Flash Extraction and Physicochemical Characterization of Oil from *Elaeagnus mollis* Diels Seeds

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Abstract: A flash extraction method was used to isolate *Elaeagnus mollis* oil (EMO). The optimal extraction parameters, sample/solvent ratio and extraction temperature, were determined to be 1:10 (g/mL) and 40°C, respectively. Especially, the extraction yield reached 49.30% when the extraction time was as short as 2 min. No obvious difference was observed in fatty acid composition, iodine value, saponification number, total phenolic content and tocopherol content between flash-extracted EMO and Soxhlet-extracted EMO, but their physicochemical values were lower than those of cold-pressed EMO. Cold-pressed EMO had higher oxidation stability, DPPH (1-diphenyl-2-picrylhydrazyl) and hydroxyl radical-scavenging activities than flash-extracted EMO and Soxlet extracted EMO. The flash extraction is demonstrated to be an alternative, efficient method for the vegetable oil production.

Key words: *Elaeagnus mollis* oil, flash extraction, fatty acid composition, antioxidant activity

1 INTRODUCTION

*Elaeagnus mollis* Diels is a rare and endangered species that belongs to the family Elaeagnaceae¹. It is distributed on hills and low mountains at altitudes of 800-1500 m in west China²⁻³. *E. mollis* is an ecologically important tree because it can grow on arid land and prevent soil erosion. It is also regarded as an important economic plant because its seeds contain a large percentage of oil and protein. The fruits of *E. mollis* can be used medicinally for anti-hypertension, anti-hyperlipemia, anti-senile and anti-oxidative treatments⁴. Previous studies of *E. mollis* have mainly focused on its morphology and anatomy⁵, reproductive biology⁶, population ecology⁷ and pharmacognosy⁸. To date, a few studies have been carried out on the separation and analysis of phytosterols⁹, the chemical composition and physicochemical properties of *E. mollis* oil (EMO)⁹⁻¹¹.

Fatty acid composition of edible oil is very important due to the growing awareness of lipids associated with nutritional and health benefits that can be classified as saturated fatty acids (SFAs), monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFAs). Vegetable oils mainly contain unsaturated fatty acids which are beneficial for human health¹². Additionally, vegetable oils generally contain beneficial compounds such as tocopherols, sterols and phenols that contribute to a strong antioxidant activity which has often been used to characterize the health-promoting properties of various products of plant origin¹³.

There are many methods for oil extraction from plant seeds, e.g. conventional solvent reflux extraction, supercritical CO₂ extraction, ultrasound-assisted extraction, and cold pressing. Flash extraction is a simple, efficient and inexpensive method developed in recent years; this method combines the effects of soaking, pulverizing, stirring, vibrating by a high-speed rotating cutter head (Fig. 1), and the schematic drawing and working principle can refer to a previous study¹⁴. Flash extraction has been widely used to extract natural products from plant materials, e.g. shikonin from *Arnebia euchroma*¹⁵, limonin from orange seeds¹⁶. However, there are few reports on the extraction of seed oils by flash extraction. The present study aimed to investigate the effects of flash extraction parameters on the oil yield, and compare the chemical composition, physicochemical characteristics, oxidation stability, antioxidant...
activities of flash-extracted EMO with Soxhlet-extracted EMO and cold-pressed EMO. The results may be helpful for the selection of oil extraction technique and the understanding of the nutritional values and health benefits of EMO.

2 EXPERIMENTAL PROCEDURES

2.1 Materials and chemicals

Fruits of *E. mollis* were collected from Houma, Shanxi province, China. The fruits were unshelled, and the kernels were ground to a 60-mesh powder and stored at \(-20^\circ \text{C}\) before use. DPPH (1-diphenyl-2-picrylhydrazyl) and the standard FAME Mix CRM47885 (a mixture containing 37 fatty acid methyl esters at known concentrations) were purchased from Sigma-Aldrich (St. Louis, MO, USA). A tocopherol standard (a mixture of equal amounts of \(\alpha\), \(\beta\), \(\gamma\), and \(\delta\)-tocopherol) was purchased from Supelco (USA). Other chemicals were purchased from the Sinopharm Chemical Reagent Beijing Co., Ltd. (Beijing, China) and were of analytical grade.

2.2 Oil extraction

Powdered sample (10 g) was flash-extracted with a set volume of solvent, and extractions were performed under different temperature and time with an Herbal Blitzkrieg Extractor JHBE-50S (Henan Zhijing Biological Technology Co., Ltd. China). This apparatus was developed by Liu *et al.* and is composed of a high-speed (4000 g) two-layer cutter head with gap of 0.3 mm. The single factor study was carried out as one factor was changed while the others kept stable in each experiment. After flash extraction, the solvent was vacuum evaporated at 40°C, and the residue was dried at 80°C for 4 h. The residue was flushed with nitrogen, a pure oil was obtained and the extraction yield was calculated as:

\[
\text{Extraction yield (\%)} = \frac{\text{weight of oil (g)}}{\text{weight of powdered sample (g)}} \times 100
\]

For Soxhlet extraction, 10 g of powdered sample were extracted for 6 h with 100 mL of \(n\)-hexane using a Soxhlet extractor. Then, the solvent was vacuum evaporated at 40°C, and the residue was dried at 80°C for 4 h.

For cold pressing, 100 g of *E. mollis* powder was pressed using an automatic oil press (YKY-6YL-550, Longyan ZhongNong Machinery Manufacturing Co., Ltd., Fujian, China), and 28 g of oil was obtained. After standing for 10 days at room temperature, the upper clear layer of oil was removed for analysis. Walnut oil and olive oil were also cold-pressed and served as controls.

2.3 Analysis of fatty acids

Fatty acid methyl esters (FAMEs) of EMO were prepared according to the method of Metcalfe *et al.* Briefly, 60 mg of EMO sample, 4 mL of isooctane and 0.2 mL of a KOH-MeOH solution (2 M) were added into a tube and sonicated for 1–2 min. Subsequently, 1 g of sodium bisulfate and 2 g of anhydrous sodium sulfate were added until the mixture clarified, and the upper layer was transferred and stored at 4°C before analysis.

The fatty acid composition was determined using a gas chromatograph (GC; Shimadzu gas chromatograph 2010 plus, Japan) equipped with a flame ionization detector (FID) and an SP-2560 capillary column (100 m × 0.25 mm, 0.20 μm film thickness). The GC oven temperature was programmed as follows: held at 140°C for 5 minutes, ramped at a rate of 4°C/min to 240°C and held for 25 minutes. The flow rate of the carrier gas (hydrogen) was 1.0 mL/min; the temperatures of the injector and detector were 260°C. The FAME injection volume was 1.0 μL with a split ratio of 1:30. When adding standard, 50 μL of the FAME standard was mixed with 25 μL of the FAME sample, and 0.75 μL of this mixture was injected with a split ratio of 1:30.

2.4 Physicochemical characteristics determination

The iodine value (IV) and saponification number (SN) of EMOs were determined according to the AOAC official methods 920.158 and 920.160, respectively. The total phenol (TP) contents of EMOs were determined using Folin–Ciocalteu reagent according to the method previously described by Tian & White. For the preparation of the calibration curve, 0.1, 0.2, 0.3, 0.4, and 0.5 mL of gallic acid (1 mg/mL) were mixed with 2 mL of 10% sodium carbonate (10%, w/v). After 2 min, 2.5 mL of Folin-Ciocalteu reagent and the amount of distilled water necessary to reach a total volume of 5 mL were added to the mixture. The mixture was shaken vigorously and kept at room temperature for 1 h, and the absorbance was measured at 765
nm. The absorbances of the test samples (2 g of EMOs instead of the gallic acid solution) were measured, and the TP contents of the EMOs were calculated according to the standard curve; results are expressed as mg gallic acid equivalent (GAE) per g of EMO.

2.5 HPLC analysis of tocopherol

The EMO samples were purified prior to HPLC analysis. Five grams of the EMO samples, 30 mL of anhydrous alcohol, 5 mL of ascorbic acid (100 g/L) and 20 mL of potassium hydroxide (1 g/L) were added into a saponification flask and saponified for 1 h on a rotary shaker. Subsequently, the mixture was transferred into a separatory funnel. The saponification flask was washed with 50 mL of water 3 times and 10 mL of diethyl ether 5 times; then, the water and diethyl ether were transferred into the separatory funnel. The funnel was shaken vigorously and then left to stand for stratification, after which the water layer was removed. The diethyl ether layer was washed with water until the pH became neutral.

The HPLC determination was performed on a Shimadzu LC-2010A HT instrument (Japan) with an RP-C18 column (4.6 mm × 250 mm, 5 μm, Shimadzu, Japan) according to the official method NY/T 1598-2008 of the Ministry of Agriculture of the P.R. China. The mobile phase was Me-OH/H2O (98:2, v/v), and the detection wavelength was 300 nm. The injection volume was 10 μL, and the flow rate was 1.0 mL/min.

2.6 Oxidation stability

The oxidation stability of the oil samples (cold-pressed EMO, Soxhlet-extracted EMO, flash-extracted EMO, walnut oil and olive oil) were determined by the method proposed by AOCS Cd 12b-92 using a Metrohm 892 Rancimat instrument (Metrohm China Co., Ltd., Hong Kong, China) under the following conditions: 3.0 g of oil sample was placed into the reaction vessel, which was filled with 60 mL of deionized water; the temperature was 110°C and the air flow was 20 L/h. The curve was automatically illustrated during the reaction, and the oxidation stability was determined in hours.

2.7 DPPH radical-scavenging activity

The radical-scavenging activity toward DPPH was determined according to a previous method with slight modifications. Briefly, the EMOs (concentrations ranging from 0.6 to 20 mg/mL) were prepared in ethanol. Then, 2 mL of each concentration of EMOs was mixed with 2 mL of DPPH (2 × 10−4 M) in an ethanol solution. The mixtures were shaken and kept at room temperature for 30 min in the dark and the absorbance was measured at 517 nm. BHT (butylated hydroxytoluene) was used as a positive control. The DPPH radical-scavenging activity (%) was calculated using the following equation:

\[
\text{DPPH radical-scavenging activity}(\%) = \frac{A_0 - (A_1 - A_2)}{A_0} \times 100
\]

where \(A_0\) is the absorbance of the control group (ethanol instead of EMOs), \(A_1\) is the final absorbance of the test group and \(A_2\) is the absorbance of the sample in the reactive system (ethanol instead of the DPPH solution).

2.8 Hydroxyl radical-scavenging activity

The hydroxyl radical-scavenging activity was determined according to the method described by Liu et al. with slight modifications. The EMOs (concentrations ranging from 0.1 to 1.6 mg/mL) were prepared in ethanol, and 2 mL of the EMO sample, 1 mL of FeSO4 (9 mM), 2 mL of salicylic acid (9 mM) in ethanol and 1 mL of H2O2 (2.8 mM) were then mixed and reacted at room temperature for 1 h. The absorbance was measured at 510 nm. BHT was served as a positive control. The hydroxyl radical-scavenging activity (%) was calculated using the following equation:

\[
\text{Hydroxyl radical-scavenging activity}(\%) = \frac{A_0 - (A_1 - A_2)}{A_0} \times 100
\]

where \(A_0\) is the absorbance of the control group (ethanol instead of EMO), \(A_1\) is the absorbance of the test group and \(A_2\) is the absorbance of the sample in the reactive system (ethanol instead of H2O2).

2.9 Statistical analysis

All experiments were carried out in triplicate, and the results are expressed as the mean values. Means were compared using Tukey’s honestly significant difference (HSD) multiple comparison test in SPSS 17.0 software (IBM corporation, Armonk, NY, USA).

3 RESULTS AND DISCUSSION

3.1 Effects of flash extraction parameters on oil yield

The effect of solvent (n-hexane, petroleum ether, anhydrous ethanol and ethyl acetate) on the extraction yield of EMO was investigated at a fixed sample/solvent ratio (1:10, g/mL), extraction temperature (40°C) and time (2 min). The extraction yields by n-hexane was 49.30%, similar to that by petroleum ether (p > 0.05) but significantly higher (p < 0.05) than those by anhydrous ethanol and ethyl acetate (Fig. 2A). The result was in accordance with “similarity principle” because the polarity of petroleum ether, n-hexane, anhydrous ethanol and ethyl acetate were 0.01, 0.06, 4.30 and 4.40, respectively. Hexane is a kind of commonly used industrial solvent for the extraction of seed oils; therefore, hexane was selected as the solvent in the subsequent experiments.

The sample/solvent ratio is an important parameter that affects the oil yield. The initial increase in the ratio of 1:6–1:10 (g/mL) lead to the rapid increase of oil yield, which is owing to the oil diffusing from particles to the solvent.

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However, further increase of ratio did not influence the yield significantly \( p > 0.05 \). The boiling point of hexane is 68.7°C; therefore, the effect of extraction temperature on the recovery of EMO was set at levels ranging from 20–60°C \( \text{Fig. 2C} \). Higher temperature can increase the interfacial turbulence and lead to higher mass transfer rate, and the extraction yield increased significantly \( p < 0.05 \) when the temperature increased from 20 to 40°C. The extraction yield kept stable when the temperature was higher than 40°C. Flash extraction can generate a large number of heats because of high-speed rotary and consequently increase the solvent temperature. Therefore, the extraction temperature was set as 40°C, and the extraction process was carried out in thermostat water bath, to avoid solvent evaporation during the extraction period.

Generally, a long extraction time is favorable for extraction yield. The oil yield increased from 47.2% to 49.3% when the time increased from 0.5 to 2.0 min \( \text{Fig. 2D} \). When the extraction time exceeded 2 min, no significant increasing \( p > 0.05 \) was observed, but the solvent temperature would increase. The extraction yield by Soxhlet method was 49.6%, therefore, the extraction rate by flash extraction reached 99.4%. The flash extraction time of 2 min is in accordance with the previous study on the mass production of limonin from orange seeds \(^{14}\). The advantage of flash extraction is rapid and efficient that the extraction time is extremely short and generally less than 3 min. The extraction time for conventional reflux extraction and ultrasonic-assisted extraction range from one to several hours and 30–60 minutes, respectively, with the extraction rate higher than 95% \(^ {25}\). Cold pressing provides high quality edible oil without hexane residues since its toxicity has been demonstrated \(^ {24}\), but the extraction yield is only 40–80%.

According to the results of single factor experiments, the extraction conditions were further optimized by a response surface methodology with Box- Behnken design. The highest extraction yield was 49.4% under the optimal extraction parameters which were determined to be sample/solvent ratio \( 1:11 \), extraction temperature \( 37°C \), and extraction time \( 1.8 \text{ min} \) \( \text{experimental procedure data were not presented} \).

### 3.2 Fatty acid composition

The fatty acid composition of EMO is shown in Table 1. Nine fatty acids were identified, which represented 99.87% of the total detected constituents in cold-pressed EMO. Linoleic (C18:2, 51.83%), oleic (C18:1, 38.47%) and palmitic (C16:0, 7.24%) acids were the major compounds, followed by a low amount of stearic (C18:0, 1.56%), α-linolenic (C18:3, 0.39%), γ-linolenic (C18:3, 0.18%), arachidic (C20:0, 0.15%) acids; C20:2 (0.03%) and C20:1 (0.02%). These data demonstrate that PUFAs (52.43%) were most abundant in EMO, followed by MUFAs (38.49%) and SFAs (8.95%). The profile of fatty acids detected in flash-extracted EMO is similar to that of cold-pressed EMO and Soxhlet-extracted EMO, and is in accordance with the data of previous reports, among which the contents of the
predominant fatty acids, linoleic, oleic and palmitic, were 44.7–54.8%, 33.6–40.6% and 3.1–5.5%, respectively\(^9\). However, some differences in minor fatty acids were observed that may depend on many factors, such as the geographical origin, climate, soil composition, and extraction method.

The compositions of fatty acids varied with the types of edible oils. The most abundant compounds in virgin olive oils from Turkey were oleic (72.00–76.74%), palmitic (11.61–13.09%) and linoleic (28.43–70.14%) acids\(^9\). The main fatty acids in walnut oils from Serbia were determined to be linoleic (57.2–65.1%), oleic (15.9–23.7%), linolenic (9.1–13.6%), and palmitic (6.3–7.7%) acids, and the PUFAs, MUFA and SFAs in walnut oil ranged in 67.4–75.7%, 15.9–23.9% and 8.3–9.4%, respectively\(^9\). Sielicka et al. studied the compositions of non-refined flaxseed, walnut, rapeseed, pumpkin seed, evening primrose, and black cumin oils. Palmitic, stearic, oleic, linoleic, and \(\alpha\)-linolenic acids were detected in all oils that these authors tested; linoleic acid was the prevailing fatty acid in walnut, pumpkin seed, evening primrose and black cumin oils, whereas the dominant fatty acids in flaxseed and rapeseed oils were \(\alpha\)-linolenic and oleic acids\(^9\).

### 3.3 Physicochemical characteristics

The IV, SN, TP and tocopherol contents of cold-pressed and flash-extracted EMOs are shown in Table 2. The IVs of cold-pressed EMO, flash-extracted EMO and Soxhlet-extracted EMO were 103, 94 and 95 g I\(_2\) per 100 g of oil, respectively. In comparison, the IVs of wild almond oils and olive oils were 89–96 and 79–82 g I\(_2\) per 100 g of oil\(^9, 30\). These results indicate that the EMOs were highly unsaturated compared to the almond and olive oils. The SN reflects the average molecular weight of fatty acids in the oil, and those of cold-pressed EMO, flash-extracted EMO and Soxhlet-extracted EMO were 207, 198 and 201 mg KOH per g of oil, respectively, similar to previous reports on EMO\(^9\), olive oil and camellia oil\(^9, 30\). Phoenins are important antioxidants that protect oil against autoxidation at the cellular level\(^32\). The TP contents of cold-pressed EMO, flash-extracted EMO and Soxhlet-extracted EMO were 0.57, 0.49 and 0.50 mg GAE/g, respectively, whereas the content in wild almond oil was 33.9–43.2 mg tannic acid equivalent per kg of oil\(^20\).

The total tocopherol content of cold-pressed EMO (24.80 mg/100 g) was significantly (\(p<0.01\)) higher than that of flash-extracted EMO (16.29 mg/100 g) and Soxhlet-extracted EMO (16.65 mg/100 g). \(\alpha\)-Tocopherol was the most abundant tocopherol in cold-pressed EMO, flash-extracted EMO and Soxhlet-extracted EMO (12.78, 8.66 and 8.75 mg/100 g, respectively), followed by \(\gamma\)-tocopherol (9.65, 7.52 and 7.70 mg/100 g, respectively) and \(\delta\)-tocopherol (2.37, 0.11 and 0.20 mg/100 g, respectively), and no \(\beta\)-tocopherol was detected. In a previous study, the contents of \(\gamma\)-tocopherol and total tocopherols were 113.3–122.2 and 119.6–128.6 mg/100 g, respectively, and \(\beta\)-tocopherol was not detected\(^9\). The difference may be caused by different growth regions and environments and phenological factors.

### Table 2

| Fatty acid          | Cold-pressed EMO | Flash-extracted EMO | Soxhlet-extracted EMO | Ref. \(^9\) | Ref. \(^9\) | Ref. \(^1\) |
|---------------------|------------------|---------------------|-----------------------|-------------|-------------|-------------|
| Myristic (C14:0)    | –                | –                   | –                     | –           | –           | –           |
| Palmitic (C16:0)    | 7.24             | 6.95                | 7.10                  | 4.5–4.6     | 5.46        | 3.1         |
| Heptadecanoic (C17:0) | –               | –                   | –                     | 0.1         | 0.03        | –           |
| Stearic (C18:0)     | 1.56             | 1.51                | 1.58                  | 2.9–3.0     | 2.89        | 1.0         |
| Arachidic (C20:0)   | 0.15             | 0.12                | 0.12                  | –           | 0.16        | –           |
| Palmitoleic (C16:1) | –                | –                   | –                     | 0.1–0.2     | 0.07        | –           |
| Oleic (C18:1)       | 38.47            | 39.63               | 39.10                 | 40.3–40.6   | 40.36       | 33.6        |
| Arachidonic (C20:1) | 0.02             | 0.02                | 0.02                  | 0.7–0.8     | 0.49        | –           |
| Arachidonic (C20:2) | 0.03             | 0.02                | 0.02                  | –           | –           | –           |
| Linoleic (C18:2)    | 51.83            | 49.39               | 50.11                 | 44.7–45.4   | 50.38       | 54.8        |
| \(\alpha\)-Linolenic (C18:3) | 0.39         | 0.30                | 0.30                  | –           | –           | –           |
| \(\gamma\)-Linolenic (C18:3) | 0.18           | 0.12                | 0.16                  | 5.9–6.0     | –           | 7.4         |
| SFA                 | 8.95             | 8.58                | 8.80                  | 7.5–7.7     | 8.57        | 4.1         |
| MUFA                | 38.49            | 39.65               | 39.12                 | 41.1–41.6   | 41.04       | 33.6        |
| PUFA               | 52.43            | 49.83               | 50.59                 | 50.6–51.4   | 50.38       | 62.2        |

SFA: saturated fatty acid; MUFA: monounsaturated fatty acid; PUFA: polyunsaturated fatty acid; Ref.\(^9\) (Liang et al., 2015), \(^9\) (Teng et al., 2007), \(^1\) (Du et al., 2005).

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the extraction method for HPLC analysis. The tocopherol content in the present study was in accordance with that of walnut oil, in which the contents of total tocopherols and \( \gamma \)-tocopherol were 28.4–42.4 and 25.4–38.4 mg/100 g, respectively.

### 3.4 Oxidation stability

Lipid oxidation is one of the most critical factors affecting the shelf life of vegetable oils. The determination of oxidation stability is a time-consuming process when the analysis is performed at room temperature. Therefore, the Rancimat method is typically used as an accelerating method to determine the oxidation stability in a shorter period of time. The Rancimat method is based on the production of volatile degradation products, assayed by the changes observed in the electrical conductivity of distilled water. The oxidative stabilities of EMOs, olive oil and walnut oil were determined by measuring their induction period (IP) using a programmed Metrohm Rancimat. The IP was recorded automatically from the plotted curves. The IP of cold-pressed EMO, flash-extracted EMO, Soxhlet-extracted EMO, walnut oil and olive oil were 8.53, 7.78, 7.80, 7.00 and 12.23 h, respectively (Table 2). Cold-pressed EMO was more stable than flash-extracted EMO and walnut oil (\( p < 0.05 \)) but less stable than olive oil (\( p < 0.05 \)). The oxidation stability is directly related to the degree of unsaturation of fatty acids in the studied oils. Generally, a high amount of unsaturated fatty acids makes the oils more susceptible to oxidation and results in shorter induction times. Olive oil had the highest level of SFAs and the lowest level of PUFAs, ranging from 3.29 to 15.54, whereas walnut oil had the highest level of PUFAs, ranging from 67.4 to 75.7.

### 3.5 Antioxidant activities

The DPPH radical is stable under normal conditions. In the presence of antioxidants, its color changes from purple to yellow and the absorbance at 515 nm decreases. Hydroxyl radical is an extremely reactive free radical formed in biological systems and has been implicated as a highly damaging species in free radical pathology, capable of damaging almost every molecule found in living cells. Therefore, DPPH and hydroxyl radicals were selected to evaluate the antioxidant activities of EMOs. Figure 3 shows that the...
antioxidant activity of EMO was dose dependent within experimental concentration range. For DPPH radical-scavenging activity, the EC_{50} (half maximal effective concentration) of the cold-pressed EMO, flash-extracted EMO, Soxhlet-extracted EMO and BHT were 14.30, 18.64, 17.29 and 0.27 mg/mL, respectively, which means that the capacity was BHT > cold-pressed EMO > Soxhlet-extracted EMO > flash-extracted EMO. However, the EC_{50} of cold-pressed EMO, flash-extracted EMO, Soxhlet-extracted EMO and BHT were 0.44, 1.36, 1.16 and >1.60 mg/mL, respectively, for hydroxyl radical-scavenging activity, indicating that EMOs had higher capacity than BHT. BHT is chemically a derivative of phenol, and is widely used to stop the auto-catalytic reaction of oil by converting peroxy radicals to hydroperoxides. In the present study, the correlation coefficients between total phenolics and EC_{50} of DPPH and hydroxyl radical-scavenging capacities were −0.9813 and −0.9957, while those of total tocopherols were −0.9634 and −0.9865, respectively. In general, a high content of tocopherols or phenolics contribute to the antioxidant activity and oxidation stability of oils.

4 CONCLUSIONS

The present study investigated the effects of different flash extraction parameters (solvent, sample/solvent ratio, temperature, time) on the oil yield. The greatest advantage for flash extraction is that the time is shorter than all other extraction methods, while the fatty acid composition remains stable after vigorous extraction process. EMO contains a considerable amount of tocopherols and phenolic compounds, which may contribute to their antioxidant capacities. The physicochemical characterizations and antioxidant activity of flash-extracted EMO were similar to those of Soxhlet-extracted EMO, which confirms that flash extraction is an efficient method in the seed oil extraction.

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Conflict of interest statement

The authors have declared that no competing interests exist.

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