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Pericarp of colored-seeded common bean (*Phaseolus vulgaris* L.) varieties a potential source of polyphenolic compounds

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Abstract. Bioactive substances produced by plants are defined as secondary metabolites causing different pharmacological effects in human organism. Various plant raw materials, some known as vegetables or spices, are their source. Pericarp of white-seeded common bean varieties is a pharmacopoeial product traditionally used as an antidiabetic agent. The object of this study was to evaluate the biological value of pericarp of colored beans (cultivars: 'Małopolanka', 'Nida', 'Rawela', 'Tip Top', and 'Nigeria') compared to the reference white-seeded cultivar ('Laponia'). Bean pericarp was characterized by a high level of polyphenolic compounds and antioxidant activity. Its phenolic acid content (expressed as caffeic acid equivalents) was at a similar level, at least 0.1 mg g^{-1} (0.01%). The highest amount of flavonoids was accumulated by the cultivars with dark blue and black seeds, respectively 0.138 and 0.139 mg g^{-1} DW, as well as by the white-seeded cultivar (0.132 mg g^{-1} DW). The highest antioxidant activity (AA) was found for bean extracts of the cultivars 'Laponia' and 'Małopolanka', respectively 12.35 and 12.10%. Phenolic acid content was significantly positively correlated with AA of the bean extracts tested. This study indicates that pericarp of the colored-seeded bean cultivars is characterized by high biological value and can be used as a source of polyphenolic compounds.

Key words: *Phaseoli pericarpium*, phenolic acids, flavonoids, tannins, DPPH.

INTRODUCTION

Leguminous plants are a good source of starch, dietary fiber, protein, and minerals as well as of bioactive substances. Legumes that are most frequently consumed in the world include bean (*Phaseolus vulgaris*), chickpea (*Cicer arietinum*), lentil (*Lentis esculenta*), pea (*Pisum sativum*), faba bean (*Vicia faba*), peanut (*Arachys hipogea*), and soybean (*Glycine max*) (Sánchez-Chino et al., 2015; Bitocchi et al., 2017). The common bean (*Phaseolus vulgaris* L.), which is also known for its health-promoting effects, is a widely used component of many traditional diets (Madhujith et al., 2004; Sánchez-Chino et al., 2015). Evangelho et al. (2016) report that protein hydrolysates extracted from black beans can be used in specialized diets as valuable protein components with high antioxidant activity and high digestibility. Numerous studies have shown that common bean polyphenols have various effects on human health, exhibiting antimutagenic, antimicrobial, antidiabetic, and anti-inflammatory activities (Yang et al., 2018). The common bean is a very diverse species in terms of its morphological and biochemical

characteristics (Stoilova et al., 2005; Bozoglu & Sozen, 2011). Bean populations with different seed form, weight and color also show a varying level of polyphenols: anthocyanins, phenolic acids, and flavonoids (Zhao et al., 2014; García-Díaz et al., 2018; Armendáriz-Fernández et al., 2019). The color of bean flowers and seeds is associated with the presence of polyphenolic compounds, mainly flavonoids such as flavonic glycosides, anthocyanins, and condensed tannins, but the presence of anthocyanins has only been found in black and blue-violet beans (Reynoso-Camacho et al., 2006). The seed coat color not only defines and characterizes a specific bean variety, but also provides protection against seed pathogens (Armendáriz-Fernández et al., 2019). Scientific research links the antioxidant activity of beans to the presence of polyphenols (Akond et al., 2011; Hanis et al., 2017; Silva et al., 2018; Armendáriz-Fernández et al., 2019). Beninger et al. (2003) demonstrated that anthocyanins, glycosides, quercetins, and proanthocyanidins present in the seed coat of common bean exhibit significant antioxidant activity. These authors suggest that the antioxidant activity of the studied extracts can be due to the presence of condensed tannins. Akond et al. (2011) proved that bean genotypes rich in anthocyanins and other polyphenols show strong antioxidant activity, while the content of the above-mentioned compounds is generally higher in dark-seeded varieties than in light-seeded ones. The studies by Madhujith et al. (2004) and Oomah et al. (2010) indicated that beans, particularly those with colored seed coats, exhibit strong antioxidant activity, which is contributed by tannins and other phenolic compounds, formerly classified as non-nutritional factors. Likewise, Dzomba et al. (2013) evaluated that dark-seeded varieties are characterized by stronger antioxidant activity than light-seeded ones. When studying the antioxidant and antiproliferative activity of polyphenolic extracts derived from seeds of old endemic bean (*Phaseolus vulgaris*) varieties grown in southern Italy, Ombra et al. (2016) demonstrated that colored (spotted, red, and black) varieties are more active than non-pigmented ones.

Common bean pericarp (*Phaseoli pericarpium*) is a pharmacopoeial product with a high level of active substances (Łabuda et al., 2017), which is traditionally used as an antidiabetic agent (Helmstädter, 2010). A bean pod extract shows hypoglycemic and hypolipidemic activity, and also prevents fatty acid changes during diabetes (Pari & Venkateswaran, 2004). Berbecaru-Iovan et al. (2016) revealed that administration of ethanol extract of bean pericarp to rats with diabetes resulted in reduced blood glucose and cholesterol. Application of this extract had a significant antioxidant effect at reduced lipid peroxidation, which suggests its protective role probably associated with the presence of polyphenols. Bean extracts are nowadays perceived as promising agents in treatment of metabolic diseases: obesity and diabetes (Carai et al., 2009; Wu et al., 2010; Carai et al., 2011). Their potential importance as protective and preserving agents is also emphasized. *Parkia speciosa* Hassk., a tropical perennial plant of the Fabaceae family called bitter bean, is an edible and medicinal plant known in south Asia; its pods with beans have antioxidant activity, while pericarp extracts are reported to be antioxidant and hypotensive agents (Ko et al., 2014). Compared to an antibiotic, extracts from *Parkia speciosa* pods exhibit strong antioxidant activity and also noticeable antimicrobial activity against foodborne disease-causing bacteria (Gram-positive and Gram-negative ones) as well as against food spoilage causing bacteria (Wonghirundecha et al., 2014). The results obtained by Ko et al. (2014) indicate that gallic acid, catechin, ellagic acid, and quercetin can be the main polyphenolic constituents contributing to the strong antioxidant activity of empty *P. speciose* pods. Taking into account the valuable and

wide biological activity of bean pericarp extracts, a study was undertaken to determine the biological value of *Phaseoli pericarpium* herbal raw material originating from colored flowered and seeded varieties of common bean (*Phaseolus vulgaris* L.) compared to a typical pharmacopoeial variety with white flowers and seeds used as a reference variety in this experiment.

MATERIALS AND METHODS

Plant material and experimental design

The experimental material was bean pericarp (*Phaseoli pericarpium*) of six common bean (*Phaseolus vulgaris* L.) cultivars varying in seed color (Table 1). Five colored-seeded cultivars: 'Małopolanka', 'Nida', 'Rawela', 'Tip Top', and 'Nigeria', and a white-seeded cultivar, 'Laponia', were used in this study. All the bean cultivars tested are dwarf cultivars, domestically bred and used for dry beans. Seed material came from the following seed breeding and production companies: Krakowska Hodowla i Nasiennictwo Ogrodnicze POLAN sp. z o.o.–'Małopolanka', Plant Breeding and Acclimatization Institute in Radzików–'Nida', PlantiCo Hodowla i Nasiennictwo Ogrodnicze Gołębiew sp. z o.o.–'Rawela' and 'Tip Top', PlantiCo Hodowla i Nasiennictwo Ogrodnicze Zielonki sp. z o.o.–'Laponia'. Bean pericarp came from field experiments carried out over the period 2014–2015 at an experimental farm of the University of Life Sciences in Lublin (south-eastern Poland; 51°23'N, 22°56'E). No mineral fertilization or plant protection products were used in bean cultivation. Bean ripening occurred in the first half of August; harvest was done once at the stage of 75% of pods fully ripe. Bean plants were cut by hand and dried in a well-ventilated and darkened storage shed for a period of 3 weeks. After the bean plants were dried completely, pods were stripped by hand, they were additionally dried for a short time (7 days) in openwork crates, marketable pods, well-grown, without any symptoms of infection by pathogenic agents, and uninjured, were separated, and beans were removed from them by hand. Bean pericarp of all the cultivars was characterized by uniform color without spots and injuries as well as by a specific bean scent; was twisted, slightly tapered at the ends of the strands, up to 20 cm long. The outer surface of the pericarp was matt, crème yellow, and the inner whitish covered with a shiny skin and met the requirements of Polish Pharmacopoeia XI (2017). The material was stored in paper bags containing 500 g of pericarp material from each cultivar in a dry room at a temperature of 15–18 °C, in the absence of light and moisture as well as without foreign odors. Randomly selected pericarp samples, 30 pieces from each cultivar, were used to determine pericarp weight and color. The pericarp color (30 pieces of each variety) was assessed by a team of 5 people previously trained in this field. The color was determined taking into account various shades of crème yellow on a scale of 1–4, where 1 was the bright color (bright crème) and 4 the darkest (sandy). 1,000 seed weight was determined for large marketable beans (at a seed moisture content of 13%) based on a weight of 100 randomly selected seeds in 4 replicates (average of 4 replicates was multiplied by 10 and a weight of 1,000 seeds per g was obtained). Dry matter content in bean pericarp was determined by the oven-dry method at 105 °C. The seed and pericarp characteristics of the studied bean cultivars based on the two-year results are shown in Table 1.

Table 1. Morphological characteristic of the seed and pericarp of common bean cultivars

Cultivar	Seed color	Weight of 1,000 seeds, g	Weigh (g) of pericarp mean ±SD	Pericarp color	Dry matter content of pericarp % mean ± SD
Małopolanka	dark chestnut	405[a] ± 65	0.54[a] ±0.08	bright crème	91.26c ±0.15
Nida	orange-brown	456[a] ±74	0.46[a] ±0.09	bright crème	91.73c ±0.11
Rawela	dark red	595[b] ±91	0.69[b] ±0.14	yellow/ crème	91.24c ±0.22
Tip Top	navy blue with beige spots	270[c] ±72	0.54[a] ±0.07	bright crème	91.67c ±0.10
Nigeria	black	773[d] ±136	1.00[c] ±0.19	sandy	90.65b ±0.32
Laponia (control)	white	554[b] ±105	0.79[b] ±0.10	yellow/ crème	90.10a ±0.24

SD standard deviation; The same letters mean no significant differences.

Chemical analysis

All of the chemicals used in this study were purchased from Sigma-Aldrich Chemical Co. (France) and/or Merck Company (Germany). A Hitachi U-2900 spectrophotometer was used for absorbance measurements. All the chemical determinations were carried out in triplicate.

Total phenolic acids estimation

Total phenolic acids estimation was carried out according to Arnov method [Polish Pharmacopoeia VI, 2002]. 20 mL of methanol were added to 2.0 g of homogenized raw material placed in a round-bottomed flask and the mixture was heated at reflux for 30 min at 70 °C in a water bath. The hydrolysate was filtered through hard filter paper into a 100-mL Erlenmeyer flask. The filtered medium was returned to the round-bottomed flask with 20 mL of methanol and heated at reflux for 30 min. This process was repeated 3 times. The combined filtrates were taken to a tube with 1 mL of blueberry extract, 1 mL of 0.5 N hydrochloric acid, 1 mL of Arnov's reagent, and 1 mL of 1 N sodium hydroxide, and filled up to 10 mL with distilled water. The absorbance was measured at 490 nm. The total phenolic acid content was expressed as caffeic acid equivalent (CAE).

Total flavonoid estimation

Total flavonoid were estimated according to the spectrophotometric method according to Christ and Müller [Polish Pharmacopoeia IX, 2011], expressed as quercetin equivalent (QE). After 45 minutes the absorbance at 425 nm was measured. The concentration of total flavonoid content in the test samples was calculated from the calibration plot ($Y = 0.0159x + 0.0048$, $R\,2 = 0.999$) and expressed as mg quercetin equivalent (QE)/g of dried plant material.

Total condensed tannin contents

The tannins were determined by Folin-Ciocalteu method. About 0.1 mL of the sample extract was added to a volumetric flask (10 mL) containing 7.5 mL of distilled water and 0.5 mL of Folin-Ciocalteu reagent, 1 mL of 35% Na_2CO_3 solution and dilute to 10 mL with distilled water. The mixture was shaken well and kept at room temperature for 30 min. A set of reference standard solutions of gallic acid (20, 40, 60, 80 and 100 μg mL^{-1}) were prepared in the same manner as described earlier. Absorbance for test and standard solutions were measured against the blank at 725 nm with an UV/Visible

spectrophotometer. The tannin content was expressed in terms of % of GAE of extract [Polish Pharmacopoeia IX, 2011].

Anti-oxidation activity (AA)

AA (%) was evaluated on a base of the ability to neutralize the DPPH radicals by means of spectrophotometry according to Chen & Ho (1997): to do this, water extracts were prepared from raw material, extracts were then evaporated till dry and lyophilized. Analyses were performed for 20 μg mL^{-1} concentration. The absorbance measurements were made at $\lambda = 517$ nm after 30 minutes wavelength using spectrophotometer UVIKON 932 (Canberra Packard). The percent inhibition of DPPH radical was calculated as: DPPH inhibition (%) = $[(Abs_0 - Abs_{30})/Abs_0] \times 100\%$, where: Abs_0 is the absorbance of the control and Abs_{30} is the absorbance of the sample after 30 min.

Statistical analysis

The obtained study results for the period 2014–2015, both as regards the morphological characteristics of bean pericarp and the laboratory tests, were at a similar level and therefore the 2-year means are presented. The results were statistically analyzed by one-way analysis of variance and Tukey's t-test at a significance level of 5%. The correlation analysis between variables was done. Correlation coefficients were determined at significance level of 0.05. Calculations were performed using Statistica 13.1 software.

RESULTS

Polyphenolic compounds

Bean pericarp (*Phaseoli Pericarpium*), originating from the common bean cultivars of different seed color and seed size (as determined by thousand seed weight), was characterized by significant variations in weight (Table 1). The bean pericarp color at the physiological maturity stage slightly varied depending on the genetic characteristics of the specific cultivar, from light crème through yellow crème to sandy color. Pericarp of the black-seeded cultivar was characterized by the darkest color (sandy). The percentage of dry matter in pericarp of the white-seeded cultivar 'Laponia' was 90.1%, being significantly lower than in the cultivars with darker beans. The phenolic acid content (expressed as caffeic acid equivalents) in bean pericarp of the studied cultivars was at a similar level (Table 2), standing at least at 0.1 mg g^{-1} (0.01%) and thus meeting the pharmacopoeial requirements (Polish Pharmacopoeia IX, 2017). According to the statistical analysis there was no significant difference between bean varieties in the content of total phenols (Table 2).

Table 2. Total phenolic acid content expressed as caffeic acid equivalents in the dry mater of the pericarp of common bean cultivars

Cultivar	Phenolic acid (CAE) mg g^{-1}			
	Value ± SD	Min.	Max.	*V* (%)
Małopolanka	$0.18^a \pm 0.01$	0.16	0.20	6.0
Nida	$0.17^a \pm 0.02$	0.15	0.19	9.5
Rawela	$0.17^a \pm 0.02$	0.15	0.19	11.2
Tip Top	$0.17^a \pm 0.04$	0.12	0.21	25.1
Nigeria	$0.16^a \pm 0.03$	0.12	0.19	21.5
Laponia (control)	$0.18^a \pm 0.02$	0.16	0.21	10.0
Mean ±SD	0.15 ± 0.02			

SD standard deviation; *V* – variability coefficient; The same letters mean no significant differences.

The dark blue- and black-seeded cultivars ('Tip Top' and 'Nigeria') accumulated most flavonoids, respectively 0.138 and 0.139 mg g^{-1} DW, as well as the control cultivar (0.132 mg g^{-1} DW) (Table 3). There was a significant statistical difference between cultivars in the flavonoid content, where Tip Top, Nigeria and Lapland had the highest concentration of these bioactive compounds, while the cultivars Małopolanka, Nida and Rawela had lower concentrations without significant statistical difference between them. The bean cultivars studied did not differ significantly in terms of pericarp tannin content (Table 4), which was from 2.51% DW in the cultivar 'Tip Top' (dark blue seeds) to 2.99% DW in cv. 'Rawela' (dark red seeds).

Table 3. Flavonoid content (expressed as quercetin equivalents) in the dry mater of the pericarp of common bean cultivars

Cultivar	Flavonoid (QE) mg g^{-1}			
	Value ±SD	Min.	Max.	*V* (%)
Małopolanka	$0.127^{a} \pm 0.013$	0.114	0.140	10.4
Nida	$0.101^{a} \pm 0.006$	0.092	0.107	6.4
Rawela	$0.111^{a} \pm 0.010$	0.099	0.122	9.2
Tip Top	$0.138^{b} \pm 0.030$	0.109	0.167	21.9
Nigeria	$0.139^{b} \pm 0.036$	0.105	0.172	25.7
Laponia (control)	$0.132^{b} \pm 0.027$	0.106	0.159	20.5
Mean ±SD	0.14 ± 0.03			

SD standard deviation; *V* – variability coefficient; The same letters mean no significant differences.

Table 4. Tanin content (%) in the dry mater of the pericarp of common bean cultivars

Cultivar	Tanins (% DM)			
	Value ±SD	Min.	Max.	*V* (%)
Małopolanka	$2.76^{a} \pm 0.30$	2.37	3.22	11.1
Nida	$2.57^{a} \pm 0.30$	1.99	2.86	11.8
Rawela	$2.99^{a} \pm 0.31$	2.49	3.34	10.5
Tip Top	$2.51^{a} \pm 0.74$	1.64	3.24	29.7
Nigeria	$2.68^{a} \pm 0.72$	1.57	3.28	26.8
Laponia (control)	$2.85^{a} \pm 0.16$	2.61	3.01	5.7
Mean ±SD	2.51 ± 0.49			

SD standard deviation; *V* – variability coefficient; The same letters mean no significant differences.

Table 5. Antioxidant activity (AA) of the pericarp extracts determinated by DPPH of common bean cultivars

Cultivar	Value ±SD	Min.	Max.	*V* (%)
Małopolanka	$12.10^{a,b} \pm 1.11$	11.02	13.26	9.55
Nida	$9.82^{a,b,c} \pm 1.12$	8.74	10.98	11.43
Rawela	$8.15^{c} \pm 1.13$	7.07	9.30	13.77
Tip Top	$9.06^{b,c} \pm 1.12$	7.98	10.22	12.39
Nigeria	$8.76^{c} \pm 1.10$	7.67	9.92	12.81
Laponia (control)	$12.35^{a} \pm 1.18$	11.02	13.26	9.54
Mean ±SD	10.04 ± 1.93			

SD standard deviation; *V* – variability coefficient; The same letters mean no significant differences.

Antioxidant activity (AA)

The study demonstrated that AA of the bean pericarp extracts, as measured by DPPH method, significantly varied depending on the cultivar (Table 5). The highest AA was found for the bean extracts from the cultivars 'Laponia' (white seeds) and 'Małopolanka' (dark chestnut seeds), respectively 12.35 and 12.10%. AA of the investigated bean extracts was determined to be a trait characterized by low variation.

The analysis of the correlation coefficients of the studied parameters provided interesting information (Table 6). Phenolic acid content was found to be significantly positively correlated (r = 0.51) with AA of the extracts tested. At the same time, the contents of phenolic acids and tannins were significantly positively correlated (r = 0.68), whereas a negative correlation (r = -0.60) was revealed between the contents of tannins and flavonoids as well as between the contents of flavonoids and phenolic acids (r = -0.55).

Table 6. Pearson correlation coefficients between the active substances content and antioxidant activity (AA) for common bean dried pericarp extracts

Variable	Tanins	Flavonoids	Phenolic acids	AA
Tanins	1.00	-0.60*	0.68*	0.22
Flavonoids	-0.60*	1.00	-0.55*	0.17
Phenolic acids	0.68*	-0.55*	1.00	0.51*
AA	0.22	0.17	0.51*	1.00

* significant correlation.

DISCUSSION

The pharmacopoeial standards define bean raw material as dried common bean pericarp of exclusively white-flowered varieties (Polish Pharmacopoeia IX, 2017). The results presented in this paper indicate that colored flower and seed varieties are also potentially important material for phytotherapeutic use. Pericarp of the bean cultivars studied was characterized by a high level of bioactive compounds and antioxidant activity (AA), both in the group of colored-seeded cultivars and in the white-seeded cultivar. Despite their high morphological variation, the investigated cultivars were not strongly differentiated in the level of the analyzed polyphenolic components in pericarp as well as in the antioxidant activity of their respective extracts. This is in agreement with the hypothesis of Bitocchi et al. (2017) who suggest that the adaptation of European common bean varieties to long days, their cold tolerance as well as resistance to pests and diseases were of key importance, and this probably led to a reduction in their initial diversity. Polyphenols participate in defensive responses during infection, excessive sun exposure, injuries, and heavy metal stress, and one of their most important characteristics is their antioxidant activity, which is strictly related to the chemical structure (Kulbat, 2016). A similar level of polyphenols and little varying AA of European common bean varieties seem to be an effect of their adaptation to different and even less favorable growth and development conditions.

Phenolic acid content has a decisive influence on the suitability of bean pericarp as pharmacopoeial raw material (Ramírez-Jiménez et al., 2015). Hanis et al. (2017) showed that colored bean cultivars are characterized by higher total phenolic content and antioxidant capacity compared to the other ones. Likewise, García-Díaz et al. (2018) proved the level of polyphenols and AA to be higher in extracts from bean cultivars with a dark-pigmented seed coat compared to those obtained from white-seeded cultivars. Troszyńska & Ciska (2002) demonstrated that the total free phenolic acids, released from soluble esters and glycosides, were higher for the colored seed coat in beans than for the white one. In the present study, the content of phenolic acids in bean pericarp of the colored cultivars was statistically equal to the content of these constituents in the reference white-seeded cultivar. It was also shown that it is phenolic acids that have a major contribution to AA of bean extracts. Furthermore, there is a possibility of synergism of the action of phenolic acids and tannins in creating the antioxidant potential of beans because the contents of the above-mentioned polyphenolic components (known for their antioxidant action) were significantly correlated with each other. Phenols perform diverse and important functions in the plant. Phenylpropanoid metabolism and the amount of phenolic compounds increase under the influence of various environmental factors and stress conditions (Michalak, 2006). Seed polyphenolic

compounds are usually stored in the seed coat due to their antipathogenic activity (Dinelli et al., 2006). The seed coat in beans is characterized by a higher concentration of phenolic compounds than cotyledons. Condensed tannins and flavonoids mainly occur in the seed coat, whereas cotyledons are rich in cinnamic acid derivatives (Ranilla et al., 2007). Therefore, bean pericarp and seed coat remain a valuable source of polyphenolic compounds, known for their antioxidant action. In the present study, AA of the bean pericarp extracts was highest for the white- and dark chestnut-seeded cultivars. This can be due to the qualitative differences of the polyphenolic complex related to genetic variation. Ombra et al. (2016) found a clear correlation between the level of polyphenols and free radical absorption properties, and they also observed certain variation that can be attributed to the qualitative differences of the polyphenol mixture. Zhao et al. (2014) showed a significant positive correlation of phenolic substances and total antioxidant activity to DPPH scavenging activity for seed extracts from legume plants. Hanis et al. (2017) also revealed a positive and significant correlation between AA and total phenolic content, which was higher for dark colored legumes than for light colored ones. Ombra et al. (2016) suggest that flavonoids and anthocyanins are responsible for the antioxidant and antiproliferative effects of bean extracts, though extracts from dark beans showed lower values with respect to AA, despite their higher anthocyanin content, than extracts from speckled beans, which indicates that mainly flavonoids are responsible for their biological activity (Ombra et al., 2016). It should be mentioned that a certain divergence in the study results can arise from the methodological differences. Anti-inflammatory activity of the bean seed coat depends on phenolic content and antioxidant activity, which is significantly affected by the cultivar and extraction solvent (Oomah et al., 2010).

White beans are usually considered to have a low level of tannins (Diaz et al., 2010). Colored bean varieties, which are characterized by uniform or non-uniform color of the seed coat, accumulate larger amounts of pigments. Diaz et al. (2010) showed the content of condensed tannins and anthocyanins to vary and they found some relationship between the level of these components and seed color. In the opinion of these authors, the primary seed color determines the majority of the biochemical characteristics of the seed coat, whereas the secondary seed color, which is limited to small sectors such as strips or spots on the seed coat, is of lesser importance. The study results presented in this paper confirm this hypothesis in some way with respect to the pericarp, but not to the seed coat. The cultivars with the darkest primary seed color ('Tip Top' and 'Nigeria') analyzed in this study accumulated in their pericarp more flavonoids than the cultivars with a lighter primary color (except for the control cultivar), regardless of the secondary color. On the other hand, the equal level of tannins in the bean extracts analyzed suggests that these compounds are accumulated in the bean pericarp predominantly for defensive purposes. Troszyńska & Ciska (2002) showed the presence of condensed tannins in the colored seed coat of pea, but they did not find them to be present in the white coat. Moreover, these authors inform that pea tannins can be considered to be thermostable natural antioxidants, effective in food systems. Similarly, Amarowicz et al. (2008) inform that tannin extracts from common bean seeds exhibit potentially useful antibacterial activity.

CONCLUSIONS

The analysis of the chemical composition and antioxidant activity of the extracts from common bean pericarp proves that (i) pericarp of the colored bean cultivars is characterized by high biological value and can be used as a potential source of polyphenolic compounds; (ii) pericarp of the bean cultivars with colored and white seeds does not differ significantly in the level of phenolic acids and tannins as well as flavonoids in the case of the cultivars with the darkest seeds ('Tip Top' and 'Nigeria'); (iii) the cultivars with dark chestnut /orange-brown seeds ('Małopolanka' and 'Nida') are distinguished by high antioxidant activity (AA), which is equal to the action strength of the reference extracts obtained from the white-seeded cultivar ('Laponia') that meets the pharmacopoeial criteria; (iiii) phenolic acids are the group of components that are mainly responsible for AA of the bean pericarp extracts. The results presented in this paper indicate that it is justified to continue further detailed research in this area.

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