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Fatty acid composition and nutritional value of purple-leaved hazelnut genotypes under forest-steppe conditions in Ukraine

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Abstract

Aims. The aim of the study was to determine the fatty acid profile of three genotypes of purple-leaved hazelnut of Ukrainian breeding, grown in the forest-steppe conditions of Ukraine. **Methods.** Hazelnut oil fatty acids were analysed by gas–liquid chromatography after modified Folch extraction with HCl/methanol transesterification and Sorbsil clean-up. ***Results.*** The fatty acid profile in the studied hazelnut genotypes was dominated by monounsaturated and polyunsaturated fatty acids, which constituted 80.63% of the total lipids. The most common fatty acid was oleic acid, which accounted for 61.86% of the total. Linoleic acid was in second place, at 16.65%. Among the saturated fatty acids, palmitic acid (12.96%) and stearic acid (5.76%) predominated. Several other fatty acids were also identified in smaller quantities. ANOVA analysis did not show statistically significant differences between the genotypes and years, which indicates the stability of their fatty acid profile. A comparison with the literature shows that these genotypes have a lower oleic acid content and a higher saturated fatty acid content than other cultivars, which is likely related to the extraction method. ***Conclusions.*** The Ukrainian purple-leaved hazelnut genotypes studied have a stable and homogeneous fatty acid profile. The significant proportion of unsaturated fatty acids identified highlights their nutritional value. The lipid extraction method has a significant impact on the final fatty acid profile, which underscores the importance of standardizing methods for accurate comparison.

Key words: Corylus avellana, fatty acid profile, unsaturated fatty acids, oleic acid.

Жирнокислотний склад та харчова цінність генотипів пурпуроволисткововоого фундука в умовах Лісостепу України

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Анотація

Мета. Метою дослідження було визначення жирнокислотного складу трьох генотипів пурпуроволисткового фундука української селекції, вирощених в умовах Лісостепу України. **Методи**. Жирні кислоти олії фундука аналізували методом газорідинної хроматографії після модифікованої екстракції за Фольчем з переетерифікацією HCl/метанолом та очищенням Sorbsil. **Результати**. У досліджених генотипах фундука в жирнокислотному складі переважали мононенасичені та поліненасичені жирні кислоти, які становили 80,63% від загальної кількості ліпідів. Найпоширенішою жирною кислотою була олеїнова, частка якої становила 61,86% від загальної кількості. На другому місці була лінолева кислота — 16,65%. Серед насичених жирних кислот переважали пальмітинова (12,96%) та стеаринова (5,76%) кислоти. Також було виявлено кілька інших жирних кислот у менших кількостях. ANOVA-аналіз не виявив статистично значущих відмінностей між генотипами та роками, що свідчить про стабільність їхнього жирнокислотного профілю. Порівняння з літературними даними показує, що ці генотипи мають нижчий вміст олеїнової кислоти та вищий вміст насичених жирних кислот, ніж інші сорти, що, ймовірно, пов'язано з методом екстракції. **Висновки**. Досліджені генотипи пурпуроволисткового фундука української селекції мають стабільний і однорідний жирнокислотний профіль. Виявлена значна частка ненасичених жирних кислот підкреслює їхню харчову цінність. Метод екстракції ліпідів має значний вплив на кінцевий жирнокислотний профіль, що підкреслює важливість стандартизації методів для точного порівняння.

Ключові слова: Corylus avellana, жирнокислотний профіль, ненасичені жирні кислоти, олеїнова кислота.

Introduction The hazelnut (*Corylus avellana* L.) is one of the world's most important nut crops, alongside the cashew, walnut, almond, and chestnut. According to the Food and Agriculture Organization, there are over 1 million hectares of hazelnut plantations worldwide, producing approximately 1.1 million tonnes of nuts (FAOSTAT, 2025). Hazelnuts are highly valued for their nutritional composition and versatility (Molnar, 2011; Goluch et al., 2019). The kernels contain oil, including many unsaturated fatty acids, as well as proteins, carbohydrates, and major vitamins and minerals, giving them their nutritional properties (Ding et al., 2018; Lu et al., 2019). Hazelnut oil contains monounsaturated oleic acid and polyunsaturated omega-3 and omega-6 fatty acids, which are important in human nutrition. For this reason, analysing the fatty acid composition is critically important. Additionally, hazelnut cultivation can be considered waste-free, as leaves, skins, shells, husks, and pruning material can be reused and given value in the context of a circular economy (Allegrini et al., 2022).

In Ukraine, industrial plantations of this crop have expanded significantly in recent years (Mezhenskyj, 2022). Both domestic and foreign varieties are used for this purpose. Scientists from the G. M. Vysotskyi Ukrainian Scientific Research Institute of Forestry and Agroforestry have carried out selective improvement of hazelnuts and developed 12 commercial cultivars (Slyusarchuk & Ryabokon, 2005). These registered varieties are hardy in winter and drought conditions, producing highly marketable nuts. Traditionally, industrial hazelnut assortments were mainly formed from green-leaved varieties, but there has recently been increasing interest in purple-leaved forms. Some cultivars, including three registered ones, were developed in the National Dendrological Park "Sofiivka" using interspecific and intervarietal hybridisation. The purple-leaved hazelnut variety ‘Fuscorubra’ was used as one of the parent forms (Kosenko et al., 2017, 2023). The purple-leaved cultivars ‘Barbakan BSI’ and ‘Bahrianyi’ were first included in the State Register of Plant Varieties in 2021–2022 (State Register…, 2025).

A number of ornamental purple-leaved hazelnut varieties have been developed in various countries (Johnson & Moore, 2023). However, there is a growing interest in developing varieties that are suitable for producing high-quality nuts. Such varieties have already been developed in Russia, Poland, and Ukraine. Breeding work with purple-leaved hazelnuts is ongoing at the National University of Life and Environmental Sciences of Ukraine and the Chorol Botanical Garden (Mezhenskyj et al., 2025). Several private breeders in Ukraine are also working in this area. Similar breeding work is also being carried out in other countries (Botu et al., 2001).

Nevertheless, the phytochemical composition of purple-leaved hazelnuts remains largely unexplored. A novel and relevant approach to this study would be to examine the fatty acid composition of purple-leaved hazelnut genotypes grown under the specific forest-steppe conditions of Ukraine.

Materials and Methodologies. ***Plant Materials.*** The top-performing genotypes of *Corylus avellana* L. (‘Profesorskyi’, ‘Aspirantskyi’, and ‘Akademichnyi’) developed at the National University of Life and Environmental Sciences of Ukraine (NULES) were selected for this study. These genotypes are cultivated in the collection orchard of the Educational, Research and Productive Laboratory of Genetic Resources, Introduction and Breeding of Rare Fruits and Ornamental Plants at NULES's Prof. V. L. Symyrenko Department of Horticulture. The orchard is situated at the Agronomic Research Station in the village of Pshenychne, located in the Bila

Tserkva district of the Kyiv region. The study area is part of the forest-steppe natural zone and has a typical warm-summer humid continental climate, according to the Köppen climate classification. The soil is meadow chernozem. Hazelnut shrubs were planted with a spacing of 5 × 4 m. Standard cultural practices were followed, including inter-row cultivation and mechanical weed control, but without irrigation. The study was conducted in compliance with the ethical standards of the Convention on Biological Diversity (2011) and the Convention on the Trade in Endangered Species of Wild Fauna and Flora (1973). Nuts were harvested in mid-August, when they had fully ripened and began to separate easily from their husks.

Determination of fatty acids. Hazelnut oil fatty acids were analysed by gas–liquid chromatography following a modified Folch extraction (Folch et al., 1957) with acid-catalyzed transesterification and Sorbsil purification as recommended by (Christie & Han, 2010). Lipids were extracted using chloroform–methanol (1:2, v/v), dehydrated, and concentrated under vacuum. Fatty acid methyl esters (FAMEs) were prepared by acid-catalyzed transesterification in sealed ampoules and purified on Sorbsil plates. FAMEs were analyzed on a Carlo Erba HRFC 5300 MEGA gas chromatograph with a 3 mm × 3 m glass column (7.5% Silar 5CP). Fatty acids were identified by retention times using Sigma and Serva standards, and peak areas were quantified automatically using a special program (Figure 1). Fatty acid content was expressed as a percentage of the total fatty acids.

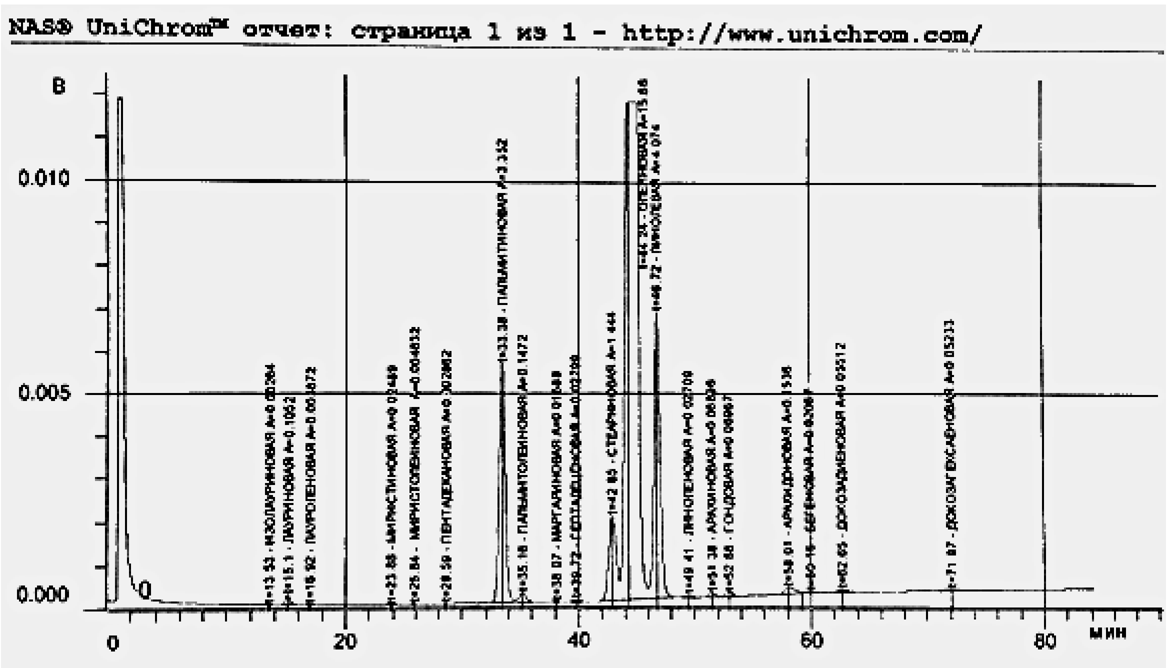

Figure 1. The chromatogram displaying the oil composition of the ‘Profesorskyi’ nuts harvested in 2003 is shown in the UniChrom™ software.

Statistical Analysis. A one-factor analysis of variance (ANOVA) was performed to evaluate the statistical significance of differences in the content of individual fatty acids among the varieties studied. The mean value ($\bar{x}$) and standard deviation (SD) were calculated for each fatty acid. These were calculated over two years (2023–2024) for each variety.

Results and discussion. The genotypes under study originated as progeny of the cross between ‘Akademik Yablokov’ and ‘Moskovsky Rubyn’. Both parent forms have purple leaves, and the progeny do too. The selections, named ‘Profesorskyi’, ‘Aspirantskyi’, and ‘Akademichnyi’, produce large nuts with a high kernel percentage (see Figure 2 and Table 1).

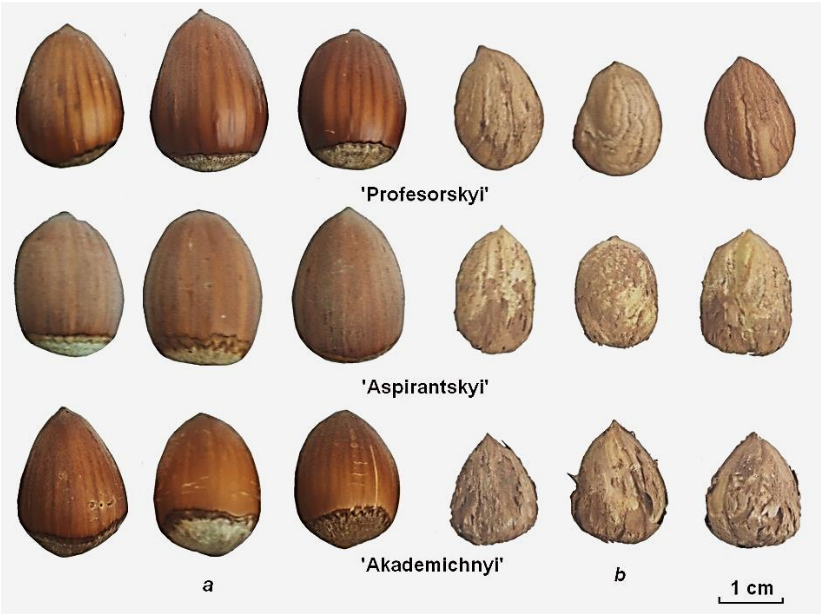

Figure 2. Selected hazelnut genotypes: *a* — nut; *b* — kernel.

The ‘Profesorskyi’ kernel does not have any fibrous material above the pellicle, whereas the ‘Akademichnyi’ kernel has a lot.

Table 1. Characteristics of the nuts of registered purple-leaved cultivars and the genotypes that were studied

Cultivar/ genotype	Nut weight, g	Kernel percentage, %	Oil content, %	References
Profesorskyi	3.2	48.0	68.1	Mezhenskyj et al., 2025; Halinskyi et al., 2025
Aspirantskyi	2.8	51.0	66.2	Mezhenskyj et al., 2025; Halinskyi et al., 2025
Akademichnyi	2.5	51.7	67.8	Mezhenskyj et al., 2025; Halinskyi et al., 2025
Bahrianyi	4.6	35.0	63.0	Bahrianyi, 2022
Barbakan BSI	2.4	47.0	53.0	Barbakan BSI, 2021

In terms of nut weight, the studied genotypes were inferior to the registered cultivar 'Bahrianyi' but exceeded 'Barbakan BSI'. However, concerning kernel percentage and oil content, all genotypes outperformed both cultivars.

The oil content observed in the studied genotypes was higher than that reported by K. Król et al. (2019), who found values ranging from 58.91% to 63.83% in six European cultivars under Polish growing conditions. A broader study conducted in Germany by A. K. Müller et al. (2020), involving 15 non-European cultivars, reported oil content varying from 47.9% to 64.8%, which is lower than the levels detected in 'Profesorskyi', 'Aspirantskyi', and 'Akademichnyi'. Notably, the highest oil content among the cultivars analysed by A. K. Müller et al. (2020) was recorded in 'Red Lambert', the only purple-leaved cultivar included in that trial. In Iran, local cultivars have been shown to contain 53.4% to 63.5% oil, according to F. Rezaei et al. (2014). Turkish cultivars, as reported by M. A. Koyuncu (2004), exhibit oil content ranging from 60.40% to 61.55%, while a wider range of 56.07% to 68.52% was found by A. İ. Köksal et al. (2006). In Italy, hazelnut cultivars accumulate between 61.15% and 68.27% oil under local conditions (Bignami et al., 2005). Nevertheless, some cultivars exhibit exceptionally high oil content. As reported by I. S. Kosenko et al. (2016), the extensive collection of the National Dendrological Park "Sofiyivka" includes accessions with oil levels exceeding 74%.

The qualitative composition of hazelnut oil in the genotypes under study, averaged over two years, is shown in Table 2.

The fatty acid profile of hazelnut oil was dominated by monounsaturated and polyunsaturated fatty acids, with oleic acid (C18:1) being the most abundant component, ranging from 56.59% to 67.21% across the studied genotypes and years. Linoleic acid was the second most prevalent, varying between 13.12% and 19.85%. Saturated fatty acids were represented mainly by palmitic acid, with levels between 11.21% and 15.41%, and stearic acid, ranging from 4.96% to 6.87%. These data are consistent with the typical order of fatty acid contribution in hazelnuts: oleic acid > linoleic acid > palmitic acid > stearic acid > linolenic acid. Furthermore, oleic acid is the predominant fatty acid (Krol & Gantner, 2020).

Minor fatty acids included palmitoleic, gondoic, and arachidic acids, each present in concentrations below 1%. Trace amounts (typically <0.5%) of several other fatty acids, such as myristic, margaric, heptadecenoic, and α-linolenic (ALA), were also detected, though their levels showed slight variability among genotypes and seasons.

Several very-long-chain and unusual fatty acids, including docosadienoic, behenic, and arachidonic acids, were consistently present at low levels (0.1–0.3%). Certain fatty acids, such as isolauric, lauric, lauroleic, pentadecylic, pentadecenoic, and docosahexaenoic acids, were detected only in trace amounts and not consistently across all samples or years. These are therefore considered non-essential components of the profile. However, their inconsistent detection could also be partially attributed to technical factors, such as incomplete or variable methylation efficiency during sample preparation for gas chromatography, particularly for rare or very-long-chain fatty acids.

Table 2. Fatty acid composition of the studied genotypes, % (mean ± SD, n=2)

Fatty acid	Lipid number	Profesorskyi	Aspirantskyi	Akademichnyi
Isolauric	iC12:0	0.005 ± 0.007	0.006 ± 0.009	0.004 ± 0.006
Lauric	C12:0	0.220 ± 0.272	0.015 ± 0.022	0.003 ± 0.004
Lauroleic	C12:1	0.008 ± 0.011	0.021 ± 0.030	0.009 ± 0.013
Myristic	C14:0	0.079 ± 0.027	0.053 ± 0.013	0.044 ± 0.003
Myristoleic	C14:1	0.015 ± 0.005	0.025 ± 0.023	0.024 ± 0.001
Pentadecylic	C15:0	0.010 ± 0.002	0.024 ± 0.019	0.011 ± 0.008
Pentadecenoic	C15:1	0.000 ± 0.000	0.005 ± 0.007	0.007 ± 0.011
Palmitic	C16:0	14.099 ± 1.364	13.443 ± 2.786	11.323 ± 0.160
Palmitoleic	C16:1	0.620 ± 0.061	0.537 ± 0.210a	0.391 ± 0.011
Margaric	C17:0	0.066 ± 0.005	0.076 ± 0.002	0.071 ± 0.002
Heptadecenoic	C17:1	0.118 ± 0.012	0.121 ± 0.007	0.104 ± 0.013
Stearic	C18:0	5.577 ± 0.113	5.280 ± 0.447	6.416 ± 0.639
Oleic	C18:1	59.618 ± 3.571	61.614 ± 4.073	64.335 ± 4.062
Linoleic	C18:2	17.904 ± 2.743	16.967 ± 4.073	15.085 ± 2.753
α-Linolenic	C18:3	0.117 ± 0.015	0.108 ± 0.016	0.140 ± 0.070
Arachidic	C20:0	0.266 ± 0.006	0.304 ± 0.045	0.289 ± 0.062
Gondoic	C20:1	0.284 ± 0.015	0.301 ± 0.009	0.279 ± 0.075
Eicosadienoic	C20:2	0.000 ± 0.000	0.005 ± 0.007	0.000 ± 0.000
Arachidonic	C20:4	0.546 ± 0.079	0.671 ± 0.293	0.943 ± 0.210
Behenic	C22:0	0.074 ± 0.059	0.108 ± 0.010	0.234 ± 0.092
Docosadienoic	C22:2	0.270 ± 0.076	0.316 ± 0.003	0.288 ± 0.020
Docosahexenoic	C22:6	0.103 ± 0.145	0.000 ± 0.000	0.000 ± 0.000

The ANOVA analysis of kernel oil composition revealed no statistically significant differences ($p \leq 0.05$) among the genotypes or between the harvest years. This indicates a high degree of homogeneity in the fatty acid profiles of the studied genotypes, as well as compositional stability across the two growing seasons. Such consistency is likely attributable to their shared genetic background. Therefore, mean values are presented in Table 3.

The beneficial effects of hazelnuts are largely attributed to their unsaturated fatty acid content (Koyuncu, 2004). In the studied genotypes, the combined proportion of monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids

(PUFA) accounts for 80.63% of total lipids. Oleic acid, the primary MUFA, constitutes 61.86% of the fatty acids.

According to A. K. Müller et al. (2020), the oleic acid content in 15 European hazelnut cultivars ranges from 65.1% to 81.7%. Similarly, F. Rezaei et al. (2014) reported a range of 64.2–81.3% in Iranian cultivars. Other studies, such as those by K. Król et al. (2019) and M. Yaman et al. (2023), found even higher ranges (78.61–82.01% and 70.47–86.88%, respectively), with the lower bounds of these ranges exceeding the oleic acid content observed in the present genotypes.

Table 3**.** Average fatty acid composition of the studied genotypes (mean ± SD, n=6)

Fatty acids	Content, %
Total monounsaturated fatty acids (MUFA)	62.81 ± 4.40
Oleic acid (C18:1)	61.86 ± 4.52
Total saturated fatty acids (SFA)	19.37 ± 0.61
Palmitic acid (C16:0)	12.96 ± 1.74
Stearic acid (C18:0)	5.76 ± 0.58
Total polyunsaturated fatty acids (PUFA)	17.82 ± 2.48
Linoleic acid (C18:2, LA)	16.65 ± 2.58
α-Linolenic acid (C18:3, ALA)	0.12 ± 0.03

New cultivars developed at “Sofiyivka” contain between 75.75% and 80.99% oleic acid, as reported by I. S. Kosenko et al. (2017). Likewise, V. Halinskyi et al. (2025) determined a higher oleic acid content of 79.8–80.8%.

The PUFA content (17.82%) in the studied genotypes falls within the variability range reported by other researchers, such as F. Rezaei et al. (2014) for Iranian cultivars (10.0–23.1%), A. K. Müller et al. (2020) for European cultivars (10.4–27.0%), and M. Yaman et al. (2023) for Turkish cultivars (4.43–21.08%). The main PUFA component is linoleic acid (LA) at 16.65%, an essential ω-6 fatty acid. The other essential fatty acid, α-linolenic acid (ALA), an ω-3, is present only in trace amounts (0.12%) in the studied genotypes.

Total saturated fatty acids (SFA) constitute 19.37%, primarily composed of palmitic acid at 12.96% and stearic acid at 5.76%. These values are notably higher than those reported by K. Król et al. (2019) (6.79–8.37%) and M. Yaman et al. (2023) (5.96–8.58%) for total SFA. Conversely, V. Halinskyi et al. (2025) reported lower contents of palmitic acid (5.35–6.59%) and stearic acid (2.74–3.19%).

A comparison of the data obtained in this study with those published by V. Halinskyi et al. (2025) highlights significant differences in the fatty acid composition of identical hazelnut samples. These differences can be attributed to several factors, primarily related to differences in extraction efficiency, transesterification protocols, chromatographic conditions, and sample preparation.

The method used by V. Halinskyi et al. (2025) primarily targets the conversion of fatty acid triglycerides into FAMEs according to DSTU ISO 5509-2002. This approach reflects the composition of hazelnut oil, in which the oleic acid content is 79.8–80.8%, which is consistent with the findings of other researchers who analyzed the composition of the oil (Müller et al., 2020; Król et al., 2019).

In contrast, the modified Folch extraction employed in the present study enabled the isolation of the total lipid fraction from hazelnut kernels, including both neutral and polar lipids such as phospholipids and glycolipids (Parcerisa et al., 1999; Christie & Han, 2010). Although both methods use FAME preparation and gas chromatography, the key difference lies in the type of lipids extracted before transesterification. The method used by V. Halinskyi et al. (2025) primarily targets neutral lipids, such as triglycerides found in oil. In contrast, the Folch-based method extracts all lipid classes, resulting in a broader spectrum of detected fatty acids, among them isolauric, lauric, lauroleic, myristoleic, pentadecylic, margaric, heptadecenoic, arachidonic, and docosahexaenoic acids, which are absent in neutral lipid fractions.

Conclusion. This study provides valuable information on the fatty acid profile of three Ukrainian purple-leaved hazelnut genotypes: 'Profesorskyi', 'Aspirantskyi', and 'Akademichnyi'. The main conclusions of this study include:

The fatty acid profile of these genotypes was dominated by unsaturated fatty acids, especially oleic acid and linoleic acid, which confirms their high nutritional value. The total proportion of mono- and polyunsaturated fatty acids is over 80%.

The results of the ANOVA analysis showed no statistically significant differences in the fatty acid composition between the genotypes and the harvest years. This indicates the genetic homogeneity and stability of these cultivars, which is an important characteristic for industrial production.

A comparison of the results of this study with other published data highlights the critical impact of the lipid extraction method on the final fatty acid profile. The use of a modified Folch method allowed for the isolation of the total lipid fraction (including neutral and polar lipids), which led to the detection of a wider spectrum of fatty acids and, accordingly, a lower content of oleic acid and a higher content of saturated fatty acids compared to methods focused exclusively on oil.

The results of the study confirm the high nutritional value of purple-leaved hazelnut genotypes, developed at the National University of Life and Environmental Sciences of Ukraine, which are a valuable source of unsaturated fatty acids and demonstrate a stable composition in the forest-steppe conditions of Ukraine.

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