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Waste from hazelnut cultivation as a potential feed source for farm animals

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Abstract: The use of agricultural and food industry by-products as alternative feed sources is gaining importance in the context of global environmental and economic challenges. The leaves and husks of hazelnuts (*Corylus avellana*) are rich in crude fibre and microelements, which may make them suitable for use in livestock feed. The aim of the study was to analyse and compare the chemical composition and nutritional value of the leaves and husks of four hazelnut varieties ('Katalоński', 'Olbrzymi z Hale', 'Olga', 'Webba Cenny') in terms of their potential use as feed components. Significant differences between biomass types and varieties were found in most of the analysed parameters. The leaves were characterised by higher nitrogen (up to 1.11%), phosphorus (up to 0.109%), calcium (up to 1.042%) and magnesium (up to 0.264%) content, which indicates their potential as a protein-mineral supplement. The husks showed higher potassium (up to 2.037%), sodium, iron (up to 3032.9 mg·kg^{-1}), manganese and zinc, suggesting their potential use as a source of fibre and trace elements. Both the leaves and husks of hazelnuts are characterised by a diverse chemical composition, indicating their potential use in livestock nutrition, especially in regions with a deficit of traditional feed sources. Further research on the digestibility and effect of these components on animal health and production parameters is needed to determine the full range of their practical usefulness in sustainable nutrition.

Keywords: by-products, *Corylus avellana*, feed, feed additives, livestock nutrition

INTRODUCTION

Progressive climate change and the limited availability of arable land and water resources necessary to meet the growing demand for food, feed, fuel and fibre, are forcing a transition from a linear economy based on the intensive exploitation of natural resources to a circular economy model characterised by higher efficiency in their use (Pinotti *et al.*, 2021; McGreevy *et al.*, 2022). In this context, the use of by-products from agricultural production and the food industry is becoming increasingly important as a response to global environmental, economic and social challenges (Ben-Othman, Jõudu and Bhat, 2020; Ashokkumar *et al.*, 2022; Awasthi *et al.*, 2022; Shah *et al.*, 2025). Waste biomass, as an alternative feed source, can significantly contribute to meeting the growing demand for livestock feed, especially in conditions of limited access to conventional natural resources (Costa *et al.*, 2023). The leaves and husks of hazelnuts (*Corylus avellana*) are one example of such raw materials. They are characterised by their fibre content, which supports digestion in animals (Wadhwa and Bakshi, 2015), and micronutrients, i.e. iron, zinc, copper and manganese, which are important for their health and productivity (Kazemi and Bezdi, 2022). Although the protein and fat content of leaves and husks is moderate, they can be a valuable addition to animal diets, especially in regions where traditional feed is limited (Abbas and Khayoon, 2021; Kocadayioğullari, Boğa and Ermetin, 2024). Research is being conducted on other plant by-products that show potential in animal nutrition. Grape leaves (*Vitis vinifera*), which are a waste product of the wine industry, contain high concentrations of flavonoids, polyphenols and amino acids, making them a valuable feed additive (Bordiga (ed.), 2016; Brenes *et al*., 2016; Dame-Korevaar *et al*., 2021; Birkinshaw *et al*., 2022; Costa *et al*., 2022; Erinle and Adewole, 2022). Corn stalks and leaves, wheat straw and the leaves of fruit trees such as mulberry and apple are also being analysed for their suitability as feed raw materials. For example, mulberry (*Morus alba*) is high in protein and is widely used in animal nutrition, especially in developing countries (Kocadayioğullari, Boğa and Ermetin, 2024).

Despite the enormous potential of plant biomass as a feed material, its use requires a number of criteria to be met, i.e. feed safety, compliance with veterinary standards and economic acceptability. In addition, the chemical composition of plants can vary significantly depending on the cultivar, growing conditions and processing methods. For example, studies on hazelnut husks have shown differences in protein, fat and ash content depending on the variety, indicating the need for a selective approach to their use (Okumuş and Sucu, 2023).

The introduction of plant biomass as a feed ingredient in sustainable agriculture is feasible, but requires further research and technological support. Techniques such as near-infrared spectroscopy (NIRS) allow for rapid and accurate assessment of the nutritional value of raw materials, facilitating their practical application (Workman and Weyer, 2012). In developed countries, the implementation of such solutions may contribute to reducing feed production costs, while in developing countries it may help to address nutritional deficiencies, particularly in the context of reducing resource waste (Wadhwa and Bakshi, 2015).

In summary, hazelnut leaves and husks, like other agricultural by-products, have the potential to become a valuable ingredient in livestock feed. However, the implementation of such solutions requires an integrated approach that takes into account technological, environmental and economic aspects.

The main objective of this study was to identify differences in the chemical composition of the leaves and husks of four hazelnut varieties and to analyse the potential use of these raw materials as feed or feed additives in the nutrition of farm animals.

MATERIALS AND METHODS

Field studies were conducted in a temperate climate, on a private horticultural farm located in the Sandomierz Upland (50°49'20.5"N, 21°44'35.0"E, Zawichost municipality, Świętokrzyskie Province). The experimental material consisted of uninoculated hazel shrubs growing on their own roots of four varieties: 'Kataloński', 'Olbrzymi z Halle', 'Olga' and 'Webba Cenny'. The shrubs were planted in spring 2002 in a row cultivation system, spaced 6×2.5 m, i.e. 666 plants per hectare, on loamy soils with loess subsoil (class II and IIab).

The plants were grown in a multi-stemmed open vase form in accordance with the natural bushy habit of the species. Samples of husks for analysis were taken in autumn at full harvest maturity from three randomly selected bushes, with three samples for each variety, which allowed the average value for the parameters tested to be determined.

One sample consisted of 100 pieces of husks. Immediately after collection, the samples were weighed to an accuracy of 0.001 kg, and then their weight was determined on a PS R2 RADWAG precision scale. The leaves were collected in autumn after the fruit harvest, from three randomly selected bushes, with three samples for each variety, which allowed the average value for the tested parameters to be determined. One sample consisted of 100 leaves. Then, their weight was determined together with the petioles by weighing them on a PS R2 RADWAG precision scale with an accuracy of 0.001 kg. After weighing, the leaves and husk were dried in a laboratory dryer at 105°C until the moisture content did not exceed 10%. The dried material was then ground. After grinding, the material was analysed using near infrared spectroscopy (NIRS) with a NIR Flex N-500 device with a ready calibration for the assessment of bulk feed from INGOT. The NIRS method uses the properties of near-infrared radiation, which penetrates the sample, interacts with its molecules and causes characteristic absorption. These are the result of oscillations of chemical bonds, especially those containing hydrogen. Analysis of the absorption spectrum obtained by this method allows the chemical composition of the sample to be determined. Based on the degree of beam absorption in a given range, its percentage content in the tested sample is determined (Marchi de et al., 2007: Workman and Weyer, 2012; Gąsior, 2013.

RESULTS AND DISCUSSION

The table presents a chemical analysis of the composition and nutrient content of leaves and husks depending on the hazelnut variety. The parameters examined included moisture content, fat, protein, ash, fibre and various amino acids (e.g. alanine, arginine, aspartic acid), as well as substances such as starch and acid-insoluble ash. In most cases, the results of the analysis showed significant differences both between individual varieties and between leaves and husks within the same variety, suggesting clear relationships between varieties and the levels of these components. Exceptions are alanine in leaves between the 'Kataloński' and 'Olbrzymi z Hale', acid-insoluble ash in the husks of the 'Olga' variety, phenylalanine in leaves and lysine in the husks of the 'Kataloński'. In these cases, the lack of significant differences means that the content of these components did not differ significantly between the tested varieties. Negative values were obtained for parameters such as glutamate, histidine, isoleucine, methionine, proline, threonine and some other amino acids. These may result from deviations from the reference values or lower content of these components compared to the reference values. Such results reflect differences in the chemical composition of the samples in relation to the calibration standards.

The highest husk moisture content was recorded for the 'Webba Cenny' (10.08%), and the lowest for 'Kataloński' (8.58%). In the case of leaves, the highest moisture content was achieved by the 'Kataloński' (11.68%), and the lowest by 'Webba Cenny' (10.52%). Within the 'Webba Cenny', the moisture content of the husk (10.08%) was slightly lower than that of the leaves (10.52%), while in the case of the 'Kataloński', the moisture content of the husk (8.58%) was lower than that of the leaves (11.68%). Leaf moisture content was higher than cover moisture content for most varieties, which may be related to their different structure and physiological functions. In studies by Abubaker *et al.* (2017) showed moisture content ranging from (11.72%) in leaves, (2.83%) in the kernel and (9.65%) in the husks (Tab. 1).

The highest fat content in the husk was recorded for the 'Olga' (2.03%), and the lowest for 'Olbrzymi z Hale' (0.99%). In

Table 1. Chemical composition and nutrient content of leaves and husks covers of selected hazelnut varieties

Parameter	Type of biomass	Nutrient content (%) in selected hazelnut variety				*p*-value
		'Kataloński'	'Olbrzymi z Hale'	'Olga'	'Webba Cenny'	
Moisture	husk	8.58 ±0.11Cb	9.58 ±0.05Bb	9.60 ±0.20Bb	10.08 ±0.22Ab	<0.0001
	leaves	11.68 ±0.03Aa	11.16 ±0.11Ba	11.32 ±0.09Ba	10.52 ±0.14Ca	<0.0001
	p-value	<0.0001	<0.0001	<0.0001	0.0413	
Fat	husk	1.49 ±0.15Bb	0.99 ±0.24Cb	2.03 ±0.13Ab	1.24 ±0.16BCb	0.0005
	leaves	4.41 ±0.06Ba	4.65 ±0.20Ba	4.45 ±0.16Ba	5.70 ±0.20Aa	<0.0001
	p-value	<0.0001	<0.0001	<0.0001	<0.0001	
Protein	husk	4.96 ±0.28Cb	7.93 ±0.06Ab	6.05 ±0.45Bb	6.41 ±0.18Bb	<0.0001
	leaves	13.23 ±0.32Aa	13.76 ±0.18Aa	13.36 ±0.19Aa	12.16 ±0.04Ba	<0.0001
	p-value	<0.0001	<0.0001	<0.0001	<0.0001	
Ash	husk	5.63 ±0.11Bb	1.57 ±0.90Db	2.61 ±0.40Cb	9.44 ±1.37Ab	<0.0001
	leaves	15.22 ±0.81Aa	11.13 ±1.19Ba	14.39 ±0.56Aa	14.43 ±1.68Aa	0.0101
	p-value	<0.0001	<0.0001	<0.0001	0.0163	
Fibre	husk	36.62 ±0.06Aa	35.05 ±0.08Ba	35.01 ±0.20Ba	32.80 ±0.13Ca	<0.0001
	leaves	17.87 ±0.10Cb	17.59 ±0.09Db	18.19 ±0.01Bb	19.28 ±0.05Ab	<0.0001
	p-value	<0.0001	<0.0001	<0.0001	<0.0001	
Acid insoluble ash	husk	7.11 ±0.07Bb	6.63 ±0.04Cb	7.42 ±0.21ABa	7.55 ±0.11Aa	<0.0001
	leaves	8.37 ±0.14Aa	7.46 ±0.04Ba	7.40 ±0.11Bb	5.84 ±0.04Cb	<0.0001
	p-value	<0.0001	<0.0001	0.8547	<0.0001	
Alanine	husk	0.83 ±0.03Aa	0.40 ±0.03Da	0.66 ±0.00Ba	0.57 ±0.02Ca	<0.0001
	leaves	0.41 ±0.02Ab	0.40 ±0.02Aa	0.29 ±0.01Bb	0.13 ±0.01Cb	<0.0001
	p-value	<0.0001	0.9146	<0.0001	<0.0001	
Arginine	husk	1.28 ±0.00Cb	1.12 ±0.02Db	1.33 ±0.02Bb	1.82 ±0.02Ab	<0.0001
	leaves	2.40 ±0.01Aa	2.40 ±0.01Aa	2.26 ±0.01Ba	2.08 ±0.01Ca	<0.0001
	p-value	<0.0001	<0.0001	<0.0001	<0.0001	
Aspartic acid	husk	2.37 ±0.02Cb	2.55 ±0.01Bb	2.49 ±0.02Bb	2.84 ±0.04Ab	<0.0001
	leaves	3.50 ±0.02Aa	3.51 ±0.01Aa	3.40 ±0.01Ba	3.39 ±0.03Ba	<0.0001
	p-value	<0.0001	<0.0001	<0.0001	<0.0001	
Cystine	husk	0.12 ±0.01Bb	0.26 ±0.00Aa	0.12 ±0.01Bb	0.04 ±0.01Cb	<0.0001
	leaves	0.33 ±0.01Ba	0.27 ±0.00Cb	0.38 ±0.01Aa	0.27 ±0.00Ba	<0.0001
	p-value	<0.0001	0.0497	<0.0001	<0.0001	
Glutamic acid	husk	0.36 ±0.08Ba	1.50 ±0.19Db	1.19 ±0.04Ca	0.13 ±0.02Aa	<0.0001
	leaves	1.19 ±0.07Bb	0.73 ±0.07Aa	1.64 ±0.12Cb	1.72 ±0.04Cb	<0.0001
	p-value	<0.0001	0.0027	<0.0001	<0.0001	
Glycine	husk	0.60 ±0.00Cb	0.99 ±0.01Ab	0.49 ±0.03Db	0.94 ±0.01Bb	<0.0001
	leaves	0.84 ±0.02Ca	1.04 ±0.01Aa	0.87 ±0.01Ca	0.97 ±0.01Ba	<0.0001
	p-value	<0.0001	0.0076	<0.0001	0.0414	
Hystidine	husk	0.09 ±0.02Ab	0.88 ±0.02Cb	0.09 ±0.01Ab	0.38 ±0.00Ba	<0.0001
	leaves	0.32 ±0.01Aa	0.03 ±0.01Ca	0.13 ±0.01Ba	0.43 ±0.00Db	<0.0001
	p-value	<0.0001	<0.0001	<0.0001	<0.0001	

cont. Tab. 1

Parameter	Type of biomass	Nutrient content (%) in selected hazelnut variety				*p*-value
		‘Kataloński’	‘Olbrzymi z Hale’	‘Olga’	‘Webba Cenny’	
Isoleucine	husk	0.88 ±0.00Db	0.33 ±0.01Ab	0.77 ±0.00Cb	0.60 ±0.03Bb	<0.0001
	leaves	0.13 ±0.01Ba	0.12 ±0.02Aa	0.16 ±0.01Ba	0.09 ±0.01Aa	<0.0001
	p-value	<0.0001	<0.0001	<0.0001	<0.0001	
Leucine	husk	0.87 ±0.01Cb	2.15 ±0.03Aa	1.30 ±0.03Bb	0.62 ±0.07Db	<0.0001
	leaves	1.71 ±0.03BCa	1.66 ±0.04Cb	1.84 ±0.03Aa	1.77 ±0.04ABa	0.0011
	p-value	<0.0001	<0.0001	<0.0001	<0.0001	
Lysine	husk	1.52 ±0.03Aa	1.08 ±0.04Cb	1.37 ±0.07Ba	1.13 ±0.06Ca	<0.0001
	leaves	1.50 ±0.02Aa	1.42 ±0.07Aa	1.47 ±0.03Aa	0.89 ±0.03Bb	<0.0001
	p-value	0.3022	<0.0001	0.0934	0.0034	
Methionine	husk	0.48 ±0.01Ba	0.02 ±0.01Aa	0.43 ±0.03Ba	0.46 ±0.01Bb	<0.0001
	leaves	0.62 ±0.01Db	0.44 ±0.01Bb	0.51 ±0.02Cb	0.34 ±0.00Aa	<0.0001
	p-value	<0.0001	<0.0001	<0.0001	<0.0001	
NDF	husk	45.12 ±0.84Ba	48.04 ±0.72Aa	46.24 ±0.99ABa	43.12 ±0.30Ca	<0.0001
	leaves	33.42 ±0.61Bb	34.29 ±0.18Bb	34.40 ±0.35Bb	36.33 ±0.39Ab	0.0002
	p-value	<0.0001	<0.0001	<0.0001	<0.0001	
Phenylalanine	husk	1.53 ±0.03Db	2.89 ±0.05Aa	2.14 ±0.01Bb	1.69 ±0.07Cb	<0.0001
	leaves	2.60 ±0.06Aa	2.52 ±0.03Ab	2.56 ±0.02Aa	2.57 ±0.02Aa	0.1211
	p-value	<0.0001	<0.0001	<0.0001	<0.0001	
Organic phosphorus	husk	0.74 ±0.03Aa	0.08 ±0.03Cb	0.30 ±0.03Bb	0.73 ±0.03Aa	<0.0001
	leaves	0.51 ±0.01Bb	0.64 ±0.02Aa	0.51 ±0.05Ba	0.56 ±0.03Bb	0.0035
	p-value	<0.0001	<0.0001	<0.0001	<0.0001	
Proline	husk	0.78 ±0.01Ca	0.16 ±0.07Aa	0.63 ±0.04Ba	0.65 ±0.04Ba	<0.0001
	leaves	0.79 ±0.03BCb	0.72 ±0.01Ab	0.77 ±0.04ABb	0.86 ±0.00Cb	0.0016
	p-value	0.3553	<0.0001	0.0197	<0.0001	
Serine	husk	0.85 ±0.01Db	1.15 ±0.00Ab	0.97 ±0.00Cb	1.04 ±0.01Bb	<0.0001
	leaves	1.51 ±0.01Aa	1.48 ±0.01Ba	1.44 ±0.01Ca	1.34 ±0.00Da	0.0053
	p-value	<0.0001	<0.0001	<0.0001	<0.0001	
Starch	husk	6.53 ±0.28Ab	6.95 ±0.74Ab	5.51 ±0.38ABb	4.09 ±0.70Bb	0.0011
	leaves	14.67 ±0.40Aa	14.91 ±0.52Aa	14.96 ±0.43Aa	13.41 ±0.22Ba	<0.0001
	p-value	<0.0001	<0.0001	<0.0001	<0.0001	
Threonine	husk	1.04 ±0.06Cb	0.51 ±0.06Aa	0.69 ±0.04Bb	0.92 ±0.05Cb	<0.0001
	leaves	0.37 ±0.04Da	0.22 ±0.04Cb	0.06 ±0.06Ba	0.47 ±0.04Aa	<0.0001
	p-value	<0.0001	<0.0001	0.0171	<0.0001	
Tryptophan	husk	0.04 ±0.01Bb	0.16 ±0.01Aa	0.14 ±0.01Ab	0.03 ±0.01Cb	<0.0001
	leaves	0.16 ±0.01Aa	0.09 ±0.00Bb	0.17 ±0.01Aa	0.10 ±0.01Ba	<0.0001
	p-value	<0.0001	<0.0001	0.0158	<0.0001	
Tyrosine	husk	1.59 ±0.02Ca	2.76 ±0.04Aa	1.81 ±0.02Ba	1.45 ±0.06Db	<0.0001
	leaves	1.59 ±0.04Ca	1.72 ±0.02Bb	1.74 ±0.02Bb	1.89 ±0.03Aa	<0.0001
	p-value	0.8185	<0.0001	<0.0001	<0.0001	
Valine	husk	0.22 ±0.01Db	0.78 ±0.01Ab	0.14 ±0.01Ab	0.02 ±0.02Cb	<0.0001
	leaves	0.93 ±0.02Ba	0.90 ±0.02Ba	1.03 ±0.01Aa	1.00 ±0.01Aa	<0.0001
	p-value	<0.0001	<0.0001	<0.0001	<0.0001	

Explanations: A–D indicate significant differences between the means denoted by the seletters within the same row, while a–b indicate differences between the means within the same columnat the ($p < 0.05$) level, NDF = neutral detergent fibre.
Source: own study.

the case of leaves, the highest fat content was recorded for the ‘Webba Cenny’. (5.70%), and the lowest for ‘Kataloński’ (4.41%). Within the ‘Kataloński’, the fat content in the husks (2.03%) was lower than in the leaves (4.45%), while in the case of ‘Olbrzymi z Hale’, the fat content in the husks (0.99%) was also lower than in the leaves (4.45%). The fat content in the leaves was higher than in the integument for most varieties. In studies by Tayer, Nobakht and Aghajeri (2012), the fat content in grapevine leaves was found to be 7.47%, while Abbas and Khayoon (2021) found it to be 6.79%. However, Abubaker *et al.* (2017), in their study on the nutrient content of macadamia leaves, seeds and husks, found a total fat content of 5.085% in the leaves, 67.96% in the kernel and 0.34% in the seed coat.

The highest protein content in the husks was found in the ‘Olbrzymi z Hale’ (7.93%), and the lowest in ‘Kataloński’ (4.96%). In the case of leaves, the highest protein content was found in the ‘Olga’ (13.36%), and the lowest in ‘Webba Cenny’ (12.16%). Within the ‘Olbrzymi z Hale’, the protein content in the husks (7.93%) was lower than in the leaves (13.76%), and in the case of ‘Kataloński’, the protein content in the husks (4.96%) was also lower than in the leaves (13.23%). Studies by Okareh *et al.* (2015) showed significant differences in protein content between different parts of plantain waste: the highest protein content was found in the leaves, and the lowest in the stipules and fruit stalks. Kocadayioğullari, Boğa and Ermetin (2024) reported a protein content of 12.83% for grapevine leaves, while in the leaves of other species, such as mulberry, apple, apricot and cherry, these values were 13.09, 11.25, 10.99 and 10.33%, respectively. In studies conducted by Abbas and Khayoon (2021), the protein content in grape leaves was 20.30%, while in seeds it was 12.30%. In turn, Abubaker *et al.* (2017) showed that the protein content in the leaves was 6.65%, in the kernel 20.81% and in the husks 6.91%.

The highest ash content in the integuments was recorded for the ‘Webba Cenny’ (9.44%), while the lowest was for the ‘Olbrzymi z Hale’ (1.57%). In the case of leaves, the highest ash content was recorded for the ‘Kataloński’ (15.22%), and the lowest for ‘Webba Cenny’ (14.43%). Within the ‘Webba Cenny’, the ash content in the husks (9.44%) was lower than in the leaves (14.43%), while in the case of ‘Olbrzymi z Hale’, the ash content in the husks (1.57%) was also lower than in the leaves (11.13%). For comparison, the study by Okareh *et al.* (2015) shows that the ash content in all samples was significantly different from each other, with the stem and fruit of the ribwort plantain having the highest value, followed by the ripe skin, and the leaf having the lowest value. In the study by Kazemi and Bezdi (2022), the ash content of grapevine leaves was 88.6 $g \cdot kg^{-1}$ dry matter, and in the study by Kocadayioğullari, Boğa and Ermetin *et al.* (2024), it was 9.47%. In the study by Abbas and Khayoon (2021), the ash content in grapevine leaves was 15.76%, and for seeds it was 3.15%. In turn, Tayer, Nobakht and Aghajeri (2012) showed an even lower ash content in grapevine leaves, amounting to 9.53%.

In the case of fibre, the highest content in the husks was obtained for the ‘Kataloński’ (36.62%), while the lowest was for the ‘Webba Cenny’ (32.01%). In turn, the highest fibre content in the leaves was found for the ‘Olbrzymi z Halle’ variety (17.59%), and the lowest for the ‘Webba Cenny’ (19.28%). The fibre content in the integuments was significantly higher than in the leaves for each variety, which may result from the different structure of the integuments, which have a protective function.

The content of acid-insoluble ash in the husks was highest for the ‘Webba Cenny’ (7.55%) and lowest for ‘Olbrzymi z Hale’ (6.63%), while in the leaves, the highest values were found for the ‘Kataloński’ (8.37%), and the lowest for ‘Webba Cenny’ (5.84%). Within the ‘Webba Cenny’, the acid-insoluble ash content in the husks (7.55%) was higher than in the leaves (5.84%), while for the ‘Kataloński’, these values were similar (8.37% in the leaves and 7.11% in the husks).

The highest starch content in the husks was recorded for the ‘Olbrzymi z Halle’ variety (6.95%), and the lowest for ‘Webba Cenny’ (4.09%), while in the leaves the highest values were found for ‘Olga’ (14.96%) and the lowest for ‘Webba Cenny’ (13.41%). For maize, which is one of the most commonly used sources of starch, its value according to the study by Shi *et al.* (2024) is 72.63% in dry matter.

In the case of alanine, the highest content in the husks was recorded for the ‘Kataloński’ (0.83%), and the lowest for ‘Olbrzymi z Hale’ (0.40%), while in the leaves, the highest values were found for ‘Kataloński’ (0.41%), and the lowest for ‘Webba Cenny’ (0.13%). Within the ‘Kataloński’ variety, the alanine content was higher in the husks (0.83%) than in the leaves (0.41%).

Arginine was highest in the husks of the ‘Webba Cenny’ (1.82%) and lowest in ‘Olbrzymi z Hale’ (1.12%), while in the leaves the highest values were found in the ‘Kataloński’ (2.40%) and the lowest in ‘Webba Cenny’ (2.08%). Within the ‘Webba Cenny’, the arginine content was higher in the husks (1.82%) than in the leaves (2.08%).

Asparagine reached the highest values in the husks of the ‘Webba Cenny’ (2.84%) and the lowest in ‘Kataloński’ (2.37%), while in the leaves the highest values were recorded for ‘Kataloński’ (3.50%) and the lowest for ‘Webba Cenny’ (3.39%). Within the ‘Webba Cenny’, the aspartate content was higher in the husks (2.84%) than in the leaves (3.39%).

The cystine content was highest in the husks of the ‘Olbrzymi z Hale’ (0.26%) and lowest in ‘Webba Cenny’ (0.04%), while in the leaves, the highest values were found in the ‘Olga’ (0.38%) and the lowest in ‘Olbrzymi z Hale’ (0.27%). Within the ‘Olbrzymi z Hale’, the cystine content was higher in the husks (0.26%) than in the leaves (0.27%).

Glutamate showed varying values in both the husks and leaves, which may indicate significant differences from the reference values. The highest glutamate values in the husks were recorded for the ‘Olbrzymi z Hale’ (1.50%), while the lowest were for ‘Webba Cenny’ (0.13%). In turn, the highest content of this amino acid in the leaves was found in the ‘Webba Cenny’ (1.72%), and the lowest in ‘Olbrzymi z Hale’ (0.73%).

The glycine content was highest in the husks of the ‘Olbrzymi z Hale’ (0.99%) and lowest in ‘Kataloński’ (0.60%), while in the leaves, the highest values were found in ‘Olbrzymi z Hale’ (1.04%) and the lowest in ‘Kataloński’ (0.84%). Within the ‘Olbrzymi z Hale’ variety, the glycine content was higher in the husks (0.99%) than in the leaves (1.04%).

The highest histidine content in the pods was recorded for the ‘Olbrzymi z Hale’ (0.88%), and the lowest for the ‘Olga’ variety (0.09%). In the case of leaves, the highest values were achieved by the ‘Webba Cenny’ (0.43%), and the lowest by ‘Kataloński’ (0.32%). Within the ‘Webba Cenny’, the histidine content in leaves (0.43%) was higher than in the husks (0.38%), while in the ‘Kataloński’, the histidine content in leaves (0.32%) was higher than in the husks (0.09%).

The highest isoleucine content in the husks was recorded for the ‘Kataloński’ variety (0.88%), and the lowest for the ‘Olga’ (0.77%). In the case of leaves, the highest isoleucine content was found in the ‘Olga’ (0.16%), and the lowest in ‘Katalonski’ (0.13%). Within the ‘Olga’, the isoleucine content in the husks (0.77%) was higher than in the leaves (0.16%).

The highest leucine content in the husks was found in the ‘Olbrzymi z Hale’ (2.15%), and the lowest in ‘Webba Cenny’ (0.62%). In the case of leaves, the highest values were achieved by the ‘Olga’ (1.84%), and the lowest by ‘Olbrzymi z Hale’ (1.66%). Within the ‘Olga’, the leucine content in the husks (1.30%) was lower than in the leaves (1.84%), while in the case of ‘Olbrzymi z Hale’, leucine in the husks (2.15%) was higher than in the leaves (1.66%).

The highest lysine content in the husks was recorded for the ‘Katalonski’ (1.52%), and the lowest for ‘Webba Cenny’ (1.13%). In the case of leaves, the highest lysine content was found in the ‘Katalonski’ (1.50%), and the lowest in ‘Webba Cenny’ (0.89%). Within the ‘Webba Cenny’, the lysine content in the husks (1.13%) was higher than in the leaves (0.89%).

The highest methionine content in the husks was recorded for the ‘Katalonski’ (0.48%), and the lowest for the ‘Olga’ (0.43%). In the case of leaves, the highest value was achieved by the ‘Katalonski’ (0.62%), and the lowest by ‘Webba Cenny’ (0.34%). Within the ‘Olga’, the methionine content in the husks (0.43%) was lower than in the leaves (0.51%).

The NDF (neutral detergent fibre) content in the husks was highest for the ‘Olga’ (46.24%) and lowest for ‘Webba Cenny’ (43.12%). In the case of leaves, the highest NDF values were recorded for ‘Webba Cenny’ (36.33%) and lowest for ‘Olbrzymi z Hale’ (34.29%). Within the ‘Webba Cenny’, the NDF content was higher in leaves (36.33%) than in husks (43.12%).

The highest phenylalanine content in the cover was recorded for the ‘Olbrzymi z Hale’ (2.89%), and the lowest for ‘Katalonski’ (1.53%). In the case of leaves, the highest values were achieved by the ‘Olga’ (2.56%), and the lowest by ‘Katalonski’ (2.60%). Within the ‘Katalonski’, the phenylalanine content in the husks (1.53%) was lower than in the leaves (2.60%).

The highest organic phosphorus content in the husks was recorded for the ‘Katalonski’ (0.74%), and the lowest for ‘Olbrzymi z Hale’ (0.08%). In the case of leaves, the highest phosphorus content was found in the ‘Olbrzymi z Hale’ (0.64%), and the lowest in ‘Webba Cenny’ (0.56%). Within the ‘Webba Cenny’, the phosphorus content was higher in the husks (0.73%) than in the leaves (0.56%).

The highest proline content in the husks was recorded for the ‘Olbrzymi z Hale’ (0.16%), and the lowest for the ‘Katalonski’ (0.78%). In the case of leaves, the highest proline content was achieved by the ‘Webba Cenny’ (0.86%), and the lowest by ‘Katalonski’ (0.79%). Within the ‘Olbrzymi z Hale’, the proline content in the husks (0.16%) was lower than in the leaves (0.72%).

The highest serine content in the husks was recorded for the ‘Olbrzymi z Hale’ (1.15%), and the lowest for ‘Katalonski’ (0.85%) (Tab. 1).

The highest fruit skin moisture content was recorded for the ‘Olga’ (12.24%), while the lowest was for the ‘Olbrzymi z Hale’ (10.69%). The highest leaf moisture content was obtained for the ‘Katalonski’ (14.15%), and the lowest for ‘Webba Cenny’ (11.38%). Leaf moisture content was higher than that of the husks for most varieties, which may be related to their different structure and physiological functions. Differences in moisture content of both husks and leaves indicate a significant influence of hazelnut variety on these parameters (Tab. 2).

The highest protein content in husks was recorded for the ‘Katalonski’ (7.44%), while the lowest was for the ‘Olbrzymi z Hale’ (0.50%). In the case of leaves, the highest protein content was found in the ‘Olbrzymi z Hale’ (2.38%), and the lowest in the ‘Webba Cenny’ (0.42%). Hazelnut leaves were characterised by higher protein content than the husks, which may result from their more intense metabolic activity. Enyiukwu, Amadioha and Ononuju (2018) in their study on the nutritional values of the above-ground parts of black-eyed peas (*Vigna unguiculata* L. Walp.) showed that protein was present in the range (11.21–34.91%), with the highest values obtained for leaves and the lowest for pods. This is consistent with the findings of Mamiro *et al.* (2011), who showed that the protein content in cowpea leaves exceeds that in seeds. It is worth noting that Kocadayioğullari, Boğa and Ermetin (2024) reported a protein content of 12.83% in their study of grapevine leaves, which is an example of the significant nutritional potential of leaves as feed ingredients.

In the case of fibre, the highest content in the husks was obtained for the ‘Olbrzymi z Hale’ (32.40%), while the lowest was for the ‘Olga’ (9.05%). In turn, the highest fibre content in the leaves was found for the ‘Webba Cenny’ (14.02%), and the lowest in the ‘Katalonski’ (0.75%). The fibre content in the cover leaves was significantly higher than in the leaves for each variety, which may result from the different structure of the cover leaves, which have a protective function. In studies conducted by Kok *et al.* (2007), the fibre content in grapevine leaves varied depending on the variety and was around 37%, while in the analyses of the leaf material studied, it was much lower, except for the bracts of the ‘Olbrzymi z Halle’

In turn, the ash content in the coverings was highest for the ‘Webba Cenny’ (25.55%), while the lowest value was recorded for the ‘Olbrzymi z Halle’ (3.63%). For leaves, the highest ash content was observed for the ‘Katalonski’ (21.62%), and the lowest for the ‘Webba Cenny’ (13.35%). The ash content was higher in leaves than in coverings for most varieties, with the exception of the ‘Webba Cenny’, where ash in coverings had a higher value than in leaves. For comparison, in studies on grape leaves, Horaczek *et al.* (2025) found significant differences in ash content, ranging from 14.55 to 21.04% depending on the grapevine variety.

The highest NDF value in the husk was recorded for the ‘Katalonski’ (64.55%), while the lowest was for ‘Olga’ (53.07%). In turn, the leaves showed the lowest NDF content for the ‘Katalonski’ (32.14%) and the highest for the ‘Webba Cenny’ (37.56%). The husk were characterised by a higher NDF value compared to the leaves, which indicates their higher content of structural compounds. In studies on grape leaves, Kazemi and Bezdi (2022) obtained an NDF of 43.5%. Kocadayioğullari, Boğa and Ermetin (2024) reported an NDF of 47.84%. Birkinshaw *et al.* (2022) reported an NDF content of 26% for vineleafpellets. Campione *et al.* (2020) tested hazelnut shells and found them to be rich in NDF (511 $g \cdot kg^{-1}$ DM).

The highest ADF content in husks was found in the ‘Katalonski’ (62.55%), and the lowest in ‘Olga’ (56.76%). In the case of leaves, the highest values were recorded for ‘Olbrzymi z Hale’ (37.16%), and the lowest for ‘Katalonski’ (39.35%). As in the case of NDF, the husks showed higher ADF values than the leaves, indicating their greater resistance to decomposition. In

Table 2. Characteristic of forage from leaves and husk of selected hazelnut varieties

Parameter	Type of biomass	Parameter value in selected hazelnut variety				*p*-value
		'Kataloński'	'Olbrzymi z Hale'	'Olga'	'Webba Cenny'	
Moisture (%)	husk	11.01 ±0.05Bb	10.69 ±0.24Cb	12.24 ±0.03Ab	11.23 ±0.03Bb	<0.0001
	leaves	14.15 ±0.01Aa	13.81 ±0.03Ca	14.01 ±0.04Ba	11.38 ±0.03Da	<0.0001
	p-value	<0.0001	<0.0001	<0.0001	<0.0001	
Protein (%)	husk	7.44 ±0.19Db	0.50 ±0.07Ab	3.72 ±0.10Bb	4.45 ±0.11Cb	<0.0001
	leaves	0.55 ±0.13Ca	2.38 ±0.14Aa	1.98 ±0.16Ba	0.42 ±0.09Da	<0.0001
	p-value	<0.0001	<0.0001	<0.0001	<0.0001	
Fibre (%)	husk	22.69 ±0.05Ba	32.40 ±0.68Aa	9.05 ±0.10Ca	9.60 ±0.15Ca	<0.0001
	leaves	0.75 ±0.10Cb	1.04 ±0.12Cb	2.57 ±0.21Bb	14.02 ±0.18Ab	<0.0001
	p-value	<0.0001	<0.0001	<0.0001	<0.0001	
Ash (%)	husk	17.55 ±0.17Bb	3.63 ±0.13Db	16.16 ±0.17Cb	25.55 ±0.11Ab	<0.0001
	leaves	21.62 ±0.12Aa	19.65 ±0.06Ba	18.33 ±0.15Ca	13.35 ±0.09Da	<0.0001
	p-value	<0.0001	<0.0001	<0.0001	<0.0001	
NDF (%)	husk	64.55 ±0.06Aa	62.10 ±0.19Ba	53.07 ±0.06Da	54.60 ±0.08Ca	<0.0001
	leaves	32.14 ±0.03Cb	35.10 ±0.10Bb	32.18 ±0.06Cb	37.56 ±0.05Ab	<0.0001
	p-value	<0.0001	<0.0001	<0.0001	<0.0001	
ADF (%)	husk	62.55 ±0.02Aa	57.37 ±0.25Ba	56.76 ±0.03Ca	57.25 ±0.06Ba	<0.0001
	leaves	39.35 ±0.07Ab	37.16 ±0.08Db	39.14 ±0.09Bb	38.29 ±0.03Cb	<0.0001
	p-value	<0.0001	<0.0001	<0.0001	<0.0001	
ADL (%)	husk	12.60 ±0.00Ba	13.51 ±0.05Aa	11.86 ±0.02Ca	11.83 ±0.03Ca	<0.0001
	leaves	8.75 ±0.03Cb	8.57 ±0.04Db	8.97 ±0.04Bb	9.48 ±0.01Ab	<0.0001
	p-value	<0.0001	<0.0001	<0.0001	<0.0001	
OM digestibility (Aufere) (%)	husk	30.01 ±0.37Cb	44.59 ±0.29Db	16.40 ±0.40Bb	9.36 ±0.44Ab	<0.0001
	leaves	20.83 ±0.22Ca	25.35 ±0.13Aa	20.52 ±0.13Ca	21.45 ±0.17Ba	<0.0001
	p-value	<0.0001	<0.0001	<0.0001	<0.0001	
DM digestibility (Aufere) (%)	husk	15.18 ±0.33Cb	42.36 ±0.47Db	4.42 ±0.29Bb	6.55 ±0.52Ab	<0.0001
	leaves	28.56 ±0.18Ba	29.18 ±0.13Aa	27.77 ±0.17Ca	26.69 ±0.10Da	<0.0001
	p-value	<0.0001	<0.0001	<0.0001	<0.0001	
Total soluble sugars (%)	husk	13.21 ±0.08Bb	14.00 ±0.05Cb	12.51 ±0.04Ab	13.93 ±0.01Bb	<0.0001
	leaves	8.53 ±0.05Aa	9.31 ±0.07Ca	8.83 ±0.06Ba	11.73 ±0.04Da	<0.0001
	p-value	<0.0001	<0.0001	<0.0001	<0.0001	

Explanations: DM = dry matter, OM = organic matter, NDF = neutral detergent fibre, ADF = acid detergent fibre, ADL = acid detergent lignin, A–D and a–b as in Tab. 1.
Source: own study.

studies on the use of grape leaves as feed for sheep, Romero *et al.* (2000), the ADF content in grape leaves is approximately 0.6%, while in the analysed material the values obtained were higher. Birkinshaw *et al.* (2022) showed an ADF content of 14.2% for vineleaf pellets. In contrast, Gürsoy (2023) obtained 24.43%, while Kocadayioğullari, Boğa and Ermetin (2024) reported 32.04% ADF for grape leaves regardless of variety.

The ADL content in the husk was highest for the 'Olbrzymi z Hale' (13.51%) and lowest for 'Webba Cenny' (11.83%). In the case of leaves, the highest values were recorded for the 'Webba Cenny' (9.48%), and the lowest for the 'Olbrzymi z Hale' (8.57%). Husk showed higher ADL values than leaves. For comparison, Birkinshaw *et al.* (2022) reported significantly lower values of 4.80%, while Kocadayioğullari, Boğa and Ermetin (2024) obtained a value of 10.2% for this parameter.

The organic matter (OM) digestibility parameters in the husks ranged from 9.36% for the 'Webba Cenny' to 44.59% for the 'Olbrzymi z Hale'. In the case of leaves, the highest digestibility was found in the 'Olbrzymi z Hale' (25.35%), and the lowest in the 'Olga' (20.52%). Leaves were characterised by higher organic matter digestibility than mulch, which may be due to their lower lignin content.

The highest dry matter digestibility in the husk was recorded for the 'Olbrzymi z Hale' (42.36%), and the lowest for

'Webba Cenny' (6.55%). In the case of leaves, the highest values were recorded for the 'Olbrzymi z Hale' (29.18%), and the lowest for the 'Webba Cenny' (26.69%). Low digestibility values for some husk may indicate their limited digestibility in raw form. However, their inclusion in feed, especially when optimising moisture and fibre content, may improve feed stability and nutritional value.

The highest soluble sugar content in husk was recorded for the 'Olbrzymi z Hale' (14.00%), while the lowest was for the 'Olga' (12.51%). In the case of leaves, the highest soluble sugar values were found in the 'Webba Cenny' (11.73%), and the lowest in the 'Kataloński' (8.53%). Low values may result from deviations from established calibration standards.

The table shows the content of selected macro- and microelements in the leaves and husks of four hazelnut varieties ('Kataloński', 'Olbrzymi z Hale', 'Olga', 'Webba Cenny'). The analysis covered nitrogen (N), phosphorus (P), potassium (K), sodium (Na), calcium (Ca), magnesium (Mg), iron (Fe), manganese (Mn), zinc (Zn) and copper (Cu). The results are given as averages per dry weight. Significant statistical differences were found for most of the analysed elements, both depending on the type of biomass (leaves vs husks) and on the variety. Significance for biomass type was noted for all parameters except zinc and copper, while significance between varieties was demonstrated for nitrogen, potassium, sodium, calcium, magnesium, iron, manganese, zinc and copper (Tab. 3).

Table 3. Macro- and microelement content in leaves and husks of selected hazelnut varieties

Element	Type of biomass	Content of elements in hazelnut variety				*p*-value
		'Katanoński'	'Olbrzymi z Hale'	'Olga'	'Webba Cenny'	
N (%)	husk	0.83 ±0.11 Ab	0.90 ±0.06 Ab	0.95 ±0.06 Ab	0.59 ±0.06 Bb	0.0014
	leaves	1.07 ±0.28 Aa	1.08 ±0.21 Aa	1.11 ±0.18 Aa	0.75 ±0.21 Aa	0.0545
	p-value	0.0001	0.0001	0.0001	0.0001	
P (%)	husk	0.082 ±0.007 Ab	0.107 ±0.006 Ba	0.073 ±0.003 Ab	0.069 ±0.008 Ab	0.0003
	leaves	0.105 ±0.025 Aa	0.109 ±0.006 Aa	0.099 ±0.029 Aa	0.092 ±0.029 Aa	0.6548
	p-value	0.0001	0.4822	0.0001	0.0001	
K (%)	husk	2.037 ±0.308 Aa	1.133 ±0.074 BCa	1.442 ±0.123 Ba	0.889 ±0.099 Ca	0.0003
	leaves	1.254 ±0.88 Ab	0.762 ±0.411 Ab	0.929 ±0.568 Ab	0.637 ±0.298 Ab	0.3139
	p-value	0.0001	0.0001	0.0001	0.0001	
Na (%)	husk	0.018 ±0.003 Aa	0.011 ±0.001 Ba	0.012 ±0.002 Ba	0.011 ±0.002 Ba	0.0029
	leaves	0.013 ±0.006 Ab	0.010 ±0.002 Aa	0.009 ±0.003 Ab	0.009 ±0.002 Ab	0.1892
	p-value	0.0001	0.0808	0.0001	0.0001	
Ca (%)	husk	0.319 ±0.028 Bb	0.607 ±0.048 Ab	0.525 ±0.053 Ab	0.274 ±0.040 Bb	0.0001
	leaves	0.931 ±0.748 Aa	0.779 ±0.195 Aa	1.042 ±0.583 Aa	0.610 ±0.37 Aa	0.0574
	p-value	0.0001	0.0001	0.0001	0.0001	
Mg (%)	husk	0.130 ±0.009 Bb	0.231 ±0.027 Aa	0.208 ±0.015 Ab	0.237 ±0.025 Aa	0.0007
	leaves	0.210 ±0.096 Aa	0.243 ±0.021 Aa	0.264 ±0.064 Aa	0.242 ±0.017 Aa	0.3697
	p-value	0.0001	0.2279	0.0001	0.9874	
Fe ($mg \cdot kg^{-1}$)	husk	1573.20 ±33.70 Ba	158.30 ±14.09 Cb	547.60 ±17.10 Ca	3032.90 ±393.50 Aa	0.0001
	leaves	1210.00 ±403.30 ABb	852.80 ±767.30 Ba	545.60 ±38.40 Ba	2210.70 ±941.30 Ab	0.0013
	p-value	0.0001	0.0001	0.9147	0.0001	
Mn ($mg \cdot kg^{-1}$)	husk	189.33 ±42.44 Bb	119.68 ±4.06 Cb	195.71 ±7.83 Bb	273.62 ±23.67 Ab	0.0005
	leaves	467.99 ±307.17 Aa	355.22 ±285.62 Aa	421.59 ±249.56 Aa	559.45 ±320.37 Aa	0.6568
	p-value	0.0001	0.0001	0.0001	0.0001	
Zn ($mg \cdot kg^{-1}$)	husk	18.76 ±4.18 Bb	17.93 ±2.96 Bb	18.12 ±1.58 Bb	31.92 ±1.88 Aa	0.0007
	leaves	32.20 ±15.06 Aa	67.46 ±55.61 Aa	30.11 ±13.18 Aa	37.07 ±16.59 Aa	0.3719
	p-value	0.0001	0.0001	0.0001	0.5096	
Cu ($mg \cdot kg^{-1}$)	husk	9.14 ±0.59 Aa	7.86 ±1.29 Aa	5.87 ±0.34 Bb	8.45 ±0.40 Aa	0.0039
	leaves	8.71 ±0.7 ABa	8.35 ±1.45 ABa	6.70 ±0.94 Ba	9.16 ±1.83 Aa	0.0209
	p-value	0.1591	0.4179	0.0001	0.4041	

Explanations as in Tab. 1.
Source: own study.

The analysis revealed significant differences in the content of the examined macro- and microelements between biomass types and between varieties. Leaves were characterised by higher nitrogen, phosphorus, calcium and magnesium content compared to husks. The nitrogen content in leaves ranged from 0.75% in the 'Webba Cenny' to 1.11% in the 'Olga', while in the husks it ranged from 0.59% in 'Webba Cenny' to 0.95% in 'Olga'. Phosphorus in leaves ranged from 0.082% in the 'Webba Cenny' to 0.109% in 'Olbrzymi z Hale', and in the integument from 0.081% in 'Kataloński' to 0.107% also in 'Olbrzymi z Hale' (Tab. 3).

In the case of calcium, the highest concentration in leaves was recorded in the 'Olga' (1.042%), and in the husks in 'Olbrzymi z Hale' (0.607%). The magnesium content in the leaves was highest in the 'Olga' (0.264%), while in the husks it was highest in 'Olbrzymi z Hale' (0.231%).

The husks, on the other hand, showed higher potassium, sodium, iron, manganese and zinc content. Potassium in the husks reached the highest value in the 'Kataloński' (2.037%), while in the leaves of the same variety it was 1.254%. The lowest potassium concentrations in both leaves and husks were recorded in the 'Webba Cenny', at 0.637% and 0.889%, respectively. Sodium in the husks ranged from 0.011% in 'Webba Cenny' to 0.018% in 'Kataloński', while in the leaves it ranged from 0.009% in 'Webba Cenny' to 0.013% in 'Kataloński'.

Among microelements, the highest iron content was found in the 'Webba Cenny', both in the husks, where the concentration was 3032.90 mg·kg^{-1}, and in the leaves (2210.70 mg·kg^{-1}). The lowest iron values in the husks were recorded in the 'Olbrzymi z Hale' (158.30 mg·kg^{-1}), and in the leaves in the 'Olga' (545.60 mg·kg^{-1}). Manganese in the husks was highest in 'Webba Cenny' (273.62 mg·kg^{-1}), as in the leaves of the same variety (559.45 mg·kg^{-1}).

The zinc content in the husks was highest in the 'Webba Cenny' (31.92 mg·kg^{-1}), while in the leaves it was highest in 'Olbrzymi z Hale' (67.46 mg·kg^{-1}). Copper did not show significant differences between biomass types, with values in the husks ranging from 5.87 mg·kg^{-1} in 'Olga' to 9.14 mg·kg^{-1} in 'Kataloński', while in the leaves they ranged from 6.70 mg·kg^{-1} in 'Olga' to 9.16 mg·kg^{-1} in 'Webba Cenny'.

In summary, the type of biomass had a significant effect on the content of most elements, confirming that leaves can be a valuable source of nitrogen, phosphorus, calcium and magnesium, while husks can be used as a raw material to enrich feed with potassium, sodium and selected microelements, especially iron, manganese and zinc. In turn, the greatest differences between varieties were observed in the case of nitrogen, potassium, iron and manganese, which should be taken into account when planning their use in livestock nutrition and designing feed mixtures (Tab. 3).

CONCLUSIONS

The conducted research showed that both the leaves and husks of the four analysed hazelnut varieties are characterised by diverse chemical composition and nutritional values, which confirms their potential as feed components in livestock nutrition.

Leaves, compared to husks, were characterised by higher nitrogen, phosphorus, calcium and magnesium content, which indicates their greater value in supplementing deficiencies of these elements in the diet of animals. In turn, the husks showed higher potassium, sodium, iron, manganese and zinc content, which may be important when formulating feed mixtures enriched with these elements.

The analysis also revealed significant differences between the tested varieties. The 'Olga' was characterised by the highest nitrogen and calcium content in the leaves, 'Olbrzymi z Hale' stood out with the highest magnesium and phosphorus content in the leaves and husks, while 'Webba Cenny' showed the highest concentrations of iron, manganese and zinc in both the leaves and husks. The 'Kataloński' was characterised by the highest potassium content in both biomass fractions.

Significant differences in the protein, fat, ash and fibre content depending on the variety and type of biomass indicate that when selecting raw materials for feed composition, both the part of the plant and the specific characteristics of the variety should be taken into account. Hazelnut leaves, due to their higher protein content and favourable macro- and microelement profile, can be a valuable addition to feed mixtures, while husks coverings can be used as a source of fibre and trace elements.

In summary, the results obtained indicate that biomass in the form of hazelnut leaves and husk can be used in livestock nutrition, especially in regions with a deficit of traditional feed sources. The variation in chemical composition depending on the variety and type of biomass highlights the need for a selective approach when planning their use, as well as further research including the assessment of digestibility and the impact on production and health parameters of animals.

CONFLICT OF INTERESTS

All authors declare that they have no conflict of interests.

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