Ratar. Povrt. 2023, 60(3): 49-60

original scientific paper
Ratar. Povrt. 2023, 60(3): 49-60
doi: 10.5937/ratpov60-46982
Manuscript submitted: 6 October 2023
Manuscript accepted: 4 December 2023

Exploring the nutritional potential of Camelina sativa genotypes: A study on minerals and bioactive compounds

Zorica Stojanović[1]* · Nada Grahovac[2] · Dajana Uletilović[1] · Žarko Kevrešan[3] · Snežana Kravić[1] · Ana Đurović[1] · Ana Marjanović-Jeromela[2]

[1]University of Novi Sad, Faculty of Technology, Novi Sad, Serbia
[2]Institute of Field and Vegetable Crops, Novi Sad, Serbia
[3]University of Novi Sad, Institute of Food Technology, Novi Sad, Serbia

*Corresponding author: zorica.stojanovic@uns.ac.rs

Acknowledgments: This research was supported by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia (Grant no. 451-03-47/2023-01/200134 and Grant no. 451-03-47/2023-01/200032).

Summary: *Camelina sativa* is a member of the Brassicaceae family and is characterized as an annual oilseed plant with a short growth cycle. Its seeds offer rich nutritional value comparable with other feed and food sources due to the presence of high-quality oils, protein, essential fatty acids, and bioactive compounds. Our study investigated mineral profile and bioactive compound contents among two different camelina genotypes. The evaluated camelina genotypes NS Zlatka and NS Slatka were developed in Serbia. The bioactive compound investigation included total phenolic and flavonoid contents, chlorophyll a and b, and total carotenoid contents. Furthermore, antioxidant activity was assessed by measuring the DPPH-scavenging capacity of camelina seed extracts. The results demonstrate differences in mineral content between the two genotypes, with variations in sodium, potassium, calcium, magnesium, zinc, iron, manganese, copper, and phosphorus levels. Both genotypes exhibit notable mineral profiles, with particularly high levels of potassium (1007.76-1047.74 mg/100 g) and magnesium (224.09-227.45 mg/100 g), which makes them potentially valuable for both animal feed and human nutrition. Furthermore, analysis reveals substantial levels of total phenolic (8.13-8.16 mg GAE/g DM) and flavonoid (5.91-6.41 mg QE/g DM) compounds in both genotypes, indicating their suitability for applications in the food and pharmaceutical industries. Chlorophyll content analysis demonstrates significant differences between the two genotypes, particularly in chlorophyll a and chlorophyll b levels. These variations suggest differences in photosynthetic capacity and seed maturity. Total carotenoid content remains consistent between the genotypes at levels from 16.43 to 17.91 μg β-CE/g DM, implying similar antioxidant protection mechanisms. Overall, this study provides valuable insights into the biochemical properties of two camelina genotypes, indicating their potential applications in agriculture and human nutrition.
Key words: camelina, carotenoids, chlorophylls, flavonoids, genotypes, phenolics, seeds

Introduction

The study of plant genotypes and their associated biochemical properties plays a fundamental role in expanding knowledge in the field of plant biology and identification of potential bioactive compound sources with various applications in human nutrition and health. Among the diverse ranges of plant species that have attracted scientific attention, *Camelina sativa* ([L.] Crtz.) emerges as an intriguing candidate due to its historical significance as an oilseed crop and its potential as a source of valuable bioactive compounds (Kurasiak-Popowska et al., 2019; Ratusz et al., 2018).

Camelina sativa, also known as false flax or gold-of-pleasure, is a spring annual oilseed plant that belongs to the Brassicaceae family (Nagl et al., 2022; Zanetti et al., 2021). It was cultivated widely in Europe until the twentieth century, afterwards its production declined (Fröhlich & Rice, 2005). However, during the last three decades, interest in camelina as an oilseed crop has increased, and its value as an alternative oil crop has been examined. Numerous studies on camelina have emphasized its potential as an oilseed crop within sustainable agricultural systems (Rodríguez-Rodríguez et al., 2013). From an agricultural perspective, this plant thrives in diverse environments, delivering a high yield with minimal input demands. Due to its adaptivity to different environmental conditions, low requirements for water and nutrients, and relatively strong resistance to pests and plant diseases, production costs are lower compared to other oil crops in specific climatic conditions (Neupane et al., 2022). Besides being used for bio-diesel production, its exceptional oil composition and valuable properties make camelina a candidate for utilization in food and feed production, as well as a range of non-food products (Berti et al., 2016; Fröhlich & Rice, 2005). Camelina can be used to improve the quality of food and feed due to its chemical composition (Abramovič et al., 2007; Ghidoli et al., 2023; Ilić et al., 2022). The high protein content, alongside the well-balanced fatty acid composition and valuable bioactive compounds in camelina seeds, not only holds nutritional significance but also offers multiple health benefits.

In recent years, researchers have been exploring the genetic diversity within camelina populations, leading to the identification of new genotypes with unique characteristics (Kuzmanović et al., 2021; Montero-Muñoz et al., 2023). These newly discovered genotypes represent a promising raw material for the exploration of their mineral composition and content of bioactive compounds which may have beneficial effects on human health. Consequently, in this work, the mineral composition, total phenolic content, total flavonoid content, chlorophyll a and chlorophyll b content, and total carotenoids were evaluated in two newly developed camelina genotypes cultivars. Understanding the mineral content of plant genotypes, particularly newly discovered camelina genotypes, can provide insights into their suitability for specific agricultural environments and their nutritional value and potential as food ingredients or animal feed additives. In addition to minerals, polyphenols and flavonoids, a class of secondary metabolites found in various plant species, have gained recognition for their potent antioxidant properties. These compounds contribute to the plant defence mechanisms and play a pivotal role in protecting against oxidative stress. Furthermore, polyphenols and flavonoids have demonstrated potential health benefits in humans, including reduced risk factors for chronic diseases and improved overall well-being (Pandey & Rizvi, 2009). Chlorophylls and carotenoids, as photosynthetic pigments, play fundamental roles in plant biology. Variations in chlorophyll a, chlorophyll b, and total carotenoid content among different camelina genotypes can elucidate their photosynthetic efficiency, adaptability to environmental stressors, and potential applications in both agricultural and nutritional contexts.

In this context, this study aims to investigate and compare the mineral composition, as well as the levels of selected bioactive compounds of two novel genotypes of camelina developed in Serbia. Through the characterization of these biochemical properties, our objective is to advance our understanding of camelina genotypes and their potential applications in various fields.

Experimental

Chemicals

All chemicals used in the experiments were of analytical reagent grade unless otherwise specified. Folin–Ciocalteu's reagent was provided by AppliChem (Darmstadt, Germany). Catechin, gallic acid, β-carotene, and DPPH (1,1-diphenyl-2-picrylhydrazyl) were procured from Sigma-Aldrich (St. Louis, MA, USA). Anhydrous sodium sulfate, sodium carbonate, sodium hydroxide, and aluminum chloride were obtained from Carl Roth (Karlsruhe, Germany). Methanol, acetone, and petroleum ether were sourced from VWR Chemicals BDH (Fontenay-sous-Bois, France), while sodium nitrite and ascorbic acid were acquired from Centrohem (Stara Pazova, Serbia). Stock solutions of Pb, Cd, Cu, and Zn in 2% HNO_3 were procured from CPAchem (Stara Zagora, Bulgaria), and the Ni stock solution was sourced from Merck (Darmstadt, Germany). Distilled water was doubly purified and utilized exclusively throughout all experiments.

Samples

Two spring genotypes of camelina seeds (*Camelina sativa*), namely NS Zlatka and NS Slatka, were utilized in this study. These genotypes were developed at the Institute of Field and Vegetable Crops in Novi Sad, Serbia and officially registered by the Ministry of Agriculture, Forestry, and Water Management of the Republic of Serbia in 2018 (Kukrić et al., 2022). Notably, they represent the first registered camelina genotypes in Serbia. Both of these genotypes belong to the group of highly valuable cultivars that have been meticulously developed through self-fertilization processes to thrive in the specific environmental conditions of the Balkans with robust production traits (Ilić et al., 2022). Camelina samples were collected in the year 2021 and seeds from two camelina genotypes are shown in Figure 1. Camelina cultivation took place at Rimski Šančevi in Serbia (45°20' N, 19°51' E, 84 m a.s.l) during the spring of 2021. The experimental protocol and agronomic management closely followed the procedures previously outlined by Marjanović Jeromela et al. (Marjanovic Jeromela et al., 2021). A plot seeder was employed to achieve a seeding rate of 500 seeds per m^2. Sowing occurred in mid-April, with harvest performed at the beginning of July. Throughout the camelina growing season at Rimski Šančevi, the average temperature was at 18.3 °C, accompanied by a precipitation level of 116.1 mm.

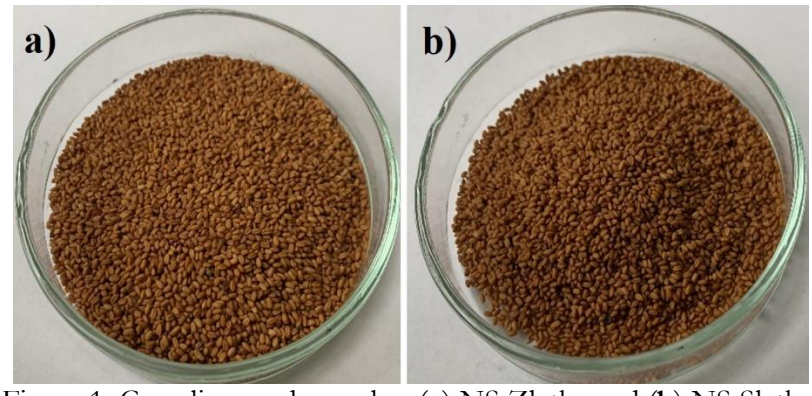

Figure 1. Camelina seed samples: (**a**) NS Zlatka and (**b**) NS Slatka.

Determination of bioactive compounds and mineral contents

Before initiating the analysis, the samples were homogenized to ensure uniformity, employing an IKA MultiDrive basic mill (Staufen, Germany). Following homogenization, the samples were sieved through a 60-mesh sieve to obtain a consistent particle size. Subsequently, the samples were subjected to distinct extraction protocols, each tailored to the specific types of analytes under

investigation. These rigorous preparation steps were crucial in ensuring the accuracy and reliability of the subsequent analytical results. All measurements were conducted in triplicate, and the results are presented as the mean ± standard deviation (n = 3).

In order to assess the antioxidant properties of the samples under investigation, we conducted estimations of their total phenolic and flavonoid contents, along with a DPPH radical scavenging assay. For all those experiments, the extraction involved the use of 80% methanol at a sample-to-solvent ratio of 1:10 (w/v), performed in an ultrasound bath for 30 minutes. Subsequently, the mixture was subjected to 24 hours of agitation on a shaker at room temperature (25 ± 1 °C). Throughout these procedures, the extracts were shielded from light by covering the conical flasks with aluminum foil. Afterward, the obtained extracts underwent centrifugation for 10 minutes at 6000 rpm, followed by filtration through a 45 μm filter (Macherey-Nagel, Düren, Germany). These obtained methanolic extracts were then employed for the subsequent determination of total phenolics, total flavonoids, and antioxidant activity.

The determination of total phenolic content (TPC) was carried out using the Folin–Ciocalteu method (Stojanović et al., 2023). In each test, 150 μL of the crude extract was combined with 5 mL of diluted Folin–Ciocalteu reagent (1/10 v/v dilution) and 2 mL of 15% sodium carbonate in a 10 mL tube. The mixture was vortexed for 30 seconds, filled up to 10 mL with doubly distilled water, and allowed to react in the dark for 45 minutes at room temperature. Subsequently, the absorbance of the mixture was measured at 760 nm against a blank. Gallic acid served as the standard for establishing the calibration curve, and the TPC results for various samples were expressed in milligrams of gallic acid equivalents per gram of dry matter (mg GAE/g DM).

Total flavonoid content (TFC) was determined using the aluminum chloride colorimetric method (Stojanović et al., 2023). In this procedure, 150 μL of each crude extract was combined with 4 mL of doubly distilled water and 300 μL of a 5% $NaNO_2$ solution. After a 5-minute incubation period, 300 μL of a 10% $AlCl_3$ solution was added and left to stand for an additional 1 minute. Subsequently, 2 mL of a 1 mol/L NaOH solution was added, filled with doubly distilled water up to 10 mL, and mixed for 10 s using a vortex apparatus. The mixture was allowed to stand for an additional 15 minutes before measuring the absorbance against the blank at 510 nm. The TFC present in the extracts was quantified using a standard calibration curve of catechin, and the results were expressed in milligrams of catechin equivalents per gram of dry matter (mg CE/g DM).

Antioxidant activity was evaluated through the assessment of free radical-scavenging capability using the DPPH (2,2-diphenyl-1-picrylhydrazyl) radical. Specifically, 25 μL of methanolic extract was diluted with 4 mL of doubly distilled water and combined with 800 μL of DPPH solution (0.4 mol/L) in methanol. Doubly distilled water was employed as a control in place of the sample. After incubation in a dark place for 30 minutes, the absorbance was measured at 515 nm. The radical scavenging activity was expressed as a percentage (%), and quantified by determining the electron-donating ability using the formula [1 − (sample or standard absorbance/control absorbance)] × 100. Ascorbic acid was used to define the calibration curve while the antioxidant activity was expressed in milligrams of ascorbic acid equivalent per gram of dry matter (mg AAE/g DM).

Evaluation of chlorophyll content was done according to the modified spectrophotometric method (Wellburn, 1994). The procedure involved the extraction of 2 grams of seed samples in 20 mL of 96% methanol, which were vigorously agitated for 20 minutes. Following the extraction process, the mixture underwent centrifugation at 6000 rpm for 10 minutes. Subsequently, the resulting supernatant was collected and utilized for subsequent spectrophotometric analysis. The concentrations of chlorophyll a and chlorophyll b were determined by measuring the absorbance at 666 nm and 653 nm, respectively, and these measurements were analysed using the following equations (Wellburn, 1994):

$$Chlorohyll\ a\left(\frac{mg}{L}\right) = 15.65\ A_{666} - 7.34\ A_{653}$$
$$Chlorohyll\ b\left(\frac{mg}{L}\right) = 27.05\ A_{653} - 11.21\ A_{666}$$

The final results of the obtained content of Chlorophyll a and Chlorophyll b were presented as micrograms per gram of dry matter.

The total carotenoid content was estimated using a modified method described by Hossain and Jayadeep (Hossain & Jayadeep, 2018). Initially, approximately 2 grams of milled sample were combined with 10 mL of extraction solvent (acetone: petroleum ether, in a 1:1 volume ratio) and placed on a magnetic stirrer (HedaS, Vršac, Serbia) for 45 minutes. After centrifugation employing an Ultra-8V centrifuge (LW Scientific, Lawrenceville, USA) at 6000 rpm and room temperature, the resulting supernatant was collected. The extraction process was repeated several times until the solvent became colourless. Afterward, any remaining acetone in the collected extracts was removed by washing with a suitable amount of double-distilled water. Following this step, the carotenoid extract in petroleum ether was transferred to a volumetric flask containing anhydrous sodium sulfate to eliminate residual water. The flask was then filled to the mark using the same solvent. Throughout the entire procedure, all laboratory glassware was shielded from light using aluminum foil to ensure protection. The absorbance of the prepared extracts was determined at a wavelength of 450 nm relative to petroleum ether using a UV–Vis spectrophotometer UV-2100, Unico Instrument Co. (Shanghai, China) with a 1 cm cell path length. To quantify the carotenoid content, β-carotene was employed as a reference compound, and its concentration was calculated *via* a standard calibration curve. The total carotenoid content was then expressed as a microgram of β-carotene equivalent per gram of dry sample (μg β-CE/g DM).

Atomic absorption spectrophotometry (AAS) was employed for the analysis of the mineral composition. For the decomposition of seed samples, 2 grams of the grounded material were used and incineration was performed in a muffle furnace at 550°C for 4 hours. The resulting ash was subsequently dissolved in 0.1 mol/L hydrochloric acid. The obtained solution was then filtered using ash-free cellulose filter paper and analysed using an atomic absorption spectrophotometer ICE3000, Thermo Fisher (Suzhou, China). According to the manufacturer's recommendations, all AAS instrumental parameters, including wavelength, slit width, and flame stoichiometry, were set before the analysis read out. The calibration curves employed were within the linear range, with an R-value of at least 0.998. The content of elemental composition was expressed as mg per 100 grams of dry matter (mg/100 g DM).

Phosphorus was analysed by spectrophotometry using the molybdenum blue method (Kravić & Stojanović, 2016). 5 mL of the samples were dried until dryness at 115°C and allowed to cool to room temperature. The dry residue of each sample was digested using 5 mL of concentrated sulphuric acid and 15 drops of nitric acid. The obtained mixture was set on a hot plate until a clear or slightly green colour was obtained (after around 1 h). After cooling, digested samples were transferred to the volumetric flask and neutralized by adding several drops of 30% NaOH (1% solution of phenolphthalein was used for the indication), and finally diluted with doubly distilled water to 100 mL. Furthermore, a certain volume of diluted sample (5, 10, 15, or 20 mL depending on the sample) was transferred to the 100 mL volumetric flask, and 5 mL 5% ammonium heptamolybdate, 1 mL 11% sodium sulfite and 1 mL 0.5% hydroquinone were added. After 45 min the absorbance was measured at 750 nm and the results were expressed as mg/L. The calibration curve was defined with KH_2PO_4 from 0.05 to 0.4 mg P/mL. The analyses were carried out in triplicate and the data reported represent the average values of three determinations ± 2 standard deviations (mean±2SD).

Statistical analysis

Descriptive statistics, including mean and standard deviation, were computed to summarize the main characteristics of the experimental data. To evaluate the significance of differences between groups, we conducted statistical comparisons of means using the t-test, chosen as the appropriate method for assessing variations between the means of two independent groups in our study. The significance level was set at 0.05 level. All statistical analyses were performed using Microsoft Excel, and p-values bellow 0.05 were considered statistically significant.

Results and Discussion

The mineral composition of seeds of two camelina genotypes is presented in Table 1. All the values presented are in milligrams per 100 grams of the sample. The mineral composition analysis revealed some differences between NS Zlatka and NS Slatka genotypes with respect to several key minerals.

NS Zlatka exhibited a sodium content of 38.95 mg/100 g, while NS Slatka showed a slightly higher sodium content of 44.30 mg/100 g. Although these differences were statistically significant, they fall within a relatively narrow range and may not have significant implications for dietary considerations. The potassium content in both genotypes was relatively high, with 1007.76 mg/100 g determined in NS Zlatka and 1047.74 mg/100 g in NS Zlatka. Potassium is an essential nutrient for various physiological processes in both plants and animals, and these results highlight the potential nutritional value of both genotypes. NS Zlatka exhibited a slightly higher calcium content (169.63 mg/100 g) compared to NS Slatka (161.13 mg/100 g). Calcium is crucial for plant cell wall structure and human bone health. The differences observed here may be attributed to genetic variations and environmental factors. Magnesium is essential for photosynthesis and enzyme function in plants, and it also plays a vital role in human health. Both genotypes demonstrated similar magnesium content, with NS Zlatka at 224.09 mg/100 g and NS Slatka at 227.45 mg/100 g. Camelina NS Slatka displayed a slightly higher zinc content (2.70 mg/100 g) compared to NS Zlatka (2.52 mg/100 g). Zinc is an essential trace element important for plant growth and human nutrition. A higher iron content (5.23 mg/100 g) was found in camelina NS Slatka compared to the NS Zlatka genotype (4.72 mg/100 g). Iron is crucial for chlorophyll production in plants and is a vital component of haemoglobin in human blood. Both genotypes had similar manganese content, with values of approximately 1.88 mg/100 g to 1.93 mg/100 g. Manganese is involved in various metabolic processes in both plants and animals. Copper is an essential micronutrient for plants and is involved in several enzymatic reactions. In the NS Zlatka seed sample, a slightly higher copper content was found (0.49 mg/100 g) in comparison to NS Slatka (0.39 mg/100 g). NS Slatka exhibited a significantly higher phosphorus content (856.09 mg/100 g) compared to NS Zlatka (710.57 mg/100 g). Phosphorus is a critical component of DNA, RNA, and ATP, and it is essential for plant growth and development.

The obtained results align with the general trend observed in camelina research (Mondor & Hernández-Álvarez, 2022; Riaz et al., 2022; Zubr, 2010), which indicates that the contents of minerals can vary among various genotypes. The relatively high levels of potassium, magnesium, calcium, and phosphorus in both genotypes make them potentially valuable for use in animal feed or as a source of these essential minerals in human diets. The variations in iron and zinc content could also be of interest to those looking to increase the nutritional content of camelina-based products.

Table 1. Mineral compositions of the two camelina genotypes, NS Zlatka and NS Slatka

Mineral	Mineral content (mg/100 g)*	
	NS Zlatka	NS Slatka
Na	38.95±1.75 [a]	44.30±3.13 [b]
K	1007.76±64.68 [a]	1047.74±54.51 [b]
Ca	169.63±6.64 [a]	161.13±9.93[a]
Mg	224.09±5.62 [a]	227.45±9.93 [b]
Zn	2.52±0.04 [a]	2.70±0.08 [b]
Fe	4.72±0.04 [a]	5.23±0.30 [b]
Mn	1.93±0.11 [a]	1.88±0.11 [a]
Cu	0.49±0.03 [a]	0.39±0.02 [a]
P	710.57±22.75 [a]	856.09±22.72 [b]

*average value ± SD, n=3
Values with the same letter in a row are not significantly different at 5%.

Comparing our mineral content data for the NS Zlatka and NS Slatka genotypes of camelina with previously published research (Ilić et al., 2022) provides valuable insights into the consistency and variability of mineral profiles. Certainly, variations in mineral content between our results and previously published data can be attributed to several factors. Mineral uptake by plants is highly dependent on environmental conditions, including soil composition, climate, and agronomic practices. Variability between samples can occur within a single genotype due to differences in sample preparation and plant age. These factors can influence the accuracy and consistency of mineral content measurements. Additionally, the stage of plant growth at which samples are harvested can influence mineral content. Minerals may accumulate or decline at different rates during plant development, and differences in harvest timing can affect the results. Further research could explore the genetic factors underlying these differences and investigate how they impact the suitability of these genotypes for specific agricultural and dietary applications. In comparison to other oilseeds such as oilseed rape (Stojanović et al., 2023), our study reveals similar mineral content patterns in NS Zlatka and NS Slatka camelina genotypes. However, in comparison to sunflower, while the overall mineral profiles exhibit similarities, certain minerals exhibit notable differences in content (Petraru et al., 2021). The variations observed may be attributed to the unique biochemical pathways and genetic makeup inherent to each plant species, as well as the influence of environmental factors on mineral uptake and accumulation.
The results regarding total phenolic and flavonoid compounds as well as antioxidant activity for both camelina genotypes are reported in Table 2.

Table 2. Polyphenols and flavonoids compositions and antioxidant activity of the studied oil crops

Parameter	NS Zlatka	NS Slatka
Total phenolic compounds (mg GAE/g DM)*	8.13±0.57 [a]	8.16±0.05 [b]
Total flavonoid compounds (mg QE/g DM)*	6.41±0.36 [a]	5.91±0.32 [a]
DPPH (mg AAE/g DM)*	2.59±0.05 [a]	2.98±0.10 [b]

*average value ± SD, n=3
Values with the same letter in a row are not significantly different at 5%.

The analysis of total phenolic compounds revealed similar levels in both genotypes, with NS Zlatka at 8.13 mg GAE/g DM and NS Slatka at 8.16 mg GAE/g DM. These values indicate a substantial presence of phenolic compounds in both genotypes, highlighting their potential for applications in the food and pharmaceutical industries. The lack of significant differences between the two genotypes suggests genetic similarity in their phenolic composition. NS Zlatka displayed a slightly higher content of total flavonoid compounds of 6.41 mg QE/g DM, compared to NS Slatka with 5.91 mg QE/g DM. While NS Slatka showed a lower content of flavonoids, these values are indicative of the presence of flavonoid compounds, which are known for their antioxidant and health-promoting properties. The DPPH assay, which measures antioxidant activity, revealed that NS Zlatka exhibited an antioxidant activity of 2.59 mg AAE/g DM, while NS Slatka demonstrated a slightly higher antioxidant activity of 2.98 mg AAE/g DM. These results suggest that both genotypes possess notable antioxidant potential, with NS Slatka displaying a slightly stronger DPPH-scavenging activity. This finding is consistent with the slight variation often observed in antioxidant activity among different plant genotypes. Our findings regarding the total phenolic and flavonoid compounds in both NS Zlatka and NS Slatka genotypes of camelina align closely with previously reported data in the literature (Bravi et al., 2023; Mondor & Hernández-Álvarez, 2022; Rahman et al., 2018; Tavarini et al., 2021; Zanetti et al., 2021). Potential small disparities can be explained by variations in cultivar selection, extraction methods, growing conditions and the equivalents used in expressing results. As an illustration, Tavarini et al. (Tavarini et al., 2021) identified concentrations of total phenols and total flavonoids ranging from 6.26 to 7.07 mg GAE/ g DM of defatted camelina meal, while total flavonoid contents were from 5.48 to 6.15 catechin equivalent/g DM of defatted camelina meal. In the defatted camelina meal too, Rahman et al. (Rahman et al., 2018) reported an average total phenolic content of 11.69 ± 0.44 mg GAE/g DW, accompanied by a total flavonoid content of 6.81 ± 0.68 mg catechin equivalent/g DM. In comparison to other oilseeds, antioxidant potential of camelina is similar to sunflower (Lužaić et al., 2023) and rape oil seeds (Stojanović et al., 2023). Further investigations into the specific antioxidant compounds and mechanisms underlying this similarity could unveil valuable insights for nutritional and industrial applications.

Table 3 presents the results obtained for chlorophyll and total carotenoid content. The determination of chlorophyll content in seeds is significant for several key reasons. It serves as an indicator of seed viability and quality, aiding in the selection of seeds for optimal germination and crop performance. Monitoring chlorophyll levels in stored seeds is crucial for seed tanks and conservation efforts, helping to identify seed deterioration and storage issues. The analysis of chlorophyll a content revealed notable differences between the two genotypes. NS Zlatka exhibited a chlorophyll a content of 0.58 μg/g DM, while NS Slatka displayed a significantly higher concentration at 1.48 μg/g DM. Similarly, there were substantial differences in chlorophyll b content. NS Zlatka had a chlorophyll b content of 0.81 μg/g DM, while NS Slatka showed a significantly higher concentration at 2.21 μg/g DM. The total chlorophyll content, which encompasses both chlorophyll a and chlorophyll b, exhibited a significant difference between the two genotypes. NS Zlatka had a total chlorophyll content of 1.39 μg/g DM, while NS Slatka displayed a markedly higher concentration at 3.69 μg/g DM. These variations in total chlorophyll content are indicative of differences in the overall photosynthetic capacity or seed maturity of the two genotypes. Previously published results on the contents of chlorophylls in oilseed rape seeds, ranging from 1.33 to 4.38 μg/g DM (Stojanović et al., 2023), and in sunflower seeds with an average of 0.99 ± 0.40 μg/g (Lužaić et al., 2023), align closely with our findings for camelina seeds. This convergence in chlorophyll content suggests a shared characteristic among these oilseeds, potentially reflecting common physiological processes or environmental influences during their growth and development.

Table 3. Chlorophyll and total carotenoid content in NS Zlatka and NS Slatka genotypes of camelina

Parameter	NS Zlatka	NS Slatka
Chlorophyll a (µg/g DM)*	0.58±0.04 [a]	1.48±0.09 [b]
Chlorophyll b (µg/g DM)*	0.81±0.08 [a]	2.21±0.17 [b]
Chlorophylls total (µg/g DM)*	1.39±0.13 [a]	3.69±0.26 [b]
Total carotenoids content (µg β-CE/g DM)*	17.91±0.94 [a]	16.43±1.11 [a]

*average value ± SD, n=3
Values with the same letter in a row are not significantly different at 5%.

In contrast to the chlorophyll results, the analysis of total carotenoid content did not show a statistically significant difference between the two genotypes. NS Zlatka had a total carotenoid content of 17.91 µg β-CE /g DM, while NS Slatka exhibited a slightly lower concentration at 16.43 µg β-CE /g DM. Carotenoids play essential roles in photosynthesis as well as providing antioxidant protection to plants. The similarity in total carotenoid content between the two genotypes suggests that both possess a comparable level of antioxidant protection. Carotenoids serve as antioxidants, protecting plant cells from oxidative damage caused by excess light or environmental stressors. As expected, the consistent carotenoid content in both genotypes implies that they share similar mechanisms for coping with oxidative stress.

Acknowledging that a combination of agricultural practices, weather conditions, and genotypes can influence the content of key ingredients in the seed is crucial. Remarkable variations may arise not solely from differences in agricultural practices but also from the intricate interplay between weather conditions across different years and the genetic makeup of the plant, as highlighted in some previous publications (Alberghini et al., 2022; Boutet et al., 2022). This work significantly contributes by providing comprehensive insights into the nutritional and bioactive properties of the examined camelina genotypes throughout the specified growing season. By addressing this crucial aspect, our study enhances the understanding of camelina seed quality, advancing the broader knowledge in this field.

Conclusions

In this study, a comprehensive analysis of the mineral composition, polyphenols, flavonoids, antioxidant activity, chlorophyll, and carotenoid content in two camelina genotypes, NS Zlatka and NS Slatka, was conducted. The results shed light on the nutritional and bioactive properties of these genotypes and their potential applications in various industries. Both genotypes exhibited significant levels of essential minerals, making them potentially valuable sources for animal feed and human diets. The analysis of total phenolic and flavonoid compounds showcased the presence of bioactive polyphenols in both genotypes. Notably, NS Zlatka and NS Slatka exhibited similar levels of total phenolic compounds, while NS Zlatka displayed a slightly higher content of flavonoid compounds. NS Slatka displayed slightly stronger antioxidant activity compared to NS Zlatka, highlighting their potential as sources of natural antioxidants for various applications. Chlorophyll and carotenoid content analysis provided insights into the photosynthetic and antioxidant properties of seeds. Differences in chlorophyll content between the genotypes suggest variations in photosynthetic capacity and seed maturity. In contrast, similar total carotenoid content in both genotypes indicates

comparable antioxidant protection mechanisms. This research not only advances our understanding of the nutritional and health-related camelina's properties but underscores the importance of conserving and exploring genetic diversity within plant species to harness their full potential for human well-being and sustainable agriculture.

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Ispitivanje nutritivnog potencijala različitih genotipova lanika: mineralni sastav i bioaktivna jedinjenja

Zorica Stojanović · Nada Grahovac · Dajana Uletilović · Žarko Kevrešan · Snežana Kravić · Ana Đurović · Ana Marjanović-Jeromela

Sažetak: Lanik (*Camelina sativa*) pripada porodici Brassicaceae i predstavlja jednogodišnju uljanu biljnu vrstu sa kratkim ciklusom rasta. Usled prisustva visokokvalitetnih ulja, proteina, esencijalnih masnih kiselina i bioaktivnih jedinjenja, seme lanika ima visoku nutritivnu vrednost, koja se može uporediti sa drugim vrstama namirnica zastupljenih u ishrani ljudi i životinja. Naše istraživanje je obuhvatilo analizu mineralnog sastava i sadržaja bioaktivnih jedinjenja u različitim genotipovima lanika. Analizirana su dva genotipa lanika razvijena u Srbiji registrovana pod nazivima NS Zlatka i NS Slatka. Ispitivanje bioaktivnih jedinjenja obuhvatalo je određivanje ukupnog sadržaja fenolnih jedinjenja i flavonoida, hlorofila a i b, kao i ukupan sadržaj karotenoida. Pored toga, antioksidativna aktivnost je procenjena merenjem kapaciteta ekstrakata semena lanika da neutrališu DPPH radikal. Rezultati su pokazali razlike u sadržaju minerala između ova dva genotipa, sa varijacijama u sadržaju natrijuma, kalijuma, kalcijuma, magnezijuma, cinka, gvožđa, mangana, bakra i fosfora. Oba genotipa sadrže značajne količine minerala, sa posebno visokim sadržajem kalijuma (1007,76-1047,74 mg/100 g) i magnezijuma (224,09-227,45 mg/100 g), što ih čini potencijalno vrednim kako za ishranu životinja, tako i za ljudsku ishranu. Takođe, analiza je ukazala na značajne količine ukupnih fenolnih jedinjenja (8,13-8,16 mg GAE/g suve materije) i flavonoida (5,91-6,41 mg QE/g suve materije) u oba genotipa, što ukazuje na

mogućnost njihove primene u prehrambenoj i farmaceutskoj industriji. Posebno treba istaći sastav hlorofila koji otkriva značajne razlike između dva genotipa, naročito u sadržajima hlorofila a i hlorofila b. Ova odstupanja ukazuju na razlike u fotosintetskoj sposobnosti i zrelosti semena. Ukupan sadržaj karotenoida je bio konzistentan između genotipova i iznosio je od 16,43 do 17,91 μg β-CE/g suve materije, što ukazuje na slične antioksidativne mehanizme. Ovo istraživanje pruža dragocen pregled biohemijskih karakteristika dva genotipa lanika, ukazujući na mogućnosti njihove potencijalne primene u poljoprivredi i ishrani ljudi.
Ključne reči: fenolna jedinjenja, flavonoidi, genotipovi, hlorofili, karotenoidi, lanik, seme