addition, the contents of various volatile components in rapeseed oil are affected by roast pretreatment. The contents of acids, aldehydes, and alcohols in cold-pressed rapeseed oil extraction by the hydraulic press were the highest, which were 2.33–6.53, 1.34–3.47, and 1.41–4.2 times those in other treatment groups, respectively. The contents of heterocycles and ketones compounds in hot-pressed rapeseed oil extraction from screw press were, respectively, 1.30–3.00 and 1.34–3.37 times higher than those in other treatment groups.

The major volatile compounds in flaxseed oils are acids (5.36%–32.27%), aldehydes (1.97%–34.77%), heterocycles (7.26%–46.79%), alcohols (3.51%–29.53%), and ketones (2.18%–20.76%). Different oil preparation processes and pretreatment affected the contents of volatile compounds in flaxseed oils. Compared to other findings, Danh et al. [38] have also revealed that the volatile components of the lavender essential oils exhibit considerable variations among the extraction methods.

Acids accounted for 5.36%–32.27% of total volatiles in flaxseed oils; however, they have a relatively high threshold value and do not significantly contribute to the odor of vegetable oils. Therefore, the aroma of oils obtained by the experiment is mainly due to only several volatile components. The content of aldehydes in flaxseed oils extraction from screw press was the highest, which was 1.70–17.65 and 1.70–3.50 times those of hydraulic press and Soxhlet extraction, respectively. Alcohols have aromatic, vegetative, rancid, and earthy flavors. Alcohols were detected mainly in the cold-pressed flaxseed oil obtained from hydraulic press method, which were 3.00–8.40 times higher than those in other treatment groups. Heterocyclic substances are the products of the Maillard reaction, which mainly include pyrazine, furan, pyrrole, pyrimidine, and thiazole. High protein oilseeds are the basic materials for the Maillard reaction. As can be seen from Table 4, the contents of heterocyclic substances in flaxseed oil samples extracted using screw press and hydraulic press methods were higher than those in oil samples extracted using Soxhlet extraction. In particular, the contents of heterocyclic substances in hot-pressed flaxseed oil extraction by the hydraulic press were the highest, 2.50–6.50 times higher than those in other treatment groups.

3.7. Total Phenol Content and Vitamin E. Total phenol and vitamin E contents of rapeseed and flaxseed oils extracted using different methods are presented in Figure 3. The total phenolic contents in rapeseed and flaxseed oils were 102.66–191.67 μg/g and 120.16–147.83 μg/g, respectively. The contents of vitamin E in rapeseed oil (474.70–849.30 mg/kg) were significantly higher than those in flaxseed oil (330.30–424.90 mg/kg).

Furthermore, the total phenol contents of the two types of oils prepared by Soxhlet extraction method were the highest. The total phenol contents in hot-pressed oils were higher than those of cold-pressed oils, which was consistent with the work of Wang et al. [39] on the steam explosion pretreatment of rapeseed. In particular, the total phenol contents of hot-pressed rapeseed oil and flaxseed oil extracted by Soxhlet extraction increased by 21.88%–68.10% and 1.11%–23.03%, respectively, compared to other methods. This may be due to the fact that the extraction time of the Soxhlet extraction method was 8 h, which was 12–60 times longer than that of other methods. Moreover, the Soxhlet extraction was continuously repeated using a condensed pure solvent; as a result, the total phenol content was the highest. These results indicate that different extraction

Table 4: SPME-GCMS analysis of volatile compounds in rapeseed and flaxseed oils.

Oil sample	Extraction methods	Pretreatment	Volatile compounds (%)								
			Acids	Aldehydes	Heterocycles	Alcohols	Alkanes	Esters	Ketones	Alkenes	Other
Rapeseed oil	Screw press	Hot	10.77	1.85	23.9	16.01	0.5	1.38	13.45	1.87	30.27
		Cold	17.75	15.12	11.12	13.03	0.87	1.63	3.99	1.58	34.91
	Hydraulic press	Hot	11.99	6.52	18.43	5.79	1.52	3.96	10.05	4.3	37.44
		Cold	43.22	22.62	—	18.29	3.26	—	12.6	—	0.01
	Soxhlet extraction	Hot	18.53	13.52	12.97	4.35	7.56	0.37	7.81	18.57	16.32
		Cold	6.62	16.83	7.96	8.18	10.12	4.2	7.78	4.44	33.87
Flaxseed oil	Screw press	Hot	32.27	34.77	12.06	9.5	2.92	3.32	2.68	—	2.48
		Cold	31.24	26.38	18.82	6.19	1.39	1.99	5.24	—	8.75
	Hydraulic press	Hot	5.36	1.97	46.79	4.69	1.2	3.75	2.18	31.52	2.54
		Cold	25.48	15.46	10.58	29.53	—	—	15.02	—	3.93
	Soxhlet extraction	Hot	21.62	9.94	10.17	3.51	7.31	5.81	20.76	3.18	17.7
		Cold	20.72	15.65	7.26	10.12	8.8	2.05	13.55	2.32	19.53

Note. —: less than 0.5% or undetectable.

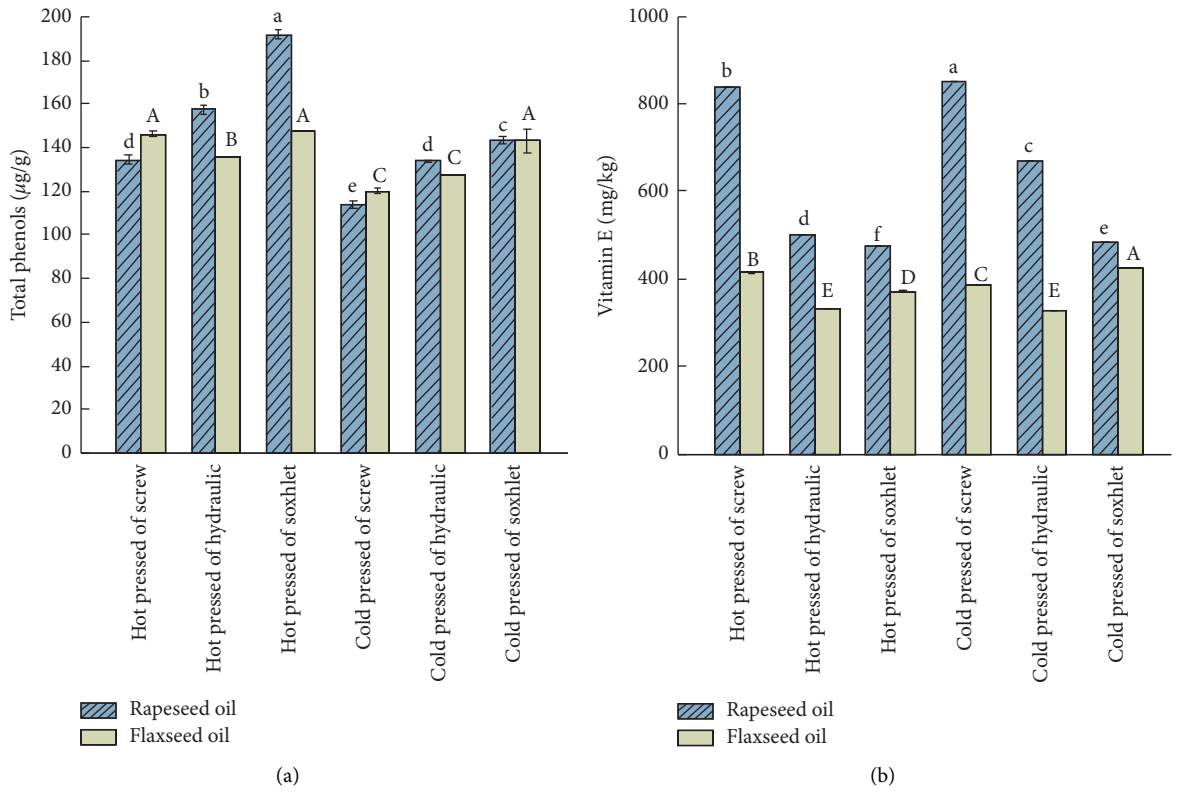

Figure 3: Total phenol and vitamin E contents in rapeseed and flaxseed oils. (a) Total phenol. (b) Vitamin E.

processes significantly affected the total phenol contents in the two types of oils.

The vitamin E contents in the two types of oils were also significantly different and were affected by other extraction processes. The vitamin E content of rapeseed oil is ~2 times that of flaxseed oil. The vitamin E content of rapeseed oil and flaxseed oil produced by screw press was higher than that of the hydraulic press and Soxhlet extraction. In addition, the contents of vitamin E in cold-pressed rapeseed oil and flaxseed oil obtained by screw press increased by 1.22%–78.91% and 3.00%–18.80%, respectively, compared to other methods. Compared with screw press, the vitamin E loss rates of the two oils obtained by hydraulic press and Soxhlet extraction were 14.00%–41.00% and 4.00%–44.00%, respectively. In general, the vitamin E content of the oil can be increased by screw press.

4. Conclusion

The mechanical press was considered superior to the Soxhlet extraction method in terms of sensory score and physico-chemical indexes (acid value, peroxide value, saponification

value, moisture, and volatiles). The physicochemical indexes of oil extracted by the screw press method were comparable to those of oil extracted by the hydraulic press. The contents of vitamin E in cold-pressed rapeseed and flaxseed oils obtained by screw press increased by 1.22%–78.91% and 3.00%–18.80%, respectively, compared to other methods. By contrast, the total phenol contents of hot-pressed rapeseed and flaxseed oils extracted by Soxhlet extraction increased by 21.88%–68.10% and 1.11%–23.03%, respectively, compared to other methods, and the oil yields increased by 30.10%–73.90% and 6.30%–54.40%, respectively. Nonetheless, the quality of the oil was inferior due to high acid value (0.93–3.36 mg KOH/g), peroxide value (0.70–5.23 meq O_2/kg), and moisture and volatile contents (0.06%–1.54%), and the possibility of using the defatted flour is limited to the presence of a residual solvent. In addition, the profiles of fatty acids obtained from different extraction methods and pretreatment were similar, but the statistical analysis showed that the profiles differed significantly. In particular, the linolenic acid contents of cold-pressed rapeseed and flaxseed oils extracted by screw press were determined to be 9.68 g/100 g and 51.01 g/100 g, respectively, which increased by 1.50%–23.80% and 1.10%–6.90% compared with other treatments, respectively. Different extraction methods did not affect the composition and content of triglycerides in the two types of oils. Aldehydes, acids, alcohols, heterocycles, and ketones were the main volatile components in both types of oils. Different extraction methods also affected the volatile components of rapeseed and flaxseed oils.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare no conflicts of interest.

Authors' Contributions

Shuzhen Wang contributed to methodology, formal analysis, data curation, and review and editing. Jinying Wang contributed to conceptualization, resources, methodology, supervision, and writing of the original draft, review and editing, and project administration. Guoxin Dong contributed to formal analysis and review and editing. Xia Chen contributed to methodology and supervision. Shulin Wang contributed to formal analysis and supervision. Feng lei contributed to data curation and review and editing. Xuebing Su contributed to provision of resources and supervision. Qin Bai contributed to provision of resources and investigation.

Acknowledgments

This work was supported by the Science and Technology Department of Qinghai Province, Qinghai Enterprise Research Transformation and Industrialization Special Project (Grant no. 2021-NK-C19).

References

[1] Y. Xie, F. Wei, S. L. Xu et al., "Profiling and quantification of lipids in cold-pressed rapeseed oils based on direct infusion electrospray ionization tandem mass spectrometry," *Food Chemistry*, vol. 285, pp. 194–203, 2019.

[2] C. X. Ji, Y. J. Zhai, T. Z. Zhang, X. Shen, Y. Bai, and J. Hong, "Carbon, energy and water footprints analysis of rapeseed oil production: a case study in China," *Journal of Environmental Management*, vol. 287, Article ID 112359, 2021.

[3] E. Beyzi, A. Gunes, S. Buyukkilic Beyzi, and Y. Konca, "Changes in fatty acid and mineral composition of rapeseed (*Brassica napus* ssp. *oleifera* L.) oil with seed sizes," *Industrial Crops and Products*, vol. 129, pp. 10–14, 2019.

[4] F. D. Goffman, W. Thies, and L. Velasco, "Chemotaxonomic value of tocopherols in Brassicaceae," *Phytochemistry*, vol. 50, no. 5, pp. 793–798, 1999.

[5] J. B. Li and Z. Guo, "Concurrent extraction and transformation of bioactive phenolic compounds from rapeseed meal using pressurized solvent extraction system," *Industrial Crops and Products*, vol. 94, pp. 152–159, 2016.

[6] Y. X. Cong, M. M. Zheng, F. H. Huang, C. Liu, and C. Zheng, "Sinapic acid derivatives in microwave-pretreated rapeseeds and minor components in oils," *Journal of Food Composition and Analysis*, vol. 87, Article ID 103394, 2020.

[7] S. C. Chew, "Chapter 7—cold pressed rapeseed (*Brassica napus*) oil," *Cold Pressed Oils*, Academic Press, London, UK, 2020.

[8] A. Delgado, S. Al-Hamimi, M. F. Ramadan et al., "Contribution of tocols to food sensorial properties, stability, and overall quality," *Journal of Food Quality*, vol. 2020, Article ID 8885865, 8 pages, 2020.

[9] Y. H. Gao, "Oilseed flax (*Linum usitatissimum* L.), an emerging functional cash crop of China," *Oil Crop Science*, vol. 5, no. 2, 2020.

[10] T. Toulabi, M. Yarahmadi, F. Goudarzi, F. Ebrahimzadeh, A. Momenizadeh, and S. Yarahmadi, "Effects of flaxseed on blood pressure, body mass index, and total cholesterol in hypertensive patients: a randomized clinical trial," *Explore-The Journal of Science and Healing*, vol. 18, no. 4, pp. 438–445, 2022.

[11] N. M. Jangale, P. P. Devarshi, A. A. Dubal et al., "Dietary flaxseed oil and fish oil modulates expression of antioxidant and inflammatory genes with alleviation of protein glycation status and inflammation in liver of streptozotocin-nicotinamide induced diabetic rats," *Food Chemistry*, vol. 141, no. 1, pp. 187–195, 2013.

[12] R. Deshpande, P. Raina, K. Shinde, P. Mansara, M. Karandikar, and R. Kaul-Ghanekar, "Flax seed oil reduced tumor growth, modulated immune responses and decreased HPV E6 and E7 oncoprotein expression in a murine model of ectopic cervical cancer," *Prostaglandins & Other Lipid Mediators*, vol. 143, Article ID 106332, 2019.

[13] M. Issaoui and A. M. Delgado, "Grading, labeling and standardization of edible oils," *Fruit Oils: Chemistry and Functionality*, Springer, Berlin, Germany, 2019.

[14] M. F. Ramadan and J. Mörsel, "Oxidative stability of black cumin (nigella sativa l.), coriander (*coriandrum sativum* l.) and niger (*guizotia abyssinica* cass.) crude seed oils upon stripping," *European Journal of Lipid Science and Technology*, vol. 106, no. 1, pp. 35–43, 2004.

[15] G. C. Mrema and P. B. McNulty, "Mathematical model of mechanical oil expression from oilseeds," *Journal of Agricultural Engineering Research*, vol. 31, no. 4, pp. 361–370, 1985.

[16] A. Rabadán, M. Álvarez-Ortí, R. Gómez, A. Alvarruiz, and J. E. Pardo, "Optimization of pistachio oil extraction regarding processing parameters of screw and hydraulic presses," *LWT--Food Science and Technology*, vol. 83, no. 15, pp. 79–85, 2017.

[17] M. D. Luque de Castro and F. Priego-Capote, "Soxhlet extraction: past and present panacea," *Journal of Chromatography A*, vol. 1217, no. 16, pp. 2383–2389, 2010.

[18] A. B. Zanqui, D. R. De Morais, C. M. Da Silva et al., "Subcritical extraction of flaxseed oil with n-propane: composition and purity," *Food Chemistry*, vol. 188, pp. 452–458, 2015.

[19] M. Yang, F. H. Huang, C. S. Liu, C. Zheng, Q. Zhou, and H. Wang, "Influence of microwave treatment of rapeseed on minor components content and oxidative stability of oil," *Food and Bioprocess Technology*, vol. 6, no. 11, pp. 3206–3216, 2013.

[20] B. G. Xu, B. X. Wei, X. F. Ren et al., "Dielectric pretreatment of rapeseed 1: influence on the drying characteristics of the seeds and physico-chemical properties of cold-pressed oil," *Food and Bioprocess Technology*, vol. 11, no. 6, pp. 1236–1247, 2018.

[21] P. Gao, Y. Cao, R. J. Liu, Q. Jin, and X. Wang, "Phytochemical content, minor-constituent compositions, and antioxidant capacity of screw-pressed walnut oil obtained from roasted kernels," *European Journal of Lipid Science and Technology*, vol. 121, no. 1, Article ID 1800292, 2018.

[22] Y. P. Zou, Y. Y. Gao, H. He, and T. Yang, "Effect of roasting on physico-chemical properties, antioxidant capacity, and oxidative stability of wheat germ oil," *LWT--Food Science and Technology*, vol. 90, pp. 246–253, 2018.

[23] S. Mildner-Szkudlarz, M. Różańska, A. Siger, P. L. Kowalczewski, and M. Rudzinska, "Changes in chemical composition and oxidative stability of cold-pressed oils obtained from by-product roasted berry seeds," *LWT--Food Science and Technology*, vol. 111, pp. 541–547, 2019.

[24] A. Szydłowska-Czerniak, A. Tymczewska, M. Momot, and K. Wlodarczyk, "Optimization of the microwave treatment of linseed for cold-pressing linseed oil—changes in its chemical and sensory qualities," *LWT--Food Science and Technology*, vol. 126, Article ID 109317, 2020.

[25] X. R. Wang, Y. Z. Han, Y. X. Li, S. Wang, and J. Wang, "Detection of Qinghai-tibet plateau flaxseed oil adulteration based on fatty acid profiles and chemometrics," *Food Control*, vol. 130, Article ID 108332, 2021.

[26] J. Y. Wang, Y. Z. Han, X. Wang et al., "Adulteration detection of qinghai-tibet plateau flaxseed oil using HPLC-ELSD profiling of triacylglycerols and chemometrics," *LWT--Food Science and Technology*, vol. 160, Article ID 113300, 2022.

[27] R. M. Ojeda-Amador, G. Fregapane, and M. D. Salvador, "Influence of cultivar and technological conditions on the volatile profile of virgin pistachio oils," *Food Chemistry*, vol. 311, Article ID 125957, 2020.

[28] K. Suri, B. Singh, A. Kaur, M. P. Yadav, and N. Singh, "Influence of microwave roasting on chemical composition, oxidative stability and fatty acid composition of flaxseed (*Linum usitatissimum* L.) oil," *Food Chemistry*, vol. 326, Article ID 126974, 2020.

[29] J. Faghim, M. B. Mohamed, M. Bagues, F. Guasmi, T. Triki, and K. Nagaz, "Irrigation effects on phenolic profile and extra virgin olive oil quality of "Chemlali" variety grown in South Tunisia," *South African Journal of Botany*, vol. 141, pp. 322–329, 2021.

[30] D. Zhang, X. J. Li, Y. P. Cao, C. Wang, and Y. Xue, "Effect of roasting on the chemical components of peanut oil," *LWT--Food Science and Technology*, vol. 125, Article ID 109249, 2020.

[31] W. T. Yin, M. Washington, X. T. Ma et al., "Consumer acceptability and sensory profiling of sesame oils obtained from different processes," *Grain & Oil Science and Technology*, vol. 3, no. 2, pp. 39–48, 2020.

[32] M. M. Özcan, K. Ghafoor, F. Al Juhaimi, I. A. M. Ahmed, and E. Babiker, "Effect of cold-press and soxhlet extraction on fatty acids, tocopherols and sterol contents of the moringa seed oils," *South African Journal of Botany*, vol. 124, pp. 333–337, 2019.

[33] N. G. Kulkarni, J. R. Kar, and R. S. Singhal, "Extraction of flaxseed oil: a comparative study of three-phase partitioning and supercritical carbon dioxide using response surface methodology," *Food and Bioprocess Technology*, vol. 10, no. 5, pp. 940–948, 2017.

[34] Q. R. Sun, J. Shi, M. Scanlon, S. J. Xue, and J. Lu, "Optimization of supercritical-CO_2 process for extraction of tocopherol-rich oil from canola seeds," *LWT--Food Science and Technology*, vol. 145, Article ID 111435, 2021.

[35] X. L. Sun, Y. J. Wang, H. K. Li, J. Zhou, J. Han, and C. Wei, "Changes in the volatile profile, fatty acid composition and oxidative stability of flaxseed oil during heating at different temperatures," *LWT--Food Science and Technology*, vol. 151, Article ID 112137, 2021.

[36] G. L. Teixeira, S. M. Ghazani, M. L. Corazza, A. G. Marangoni, and R. H. Ribani, "Assessment of subcritical propane, supercritical CO_2 and soxhlet extraction of oil from sapucaia (*Lecythis pisonis*) nuts," *The Journal of Supercritical Fluids*, vol. 133, no. 1, pp. 122–132, 2018.

[37] H. Zhong, D. R. Bedgood, A. G. Bishop, P. D. Prenzler, and K. Robards, "Effect of added caffeic acid and tyrosol on the fatty acid and volatile profiles of camellia oil following heating," *Journal of Agricultural and Food Chemistry*, vol. 54, no. 25, pp. 9551–9558, 2006.

[38] L. T. Danh, L. N. Han, N. D. A. Triet, J. Zhao, R. Mammucari, and N. Foster, "Comparison of chemical composition, antioxidant and antimicrobial activity of lavender (*lavandula angustifolia* L.) essential oils extracted by supercritical CO_2, hexane and hydrodistillation," *Food and Bioprocess Technology*, vol. 6, no. 12, pp. 3481–3489, 2013.

[39] W. J. Wang, B. Yang, W. L. Li, Q. Zhou, C. Liu, and C. Zheng, "Effects of steam explosion pretreatment on the bioactive components and characteristics of rapeseed and rapeseed products," *LWT--Food Science and Technology*, vol. 143, Article ID 111172, 2021.