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Research Article

Comparative Analysis on Essential Nutrient Compositions of 23 Wild Hazelnuts (*Corylus heterophylla*) Grown in Northeast China

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The essential nutrients of 23 wild hazelnuts (*Corylus heterophylla*) grown in northeast China were analyzed in order to sieve good species and study the factors effected on nut quality. Hazelnut kernels contained 45.76–62.78% fat similar to *Corylus avellana* and main fatty acids were oleic acid (79.75%), linoleic acid (15.42%), palmitic acid (3.29%), and polyunsaturated fatty acids ranged between 10.37% and 25.88%. Average protein, soluble sugar, starch, and ash contents of hazelnut kernels were 25.12%, 4.98%, 2.03%, and 3.04%, respectively. The amount of amino acids, mostly as glutamic acid, arginine, and aspartic acid, was also determined by the hazelnut varieties. The abovementioned variation was explained by growing environmental differences. Among them, the 11th sample was highest in protein content (30.21%) and 18th sample highest in fat content, while the 5th and 14th samples had relatively balanced nutrients. So, when planning to select new cultivars, we primarily considered different hazelnut qualities.

1. Introduction

There are about 20 species of *Corylus* around the world, widely distributed in temperate regions of Asia, Europe, and Americas. *C. avellana* is the most widely distributed variety in the world [1, 2] and is mainly grown in Turkey, Italy, Spain, and other countries for now, among which the Turkey's hazelnut production accounted for 70% of the world's total output [3, 4]. Turkey' climate is hot and dry in summer and mild and rainy in winter, so *C. avellana* likes warm and humid climate, the place with plenty of light, and can adapt to a variety of soil. Also, China is the country of origin of *Corylus*, including *C. heterophylla* Fisch, *C. mandshurica* Maxim., *C. kweichowensis* Hu, *C. chinensis* Franch, *C. fargesii* Schneid, *C. yunnanensus* A. Camus, *C. ferox* Wall, and *C. wangii* Hu, distributed in over 20 provinces and autonomous regions [5]. The history of the use of wild hazelnut in China has been for 5000~6000 years [6], but systematic evaluation on chemical compositions of Chinese hazelnut has not been a more in-depth research.

Among China's origin, wild hazelnut, *C. heterophylla*, is the most economically valuable resource and is mainly distributed in Heilongjiang, Jilin, Liaoning, Neimongol, Hebei, and Shanxi provinces in China, but the resource of hazelnut is the largest and the quality is good in Northeast China [7]. In the region, the average precipitation and temperature are 460.8 mm and 7.7°C, and the climate is cold and dry. So, this variety of hazelnut has good cold resistance, strong adaptability, and rich nutrition of kernel. China has obtained some progress in the utilization of wild *C. heterophylla* resources. It has been reported that there are some differences in nutritional quality compared with other hazelnut varieties [5, 8].

Hazelnut is a kind of favorite dried fruit which can be eaten raw and fried, not only delicious, but also has high calorific value [9, 10]. In the food industry, hazelnut can be processed in cakes, confectionery, chocolates, and some senior nutrition such as ground hazelnut and hazelnut milk [11–13]. Hazelnut can be processed in oil. It is a kind of high-quality edible oil rich in unsaturated fatty acid which has yellow color and flavor [9, 14–16]. Besides the edible

function, hazelnut oil can also be processed in soap, cosmetics, candles, etc [17]. According to the Chinese medicine book "Materia Medica for Dietotherapy," it is also a kind of medicine. Hazelnut has sweet taste, gentle effect, can strengthen the body, and benefit the stomach [6]. At present, the hazelnut processing industry in China is relatively single as mostly raw and fried food while the deep processing products are relatively few and mainly hazelnut oil, ground hazelnut, and hazelnut protein beverage [18]. The aim of this study is to compare the composition of different *C. heterophylla* growing in the Chinese northeast region and obtain wild *C. heterophylla* varieties with high nutrition. Furthermore environmental factors influencing the nutrient accumulation in hazelnut are also discussed. It can provide the selection of fine varieties for industry development of hazelnut and also offer basic information for intensive study of nutritional components of *C. heterophylla*.

2. Materials and Methods

2.1. Samples. Twenty-three samples of wild *C. heterophylla* were collected from the northeast region, including Jilin, Liaoning, Heilongjiang, and Neimongol Province of China (Figure 1, Table 1) by Jilin Provincial Academy of Forest Sciences in 2016 and used in this study. The hazelnut was naturally dried and the shell was broke to get the kernel samples after the harvest season. The hazelnut samples were polished and stored at −18°C in the refrigerator.

2.2. Reagents. Twelve kinds of mixed standard fatty acid methyl esters (equal mass ratio), 20 kinds of amino acids, and D-(+)-glucose standard compounds were purchased from Sigma-Aldrich, Saint Louis, USA. Solvents for chromatography, namely hexane, acetone, methanol, hydrochloric acid, butanol, phosphate buffer solution and acetic acid were from Fisher Scientific, USA. Copper sulphate, sodium hydroxide, anthrone ethyl acetate, sulfuric acid, and boric acid were of analytical grade (>98%; Merck, Darmstadt, Germany).

2.3. Methods

2.3.1. Water. The water content of samples was determined by drying at 103 ± 2°C until they reached constant weight (AOAC, 925.40) [19].

2.3.2. Protein. Protein content was measured by the Kjeldahl method (Kjeltec 2300II, Foss, Sweden) [20]. Nitrogenous organic compounds in the samples were converted into ammonium sulphate, which further was reduced to molecular nitrogen. Protein content was calculated as total nitrogen by a conversion factor of 6.25 (AOAC 2001.11) [21].

2.3.3. Starch. In order to determine starch content, the acid hydrolysis method was used. 1 g dried residual extract removing soluble sugar and fat from each sample was homogenized with 30 ml of 1 mol/L HCl in a water bath at 90°C for 2 h to hydrolyze the starch. The suspension was neutralized with 1 mol/L NaOH, the sample was treated as previously described for soluble sugars according to GB 5009.9-2016 [22]. All analyses were conducted in triplicate for each variety.

2.3.4. Soluble Total Sugars. Quantitative determinations of soluble total sugars were carried out by the anthrone colorimetry method according to AOAC, 2000 [23]. 0.3 g hazelnut was extracted with 10 ml water for 30 min in a boiling water bath. After filtration, 0.2 ml filtrate and 1.8 ml water were blended, then 0.5 ml anthrone ethyl acetate reagent and 5 ml sulfuric acid were added, fully oscillated, and then cooled down to room temperature, detected at 620 nm by using a UV-2550 spectrophotometer (Shimadzu Corporation, Kyoto, Japan).

2.3.5. Total Ash. Total ash was determined by using dried samples following the AOAC method 950.49 [24], and then the samples were weighed and the crucible was transferred to a muffle furnace. The temperature was preheated to 525°C, and the samples were ashed for 4 h to a white powder. The crucibles were transferred into desiccators, cooled, and weighed.

2.3.6. Total Fat. Total fat was extracted with n-hexane (60°C) for 8 h using a Soxhlet apparatus (AOAC method 948.22) [25]. Hexane was separated by evaporation at room temperature. The flasks were cooled and the crude fat was weighed.

2.3.7. Fatty Acid. Fatty acid composition was analyzed by gas chromatography (Thermo Trace 1300, USA) with a flame ionisation detector (FID). N_2 was used as the carrier gas at a flow rate of 2 ml/min. For separation of the fatty acids, a fused silica capillary column (15.00 m × 0.25 mm × 25 μm film thickness, provided by GE Company, New York, USA) was used and the temperature of the column and detector was set at 240°C, and the injection temperature was 220°C. Fatty acids were identified by comparison with retention times of external standards (AOCS, 1990) [26].

2.3.8. Free Amino Acids. Free amino acids were determined using a amino acid analyzer (S433D, Sykam, Germany). The amino acid analyzer was used with an Amino Sep Na + AA-911 (250 × 4.6 mm) and ultraviolet-visible spectrometer (T6-1650E, Persee, China) at 570 nm.

2.4. Statistical Analysis. Statistical analysis of the data was performed using one-way ANOVA (SPSS Statistics 17.0, SPSS Inc. Chicago, USA). Differences were considered significant when $P < 0.05$. All analyses were conducted in triplicate for each variety.

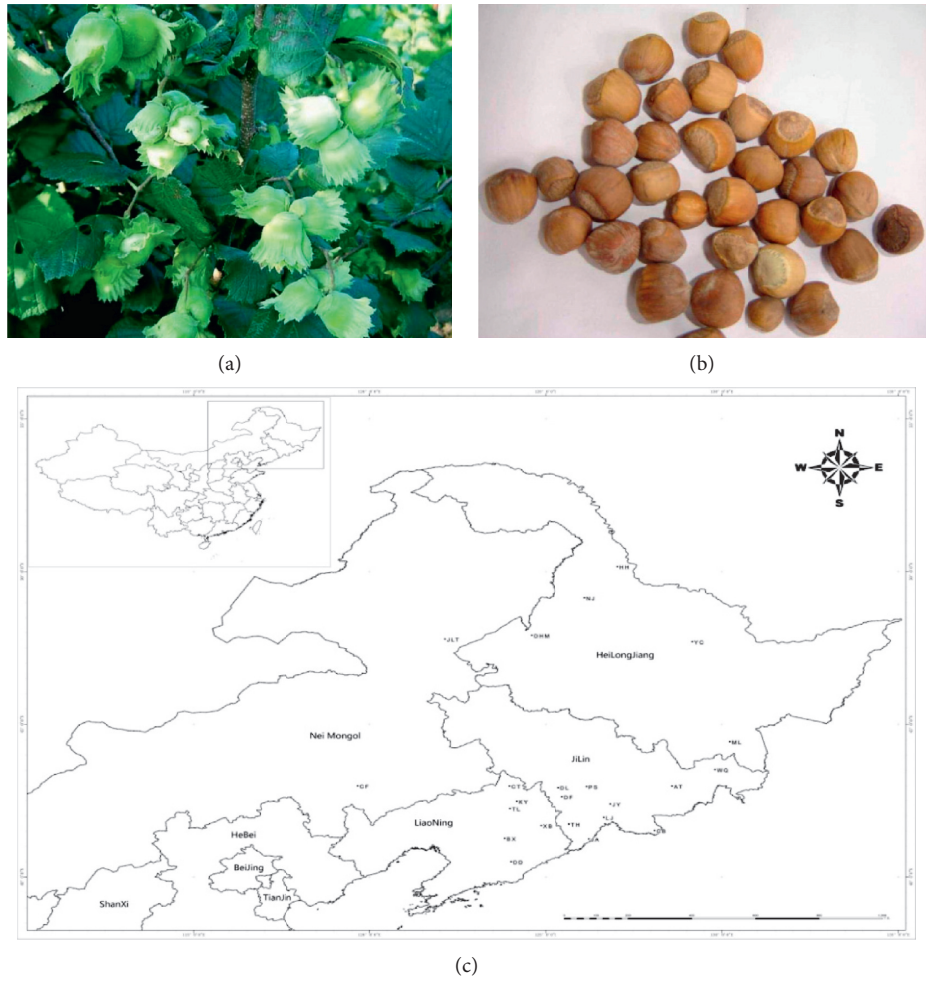


Figure 1: Wild hazelnut tree and fruits of *C. heterophylla*; distribution map of hazelnuts collected from the northeast region (Jilin, Liaoning, Heilongjiang, and Neimongol) of China.

Table 1: The collection location, abbreviation, and weight of 23 wild *C. heterophylla* samples tested in this study.

Hazelnut variety	Location	Abbreviation	Weight (kg)	Longitude and latitude
P-1	Da Hinggan Mountains of Heilongjiang	DHM	6.000	124.1 e, 50.42 n
P-2	Heihe of Heilongjiang	HH	5.000	127.5 e, 50.25 n
P-3	Muleng of Heilongjiang	ML	5.000	130.5 e, 44.92 n
P-4	Nengjiang of Heilongjiang	NJ	5.000	125.2 e, 49.17 n
P-5	Yichun of Heilongjiang	YC	5.000	128.9 e, 47.73 n
P-6	Dongfeng County of Jilin	DF	5.000	125.5 e, 42.68 n
P-7	Antu County of Jilin	AT	7.000	128.3 e, 42.58 n
P-8	Jian of Jilin	JA	5.000	126.2 e, 41.15 n
P-9	Jingyu County of Jilin	JY	3.000	126.8 e, 42.38 n
P-10	Linjiang of Jinlin	LJ	3.000	126.9 e, 41.80 n
P-11	Panshi of Jilin	PS	5.000	126.0 e, 42.93 n
P-12	Wangqing County of Jilin	WQ	5.000	129.8 e, 43.32 n
P-13	Tonghua County of Jilin	TH	5.000	125.9 e, 41.49 n
P-14	Benxi County of Liaoning	BX	5.000	123.7 e, 41.30 n
P-15	Changtu County of Liaoning	CT	5.000	124.1 e, 42.80 n
P-16	Dandong of Liaoning	DD	5.000	124.4 e, 40.13 n
P-17	Kaiyuan of Liaoning	KY	5.000	124.0 e, 42.53 n
P-18	Tieling County of Liaoning	TL	5.000	123.9 e, 42.32 n
P-19	Xinbing of Liaoning	XB	5.000	125.0 e, 41.72 n
P-20	Cifeng of Neimongol	CF	5.000	118.9 e, 42.28 n
P-21	Jalantun of Neimonggol	JLT	5.000	122.7 e, 48.00 n
P-22	Changbai County of Jilin	CB	5.000	128.2 e, 41.43 n
P-23	Dongliao County of Jilin	DL	5.000	125.0 e, 42.92 n

3. Results and Discussion

3.1. Nutrient Analysis. According to the measurement of nutritional composition, the content of water, starch, soluble total sugar, protein, total ash, and fat of 23 species of hazelnut kernels were presented in Figure 2: the water content changed between 3.45% (P-5) and 5.00% (P-4), the starch content ranged between 0.96% (P-9) and 5.16% (P-1), the soluble total sugar content changed between 2.95% (P-5) and 9.20% (P-2), the protein content changed between 21.38% (P-18) and 30.21% (P-11), the fat content changed between 45.76% (P-11) and 62.78% (P-18), and the total ash changed between 2.5% (P-5) and 4.0% (P-11). The fat was the predominate component in all hazelnut kernels, and protein was the second major component, followed by soluble total sugar, water, total ash, and the starch [27–29].

Varieties of the hazelnut nutrition exhibit a few difference, and some of them are significant ($P < 0.05$). The amount of variation was explained by environmental factors of all variables investigated, such as temperature, latitude, rain, sunshine time, and soil composition [15, 16]. Larger temperature difference between day and night and high latitudes probably benefit sugar and starch accumulation, and high temperature and low latitudes (much rain and long sunshine time) are good for fat synthesis. Among all hazelnut kernels, P-11 presented higher protein (30.21%), soluble sugar (8.02%), water (4.94%) and ash (4.00%), and lower total fat (45.76%); P-18 presented highest total fat (62.78%), and lower protein (21.38%), soluble sugar (3.82%), starch (1.57%), and ash (2.60%). Maybe it is because Panshi of Jilin is located at the foot of ChangBaishan Mountains and has a large temperature difference, while Tieling County of Liaoning is laid on the middle of Songliao Plain and the climate is warm and rainy. If compared with P-11 (high protein) and P-18 (high fat), it seemed that P-5 and P-14 had relatively balanced nutrients. Nutritional quality can be used as an important indicator in the selection and promotion of dominant varieties of hazelnut. In the production, it can be selected and produced according to different needs.

3.2. Water and Ash Content. There were differences in water content of different varieties, and the mean value was 4.18%. The water content of P-4 was higher than that of other species, while the degree of drying was consistent with the harvest time, storage conditions, and transportation ways of different varieties of hazelnut [30]. Low water content was benefit to prolong the storage time of hazelnut kernel. Ash mainly reflected the content of inorganic elements, for example, Ca, Mg, K, Na, Si, P, S, Fe, Al, etc. The average ash content of the hazel varieties was found to be 3.04% and higher than *C. avellana* [27]. The minimum and maximum values were distinctions between compositions of the hazelnut varieties, based on mineral compositions of the soil in different regions. The soil in Northeast China is mainly black soil and chernozem, rich in humus, Ca, Mg, Fe, K, Na, and so on [31].

3.3. Soluble Sugars and Starch Content. High levels of soluble sugars were also observed in P-1, P-2, P-4, P-7, P-11, and P-12, whose values were above 6%. Sugar content differed among areas; the average content of Heilongjiang' western and Jilin' eastern mountain area was 7.23%, a value obviously higher than those in the other areas (P-14~23, 3.97%). Due to the large temperature difference between day and night in mountain area, it is probably benefit for sugar accumulation [32]. These differences in sugar content confirmed previous results [27] and should help in cultivar characterization. Even if present at low concentrations, sugar should be involved in kernel taste and favor; thus it plays an important role in nut quality determination [33].



Figure 2: The content of water, protein, starch, soluble sugar, total ash, and total fat of hazelnut kernel from different areas (Northeast of China). Each value is a mean of three determinations.

Starch content showed markedly differences among areas (Figure 2). The mean value of starch content was lower in samples collected in Liaoning' east regions than those collected in others, whereas soluble sugar levels were lower. This result is consistent with the capacity of high temperature to modify seed composition, where the proportion of soluble sugars to starch decreases with increasing temperature [34]. Eastern regions of Liaoning province were characterized by relatively low latitudes and high temperatures.

3.4. Total Fat and Fatty Acid. The total average fat content ranged between 45.76% in P-11 and 62.78% in P-18, with significant differences among samples (Figure 2). P-3, P-5, P-6, P-10, P-15, P-17, and P-18 contained more oil (61.00%) than the other samples. Palmitic (C16 : 0), stearic (C18 : 0), oleic (C18 : 1), linoleic (C18 : 2), arachidic (C20 : 0), and linolenic (C18 : 3) acids were the main fatty acids to be identified. The analysis of variance indicated distinct differences in fatty acid composition among samples, as shown in Figure 3.

The main fatty acid was oleic acid (C18 : 1), ranging between 85.53% in P-5 and 69.80% in P-2, consistent with results reported [15]. Linoleic acid (C18 : 2) showed pronounced differences among samples, the lowest content being found in P-5 (10.24%) and the highest in P-2 (25.65%). A negative relationship between oleic and linoleic acids was observed (Figure 3(a)), as previously reported by Parcerisa

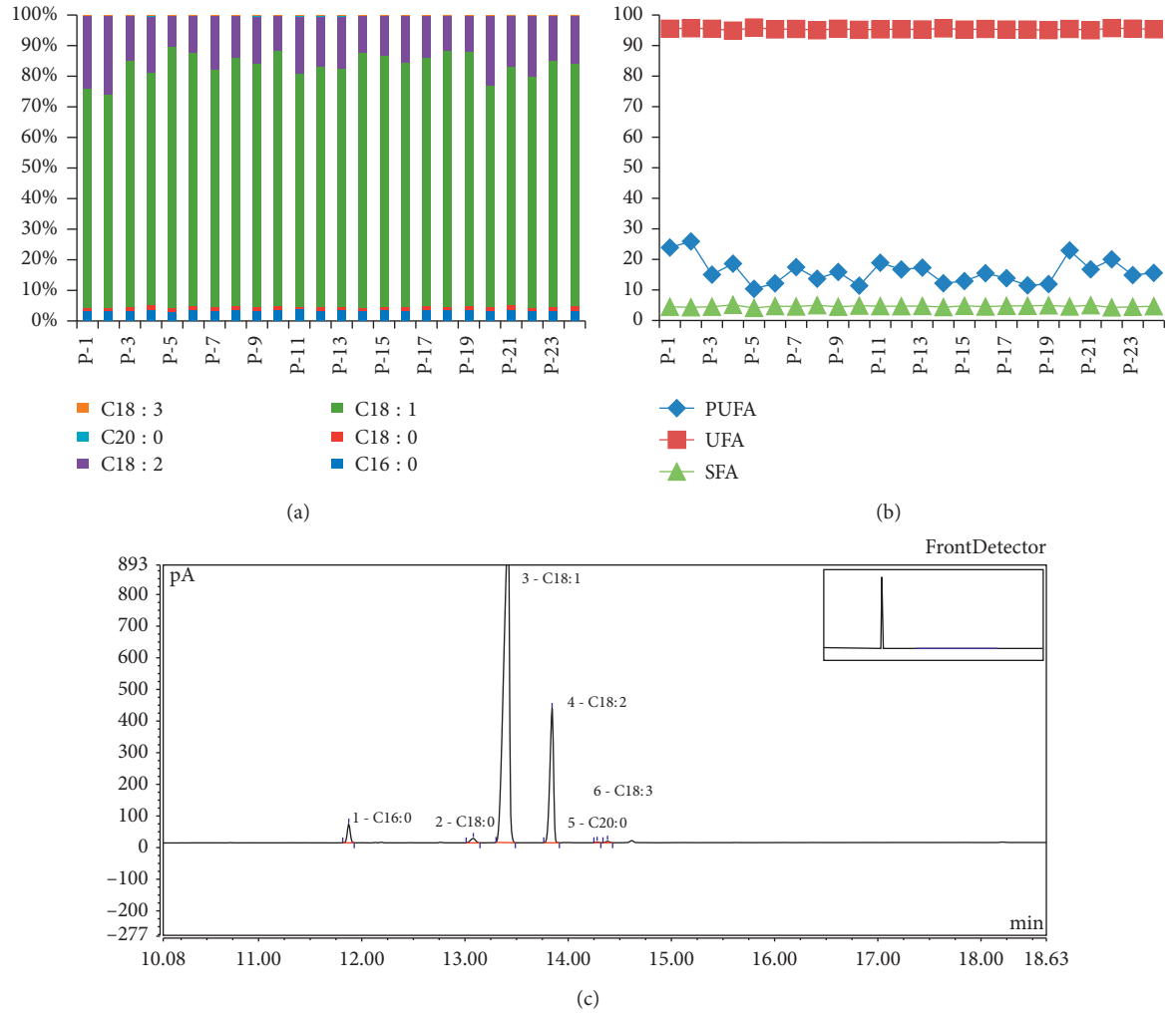


Figure 3: (a) Fatty acid composition (%) of total fat. (b) Polyunsaturated fatty acids (PUFA), unsaturated fatty acids including polyunsaturated and monounsaturated (UFA), and saturated fatty acids (SFA) of hazelnut kernel from different areas (Northeast of China). (c) Fatty acid profile of the hazelnut by gas chromatography. Each value is a mean of three determinations.

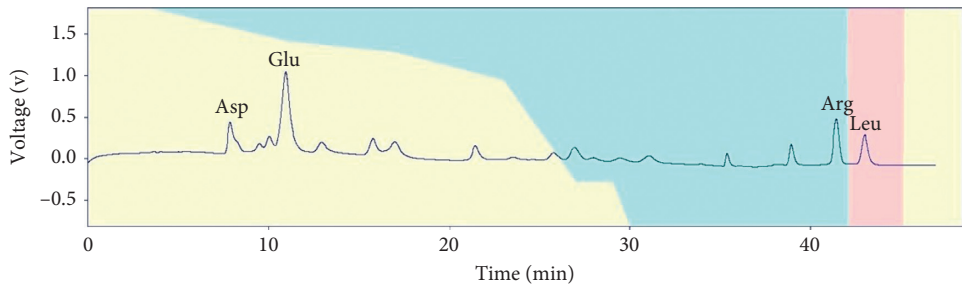


Figure 4: Amino acid profile of the hazelnut by using an amino acid analyzer.

et al. [16]. Moreover, P-1, P-2, P-20, and P-22 were characterized by the highest levels of linoleic acid and polyunsaturated fatty acids (PUFA), which was more than 20.00% [35]. Linolenic acid (C18 : 3) ranged between 0.10% in P-6 and 0.32% in P-11. This fatty acid, even in traces, can negatively affect nut storability because of its low stability [36, 37], but was healthy for human physical well-being [38].

The saturated fatty acid (SFA) content was less than 6% of the total in all samples, ranging between 4.11% in P-5 and 5.12% in P-4 (Figure 3(b)). The predominant SFA was palmitic acid (C16 : 0) whose content ranged between 2.91% in P-5 and 3.75% in P-11. The mean levels of ostearic acid (C18 : 0) were quite variable, ranging from 0.81% in P-11 to 1.63% in P-4. The differences among samples could

Table 2: Hydrolyzed amino acids, essential and nonessential amino acids g/100 (g), and contents of hazelnut kernel from different areas (Northeast of China).

Samples	Asp	Thr	Ser	Glu	Pro	Gly	Ala	Val	Met	Ile	Leu	Tyr	Phe	His	Lys	Arg	Essential	Nonessential
P-1	2.87 ± 0.74^{b}	0.76 ± 0.018^{b}	1.11 ± 0.033^{ab}	6.89 ± 0.24^{c}	1.04 ± 0.032^{ab}	1.27 ± 0.035^{bc}	1.03 ± 0.015^{a}	1.22 ± 0.031^{c}	0.28 ± 0.004^{b}	0.96 ± 0.028^{b}	1.84 ± 0.072^{b}	0.84 ± 0.024^{b}	1.22 ± 0.031^{bc}	0.80 ± 0.024^{b}	0.89 ± 0.024^{ab}	4.45 ± 0.12^{ab}	7.17 ± 0.28^{b}	14.34 ± 0.41^{c}
P-2	2.63 ± 0.11^{bc}	0.71 ± 0.015^{bc}	1.03 ± 0.019^{b}	6.08 ± 0.31^{d}	0.98 ± 0.029^{b}	1.24 ± 0.026^{bc}	0.98 ± 0.022^{ab}	1.19 ± 0.049^{c}	0.27 ± 0.004^{b}	0.91 ± 0.019^{bc}	1.72 ± 0.046^{bc}	0.76 ± 0.018^{bc}	1.09 ± 0.045^{c}	0.78 ± 0.029^{b}	0.91 ± 0.041^{ab}	4.03 ± 0.15^{b}	6.80 ± 0.14^{c}	13.60 ± 0.18^{c}
P-3	2.18 ± 0.09^{c}	0.63 ± 0.021^{c}	0.95 ± 0.042^{bc}	6.13 ± 0.28^{d}	0.97 ± 0.018^{b}	1.05 ± 0.020^{c}	0.79 ± 0.019^{b}	1.00 ± 0.045^{d}	0.25 ± 0.006^{c}	0.80 ± 0.037^{c}	1.53 ± 0.065^{d}	0.69 ± 0.021^{c}	1.02 ± 0.015^{cd}	0.65 ± 0.015^{c}	0.62 ± 0.013^{c}	3.58 ± 0.09^{c}	5.85 ± 0.21^{d}	11.70 ± 0.43^{d}
P-4	2.46 ± 0.10^{bc}	0.62 ± 0.013^{c}	1.05 ± 0.025^{b}	6.54 ± 0.09^{cd}	0.86 ± 0.033^{b}	1.32 ± 0.031^{bc}	0.77 ± 0.028^{b}	1.27 ± 0.036^{bc}	0.27 ± 0.010^{b}	0.86 ± 0.023^{bc}	1.75 ± 0.075^{bc}	0.77 ± 0.031^{bc}	1.12 ± 0.026^{c}	0.62 ± 0.013^{c}	0.79 ± 0.035^{b}	3.69 ± 0.14^{c}	6.68 ± 0.24^{c}	13.36 ± 0.26^{c}
P-5	2.76 ± 0.08^{b}	0.65 ± 0.025^{c}	1.16 ± 0.068^{ab}	6.97 ± 0.28^{c}	0.99 ± 0.017^{ab}	1.42 ± 0.041^{b}	0.95 ± 0.017^{ab}	1.35 ± 0.057^{b}	0.32 ± 0.011^{a}	0.81 ± 0.025^{c}	1.84 ± 0.029^{b}	0.78 ± 0.019^{bc}	1.17 ± 0.055^{c}	0.64 ± 0.023^{c}	0.76 ± 0.008^{b}	4.13 ± 0.10^{b}	6.90 ± 0.15^{c}	13.80 ± 0.39^{c}
P-6	2.23 ± 0.09^{c}	0.60 ± 0.012^{c}	0.92 ± 0.026^{c}	5.83 ± 0.15^{d}	0.77 ± 0.031^{c}	1.06 ± 0.033^{c}	0.61 ± 0.030^{bc}	1.09 ± 0.045^{cd}	0.25 ± 0.005^{c}	0.82 ± 0.045^{c}	1.67 ± 0.036^{c}	0.57 ± 0.025^{d}	0.88 ± 0.014^{d}	0.53 ± 0.025^{d}	0.65 ± 0.023^{c}	3.07 ± 0.11^{d}	5.96 ± 0.23^{d}	11.92 ± 0.65^{d}
P-7	2.69 ± 0.12^{b}	0.77 ± 0.018^{b}	1.10 ± 0.044^{b}	6.75 ± 0.23^{c}	1.06 ± 0.044^{ab}	1.21 ± 0.015^{bc}	0.83 ± 0.014^{b}	1.49 ± 0.045^{ab}	0.28 ± 0.005^{b}	0.97 ± 0.024^{b}	1.96 ± 0.089^{ab}	0.80 ± 0.022^{bc}	1.24 ± 0.026^{bc}	0.73 ± 0.031^{b}	0.90 ± 0.015^{ab}	4.38 ± 0.19^{ab}	7.61 ± 0.35^{b}	15.22 ± 0.61^{bc}
P-8	3.13 ± 0.10^{ab}	0.82 ± 0.027^{ab}	1.23 ± 0.016^{a}	7.92 ± 0.19^{ab}	1.04 ± 0.037^{ab}	1.51 ± 0.057^{ab}	0.92 ± 0.023^{ab}	1.31 ± 0.055^{b}	0.33 ± 0.007^{a}	0.94 ± 0.027^{b}	1.94 ± 0.077^{ab}	0.86 ± 0.023^{b}	1.36 ± 0.048^{b}	0.75 ± 0.017^{b}	0.87 ± 0.036^{ab}	4.60 ± 0.24^{ab}	7.57 ± 0.17^{b}	15.14 ± 0.47^{bc}
P-9	3.34 ± 0.08^{a}	0.86 ± 0.023^{a}	1.25 ± 0.021^{a}	8.42 ± 0.21^{a}	1.12 ± 0.016^{a}	1.60 ± 0.043^{a}	0.74 ± 0.031^{b}	1.54 ± 0.037^{a}	0.29 ± 0.012^{b}	1.00 ± 0.043^{b}	1.96 ± 0.068^{ab}	0.93 ± 0.048^{a}	1.48 ± 0.047^{ab}	0.84 ± 0.024^{ab}	0.97 ± 0.045^{a}	4.94 ± 0.17^{a}	8.10 ± 0.30^{a}	16.20 ± 0.27^{bc}
P-10	2.43 ± 0.06^{bc}	0.62 ± 0.017^{c}	0.97 ± 0.035^{bc}	6.36 ± 0.18^{cd}	0.85 ± 0.025^{bc}	1.12 ± 0.016^{c}	0.72 ± 0.026^{b}	1.20 ± 0.032^{c}	0.27 ± 0.010^{b}	0.84 ± 0.032^{bc}	1.68 ± 0.048^{c}	0.80 ± 0.041^{bc}	1.27 ± 0.036^{b}	$0.60 \pm 0.016^{c,d}$	0.70 ± 0.031^{bc}	3.47 ± 0.13^{c}	6.58 ± 0.23^{c}	13.16 ± 0.58^{c}
P-11	3.09 ± 0.12^{ab}	0.85 ± 0.025^{a}	1.22 ± 0.051^{a}	8.05 ± 0.25^{ab}	1.04 ± 0.012^{ab}	1.65 ± 0.028^{a}	1.09 ± 0.045^{a}	1.54 ± 0.046^{a}	0.30 ± 0.006^{ab}	1.28 ± 0.041^{a}	1.86 ± 0.039^{b}	0.87 ± 0.034^{b}	1.53 ± 0.065^{a}	0.96 ± 0.028^{a}	0.91 ± 0.043^{ab}	4.87 ± 0.14^{a}	8.27 ± 0.31^{a}	16.54 ± 0.24^{b}
P-12	2.86 ± 0.09^{b}	0.88 ± 0.022^{a}	1.03 ± 0.045^{b}	6.93 ± 0.26^{c}	1.06 ± 0.035^{ab}	1.37 ± 0.056^{b}	0.79 ± 0.014^{b}	1.47 ± 0.035^{ab}	0.26 ± 0.008^{b}	0.84 ± 0.029^{bc}	1.80 ± 0.045^{b}	0.76 ± 0.037^{bc}	1.26 ± 0.036^{b}	0.73 ± 0.036^{b}	0.88 ± 0.014^{ab}	4.25 ± 0.12^{b}	7.39 ± 0.26^{b}	14.78 ± 0.37^{c}
P-13	2.52 ± 0.07^{bc}	0.62 ± 0.014^{c}	0.97 ± 0.038^{bc}	6.25 ± 0.12^{cd}	0.84 ± 0.024^{bc}	1.23 ± 0.016^{bc}	0.57 ± 0.025^{bc}	1.23 ± 0.065^{c}	0.28 ± 0.004^{b}	0.96 ± 0.042^{b}	1.78 ± 0.049^{bc}	0.87 ± 0.014^{b}	1.24 ± 0.026^{bc}	0.60 ± 0.022^{cd}	0.73 ± 0.026^{bc}	3.51 ± 0.15^{c}	6.84 ± 0.19^{c}	13.68 ± 0.48^{c}
P-14	2.49 ± 0.12^{bc}	0.63 ± 0.023^{c}	0.97 ± 0.027^{bc}	6.62 ± 0.30^{c}	0.87 ± 0.034^{bc}	1.28 ± 0.046^{bc}	0.50 ± 0.021^{c}	1.21 ± 0.056^{c}	0.28 ± 0.011^{b}	0.86 ± 0.038^{bc}	1.69 ± 0.048^{c}	0.64 ± 0.020^{c}	1.15 ± 0.037^{c}	0.59 ± 0.025^{cd}	0.70 ± 0.015^{bc}	3.51 ± 0.07^{c}	6.52 ± 0.26^{c}	13.04 ± 0.29^{c}
P-15	2.54 ± 0.07^{bc}	0.65 ± 0.016^{c}	0.99 ± 0.039^{bc}	6.67 ± 0.24^{c}	0.94 ± 0.017^{b}	1.23 ± 0.036^{bc}	0.66 ± 0.023^{bc}	1.23 ± 0.016^{c}	0.28 ± 0.014^{b}	0.90 ± 0.015^{bc}	1.83 ± 0.015^{b}	0.77 ± 0.032^{bc}	1.25 ± 0.024^{b}	$0.58 \pm 0.019^{c,d}$	$0.74 \pm 0.027^{b,c}$	3.57 ± 0.12^{c}	6.88 ± 0.12^{c}	13.76 ± 0.48^{c}
P-16	2.81 ± 0.10^{b}	0.71 ± 0.015^{bc}	1.09 ± 0.045^{b}	6.65 ± 0.23^{c}	0.95 ± 0.045^{b}	1.35 ± 0.057^{b}	0.71 ± 0.035^{b}	1.40 ± 0.056^{b}	0.31 ± 0.014^{ab}	1.00 ± 0.033^{b}	1.94 ± 0.078^{ab}	0.80 ± 0.009^{bc}	1.19 ± 0.049^{c}	0.67 ± 0.019^{c}	0.77 ± 0.028^{b}	3.93 ± 0.16^{bc}	7.32 ± 0.24^{b}	14.64 ± 0.32^{c}
P-17	2.73 ± 0.06^{b}	0.66 ± 0.024^{c}	0.92 ± 0.026^{c}	6.40 ± 0.02^{cd}	0.97 ± 0.038^{ab}	1.27 ± 0.036^{bc}	0.75 ± 0.028^{b}	1.40 ± 0.019^{b}	0.31 ± 0.010^{ab}	0.97 ± 0.044^{b}	1.83 ± 0.056^{b}	0.79 ± 0.030^{bc}	1.04 ± 0.022^{cd}	0.66 ± 0.011^{c}	0.77 ± 0.035^{b}	3.75 ± 0.21^{bc}	6.98 ± 0.18^{bc}	13.96 ± 0.61^{c}
P-18	2.44 ± 0.10^{bc}	$0.70 \pm 0.018^{b,c}$	0.98 ± 0.039^{bc}	6.25 ± 0.16^{cd}	0.86 ± 0.026^{bc}	1.03 ± 0.019^{c}	0.56 ± 0.034^{bc}	1.33 ± 0.058^{bc}	0.29 ± 0.004^{ab}	0.86 ± 0.034^{bc}	1.62 ± 0.018^{c}	0.79 ± 0.017^{bc}	1.08 ± 0.044^{cd}	0.56 ± 0.018^{d}	0.70 ± 0.019^{bc}	3.49 ± 0.05^{c}	6.58 ± 0.29^{c}	13.16 ± 0.56^{c}
P-19	2.47 ± 0.11^{bc}	0.66 ± 0.022^{c}	0.98 ± 0.017^{bc}	6.46 ± 0.27^{cd}	$0.83 \pm 0.041^{b,c}$	1.18 ± 0.029^{c}	0.65 ± 0.026^{bc}	1.22 ± 0.016^{c}	0.26 ± 0.004^{c}	0.89 ± 0.028^{bc}	1.71 ± 0.055^{c}	0.64 ± 0.023^{c}	1.00 ± 0.015^{cd}	0.58 ± 0.009^{cd}	0.69 ± 0.021^{bc}	3.51 ± 0.15^{c}	6.43 ± 0.25^{c}	12.86 ± 0.42^{cd}
P-20	2.74 ± 0.07^{b}	$0.74 \pm 0.017^{b,c}$	1.06 ± 0.037^{b}	6.94 ± 0.10^{c}	0.88 ± 0.037^{bc}	1.31 ± 0.012^{bc}	0.73 ± 0.024^{b}	1.32 ± 0.034^{bc}	0.30 ± 0.009^{ab}	0.93 ± 0.041^{b}	1.82 ± 0.024^{b}	0.82 ± 0.014^{bc}	1.27 ± 0.032^{b}	0.65 ± 0.025^{c}	$0.86 \pm 0.033^{a,b}$	3.92 ± 0.11^{bc}	7.24 ± 0.16^{b}	14.48 ± 0.24^{c}
P-21	3.18 ± 0.09^{ab}	$0.83 \pm 0.015^{a,b}$	1.15 ± 0.048^{ab}	7.63 ± 0.19^{b}	1.08 ± 0.027^{ab}	1.55 ± 0.017^{ab}	0.88 ± 0.034^{b}	1.46 ± 0.037^{ab}	0.32 ± 0.015^{a}	0.96 ± 0.018^{b}	2.00 ± 0.056^{a}	0.87 ± 0.043^{b}	1.23 ± 0.016^{b}	0.76 ± 0.018^{b}	0.97 ± 0.018^{a}	4.58 ± 0.22^{ab}	7.77 ± 0.34^{b}	15.54 ± 0.40^{bc}
P-22	2.59 ± 0.09^{bc}	0.65 ± 0.027^{c}	0.98 ± 0.026^{bc}	6.37 ± 0.28^{cd}	$0.81 \pm 0.038^{b,c}$	1.13 ± 0.052^{c}	0.86 ± 0.043^{b}	1.31 ± 0.051^{b}	0.30 ± 0.005^{ab}	0.98 ± 0.029^{b}	1.87 ± 0.034^{b}	0.75 ± 0.012^{bc}	1.08 ± 0.050^{cd}	$0.62 \pm 0.021^{c,d}$	$0.74 \pm 0.037^{b,c}$	3.68 ± 0.14^{c}	6.93 ± 0.31^{bc}	17.79 ± 0.58^{ab}
P-23	2.68 ± 0.11^{b}	$0.73 \pm 0.019^{b,c}$	1.00 ± 0.024^{b}	6.39 ± 0.19^{cd}	0.90 ± 0.037^{b}	1.28 ± 0.045^{bc}	0.86 ± 0.021^{b}	1.39 ± 0.059^{b}	$0.29 \pm 0.015^{a,b}$	0.91 ± 0.039^{bc}	1.70 ± 0.057^{c}	0.68 ± 0.020^{c}	1.07 ± 0.045^{cd}	0.67 ± 0.037^{c}	0.75 ± 0.035^{b}	3.87 ± 0.09^{bc}	6.84 ± 0.32^{b}	18.33 ± 0.65^{a}
MEAN	2.65 ± 0.09	0.71 ± 0.026	1.03 ± 0.020	6.72 ± 0.26	0.93 ± 0.020	1.26 ± 0.034	0.76 ± 0.018	1.29 ± 0.046	0.29 ± 0.008	0.91 ± 0.027	1.77 ± 0.058	0.77 ± 0.025	1.17 ± 0.043	0.67 ± 0.024	0.78 ± 0.029	3.88 ± 0.16	7.17 ± 0.18	14.34 ± 0.39

Each value is a mean of three determinations. Red is maximum values, and green is minimum values.

be relevant to the harvesting period, geographical location, and genetic mutation [37]. At the same time, these differences should be dependent on climatic conditions during the growing season, in particular, during the summer months.

In Liaoning province, the summer was relatively hot, with a mean maximum temperature in June, July, and August about 3°C higher and a mean minimum temperature 1.9°C higher than in 2016. So, the PUFA content of *C. heterophylla* from Liaoning province was not beyond 20.00%. Climate and latitude of cultivation are among the factors which can affect the unsaturated degree of fatty acid and the percentage of different fatty acids in *C. avellana*. [39]. It was the same as other oil seeds such as olive and walnut. Olive fruits from cool areas contain oil with more unsaturated fatty acids than fruits from dry and warm areas [40]. In walnut, models of the response of fatty acid composition to temperature have been proposed as a basis for oil quality prediction [41].

So, fat is the most important nutrients in *C. heterophylla* and it is in accordance with *C. avellana*. Unsaturated fatty acids with health properties, mainly oleic (C18 : 1) and linoleic (C18 : 2), are high levels. P-15, 17, 18 show relatively high fat content, but the weak point on nutrition is attenuated by low level of other compositions. There are differences between the flavor, of which may be related to the different compositions and contents of fatty acids in hazelnut oil.

3.5. Total Protein and Free Amino Acid. In this study, all of the hazelnuts had protein contents above 20.00%, and the mean value was 25.13% (Figure 1) [42]. We find that protein was the second important nutrient composition in hazelnut kernels and are parallel results of Köksal et al. [27]. There are sixteen different kinds of amino acids including seven essential and nine nonessential amino acids (Figure 4, Table 2). The content of total essential and nonessential amino acids ranged from 5.85% (P-3) to 8.27% (P-11) and from 11.70% (P-3) to 18.33% (P-23), respectively.

It was mostly composed of nonessential amino acids such as glutamic acid, arginine, and aspartic acid. In the protein of all hazelnut varieties, glutamic acid was determined as the most predominant nonessential amino acid [43], with amounts between 5.83% (P-6) and 8.42% (P-9), and a mean value of 6.72% for the twenty-three different samples. The second major amino acid was the arginine in a range from 3.07% (P-6) to 4.94% (P-9), with a mean value of 3.88%, followed by aspartic acid ranging from 2.18% (P-3) to 3.34% (P-9), the glycine ranging from 1.05% (P-3) to 1.65% (P-11), the proline ranging from 0.81% (P-22) to 1.12% (P-9), etc. Based on the mean values of 0.29%, methionine was found at the lowest level for all hazelnut varieties.

Except for nonessential amino acid, leucine, valine, lysine, phenylalanine, threonine, and iosleucine were determined as the essential amino acids. Leucine and valine were found as the most abundant (Table 2), which levels in the samples ranged between 1.53% (P-3) and 2.00% (P-21) and 1.00% (P-3) and 1.54% (P-9, 11), respectively. But, based on the mean values of the samples, threonine (0.60%–0.88%) was the most nonobvious amino acid. As a result of this research, hazelnut seems to be a good source of protein and also amino acids, but there are not enough further studies on hazelnut protein and amino acids [44].

The protein content in *C. heterophylla* is higher than that of *C. avellana*, and the amino acid profile showed that it is a good source of amino acids including sixteen kinds of amino acids with nutrition effects, such as glutamic acid, arginine, and aspartic acid. P-1, -9, and -11 appear at high concentrations in protein content and low concentrations in fat content. The information relating other components is useful for discriminating hazelnut, and we think P-5 and P-14 had relatively balanced nutrients.

4. Conclusion

Therefore, *C. heterophylla* is a valuable wild product, based on its beneficial nutrient composition, especially for human health. This study is helpful to screen different targets that put together targets of high level of nutritional components through comparison. However, certain growing conditions and genetic variations influencing the nutritional value of hazelnut varieties will be the subject of further research projects.

Data Availability

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

Conflicts of Interest

The authors declare no conflicts of interest.

Acknowledgments

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