Lipid Characterization of Chinese Wild Hazelnuts (*Corylus mandshurica* Maxim.)

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Abstract: To develop and use the hazelnut, the main composition, and the physicochemical characteristics, fatty acid compositions, triacylglycerol (TAG) distribution and tocol contents of Hazelnut (*Corylus mandshurica* Maxim.) which growing in Changbai mountain of Jilin province (HO1) and Anshan city of Liaoning province (HO2) in China were investigated, and the comparative study between the two hazelnut oils and American hazelnut / Turkish hazelnut were also explored. The content of crude lipid and protein in HO1 and HO2 were approximately 54% and 17%, 55% and 16%, respectively. The two hazelnut oils were abundant in unsaturated fatty acids, with the primary unsaturated fatty acids were oleic acid (78%-80%) and linoleic acid (14-16%), which accounted for above 90% of the oils. Therefore, both of the hazelnut oils were important sources of essential fatty acid. In addition, the main saturated fatty acid of the two hazelnut oils were palmitic acid (3%) and stearic acid (1-2%). The main triacylglycerols (TGA) profile were dioleolinolein (OOL), oleodilinolein (OLL) and triolein (OOO). The contents of tocol were 574.44 µg/g, 647.49 µg/g oil in HO1 and HO2, respectively, both of them were higher than that of grape seed oils (454 µg/g), olive oils (209 µg/g) and walnut oils (255 µg/g). The total phytosterol contents were over 2000µg/g and β -sitosterol was the most predominant sterol in two oils.

Key words: *Corylus mandshurica* Maxim., hazelnut oil, lipid characterization, fatty acid, tocopherol, triacylglycerol

1 Introduction

Hazelnut is one of the four major arboroid nuts in the world. There are about 20 species of hazelnuts, several species of hazelnuts such as *C. America*, *C. avellana* and *C. colurna* were widely cultivated in Asia, Europe and North America. Turkey is the world's leading producer of hazelnuts with a production of 400 000 tones, followed by European Union (145 000 tones), USA (37 200 tones) and Azerbaijan (35 000 tones)¹. In China, Hazelnut large area of cultivation is less, but there are wild varieties in the northeast and north of the mountains, Varieties are mainly *Corylus heterophylla* Fisch. and *Corylus mandshurica* Maxim. The main distribution of *Corylus mandshurica* Maxim is Hilly mountain in Heilongjiang, Liaoning and Jilin provinces of China. The average single weight and diameter of *Corylus mandshurica* Maxim is about 0.9 g and 1.37 cm, respectively, which is smaller than other species of hazelnuts.

Currently, Hazelnuts are mainly used in the manufacture of food products including candy, chocolate, biscuits and pastries². In addition, other widely consumed product from hazelnuts is hazelnut oil³. Hazelnut oil could be used

for different purposes such as cooking, salad dressing, condiments and cosmetics^{4,5}.

Recent studies found that hazelnut oil is a good supplier of monounsaturated fatty acids (MUFA) and polyunsaturated (PUFA) fatty acids, particularly oleic acid⁴. There is evidence that replacement of SFA with MUFA can help lower coronary heart disease (CHD) risk⁶ and also has preventive effects on atherosclerosis and thrombosis⁷. MUFAs are more resistant to oxidation than PUFAs and can extend the shelf life of edible oils. Besides a favorable fatty acid profile, hazelnut oils are rich in tocopherols and phytosterols, which are known to have health promoting effects⁸⁻¹¹. Especially, hazelnut contains taxol which is a diterpene compound isolated from *Taxus brevifolia*. The structure of taxol is shown in Fig. 1, and it has been confirmed the unique anticancer mechanism by the American Cancer Center (NCI) in 1979. Some studies indicated that hazelnut was an excellent source of taxol (0.0059% in peel, 0.0048% in bark and 0.0033% in leaves but only 0.00015% in *Taxus brevifolia*)¹². It also has been reported to have high oxidative stability due to its high α -tocopherol or sterols content even though hazelnut oil is rich in unsaturated (about

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Fig. 1 Structure of taxol.

90%)¹³. Hazelnut oil is increasingly popular for its contribution to the nutritional value of human diets.

Although plenty of studies have been carried out on the chemical constituents of hazelnut oil obtained from various countries, including Turkish¹⁴, Portugal¹⁵, Italy¹⁶, Spain¹⁷, New Zealand¹⁸, and USA¹⁹. However, to best of our knowledge, there has little literature on the characteristics of *Corylus mandshurica* Maxim and little information on fatty acid distributions in triacylglycerols.

The purpose of this work would provide basic information about the fatty acid profile, some physicochemical characteristics, and TAG composition of the oils extracted from *Corylus mandshurica* Maxim which is growing in two different localities (Changbai mountain of Jilin province and Anshan city of Liaoning province in China).

2 Experimental

2.1 Samples preparation

Two different varieties of hazelnut (*Corylus mandshurica* Maxim) which growing in Changbai mountain of Jilin province and Anshan city of Liaoning province in China were purchased and they were numbered as HN1 and HN2 respectively. The samples were firstly dried at 70°C for 2 h. Subsequently, the outer shells were removed by manually crushing, then ground using a high speed rotary cutting mill and sieved through 60 mesh. The powders were collected and stored at a refrigerator until used for further oil extraction. The weight ratio of shell and kernel was found to be 1.8 (shell/kernel, dry weight).

2.2 Reagents and standards

The standard samples of fatty acid methyl esters, standard tocopherols (α -, β -, γ -, and δ -isomers), standard tocotrienols (α -, β -, γ -, and δ -isomers) and standard sterols (5 α -cholestan-3 β -ol, campesterol, stigmasterol, sitosanol and β -sitosterol) were all purchased from Sigma Chemical Co.

Ethanol, Potassium hydroxide, sodium hydroxide, *n*-hexane, sodium carbonate, hydrochloric acid, sulphuric acid, and other chemicals used were of chromatographic or analytical grade and directly used as bought without

further purification.

2.3 Approximate composition analysis for hazelnut

Moisture, Ash, crude protein, fiber), and lipid contents of the samples were measured by Association of Official Analytical Chemists (AOAC) Methods²⁰ and expressed on a dry basis. The lipid content was analyzed by Soxhlet extraction, total protein content was performed on a Foss 2006 digester which was calculated by multiplying the total nitrogen content by a factor of 6.25. The crude fiber analysis was performed using a SCINOTMFT350 semiautomatic fiber analyzer (FOSS Technologies Co., Sweden).

2.4 Extraction of oil from hazelnut

The test milled hazelnut samples were extracted by petroleum ether (b.p. 30-60°C) in a Soxhlet extraction apparatus for 12 h at 50°C. The solvent was removed by rotary evaporation, afterward, the oils were heated at 105°C for 3 hours. The oil was purged with nitrogen and stored at -4°C until it was analyzed. The oil extracted from HN1 and HN2 were number HO1 and HO2 respectively.

2.5 Physicochemical property of the crude hazelnut oils

Important physicochemical properties of the crude oil, concerning refractive index, saponification value (SV), acid value (AV), iodine value (IV), peroxide value (PV) and color were characterized based on the AOCS official Methods Cc7-25, Cd3a-94, Cd3d-63, Cd1-25, Cd8-53 and Cc 13e-92, respectively²⁰. The specific UV spectroscopic absorptivity indices, conjugated diene (K232) and conjugated triene (K270) values, were determined by ISO-3656:2002 (E) method²¹, and the oil was diluted with *n*-hexane.

2.6 Analysis of fatty acid in oil

Fatty acid profiles were measured using a gas chromatography (GC) after derivatization to fatty acid methyl esters (FAMES). The preparation of FAMES was carried out by the standard method (ISO 5509:2000)²². The fatty acid profiles of crude hazelnut oils were analyzed according to IUPAC method 2.303²³.

Oil (200 mg) was methylated with 6 mL of 20% Boron trifluoride prepared in methanol for 8 min. After the resulting sample was centrifuged at 4500 $\times$ g for 15 minutes, the upper phase was taken into a vial. 1 μ L of sample was injected into a GC system (Agilent 7890B) equipped with a flame ionization detector (FID) and a HP-88 capillary column (100 m $\times$ 0.25 mm, 0.2 μ m). The temperatures of column was initially maintained at 140°C for 5 minutes, then increased to 240°C at the rate of 4°C/min and held for 10 minutes, and the injector and detector temperatures were set at 240 and 280°C, respectively. The flow rate of carrier gas N₂ with a split ratio of 1:50 was set at 2 mL/min. The injection size was 1 μ L.

Fatty acid profiles were identified by comparing the re-

tention time with those of standard FAMES performed at the same conditions and expressed as percentages of their relative areas.

2.7 Composition of the triacylglycerols of the oil

The main triacylglycerols (TGA) profile were performed according to Ref.^{24, 25}. Oil was dissolved in *n*-hexane at about 48 mg/mL, and this solution was then diluted by the mixed solution of acetonitrile (ACN) and isopropanol (7:3, v/v) containing 0.5% ammonia to 4.8 mg/mL. The analysis of the TAG profile in hazelnut oil was performed using high-performance liquid chromatography (Agilent 1200, American Agilent Technologies) equipped with atmospheric pressure chemical ionization (APCI) mass spectrometry and G1312A bin pump. The column was Agilent ZORBAX SB-C18 (4.6 mm × 250 mm × 5 μm). The mobile phase used was 100% acetonitrile (solvent A) and 0.5% aqueous ammonia in isopropanol (solvent B). Elution was performed at a solvent flow rate of 0.8 mL/min with the following gradient, 0–20 min, 33% B; 20–75 min, 35% B; 75–80 min, 47% B; and then returning to the initial conditions. The column temperature was 30°C and the injection volume was 5 μL.

2.8 Tocol (tocopherol and tocotrienols) contents of the oil

As reported in the ISO 9936:2006²⁶, Transfer Oil (about 0.5 g) to a 10 mL volumetric flask, dilute with *n*-hexane (HPLC grade) to volume, which mixed by vortex mixer and ultrasonic extractor. The combined extracts were filtered through a 0.22 μm nylon filter prior to analysis. Tocopherols were analyzed by using a Waters e2695 (American Waters) high-performance liquid chromatography system consisting of an autosampler, a temperature controlled column oven, a quaternary pump and a 2475 fluorescence detector. Tocopherols were separated on Sphersorb® S5 NH₂ column (250 × 4.6 mm, 5 μm) using the mixture of isopropanol and *n*-hexane (1:99, v/v) at a flow rate of 0.8 mL/min at 35°C. The injection volume was 10 μL. The fluorescence detector excitation and emission wavelengths were 298 and 325 nm, respectively. The concentrations of each tocopherol and tocotrienol were qualitatively by the relative retention time and quantified by means of calibration curves established between 1.0 and 100 mg/L.

2.9 Phytosterols contents of the oil

Sterols are commonly analyzed in oil according to the ISO 12228:1999 method²⁷. Following the procedure, first 1g of oil was weighted into screw-capped glass tube, and then 1mL of an internal standard of 5α-cholestan-3β-ol (2mg/mL in *n*-hexane) was added. After waiting for 1h, the mixture was saponified for 2h by adding 20mL of KOH 4M in 95% ethanol at 85°C. The resulting saponification products were extracted three times by *n*-hexane. The volume of each extract was reduced to 10mL under N₂, followed by

washed to neutral by water. The aqueous fraction was withdrawn and the organic phase was dried treatment with anhydrous sodium thiosulfate. Steroid fraction was obtained after TLC with *n*-hexane/diethyl ether 65:35 (v:v) as developing solvent and a methanol spray to visualize the band. Derivatization was performed with 200μL of N,O-Bis (trimethylsilyl) trifluoro-acetamide with trimethylchlorosilane at 85°C for 50min.

Silylated samples were analyzed on the same GC used for fatty acid analysis. The instrument fitted was fitted with a hydrogen flame ionization detector and a HP-5 Capillary column (30 m × 0.32 mm × 0.25 μm). Injector and detector temperatures were 300°C and 360°C, respectively. Nitrogen carrier gas at a flow rate of 1.0 mL/min was used, and split ratio was 1:20. The oven temperature was set at 285°C and injection volume was 1 μL.

Identifying sterols in the sample was achieved by comparing the retention times of the standards and quantifying by each calibration curves of the standard peak areas.

2.10 Thermal analysis

The thermal analyses of HO were evaluated by thermogravimetric (TG). TG curves were obtained from a thermogravimetric analyzer (TGA Q50, USA). The weight loss and pyrolysis temperature of 10 mg oil samples were recorded from room temperature to 600°C with a heating rate of 10°C /min. N₂ was used as purge gas at a flow rate of 40 mL/min in these tests. The derivative thermogravimetric (DTG) curves were analyzed from the first derivative of TG.

2.11 Statistical analysis

All analysis was performed in triplicate. The reported data were expressed as mean ± standard deviations ($\bar{X} \pm SD$). The experimental data analysis and curve-fitting were carried out using origin 8.5 software.

3 Results and Discussion

3.1 Composition of hazelnuts

Table 1 described that the two hazelnut cultivars were rich in oil and protein. The main ingredient contents of different hazelnuts hadn't significant differences. The lipid contents of two locations of wild hazelnuts were all over 50%, and they were similar to American hazelnut²⁸ and Turkish hazelnut^{1, 2}. The contents of crude protein and ash of two locations of wild hazelnuts were similar, meanwhile, there were all higher than American hazelnut²⁸ and Turkish hazelnut^{1, 2}. The crude fiber, ash and the crude lipids contents of HN2 were slightly higher than HN1. The differences in different varieties of the same origin and the different origin among the main composition may be due to the local growing condition such as climates and soils²⁹.

Table 1 Composition of two locations of hazelnut.

Composition (%w/w)	HN1 ^a	HN2 ^a
Crude protein ^b	17.22 ± 0.26	15.55 ± 0.34
Lipids ^b	54.00 ± 0.12	55.01 ± 0.09
Ash ^b	2.03 ± 0.06	2.17 ± 0.12
Moisture ^b	3.65 ± 1.74	3.60 ± 0.38
Crude fiber ^b	0.64 ± 0.08	0.77 ± 0.04

^a In this table in the paper, the HN1 and HN2 represents each locations of China-grown wild hazelnut, respectively.

^b Values are means ± standard deviation of triplicate determinations.

3.2 Physicochemical characteristics of HO

The physicochemical properties of hazelnut oils are given in **Table 2**. The physicochemical properties are very important because they showed some information about the composition and application of wild hazelnut oil. The refractive index (n^{20}) and SV (mg KOH/g oil) of crude hazelnut

oil were 1.4682 and 189.3 (HO1), 1.4650 and 182.9 (HO2), respectively. The refractive index for hazelnut oil were similar to that of American hazelnut²⁸⁾ and Turkish hazelnut^{1, 2)} oil. The AV (mg KOH/g oil) and PV (mmol O₂/kg oil) for hazelnut oil were 0.75 and 1.81 (HO1), 0.61 and 2.03 (HO2), respectively, which indicated that the amount of primary oxidation products and free acids released by hydrolysis in the oil were lower. The iodine value (90.38 and 88.74 g/100 g) of HO1 and HO2 was slightly lower than that of soybean oil (122.56 g/100 g oil) and corn oil (117.44 g/100 g oil). The saponification value of HO (189.3 and 182.9 mg KOH/g oil) was close to that of linseed oil (190.86 mg KOH/g oil), soybean oil (179.45 mg KOH/g oil), and sunflower oil (188.98 mg KOH / g oil), which indicated a relatively high content of small molecular weight triacylglycerols.

Specific extinction coefficient at 232 nm (K_{232}) was closely related to the amount of primary oxidation (such as hydroperoxides) of oil, whereas K_{270} was proportional to the secondary oxidation products (such as α -unsaturated ketone,

Table 2 Some characteristics and the tocol contents of HO1 and HO2.

Characteristic	HO1 ^a	HO2 ^a
Refractive index (n^{20})	1.4682 ± 0.0004	1.4650 ± 0.0011
Saponification value (mg KOH/g) ^b	189.3 ± 0.49	182.9 ± 0.33
Acid value (mg KOH/g oil) ^b	0.75 ± 0.23	0.61 ± 0.34
Iodine value (g I ₂ /100 g) ^b	90.38 ± 0.31	88.74 ± 0.22
Peroxide value (mmol O ₂ /kg oil) ^b	1.81 ± 0.18	2.03 ± 0.22
Color (Lovibond, 1 in.)	Y35, R0.6	Y35, R0.9
K_{232}	3.08	3.15
K_{270}	2.83	2.92
ΣTocol (μg/g)	574.44	647.49
α-TP ^c	368.13	350.67
α-TT ^c	—	92.02
β-TP ^c	—	79.51
γ-TP ^c	124.92	—
(β+γ)-TT ^c	42.33	132.49
δ-TP ^c	24.52	74.09
δ-TT ^c	14.53	—
Σphytosterol (μg/g)	2301.2	2191.0
Campesterol	79.0	81.3
Stigmasterol	94.8	100.9
β-Sitosterol	1772.0	1594.6
β-Sitostanol	355.4	414.2

^a In this table, the HO1 and HO2 represents each locations of China-grown wild hazelnut oils, respectively.

^b Values are means ± standard deviation of triplicate determinations.

^c TP means tocopherol, TT means tocotrienol.

α -diketone)³⁰⁾. In addition, K_{232} and K_{270} were also indicator of conjugation substances³⁰⁾. From Table 2, K_{232} (3.08 in HO1 and 3.15 in HO2) and K_{270} (2.83 in HO1 and 2.92 in HO2) of HO are both higher than Australian chia seed oil ($K_{232} = 1.62$ and $K_{270} = 0.35$)³¹⁾ and virgin olive oil ($K_{232} = 1.90$ and $K_{270} = 0.21$)³²⁾. In generally, these results will be considered that the HO extracted in this study contained a big trace of primary and secondary oxidation products. However, this finding was not corroborated by its PV value of 1.7-2.2 mmol O_2 /kg oil. So, the higher K_{230} and 270 values may be due to other compounds with conjugated structure such as phenol, flavonoid, VE and flavor substances in HO.

Therefore, above physicochemical informations illustrate that the wild HO extracted in the study is an excellent source for use as a functional edible oil.

3.3 Fatty acid compositions and positional distribution in HO

The fatty acid compositions and distribution of the oil could affect its physicochemical properties and the results showed in Tables 3 and 4.

The fatty acid composition is a good indicator of the quality and stability of oil. Therefore, standardization of oils based on fatty acid compositions is mandatory³³⁾. The GC chromatogram shows that palmitic (P), palmitoleic (Po), stearic (S), oleic (O), linoleic (L), and linolenic acid (Ln) are present in hazelnut oil. Oleic and linoleic acid were the predominant unsaturated fatty acid. Higher contents of linoleic and oleic acid in hazelnut oil were noteworthy which has been associated with various diseases such as inflammatory, autoimmune, cardiovascular and cancer diseases, etc. Therefore, the hazelnut oil can play a significant role in lowering blood cholesterol levels when consumed regularly as part of the diet. As a comparison, the fatty acid compositions of the two kinds of hazelnut oil had similar degrees of unsaturation, however, this profiles was no significant difference with previous reports about American hazelnut oil (3.1% palmitic, 1.6% stearic, 80.6% oleic, and 14.5% linoleic acid)²⁸⁾ and Turkish hazelnut oil (0.03% myristic, 5.58% palmitic, 0.26% palmitoleic, 0.04% heptadecanoic, 0.07% heptadecenoic, 2.47% stearic, 83.85% oleic, 7.35% linoleic, 0.10% linolenic, 0.11% arachidic and 0.14% gadoleic)¹⁾.

The triacylglycerol molecules have important physiological and nutritional effects on humans³⁴⁾. Table 4 present the predicted triacylglycerol composition of hazelnut oils from two locations, which were analyzed by reversed phase HPLC and MS detector. The triacylglycerols of the two hazelnut oils were triolein (OOO), palmitodilinolein (PLL), oleodilinolein (OLL), palmitodiolein (POO), dioleolinolein (OOL), palmitooleolinolein (POL), trilinolein (LLL) and a few of dioleostearin (OOS) (Fig. 2). The main constituents triacylglycerol of the two HO were OOL (HO1 34.04% and

Table 3 Fatty acid compositions (%) of HO1 and HO2.

Fatty acid (%) ^a	HO1	HO2
palmitic (16:0, P)	3.11 ± 0.13	3.40 ± 0.18
palmitoleic (16:1, Po)	0.26 ± 0.05	0.14 ± 0.02
stearic (18:0, S)	1.84 ± 0.08	1.30 ± 0.11
oleic (18:1, O)	78.46 ± 0.48	80.21 ± 0.73
linoleic (18:2, L)	15.91 ± 0.24	14.62 ± 0.13
linolenic (18:3, Ln)	0.41 ± 0.07	0.32 ± 0.01
UFA	95.04 ± 0.84	95.29 ± 0.89
SFA	4.95 ± 0.21	4.70 ± 0.29
U/S	19.20	20.27

^a Only the major fatty acids are listed in this table.

UFA, unsaturated fatty acid; SFA, saturated fatty acids; U/S, unsaturated/saturated fatty acids ratio.

Table 4 Predicted major triacylglycerol molecular species in HO1 and HO2 (P, palmitic acid; S, stearic acid; O, oleic acid; L, linoleic acid).

species	Content in HO1 (%)	Content in HO2 (%)
OOO	22.89	23.98
PLL	1.59	2.12
OLL	25.06	19.62
POO	1.13	3.79
OOL	34.04	37.91
POL	2.85	4.19
LLL	11.65	7.38
OOS	0.79	1.01

HO2 37.91%, respectively), OLL (HO1 25.06% and HO2 19.62%), OOO (HO1 22.89% and HO2 23.98%), LLL (HO1 11.65% and HO2 7.38%), POL (HO1 2.85% and HO2 4.19%), POO (HO1 1.13% and HO2 3.79%) and PLL (HO1 1.59% and HO2 2.12%). Whereas Sezer Kiralan *et al.*¹⁾ reported 59.14%-68.99% of OOO for Turkish hazelnut oils. The differences in the triacylglycerol composition of the two oils were significant.

3.4 Tocol (tocopherol and tocotrienols) contents of HO

Tocols (including tocopherols and tocotrienols) are well recognized for their effective inhibition of lipid oxidation in biological systems, foods and as human nutrition, thereby, to increase their storage life³⁵⁾. The tocopherols are mainly present in leaves, other green part of plants and oil seeds. Generally, it is widespread agreed that the relative antioxidant activity of the tocopherols is in the order $\alpha > \beta > \gamma > \delta$. β -tocopherol and α -tocotrienol were not detected in HO1 and HO2, α -tocopherol was found to be the most abundant (above 50% of the total tocopherols) in two samples, and the α -tocopherol content of HO1 (368.13) was higher than

Fig. 2 Total ion flow of triacylglycerol profile of HO1 obtained by HPLC-MS (P, palmitic acid ; S, stearic acid; O, oleic acid; L, linoleic acid).

HO2 (350.67). As showed in Table 2, the total tocopherols in the wild hazelnut oil (574.44 in HO1 and 647.49 in HO2) was higher than they were in the commercial oils of grape seed oil (454)³⁶⁾, olive oils (209)³⁷⁾ and walnut oil (255)³⁸⁾.

3.5 phytosterol contents of HO

Phytosterols have been used as a fingerprint to assess authenticity of vegetable oils. Besides, their determination is of most interest due to their antioxidant activity and impact on health^{39, 40)}. The identified compounds for phytosterol of HO1 and HO2 are listed in Table 2. Although β -sitosterol was the major predominant sterol in two samples, traces of stigmasterol, campesterol and sitosanol were also detected, as found by other Researcher⁴¹⁾. Among the different phytosterols, β -sitosterol have many physiological functions such as lowering blood cholesterol levels⁴²⁾, anti-inflammatory, anti-pyretic, anti-carcinogenic (prostate essentially)⁴³⁾, and enhances immunity⁴⁴⁾. The total sterol contents in hazelnuts oil were over 2000 $\mu\text{g/g}$, which equal amounts with soybean oil (2050-2870)⁴⁵⁾.

3.6 TG/DTG analysis

TG of HO1 and HO2 are similar shape. This following chart only shows the TG and DTG of HO1, and its thermal stability analysis is discussed.

TG and DTG are mainly used to monitor the thermal decomposition process for oils. Figure 3 illustrates the TG / DTG curves of HO1 in normal air atmosphere. The mass has nearly no change between 40°C and 300°C. From 300°C and 450°C, the mass began to reduced drastically, which was decreased by 50% at 402.8°C. It can be seen from the DTG curve that the decomposition rate reaches a maximum at 408.5°C.

Fig. 3 TG/DTG curves of HO1.

hazelnut oil extracted by petroleum ether were analyzed in this study. The results showed that the hazelnut oil was a potential source of edible oil, which have been associated with rich in oleic acid (about 80%). The crude protein and lipid contents in hazelnut were about 16 and 55% on a dry weight basis, respectively. The content of tocopherol in the hazelnut oil was high. The main unsaturated fatty acids in both hazelnut oil were oleic and linoleic acid, which accounted for above 90% of the oil. The dominant triacylglycerols were OOL, OLL and OOO. Slightly higher thermal stability of hazelnut oil was also observed. This paper may be helpful in the investigation and applications of hazelnut and its oil.

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4 Conclusion

Chemical characteristics and fatty acid compositions of

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