Chemical Characterization of Chinese Perilla Seed Oil

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Abstract: Physicochemical properties and chemical composition of Chinese perilla seed oil has been characterized in this study. The result showed that both the cold press oil and the solvent extracted oil possessed low acid value and peroxide value. The fatty acid composition result showed that the oil has high content of linolenic acid (C18:3) up to 66.4 g/100 g, followed by linoleic acid (C18:2) of 15.3 g/100 g. The total triacylglycerol (TAG) profiles results showed that the oil contained 20 TAGs including 17 regioisomers, including LnLnLn (35.8 g/100 g), LLnLn (20.2 g/100 g), LLLn (17.7 g/100 g) and PLnLn (14.9 g/100 g) (Ln, linolenic acid; L, linoleic acid; P, palmitic acid). With content of only 0.57 g/100 g oil, the unsaponifiable matters were mainly composed of phytosterols, squalene, tocopherol, alcohols and hydrocarbons. The total phytosterols content was 0.39 g/100 g oil, in which β-sitosterol has high content of 0.31 g/100 g oil.

Key words: fatty acid composition, perilla seed oil, triacylglycerol, unsaponifiable matter

1 Introduction
Perilla (Perilla frutescens L.) is an annual aromatic plant that belongs to the Labiatae family. Perilla is now widely distributed in China, Southeast Asia, Europe and North America1. The perilla seed oil has high α-linolenic acid (C18:3, ALA) level of 52.58-61.98 g/100 g oil2. It also contains natural antioxidants, including tocopherols, squalene, flavonooids, phytosterols, and so on3. With good nutritional properties, perilla seed oil is an important edible oil in many countries4. It is widely used in cosmetics, skincare products and medicinal preparations on purpose of anticancer, anti-inflammatory, mental health care, cardiocerebrovascular diseases treatment, and so on5-7. Perilla seed oil is now used to make health care drugs, such as capsules and oil drops, in China.

Several extraction methods of the perilla oil were investigated, such as solvent extraction, aqueous enzymatic extraction, mechanical pressing and supercritical extraction8. Supercritical extraction and aqueous enzymatic extraction methods are costly, and solvent extraction is effective and commonly used. Although the yield of the mechanical pressing was relatively lower than other methods, the loss of active ingredients such as linolenic acid and phytosterols was avoided in the cold pressing process9. The triacylglycerols (TAG) composition of the oil have been determined by non-aqueous reversed-phase HPLC method (NARP), but only five TAGs were detected, including LnLnLn, LnLnL, LnLL, LnLnO and LnLnP (Ln, linolenic acid; L, linoleic acid; P, palmitic acid; O, oleic acid)10.

However, the overall TAG profiles and the positional isomers of the perilla seed oil was still unknown. In this study, chemical composition of Chinese perilla seed oil was analyzed, especially the overall TAG and unsaponifiable matters compositions, in the objective of better utilization and further research of the perilla seed oil.

2 Materials and Methods
2.1 Materials
Perilla seed samples were collected from a perilla farm in Huaihua (Hunan Province, Northeast of China). After removing the impurity, perilla seeds were milled in a FW100 crusher (Taiseite, Tianjin, China) and was sieved through a 2 mm mesh screen. The raw material (total carbohydrate 9.20%, protein 21.29%, oil 45.56%, moisture 5.68%, ash 4.14% and crude fiber 15.69%) was stored at 4°C in a sealed pouch. α-Colestanol, eicosanol, and BSTFA + TMCS (99:1) of analytical grade were from Supelco. Fatty acid esters and tocopherol (α-, β-, γ- and δ-isomers) standards used for chromatography analyses were from Sigma-Aldrich. Other solvents were of analytical grade and purchased from Kermel (Tianjin, China).

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2.2 Perilla seed oil extraction

Two methods were selected for oil extraction: solvent extraction and cold pressing. The perilla seed powder of 100 g was extracted by 600 mL n-hexane at 40°C. The extraction was carried out for 8 h. The solvent was collected, evaporated and centrifuged, after which the perilla seed oil was obtained. Cold pressing was carried out using a screw oil press (CA-59-G model, TBG, Germany) without heat treatment. The obtained oil was stand for 30 min, and then centrifuged at 3500 r/min for 10 min to separate oil from sediments. Both oil samples were stored at −20°C in amber bottles to avoid oxidation.

2.3 Analysis of the perilla seed oil

2.3.1 Physicochemical parameters

Determination of acid value (AV), peroxide value (PV), saponification value, and unsaponifiable matter content of the oil was carried out according to AOCS methods.

The tocopherol (α-, β-, γ- and δ-isomers) level of the oil were determined as described by using an Agilent 1200 HPLC system (Agilent, USA) equipped with Supelcosil LC-Si column (250 × 4.6 mm, 5 μm) (Supelco, USA) and fluorescence detector. The emission and excitation wavelength were set at 330 and 290 nm, respectively. The column temperature was held at 20°C. The oil samples were dissolved in hexane at 100 μg/mL. A 5 μL volume of the loaded sample on the column was eluted with n-hexane/isopropyl ether (93/7, v/v) isocratically at 1.5 mL/min. The absolute contents of tocopherols were determined by comparison with the calibrated standard curves.

2.3.2 Fatty acid composition

Derivatisation reaction of the oil was carried out by using the literature method. Analysis of the obtained fatty acid methyl esters was carried out on Agilent 7890B gas chromatograph system equipped with BPX70 capillary column (30 m × 0.25 ωm × 0.25 μm) (Agilent, USA) and flame ionisation detector (FID). The column, injector, and detector temperatures were set at 210, 230, and 300°C, respectively. The flow rate of carrier gas N2 with split ratio of 1:50 was set at 50 μL/min. The fatty acids were identified with reference to the retention times of standard fatty acid methyl ester performed at the same conditions.

2.3.3 TAG profile analysis

Overall TAG profile analysis was carried out using off-line 2D HPLC system coupled with atmosphere pressure chemical ionisation (APCI) MS according to the literature. The oil sample was first separated by non-aqueous reversed-phase (NARP) using Agilent 1200 HPLC system equipped with an Agilent ZORBAX SB-C18 column (250 × 4.6 mm, 5 μm). Each fraction of the NARP eluent was collected following ten injections. Same fractions were combined and condensed by nitrogen dryer. Fractions collected in NARP dimension were solubilized in hexane, and then injected into the silver ion HPLC (Ag-HPLC) system, using Agilent 1200 HPLC system equipped with Agilent Chrom-Spher 5 Lipids column (250 × 4.6 mm, 5 μm). LC-MS detection was achieved through Agilent 6300 Mass Spectrometer Detector ion trap (Agilent, USA) equipped with APCI.

2.3.4 Unsaponifiable matters of the oil

Saponification reaction was performed at present of internal standards (α-colestanol and eicosanol) according to the literature. The obtained unsaponifiable matters was then boiled with BSTFA + TMCS (99:1) for derivatisation reaction. Derived unsaponifiable matters were analyzed by Agilent GC-7890B GC-MS with an HP-5MS column (30 m × 250 μm × 0.25 μm, Agilent, USA); carrier gas: helium; flow rate: 1 mL/min; injection temperature: 280°C; detection temperature: 280°C. The temperature was firstly kept at 50°C for 1 min, increased from 50°C to 150°C at 8°C/min and kept at 150°C for 1 min, then increased from 150°C to 300°C at 5°C/min, and kept at 300°C for 10 min at last. MS parameters were as follows: electronic ionization voltage, 70 eV; ion source temperature, 250°C; scan range, m/z 50-550. Unsaponifiable matters identification was performed by comparison of the retention times and mass spectra of eluting compounds to those of the Wiley library (WILEY 275, NIST 98; Wiley, West Sussex, UK).

2.4 Statistical analysis

All experiments were repeated in triplication, and results were expressed as mean ± standard deviation.

3 Results and Discussion

3.1 Physicochemical parameters of perilla seed oil

Table 1 shows the physicochemical properties of the perilla seed oil. The oil yield of the solvent extracted method was up to 39.61 g/100 g, while that of the cold press method was only 34.40 g/100 g. Both of them were higher than the aqueous enzymatic extracted method (31.28 g/100 g) (17). Recently, the oil yield has been reported to be 78.81 g/100 g by superheated steam treatment method and 78.81 g/100 g by freeze-thaw pretreatment method. Both oil presented pleasant golden yellow color. Low acid value (0.57 and 0.62 mg KOH/g oil) and peroxide value (1.60 and 1.78 meq O2/kg oil) indicated good quality of the oil. But the aqueous enzymatic extracted oil possessed relatively higher acid value (3.06 mg KOH/g oil) and peroxide value (3.20 meq O2/kg oil) (17). High iodine value indicated high unsaturated fatty acids content of the two oils. Total content of tocopherols in the solvent extracted oil was up to 743.3 mg/kg oil, higher than the peanut oil (345.0 mg/kg oil), peanut oil (455.0 mg/kg oil), and most grape seed oil (397.8-755.8 mg/kg) (19-21). It has been reported that the tocopherol content of polysaturated fatty acid (PUFA) rich oils was higher than that of the oleic acid-
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3.2 Fatty acid composition

Fatty acid composition of the cold press perilla seed oil (g/100 g) was shown in Table 2. The majority fatty acid of the perilla seed oil was α-linolenic acid (C18:3, ALA) at concentration of 66.4 g/100 g, which has high nutrition and medicinal value. This was comparable to that of the aqueous enzymatic extracted oil (64.1 g/100 g) and ultrasound-assisted hexane extracted oil (61.9 g/100 g). It has been reported that after a series of metabolic activities in the body, ALA could finally produce eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), which are especially beneficial to human health.

The common commercial oils contain relatively lower content of ALA, such as soybean oil (5.0-11.0 g/100 g), rapeseed oil (5.0-13.0 g/100 g) and peanut oil (<0.3 g/100 g). The ALA content of the perilla seed oil is higher than these oils. With good antioxidant, tocopherol in the perilla oil could reduce free radical, therefore protecting the unsaturated fatty acids of the oil. However, the unsaponifiable matter of this oil was only 0.57 g/100 g, relatively lower than olive oil (1.23 g/100 g), peanut oil (0.94 g/100 g) and sunflower oil (0.81 g/100 g).

**Table 2** Fatty acid composition of the cold press Chinese perilla seed oil (g/100 g).

| Fatty acid       | Cold Press PS-CHI oil | Aqueous enzymatic extracted PS-CHI oil (17) | Ultrasound-assisted hexane extracted PS-CHI oil (9) |
|------------------|-----------------------|---------------------------------------------|--------------------------------------------------|
| Palmitic acid (C16:0) | 5.6 ± 0.0             | 4.4 ± 0.1                                   | 4.1 ± 0.2                                         |
| Stearic acid (C18:0)   | 1.5 ± 0.0             | 1.9 ± 0.0                                   | 1.9 ± 0.0                                         |
| Oleic acid (C18:1)      | 11.3 ± 0.0            | 20.4 ± 0.2                                  | 16.7 ± 0.1                                        |
| Linoleic acid (C18:2)   | 15.3 ± 0.0            | 9.1 ± 0.1                                   | 14.3 ± 0.1                                        |
| Linolenic acid (C18:3)  | 66.4 ± 0.0            | 64.1 ± 0.2                                  | 61.9 ± 0.1                                        |
| SFA                | 7.0                   | 6.3                                         | 7.0                                               |
| MUFA               | 11.3                  | 20.4                                        | 16.8                                              |
| PUFA               | 81.7                  | 73.2                                        | 76.3                                              |
| USFA               | 93.0                  | 93.6                                        | 93.0                                              |
| PUFA/SFA           | 11.6                  | 11.6                                        | 10.9                                              |

Results are presented as mean value ± standard deviation (n=3).

PS-CHI, perilla seed samples harvested from Sichuan Province of China; SFA, saturated fatty acids; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids; USFA, unsaturated fatty acids.

rich oils. With good antioxidant, tocopherol in the perilla oil could reduce free radical, therefore protecting the unsaturated fatty acids of the oil. However, the unsaponifiable matter of this oil was only 0.57 g/100 g, relatively lower than olive oil (1.23 g/100 g), peanut oil (0.94 g/100 g) and sunflower oil (0.81 g/100 g).
was higher than that other ALA rich oils, such as linseed oil (52.1 g/100 g), sacha inchi oil (50.7 g/100 g), and chia oil (63.5 g/100 g). The second one was linoleic acid (C18:2) with concentration of 15.3 g/100 g, while the third one was oleic acid (C18:1) at 11.3 g/100 g. The unsaturated fatty acids content was 93.0 g/100 g, among which polyunsaturated fatty acids amounted up to 81.7 g/100 g. The polyunsaturated/saturated fatty acids (PUFA/SFA) ratio reached up to 11.6 g/100 g. High PUFA/SFA ratio has been reported to be relative with reduction of cholesterol, therefore decreasing cardiovascular and atherosclerosis disease.

3.3 TAG composition

The oil sample was separated into six TAGs fractions in NARP dimension, but baseline separation was not achieved in peak 3, 4 and 5. Since the separation of TAGs in NARP was dependent on the equivalent carbon number (ECN), overall separation of TAGs with the same ECN could not be resolved by NARP. Especially positional isomers were always co-eluted in NARP-mode. For instance, PLnLn and LLLn with same ECN value of 40 are co-eluted in fraction 3, LLnP and OLnL with same ECN value of 42 are co-eluted in fraction 4, while PLL, POLn, LLO and OOLn with same ECN value of 44 are co-eluted in fraction 5. The separation of TAG in Ag-HPLC depends on the interaction of fatty acid double bonds and silver ions. Resolution of TAGs with the same ECN could be achieved by Ag-HPLC. Therefore, it is necessary to combine the NARP with the Ag-HPLC separation for overall TAGs profiles analysis.

Figure 2 shows the Ag-HPLC-MS chromatogram of fraction 1. As LnLnLn has no positional isomers, there is only one peak in Ag-HPLC mode.

As shown in Fig. 3, fraction 2 is separated into two regioisomers in Ag-HPLC mode: sn-LnLnLn and sn-LnLLLn. With both linolenic acids located in sn-1/3 position, sn-LnLnLn is more retained than sn-LLLn.

Fraction 3 is separated into sn-PLnLn, sn-LnPnL, sn-LLnLn and sn-LLLn in Ag-HPLC (Fig. 4). With a higher unsaturation degree, the LLnL group are more retained than the PLnLn group. As shown in Table 4, PLLn has 7 double bonds, while PLnLn has 6 double bonds. sn-LnPLn is more retained than sn-PLnLn due to the linolenic acids position. Similarly, sn-LLLm is more retained than sn-LLLn.

As shown in Fig. 5, fraction 4 is separated into 5 species: sn-LnLP, sn-LnPnL, sn-LLnO, sn-LnLO and sn-LOLn. LnLO group are more retained because LnLO has 6 double bonds, more than LnLP (5). For the LnLP group, the relative abundance of [LLn]⁺ (597.3) in the first peak is relatively higher the other peak, as well as that of [PLn]⁺.
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As shown in Fig. 6, fraction 5 is separated into 7 species in Ag-HPLC. Having more double bonds (5), LLO and LnOO groups are more retained than LPL and POLn groups (4). With higher relative abundance of [PLn]** (577.4), the second peak is sn-PLnO. For the LLO group, the relative abundance of [LLn]** (599.4) in sn-LLO is higher than sn-LOL, and sn-LOL is more retained than sn-LLO. So the fourth peak is sn-LLO, and the fifth one is sn-LOL. In the sixth peak, the relative abundance of [OLn]** (599.4) is higher than that of [OO]** (603.5), so this one is sn-OLnO.

As shown in Fig. 7, fraction 6 is separated into 2 species: sn-OLnS (8, stearic acid) and sn-OSLn. The relative abundance of [OS]** (605.4) in the first peak and [OLn]** (599.4) in the second peak are relatively lower. Also, the retaining of sn-OSLn is stronger than sn-OLnS. So the first and second peak is sn-OLnS and sn-OSLn, respectively.

The TAG profiles of Chinese perilla seed oil analysis results were listed in Table 3. With content of 35.8 g/100 g, LnLnLn is the dominant TAG of this oil. Principal TAGs include LLnLn (20.2 g/100 g), LLLn (17.7 g/100 g) and PLnLn (14.9 g/100 g). Other TAGs are minor TAGs, such as...
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**Table 3** Molecular mass, partition number, fragmentation ions obtained for TAGs identified in the cold press Chinese perilla seed oil by RPLC-HPLC-APCI-MS.

| Fraction | TAG   | Relative abundance (g/100 g) | Mr   | DB | CN | ECN | [M+NH₄]⁺ | [DG]⁺ | [DG]⁺ | [DG]⁺ |
|----------|-------|-----------------------------|------|----|----|-----|---------|-------|-------|-------|
| 1        | LnLnLn | 35.8 ± 0.1                  | 872.7 | 9  | 54 | 36  | 890.7  | LnLn 595.5 |
| 2        | LLLn   | 20.2 ± 0.0                  | 874.7 | 8  | 54 | 38  | 892.7  | LLLn 597.4 |
| 3        | PLnLn  | 14.9 ± 0.0                  | 850.6 | 6  | 52 | 40  | 868.6  | PLnL 573.3 |
|          | LLLn   | 17.7 ± 0.0                  | 876.7 | 7  | 54 | 40  | 894.7  | LLLn 597.3 |
| 4        | LnPL   | 2.5 ± 0.0                   | 852.7 | 5  | 52 | 42  | 870.7  | PLnL 575.3 |
|          | LLLn   | 4.2 ± 0.0                   | 878.6 | 5  | 54 | 42  | 896.7  | LLLn 597.3 |
| 5        | PLL    | 8.0 ± 0.0                   | 854.7 | 4  | 52 | 44  | 872.7  | PLL 575.3  |
|          | PLnO   | 1.6 ± 0.0                   | 854.7 | 4  | 52 | 44  | 872.8  | PLn 573.3 |
|          | LLO    | 1.1 ± 0.0                   | 880.8 | 5  | 54 | 44  | 898.8  | LLO 599.4 |
|          | OOLn   | 2.0 ± 0.0                   | 880.8 | 5  | 54 | 44  | 898.8  | OOLn 599.4 |
| 6        | SOLn   | 0.3 ± 0.0                   | 882.8 | 4  | 54 | 46  | 900.8  | SOLn 605.4 |

Results are presented as mean value ± standard deviation (n=3).
P, palmitic acid; O, oleic acid; L, linoleic acid; Ln, linolenic acid; S, stearic acid; TAG, triacylglycerol; Mr, molecular mass; DB, double bond; CN, carbon number; ECN, equivalent carbon number; [M+H]+, pseudomolecular ion; [DG]+, diglyceride ion.

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**Table 4** Relative abundance of TAG isomers in cold press Chinese perilla seed oil.

| Fraction | TAG   | Isomers | Relative abundance (mol % of total) |
|----------|-------|---------|------------------------------------|
| 2        | LLLn  | sn-LLn  | 95.9 ± 0.0                          |
|          |       | LnLn    | 4.1 ± 0.0                           |
| 3        | PLnLn | sn-PLn  | 98.1 ± 0.0                          |
|          |       | LnPL    | 1.9 ± 0.0                           |
| 4        | LLLn  | sn-LLn  | 31.4 ± 0.0                          |
|          |       | LnLn    | 68.6 ± 0.0                          |
| 5        | LnPL  | sn-LnP  | 93.9 ± 0.0                          |
|          |       | LnPL    | 6.1 ± 0.0                           |
| 6        | SOLn  | sn-OLn  | 96.9 ± 0.0                          |
|          |       | LnOL    | 3.1 ± 0.0                           |
| 6        | SOLn  | sn-SLn  | 38.1 ± 0.1                          |
|          |       | SnOSn   | 61.9 ± 0.1                          |

Results are presented as mean value ± standard deviation (n=3).
P, palmitic acid; O, oleic acid; L, linoleic acid; Ln, linolenic acid; S, stearic acid; TAG, triacylglycerol.

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**Table 5** Composition of the hydrocarbons from cold press Chinese perilla seed oil.

| Retention time (min) | Compounds | Content (mg/kg oil) |
|----------------------|-----------|---------------------|
| 21.99                | Octadecane| 0.68 ± 0.01         |
| 34.30                | Pentacosane| 5.07 ± 0.07        |
| 37.27                | Heptacosane| 15.15 ± 0.16       |
| 40.05                | Nonacosane| 23.12 ± 0.21        |

Total hydrocarbons 44.02 ± 0.45

Results are presented as mean value ± standard deviation (n=3).

LLnO (4.2 g/100 g), LnPL (2.5 g/100 g), OOLn (2.0 g/100 g), and so on. Relative abundance of TAG regioisomers was listed in Table 4. LLLn has three isomers, while other 7 TAGs all have two isomers. The total TAG profiles results showed that this oil contained 20 TAGs including 17 regioisomers.

3.4 Unsaponifiable matters composition

As shown in Tables 5-7, the unsaponifiable matters of Chinese perilla seed oil were composed of sterols, squalene, tocopherol, alcohols and hydrocarbons. Total hydrocarbons content was 44.02 mg/kg.

As shown in Table 6, total alcohols content was 299.3 mg/kg, including phytol and farnesol with contents of 53.20 mg/kg and 30.93 mg/kg, respectively. Phytol and farnesol has good anti-carcinogenic, anti-inflammatory and anti-metabolic-syndrome properties.

As shown in Table 7, the total phytosterols were mainly
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composed of campesterol, stigmasterol, \( \beta \)-sitosterol, isofucosterol and lanosterol. The total phytosterols content of the perilla seed oil (0.39 g/100 g oil) was higher than that of the grape seed oil (0.23-0.34 g/100 g oil)\(^{20}\) and the peanut oil (0.28 g/100 g oil). Phytosterols have been reported to have important antioxidant, analgesic, anti-inflammatory and anticancer properties\(^{32, 33}\). The content of \( \beta \)-sitosterol was up to 0.31 g/100 g oil. Other important sterols include campesterol (273.3 mg/kg), stigmasterol (237.1 mg/kg) and lanosterol (201.7 mg/kg). Campesterol and \( \beta \)-sitosterol have been proved to be effective in inhibiting intestinal cholesterol absorption in humans\(^{34, 35}\). The squalene content of the oil was tested to be 275.4 mg/kg. It has been certified that squalene has several beneficial health effects, such as antioxidant activity, decreasing cancer, and reducing the side effects of chemotherapy\(^{36}\). \( \delta \)-Tocopherol and \( \gamma \)-tocopherol were also found with contents of 2.87 mg/kg and 151.5 mg/kg, respectively. Previous studies reported the health benefits of tocophorals, including neuroprotective, cardioprotective and anti-inflammatory activities\(^{37}\).

4 Conclusions

The results showed that the oil yield of the solvent extracted method was up to 39.61 g/100 g, higher than that of the cold press method (34.40 g/100 g). Both oil possessed low acid value and peroxide value. Total content of tocopherols in the solvent extracted oil was up to 743.3 mg/kg oil. The majority fatty acid of the Chinese perilla seed oil was linolenic acid (66.4 g/100 g), followed by linoleic acid (15.3 g/100 g). The overall TAG profile showed that this oil contained 20 TAGs including 17 regioisomers, in which LnLnLn (35.8 g/100 g) was dominant. The unsaponifiable matters of this oil possessed high content of phytosterols (0.39 g/100 g oil), among which \( \beta \)-sitosterol was the most predominant (0.31 g/100 g oil). Therefore, the Chinese perilla seed oil is a good edible oil. And it also can be a good source of biological activity compounds, especially linolenic acid and \( \beta \)-sitosterol.

| Retention time (min) | Compounds   | Content (mg/kg oil) |
|----------------------|-------------|---------------------|
| 11.91                | 1-Decanol   | 1.12 ± 0.01         |
| 12.03                | 1-Nonanol   | 0.29 ± 0.01         |
| 12.14                | Glycerol    | 0.36 ± 0.01         |
| 13.64                | 1-Deccanol  | 0.40 ± 0.01         |
| 17.40                | 1-Dodecanol | 1.27 ± 0.01         |
| 21.36                | 1-Tetradecanol | 0.84 ± 0.01     |
| 29.18                | Phytol      | 53.20 ± 0.63        |
| 30.61                | Farnesol    | 30.93 ± 0.28        |
| 32.11                | 1-Eicosanol | 36.68 ± 0.38        |
| 33.62                | 1-Heneicosanol | 1.80 ± 0.01       |
| 35.16                | Docosanol   | 37.44 ± 0.42        |
| 36.58                | 1-Tricosanol| 6.50 ± 0.05         |
| 38.06                | Tetracosanol| 52.96 ± 0.44        |
| 39.36                | 1-Pentacosanol | 8.44 ± 0.06       |
| 40.74                | 1-Hexacosanol | 67.08 ± 0.88       |
| **Total alcohols**   |             | **299.3 ± 3.2**     |

Results are presented as mean value ± standard deviation (\( n = 3 \)).

| Retention time (min) | Compounds         | Content (mg/kg oil) |
|----------------------|-------------------|---------------------|
| 39.29                | Squalene          | 275.4 ± 2.9         |
| 40.22                | \( \delta \)-Tocopherol | 2.87 ± 0.01       |
| 41.65                | \( \gamma \)-Tocopherol | 151.5 ± 1.3      |
| **Total tocopherols**|                   | **154.4 ± 1.3**     |
| 44.94                | Campesterol       | 273.3 ± 2.1         |
| 45.26                | Stigmasterol      | 237.1 ± 2.4         |
| 45.40                | Ketocholesterol   | 6.78 ± 0.01         |
| 46.80                | \( \beta \)-Sitosterol | 3110 ± 27       |
| 46.05                | Isofucosterol     | 85.8 ± 0.7          |
| 47.93                | Lanosterol        | 201.7 ± 1.9         |
| **Total sterols**    |                   | **3914 ± 33**       |

Results are presented as mean value ± standard deviation (\( n = 3 \)).

Table 6  Composition of the alcohols from cold press Chinese perilla seed oil.

Table 7  Composition of the squalene, tocopherols and sterols from cold press Chinese perilla seed oil.
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