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Chemical Profile of Cold-Pressed Beech Nut (*Fagus sylvatica* L.) Oil

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Abstract: The objective of this study was to assess the chemical characteristics of cold-pressed beech nut oil. The nuts, gathered from the forest, comprised 25.35% water, 13.19% oil, and 19.40% protein. The predominant fatty acid was linoleic acid (40.5%), followed by oleic acid (35.0%) and gondoic acid (7.7%). All four tocopherols were present in the oil, with γ-tocopherol being the dominant form at 99.38 mg per 100 g of oil. The total sterol content was 2708.73 mg per kg of oil, with β-sitosterol constituting 80.5% of all sterols. The main characteristics of the oil included its relatively high tocopherol and gondoic acid content, a dominant oleic–linoleic fatty acid profile, and elevated levels of carotenoids.

Keywords: *Fagus sylvatica* L.; cold-pressed oil; fatty acids; tocopherols; sterols

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1. Introduction

Tree nuts serve as intriguing and cost-effective sources of diverse macronutrients and bioactive compounds. While extensive data exist on the composition of popular nuts such as hazelnut, almond, Brazil nut, cashew, macadamia, pecan, pine nut, pistachio, and walnut, information on wild-grown nuts remains relatively scarce [1,2]. The European beech (*Fagus sylvatica* L.) stands out as the most widespread forest tree in Europe, extending from southern Scandinavia to Spain, Sicily, and northwest Turkey. The common beech tree typically boasts a lifespan ranging from 150 to 300 years, with an economically viable period lasting up to 100 to 150 years. This species exhibits a late reproductive cycle, often initiating reproduction around 40 to 50 years of age. Additionally, it is characterized by irregular seed production and fruiting, occurring approximately every 5 to 8 years [3,4]. Beech covers an estimated 14 million hectares of Europe (excluding the Caucasian mountains), with a maximum yield of beech nuts per hectare reaching up to 4 tons [5,6].

The oil yield in beech nuts varies between 15–20%, significantly influenced by moisture content, which can go up to 30% [2,7]. The theoretical production potential for beech nut oil in Europe falls within the range of 8.4 to 11.2 million tons per year. According to the latest FAO data, this theoretically constitutes approximately 4.7% of global oil production [8]. Scientific data on beech nut composition is extremely limited, primarily covering information on oil and moisture quantity. Notably, a recent paper by Siger et al. delves into the physicochemical characteristics of beech nut oil, and a study by Dandik et al. provides insights into the fatty acids and technological characteristics of the closely related *Fagus orientalis* [1,2,5,7]. This paper aims to offer more detailed information on European beech nut cold-pressed oil, with a primary focus on fatty acid composition and the unsaponifiable fraction.

2. Materials and Methods

2.1. Samples

Nuts from the European beech (*Fagus sylvatica* L.) were harvested in early autumn from the northwest region of Croatia, specifically within the confines of Nature Park Žumberak. Upon reception, the moisture, oil, and protein yield were meticulously measured, following which the nuts underwent a drying process at 60 °C until their moisture content dropped below 10%. Subsequently, the dried nuts were stored in a dry and dark environment until the oil extraction process.

2.2. Oil Extraction

The oil production process commenced within two weeks after the collection and drying of the nuts, involving the cold pressing of 600 g of nuts. The temperature during this process did not surpass 50 °C. A laboratory screw press, specifically the Komet CA/53 (Monforts & Reiners, Rheydt, Germany), was utilized for the oil pressing. Subsequently, the oil underwent filtration through a sintered glass filter with a pore size ranging from 10 to 16 µm. The filtered oil was then stored in a dark bottle at room temperature under a nitrogen atmosphere until further analysis.

2.3. Reagents

All chemicals and solvents were analytical grades and obtained from Carlo Erba Réactifs-SdS (Chaussée du Vexin, France). Fatty acid methyl ester (FAME) standards (C8–C22) were obtained from Supelco (Bellefonte, PA, USA). Sterol standards (β-sitosterol, campesterol, and stigmasterol) were all purchased from Sigma-Aldrich Co. (St. Louis, MO, USA). Tocopherols (α-, β-, γ- and δ-) were acquired from Merck KGaA (Darmstadt, Germany).

2.4. Oil Analysis

Quality parameters of oil.

2.5. Peroxide Value (PV) (ISO 3960:2007) [9]

An amount of 5 g of oil is weighed in a 300 mL Erlenmeyer flask that has been purged with an inert gas. The sample is dissolved in a 2:3 (v/v) mixture of isooctane and acetic acid (50 mL total volume). Then, 0.5 mL of a saturated solution of potassium iodide is added, and the mixture is stirred precisely for 1 min ± 1 s. The reaction is stopped by adding 100 mL of water, followed by the addition of 0.5 mL of a 1% starch solution. The solution is immediately titrated with a sodium thiosulfate solution (c ($Na_2S_2O_3$) = 0.01 mol L^{-1}) until the color disappears.

The same procedure is performed for a blank test. The peroxide number is calculated using the following formula:

$$PB = (V - V_0)/(m \times 5) \quad (1)$$

where:

V is the volume of sodium thiosulfate used for titration, in mL,
V_0 is the volume of sodium thiosulfate used for titration in the blank test, in mL,
m is the mass of the oil or fat sample, in grams.

2.6. Free Fatty Acids (FFA) (ISO 660:2009) [10]

The procedure involves taking about 10 g of the oil sample in an Erlenmeyer flask, which is then dissolved in a 1:1 (v/v) mixture of previously neutralized diethyl ether and ethanol (50 mL total volume). This mixture contains 0.3 mL of phenolphthalein per 100 mL. The prepared solution is titrated with a 0.1 mol L^{-1} sodium hydroxide solution until the first change in the color of the indicator, which must be maintained for at least 15 s. The

percentage of free fatty acids is expressed as the percentage of oleic acid and is calculated using the following formula:

$$\text{FFA (\%oleic)} = (V \cdot c \cdot M)/(10\ m) \quad (2)$$

where:

V is the volume of the standardized sodium hydroxide solution used for titration (mL),
c is the concentration of the standardized sodium hydroxide solution (mol L^{-1}),
M is the molar mass of oleic acid (Mr = 282 g mol^{-1}),
m is the mass of the weighed oil sample (g).

2.7. UV Extinction Coefficients (K_{232} and K_{270}) (ISO 3656:2011) [11]

From a homogeneous sample, free from impurities, 0.1 g is weighed into a 10 mL volumetric flask. The flask is then filled to the mark with isooctane of spectrophotometric purity. Using the prepared solution, a quartz cuvette with a path length of 1 cm is filled, and absorbances are measured on a UV/Vis spectrophotometer at wavelengths from 232 nm to 270 nm. Extinction coefficients at various wavelengths are calculated using the following formula:

$$K_\lambda = E_\lambda / (c \cdot s)$$

where:

K_λ is the specific absorbance at wavelength λ,
E_λ is the measured absorbance at wavelength λ,
c is the concentration of the solution in g/100 mL,
s is the length of the light path in cm.

2.8. Pigments

Pigments were determined spectrophotometrically. Total chlorophylls, expressed as pheophytin a, were determined by using the method of Pokorny et al. [12] and by measuring the absorbance of the oils against the air at 630, 670, and 710 nm. Total carotenoids were determined by measuring the absorbance of oil solution in cyclohexane at 445 nm using the BSI method [13]. Equations (1) and (2) were used to calculate total chlorophylls and carotenoid content, respectively.

$$\text{Total chlorophylls} = 34.53\ \frac{A_{670} - 0.5(A_{630} + A_{710})}{L} \quad (3)$$

$$\text{Total carotenoids} = \frac{383 \times A_{445}}{L \times c} \quad (4)$$

where A_i was absorbance at the specified wavelength, L was the thickness of the glass cell (cm), and c was the concentration (g/100 mL) of oil solution in cyclohexane.

2.9. Fatty Acid Composition

The fatty acid composition was determined by using gas chromatography. Fatty acid methyl esters (1 µL), prepared by ISO 12966-2:2017 [13], were injected into a GC equipped with an FID detector according to ISO 12966-4:2015 [14]. Fatty acid methyl esters were separated on a TRACE TR-FAME capillary column (30 m × 0.22 mm × 0.25 µm) using a stationary phase of 70% cyanopropyl polysilphenylene–siloxane (Thermo Scientific, Waltham, MA, USA). Helium was used as the carrier gas at a 0.7 mL/min flow rate. The temperature of the injector was set at 250 °C and of the detector at 280 °C. The temperature of the oven was programmed to increase 4 °C/min from an initial value of 120 to 160 °C, and then at 10 °C/min to 190 °C, where it was held for 10 min. The split ratio was 75:1. Fatty acid methyl ester peaks were identified by comparing their retention times with those of FAME standards (C8–C22).

2.10. Tocopherols

The determination of tocopherol content followed ISO method 9936 [15] using normal-phase HPLC analysis. Samples were prepared by dissolving 0.1 g of oil in 10 mL of n-hexane and subsequently analyzed via HPLC equipped with a fluorescence detector and a Li-ChroCART Silica 60 column (250 mm × 4.6 mm, 5 µm; Merck, Darmstadt, Germany). Tocopherols were detected at excitation–emission wavelengths of 295 nm and 330 nm and were separated through isocratic chromatography using a mobile phase consisting of 0.7% propan-2-ol in n-hexane at a flow rate of 0.9 mL/min. The analyses were conducted at room temperature. Tocopherols were quantified using standard calibration curves for α-, β-, γ-, and δ-tocopherols.

2.11. Sterol Content

For sterol content and composition, the ISO 12228:2014 method was employed [16], utilizing both GC-FID and GC-MS analysis. The unsaponifiable fraction subjected to analysis was isolated through column chromatography using aluminum oxide (neutral, particle size 0.063 to 0.200 nm, activity grade I), with ethanol and diethyl ether as solvents. The separated unsaponifiables were collected in a round-bottom flask, and solvents were removed using a rotary evaporator. The resulting residue was then dissolved in a small amount of diethyl ether. This solution underwent further separation via silica thin-layer chromatography (20 × 20 cm plates, layer thickness 0.25 mm) using a diethyl ether/hexane (50:50) solvent system. Sterol-containing zones were identified by methanol spraying, scraped from the plates with a spatula, dissolved in ethanol and diethyl ether, and evaporated to dryness using a rotary evaporator. The resulting residue was re-dissolved in 1 mL of diethyl ether for transfer into a test tube after the solvent was removed with a stream of nitrogen. Sterols were derivatized using pyridine/hexamethyldisilazane/trimethylchlorosilane (5:2:1, *v*/*v*/*v*).

Chromatographic conditions were set as follows: a 1 µL injection of the prepared sterol fraction, split mode 13.3:1, helium as the carrier gas at a flow rate of 1.5 mL/min, and an inlet pressure of 0.51 bar. The injector temperature was set to 290 °C, and the detector temperature to 250 °C. The column temperature regime was programmed to increase by 6 °C/min from 180 to 270 °C, then held at 270 °C for 30 min. The mass-selective detector operated in the electron impact-selected ion-monitoring (EI-SIM) mode with an ionizing voltage of 70 eV. Peak identification was achieved by comparing the retention times with standards and mass spectra with the available literature and the NIST 2017 library. The quantification of all sterols utilized an internal standard method with α-cholestanol (~95%).

Total sterols were expressed as g kg^{-1}, while concentrations of individual sterols represent % in a total fraction of sterols. Results are presented as mean values ± standard error (SE) (n = 3).

2.12. Statistical Analysis

When experimental values were issued from three independent extractions, data were expressed as mean values ± standard deviation (SD).

3. Results

3.1. Beech Nut Properties

Beech nuts are composed of approximately 33% husk and 67% kernels [7]. When freshly collected, beech nuts exhibit a notably high moisture content of 25.4%, posing a significant challenge for storage and oil quality (Table 1). Previous studies suggest that moisture content can reach as high as 30.0%, potentially impacting oil quality due to the potential hydrolyzation of triglycerides [17]. Following initial assessments of moisture, oil, and protein content, the nuts underwent a drying process at 60 °C until the moisture value fell below 10.0%, adhering to recommendations from the literature for storage conditions [17] and in alignment with the work of Siger et al. [2].

Table 1. Physical and chemical properties of *Fagus sylvatica* L. nut.

Component	
Water content (%)	25.35 ± 0.07
Oil content (%)	13.19 ± 0.01
Protein content (%)	19.40 ± 0.27

3.2. Physicochemical Characteristics of Oil

The oil extraction process involved cold pressing under laboratory conditions, employing a screw press. Subsequently, sedimentation and filtration processes were conducted to yield pure virgin oil. The resulting oil displayed a light-yellow color and featured a distinctive nutty aroma reminiscent of the original raw material (Table 2).

Table 2. Physicochemical properties of *Fagus sylvatica* L. nut oil.

Component	
Free fatty acids (%)	1.74 ± 0.11
Peroxide value (mEq O_2 kg^{-1})	1.86 ± 0.18
K_{232}	1.88 ± 0.06
K_{270}	0.32 ± 0.02
Chlorophyll (mg kg^{-1})	1.47 ± 0.09
Total carotenes (mg kg^{-1})	7.16 ± 0.39

3.3. Fatty Acid Profile

The fatty acid results for the analyzed oil are summarized in Table 3. The composition is characterized by low levels of saturated fatty acids (SFA) at 11.4%, with relatively equal values for monounsaturated fatty acids (MUFA) at 42.9% and polyunsaturated fatty acids (PUFA) at 45.7%.

Table 3. Fatty acid profile of *Fagus sylvatica* L. nut oil.

Fatty Acid			(%)
Saturated			
	Myristic acid	$C_{14:0}$	0.2 ± 0.00
	Palmitic acid	$C_{16:0}$	7.3 ± 0.01
	Margaric acid	$C_{17:0}$	0.1 ± 0.00
	Stearic acid	$C_{18:0}$	2.8 ± 0.00
	Arachidic acid	$C_{20:0}$	0.6 ± 0.02
	Heneicosylic acid	$C_{21:0}$	0.3 ± 0.01
Monounsaturated			
	Palmitoleic acid	$C_{16:1}$	0.2 ± 0.00
	Oleic acid (n-9)	$C_{18:1}$	35.0 ± 0.01
	Gondoic acid (n-9)	$C_{20:1}$	7.7 ± 0.01
Polyunsaturated			
	Linoleic acid (n-6)	$C_{18:2}$	40.5 ± 0.01
	α-Linolenic acid	$C_{18:3}$	5.2 ± 0.00
	SFA		11.4 ± 0.03
	MUFA		42.9 ± 0.02
	PUFA		45.7 ± 0.01

SFA: saturated fatty acids; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids.

3.4. Tocopherols

All four tocopherols alpha (α-T), beta (β-T), gamma (γ-T), and delta (δ-T) were detected in the sample (Table 4) with a total of 117.93 mg 100 g^{-1} oil.

3.5. Sterols

Results for individual and total sterols are presented in Table 5. There were four sterols detected: campesterol, stigmasterol, β-sitosterol, and Δ5-avenasterol.

Table 4. Tocopherol profile and pigments of *Fagus sylvatica* L. nut oil.

	mg 100 g^{-1} Oil	(%)
α-Tocopherol	15.32 ± 0.63	12.99%
β-Tocopherol	1.65 ± 0.18	1.40%
γ-Tocopherol	99.38 ± 3.41	84.27%
δ-Tocopherol	1.58 ± 0.06	1.34%
Total	117.93 ± 3.92	

Table 5. Sterol profile of *Fagus sylvatica* L. nut oil.

	mg kg^{-1} Oil	(%)
Campesterol	222.79 ± 12.39	8.2%
Stigmasterol	58.19 ± 19.91	2.1%
β-sitosterol	2181.13 ± 103.49	80.5%
Δ5-avenasterol	246.62 ± 23.01	9.1%
Total	2708.73 ± 140.53	

4. Discussion

The oil content of the nuts was determined to be 13.2% (equivalent to 17.7% of the dry matter), which was lower than previously reported research for *F. orientalis* (15–20%) [7] and *F. sylvatica* (27.25%) [2]. Cesarettin and Shahidi [1] reported an oil content of 50.0% but with a moisture value of 6.6%. The same authors also published values for acorns, a similarly widespread type of oak tree nut, with 27.9% moisture and 23.9% oil. It is worth noting that oaks belong to the Quercus genus, consisting of 350–400 species, where the oil content of acorns from white oaks does not exceed 12%, while some black and red oaks can contain up to 31% oil [4,18].

The limited number of studies and variations between laboratory measurements and real-world oil production circumstances contribute to the challenges in understanding the oil content of beech nuts. Previous research differentiates between oil determination and oil production, using just kernels for oil determination and the whole nut for oil production [2,7]. While kernels may show higher oil content, using whole nuts is more practical for real-life conditions, considering the demands on equipment and potential confusion for private investors. The reported oil content in this study is based on the whole nut, including the hull.

The protein yield was determined to be 19.4%, comparable to the protein content in cashew, hazelnut, and pistachio [1], and significantly higher than the previously reported values of 6.2% from Cesarettin and Shahidi [1] and under 25% from Kaliniewicz et al. [5]. However, these studies lacked detailed information about the methods of determination. Upon closer examination of their cited data, Cesarettin and Shahidi [1] referenced results from the U.S. Department of Agriculture (USDA), while Kaliniewicz et al. [5] cited Pukacka and Ratajczak [17] and Reyes et al. [19], which did not provide data on the protein content of beech nuts.

The free fatty acid content, indicative of oil hydrolysis and seed quality, was relatively high at 1.74%, yet still below the 2% limit recommended for cold-pressed and virgin oils in the Codex Standard for Named Vegetable Oils [20]. This borderline value is expected due to the higher moisture content compared to typical oilseeds and nuts. It underscores the critical importance of moisture control during the process of collecting and storing forest nuts for maintaining oil quality.

The peroxide value, indicating primary oxidation, for the freshly cold-pressed oil was measured at 1.86 meq O_2 kg oil^{-1}, a value well below the upper limit set by the Codex Standard for Named Vegetable Oils [20]. A similar value of 1.11 meq O_2 kg oil^{-1} was reported in the study by Siger et al. [2]. The extinction parameters for primary oxidation products (conjugated peroxides) at 232 nm exhibited an absorption of 1.88. In an extensive investigation of the oxidative stability of cold-pressed oils, Dedebas et al. [21] reported

K232 values for fresh oils (sesame, black cumin, grape seed, flaxseed, coriander) between 1.01 and 2.96. Analyzing their data further, fresh sesame oil, with a fatty acid profile similar to beech nut oil (where oleic and linoleic fatty acids constitute around 80% of the total), had a K232 value of 1.70. The absorption for secondary products of oxidation (aldehydes and ketones) at 270 nm was 0.34. Comparatively, K270 values in Dedebas et al.'s [21] findings ranged from 0.17–0.64, with sesame oil at 0.44.

Total chlorophyll and carotenoids in the oil were determined spectrophotometrically, with chlorophyll levels at 1.47 mg kg^{-1}, which was relatively low and below the 2.56 mg kg^{-1} reported by Siger et al. [2]. Chlorophyll levels decrease during plant maturation and are undesired in oils due to their photooxidative properties under UV light. Although the upper limits of chlorophyll are not strictly regulated for cold-pressed oils, certain large-scale industrial crude oils, like rapeseed in Canada, have maximum levels set before refinement at 30 mg kg^{-1} [22]. The total carotenoids detected in the oil were 7.16 mg kg^{-1}, slightly less but comparable to the 10.68 mg kg^{-1} reported by Siger et al. [2]. Carotenoids are desirable pigments in oils, enhancing their nutritional value while protecting against oxidation. Among other tree nut oils, only pistachio oil has relatively higher levels of carotenoids (6.70 mg kg^{-1}), while others are much lower (hazelnut oil at 2 mg kg^{-1}) [2] or not detected in almond, walnuts, pecan, macadamia, cashew, and Brazilian nuts [23].

The most dominant fatty acid in the oil was essential omega-6 linoleic acid at 40.5%, followed by oleic acid at 35.0%. This fatty acid profile aligns with previous research on beech nut oil, which reported values such as 38% oleic and 38.6% linoleic [2], 30.3% oleic and 48.7% linoleic [24], and 37.5% and 42.3% [25]. Gondoic acid (C20:1 n-9) at 7.7% was the third most represented fatty acid in the oil. Gondoic acid is relatively rare and is found in high quantities in jojoba oil [26], and less in rapeseed, mustard seed [20], and camelina [27] oils. Research on the nutritional value and health effects of gondoic acid is still in its early stages, with varying findings from neutral effects on mortality and cardiovascular health [28], to positive effects in inhibiting inflammation [29], to potentially negative effects on glucose metabolism [30].

The fatty acid profiles of beech nut oil, characterized by similar proportions of saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), and polyunsaturated fatty acids (PUFA) with a dominant oleic–linoleic profile, are comparable to those found in sesame, peanut, and pumpkin seed oils [31–33]. The main distinguishing feature is the higher content of essential omega-3 α-linolenic fatty acid (ALA) in beech nut oil at 5.2%, contrasting with under 1% in the mentioned oils. Other researchers reported similar or smaller values for ALA, such as 4.3% [25], 0.2% [24], and 0.4–2.8% [7]. Notably, Siger et al. [2] did not detect ALA but found γ-linolenic fatty acid at 4.2%, a component not present in the current study or other previously published papers.

Among the saturated fatty acids (SFA) in beech nut oil, palmitic acid (C16:0) accounted for 7.3%, and stearic acid (C18:0) for 2.8%, with small quantities of myristic acid (C14:0) at 0.2%, heptadecanoic acid (C17:0) at 0.1%, and behenic acid (C21:0) at 0.3%. Palmitic and stearic fatty acids exhibited similar values in other previously published research [2,7,24,25].

There is only one previously published study on tocopherols in beech nut oil by Siger et al. [2], reporting a similar total tocopherol content at 110.23 mg per 100 g of oil, with three tocopherols detected (excluding β-T). Siger et al. [2] collected their samples from Poland in a much colder climate than the current study's samples, and their research showed more than a 20× higher content of δ-T.

When compared with other tree nut oils, the tocopherol content in beech nut oil is 2 to 7 times higher than almond, hazelnut, pistachio, pecan, pine nut, and walnut oils, as reported in Miraliakbari and Shahid's research [34]. The dominant tocopherol in beech nut oil was γ-T, constituting 99.38 mg per 100 g of oil or 84.27% of the total. α-T was detected at 15.32 mg per 100 g of oil (12.99%), while β-T was 1.65 mg per 100 g of oil, and δ-T was 1.58 mg per 100 g of oil. Other tree nuts with a similar tocopherol profile, featuring dominant γ-T with smaller quantities of α-T, include Brazilian nuts, pine nuts, cashews, and peanuts [1,23,34]. Almonds and hazelnuts are dominant in α-T, while pecans,

pistachios, and walnuts are dominant in γ-T, with no or significantly low levels of α-T. The biologically most active α-T has a cardioprotective effect by inhibiting LDL oxidation, while γ-T is recognized as the most potent antioxidant in oils [23]. Variations in tocopherol levels compared to Siger et al. [2] could be attributed to plants adjusting to environmental conditions and stages of seed/nut maturity. Research on soybean oil showed that α-T, β-T, and γ-T increase during maturation, while δ-T remains relatively static from early stages to full maturation. Additionally, δ-T serves as an important antioxidant during earlier stages of seed development or lower temperatures, while its biosynthetic pathway is not as active during later phases [35,36].

Daily consumption of nuts and nut oils rich in α-T is one of the easiest ways to meet the Recommended Dietary Allowances (RDAs) for Vitamin E, which range from 6 to 13 mg per day for both children and adults [37]. Incorporating beech nut oil into the diet could effectively contribute to fulfilling these nutritional recommendations.

The total sterol content in beech nut oil was measured at 2708.73 mg per kg of oil, which is twice as high as reported in the only previous research conducted by Siger et al. [2]. In comparison to other tree nut oils, beech nut oil exhibited similar values to pecan, almond, and walnut oils (2620–2990 mg per kg of oil) while surpassing Brazilian nut, pine nut, pistachio, and hazelnut oils (1290–2060 mg per kg of oil) [34].

The primary membrane sterols in higher plants are β-sitosterol, stigmasterol, and campesterol. Sterols differ from each other based on the presence of a methyl or ethyl group in the side chain at the 24th carbon atom, and they are categorized as 24-methyl sterols (campesterol) or 24-ethyl sterols (β-sitosterol and stigmasterol) [38]. The predominant sterol in the beech nut oil sample was β-sitosterol, accounting for 2181.13 mg per kg of oil, which represents 80.5% of all sterols. β-sitosterol is a natural micronutrient present in higher plants, and humans acquire it through a balanced diet. In healthy individuals, its concentration in the serum and tissues is 800-to-1000-fold lower than that of endogenous cholesterol [39]. The second most abundant sterol was Δ5-avenasterol (246.62 mg per kg of oil or 9.1%). A potential correlation between Δ5-avenasterol and β-sitosterol, observed in previous findings on olive oil, suggests that β-sitosterol is present in minimal amounts and Δ5-avenasterol in maximal amounts when olives are harvested at their optimum [40]. This observation may serve as a valuable tool for determining the optimal time for harvesting beech nuts. Campesterol was present at 222.79 mg per kg of oil or 8.2%, while sitosterol constituted 58.19 mg per kg of oil or 2.1% of the total sterols.

Differences in the sterol composition between the findings of Siger et al. [2] (which identified 9 different sterols, 4 of which were the same, and 5 different—cholesterol, sitostanol, cycloartenol, 24-methylenecycloartanol, and citrostadienol) and the current study can be attributed to climate variations and the plant's adaptation to its specific environmental conditions. The role of sterols in plant adaptation to diverse environments is well documented. It has been proposed that a plant's ability to synthesize 24-ethyl sterols, such as β-sitosterol and stigmasterol, may be a component of evolutionary adaptation to environmental stresses, contributing to the maintenance of crucial membrane-associated metabolic processes [41].

Comparing the total and individual sterol profiles, the closest match to beech nut oil, among globally recognized industrial oils, is found in cottonseed oil (2700–6400 mg per kg of oil, with β-sitosterol ranging from 76.0–87.1%) [16].

5. Conclusions

Recent trends in nutrition underscore a return to traditional and overlooked foods, driven by a growing interest among consumers in cold-pressed oils with distinctive tastes and aromas. This trend opens up potential opportunities for the production and sale of beech nut oil. The common beech tree (*Fagus sylvatica* L.) is widely distributed across continental Europe and most of Great Britain, thriving in diverse altitudes ranging from lowland areas up to 2000 m above sea level. It holds a prominent position as the most important deciduous tree in Europe, considering both total abundance and its share in the overall wood volume.

The chemical composition of beech nut oil exhibits significant variations influenced by the diverse habitats in which the tree grows. Current data on its chemical profile are scarce, highlighting the pressing need for further research. Beech nut oil stands out for its relatively high content of tocopherols and gondoic acid, featuring a dominant oleic–linoleic fatty acid profile and elevated levels of carotenoids. Future studies should focus on the chemical profiling of oil from different habitats, exploring potential applications in the cosmetic industry and as a key component of health-conscious diets.

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