processes

MDPI

Article

Phenolic Profile and Antioxidant Potential of Beverages from Buckwheat and Side Streams after Beverages Production

Michał Adam Janiak [1], Magdalena Karamać [1], Katarzyna Sulewska [1], Ryszard Amarowicz [1], Petko Denev [2,*] and Adriana Slavova-Kazakova [3,*]

[1] Institute of Animal Reproduction and Food Research, Polish Academy of Sciences, Tuwima 10, 10-748 Olsztyn, Poland; m.janiak@pan.olsztyn.pl (M.A.J.); m.karamac@pan.olsztyn.pl (M.K.); k.sulewska@pan.olsztyn.pl (K.S.); r.amarowicz@pan.olsztyn.pl (R.A.)
[2] Laboratory of Biologically Active Substances, Institute of Organic Chemistry with Centre of Phytochemistry, Bulgarian Academy of Sciences, Plovdiv, 139 Ruski Blvd., 4000 Plovdiv, Bulgaria
[3] Laboratory of Lipid Chemistry, Institute of Organic Chemistry with Centre of Phytochemistry, Bulgarian Academy of Sciences, Acad. G. Bonchev Str. Bl. 9, 1113 Sofia, Bulgaria
* Correspondence: petko.denev@orgchm.bas.bg (P.D.); adriana.kazakova@orgchm.bas.bg (A.S.-K.); Tel.: +359-32-642759 (P.D.)

Abstract: Plant-based milk alternatives are a fast-growing segment of food industry resulting in the generation of large amounts of by-products, often containing comparable and even higher amounts of valuable phytochemicals than the target products. Common buckwheat (*Fagopyrum esculentum* M.) *Panda* variety has been selected for this study, which aims to compare the antioxidant potential of beverages produced from buckwheat whole and dehulled grains, as well as cakes obtained as residues. After combining, evaporating and freeze-drying, extracts were subjected to RP-HPLC-DAD, total phenolics and in vitro antiradical and antioxidant assays (FRAP, ABTS, DPPH and lipid autoxidation). Flavonoids (3.09 mg/100 mL) exceeded the content of phenolic acids (2.35 mg/100 mL) in the beverages prepared from dehulled grains, but their content (1.69 mg/100 mL) in the beverages from whole grains was lower than that of phenolic acids (2.93 mg/100 mL). The antiradical capacity of beverages did not differ significantly, regardless of the method used. In case of by-products, a higher ferric-reducing capacity and scavenging activity towards DPPH$^{\bullet}$ of cakes from whole grains compared to that from dehulled grains was established. The activity of cake extracts under lipid autoxidation conditions increased with the increase in their concentrations from 0.12 wt% to 0.16 wt% in the oxidizable substrate.

Keywords: dairy alternatives; buckwheat; functional beverages; polyphenols; antioxidant activity

check for updates

Citation: Janiak, M.A.; Karamać, M.; Sulewska, K.; Amarowicz, R.; Denev, P.; Slavova-Kazakova, A. Phenolic Profile and Antioxidant Potential of Beverages from Buckwheat and Side Streams after Beverages Production. *Processes* **2023**, *11*, 3205. https://doi.org/10.3390/pr11113205

Academic Editors: Iliyan Ivanov, Stanimir Manolov and Chi-Fai Chau

Received: 6 September 2023
Revised: 27 September 2023
Accepted: 7 November 2023
Published: 10 November 2023

Copyright: © 2023 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

1. Introduction

Dairy alternatives take the prevailing position in the global health and wellness food market, especially in the functional beverages sector. The demand for nondairy beverages has significantly increased (by 61% since 2012) [1]. Many researchers explain this phenomenon as a result of the rising number of people suffering from lactose intolerance or consider it as a result of new lifestyles including vegetarian or vegan diets, environmental issues and ethical concerns regarding the consumption of animal milk [2–7]. Vakima et al. stated that plant-based milk alternatives (PBMAs) are not an entirely new product category, as they have historically been part of many food cultures; for example, soy milk in China and horchata (tigernut milk) in Spain [4]. However, increasing the consumption of plant-based foods while decreasing the consumption of animal products at the same time has emerged as a major dietary trend in the last two decades [8].

The most popular PBMA is soymilk, but the market focus is expected to shift from the common soya, almond or rice-based products to new ones from other plant sources [6]. Thus, their processing leads to the generation of large amounts of by-products, i.e., residues,

often containing comparable and even higher amounts of valuable phytochemicals than the target products. Side streams from agriculture and the food industry can be considered as a permanent and cheap source of high added-value components, since modern technologies allow their recovery [9–12].

A suitable raw material for PBMAs' production is buckwheat, which, despite its advantages over other widespread sources like soy, rice, oat and even almond, does not fall into the mandatory assortment of most manufacturers. Buckwheat belongs to the genus *Fagopyrum* of the Polygonaceae family. The genus contains 15 to 16 species of plants including two important food crops—buckwheat (*F. esculentum* Moench) and tartary buckwheat (*F. tartaricum* (L.) Gaertn.) and cultivated tall buckwheat (*F. cymosum*) and *F. homotropicum*. Buckwheat does not require chemical treatment (pesticides) like rice fields, for instance, or even soil improvers. The plant itself renews the ecosystem in which it grows, improving the soil properties, and also helps to preserve and expand the bee population [13]. In the diet, buckwheat grain is a valuable source of nutrients. It is high in protein, B vitamins and minerals including potassium, magnesium, calcium, iron, manganese, and zinc [14]. Also noteworthy is the high content of phenolic compounds including phenolic acids, flavonoids and tannins, which are known for their bioactivity and may have a beneficial effect on the human body [15–17]. Positive effects attributed to buckwheat consumption were observed in conditions such as hypertension, hypercholesterolemia, diabetes and other cardiovascular diseases. Most of the scientific data concerning its primary and secondary metabolites refer to buckwheat hulls, whole grains or the groats from which the flour is made [14–18]. In recent years, the use of buckwheat flour or flakes as additives in the preparation of innovative products with functional food values, including bakery products (bread, cookies and biscuits), noodles, pasta and porridge, as well as tea and beer, is being considered [19]. Moreover, there are several studies on the use of buckwheat for the development of cereal-based non-alcoholic beverages, like kvass and boza, the preparation of which involves fermentation [20–24].

Plant-based analogues of milk are typically produced from plant grains, seeds and nuts via classical water extraction [25]. This process can be supported by innovative technologies with high-pressure processing, pulse electric field, ohmic heating, cold plasma or ultrasound treatment. Controlled fermentation is also often used in the production of PBMA beverages [25,26]. After extraction, the beverage is filtered from the solid residue (cake), which is the main waste in the production of beverages. However, this material is still valuable from a nutritional point of view, e.g., cake, or in case of soy milk production 'dregs', is a functional product that contains proteins, lipids, crude fiber and phenolic compounds [27]. The research on buckwheat-based milk alternatives is very limited compared to research on the other crops listed above, and more efforts are required to continue innovation of less-studied sources for PBMAs production. We hypothesized that, similarly to other pseudocereals, buckwheat could be a suitable raw material for the production of PBMA; moreover, seed cakes obtained after processing could be a useful source of biologically active phenolic compounds. Therefore, the aim of the study was to evaluate the phenolic profile and antioxidant capacity of the target milk-like beverages (from dehulled and whole grain buckwheat) and cakes obtained as side streams during beverages production. Different model systems (autoxidation in model lipid substrate, ferric-reducing antioxidant power (FRAP) assay, as well as antiradical activity toward $ABTS^{\bullet+}$ and $DPPH^{\bullet}$) have been applied in order to obtain information about the antioxidant potential of the buckwheat-based beverage(s) and the remaining by-product, i.e., the cake.

2. Materials and Methods

2.1. Plant Material and Chemicals

Whole and dehulled grains of common buckwheat (*Fagopyrum esculentum* Moench), Panda cultivars, were obtained from the Department of Cultivation and Production in Palkije, Poland. They were placed in paper bags and stored at room temperature until the analyses were performed.

Folin–Ciocalteu's phenol reagent (FCR), 2,2-diphenyl-1-picrylhydrazyl (DPPH) radicals, gallic acid, 2,2′-azinobis-(3-ethylbenzothiazoline-6-sulfonic acid) diammonium salt (ABTS), 6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid (Trolox), 2,4,6-tris(2-pyridyl)-s-triazine (TPTZ), high-performance liquid chromatography (HPLC) standards, including gallic acid, caffeic acid, *p*-coumaric acid, protocatechiuc acid, *p*-hydroxybenzoic acid, (+)-catechin, (–)-epicatechin, orientin (luteolin 8-*C*-β-d-glucoside), homoorientin (luteolin 6-*C*-β-d-glucoside), rutin (quercetin 3-*O*-β-rutinoside), hyperoside (quercetin 3-*O*-β-D-galactoside) and quercetin were obtained from Sigma-Aldrich (St. Louis, MO, USA). Sodium persulfate, ferrous chloride and the solvents were provided by Avantor Performance Materials (Gliwice, Poland).

2.2. Preparation of Buckwheat Beverage

Preliminarily soaked (for at least 8 h) dehulled and whole buckwheat grains were rinsed and ground in a blender with water at ratio 1:4 (*v*/*v*). The resulting homogenates were subjected to filtration using ERNESTO® Veggie Drink Maker (Berlin, Germany) in order to separate the cream-like beverages and the residues (cakes). Beverages from whole and dehulled buckwheat grains were called BWG and BDH, respectively, and the names of cake samples from whole and dehulled grains were abbreviated to CWG and CDH, respectively. Both separated fractions were freeze-dried (FreeZone 6 Liter Console System, Labconco, Kansas City, MO, USA) prior to the future analyses. The procedure of obtaining beverages and cakes was carried out in triplicate for each type of material.

2.3. Extraction Procedure

The freeze-dried beverages and cakes were extracted using 80% methanol (*v*/*v*) and 80% acetone (*v*/*v*), sequentially [28]. First, solid material was suspended in 80% methanol (*v*/*v*) in ratio of 1:10 (*w*/*v*). After 15 min shaking at 60 °C with solvent, the suspension was filtered. The procedure was repeated three times, and the obtained filtrates were combined. In the next step, the residue after extraction with 80% methanol (*v*/*v*) was mixed with 80% acetone (*v*/*v*) and extracted exactly as described in the first step. The filtrates were combined with the methanolic ones. Organic solvents were removed using a rotary evaporator (R-210, Büchi Labortechnik AG, Flawil, Switzerland) and water residue was freeze-dried. Crude extracts were grained using a mortar and pestle and stored in closed containers in darkness until analyses of total phenolic content, phenolic profile and antioxidant capacity were conducted.

2.4. Total Phenolic Content Determination

The total phenolic content of the beverages and cakes was determined, according to Sulewska et al. [29] with (+)-catechin as a standard. The results for beverages were expressed as mg of (+)-catechin equivalents per 100 mL of final product (mg catechin/100 mL) and for cakes as mg of catechin equivalents per 100 g of dry weight of cake (mg catechin/100 g DW).

2.5. Analysis of the Phenolic Profile Using RP-HPLC-DAD

Phenolic compound profiles of the buckwheat cakes and beverages were analyzed [30,31] using the UHPLC Shimadzu Nexera X2 system (Shimadzu, Kyoto, Japan), which consisted of modules: a CBM-20A system controller, a CTO-20AC column oven, a DGU-20A5R degassing unit, two LC-30AD pumps, a SIL-30AC autosampler and a SPD-M30A photodiode array detector (DAD). Separation was achieved with a Kinetex C18 column (3 × 75 mm, 2.6 μm; Phenomenex, Torrance, CA, USA). The column oven was set up to 25 °C. The binary gradient mode used with mobile phase consisted of solvent A: acetonitrile–water–trichloroacetic acid (5:95:0.1; *v*/*v*/*v*) and solvent B: acetonitrile–trichloroacetic acid (100:0.1; *v*/*v*). Gradient was set along these parameters: 0–12 min, 0–20% B; 12–17.5 min, 60% B; 17.5–18 min 0% B; 18–20 min, 0% B. the flow rate was 0.5 mL/min. Before the injection, (1.5 μL) samples were filtered (0.22 μm, polyethersulfone membrane filter, TPP Techno

Plastic Products AG, Trasadingen, Switzerland). The elution was monitored over a wavelength range of 200–400 nm. The phenolic quantification performed using the external standard method was carried out at a wavelength of 280 and 350 nm for phenolic acids and flavonoids, respectively. The content of the compounds in beverages was expressed as mg per 100 mL of final product (mg/100 mL) and in cakes as mg per g of dry weight of cake (mg/g DW).

2.6. Determination of Antiradical Capacity towards $ABTS^{\bullet+}$

$ABTS^{\bullet+}$ scavenging capacity of the beverages and cakes was determined according to method of Re et al. [32]. The results were calculated as the Trolox equivalent and were presented as mmol Trolox per 100 mL of final product (mmol Trolox/100 mL) for beverages and as mmol Trolox per 100 g of dry weight (mmol Trolox/100 g DW) for cakes.

2.7. Determination of Ferric-Reducing Antioxidant Power

FRAP assay was performed in the conditions described by Benzie & Strain [33]. The results were expressed as mmol of Fe^{2+} per 100 mL of final product (mmol Fe^{2+}/100 mL) for beverages and for cakes as mmol of Fe^{2+} per 100 g of dry weight of cake (mmol Fe^{2+}/100 g DW).

2.8. Determination of DPPH Radical Scavenging Capacity

Radical scavenging capacity using the stable $DPPH^{\bullet}$ was assayed according to the previously published method [30,34]. The results were calculated based on the standard curve on the Trolox and expressed as mmol Trolox per 100 mL of final product (mmol Trolox/100 mL) for beverages and as mmol Trolox per 100 g of dry weight (mmol Trolox/100 g DW) for cakes.

2.9. Determination of Chain-Breaking Antioxidant Activity

Lipid substrate (lard) was oxidized at 80 °C in a flow of air blowing at a rate of 100 mL/min. Samples containing 0.12 wt%, 0.16 wt%, and 0.2 wt% of the studied extracts were prepared by adding aliquots of their methanol solutions to 2 g of the substrate [35]. The concentration of peroxides was determined via a modified iodometric method [36], at certain time intervals, and was monitored graphically. Kinetic curves were plotted based on the mean values of three independent experiments.

2.10. Statistical Analysis

Three samples of each type of product were prepared. All the analyses were performed in triplicate. The results were subjected to analysis in the form of Student's *t*-test, which was performed for a pair of products (beverages and cakes). Those analyses were performed using STATISTICA 10 (StatSoft Inc., Tulsa, OK, USA).

3. Results and Discussion

The total phenolic content of buckwheat grain beverages and cakes is shown in Table 1. The beverages prepared from dehulled (BDH) and whole (BWG) buckwheat grains did not differ significantly ($p \geq 0.05$) in terms of total phenolic content. In turn, the total phenolic content of cake from whole buckwheat grains (CWG) was 681 mg catechin/100 g DW and this value was significantly higher ($p < 0.05$) than that determined for cake from dehulled buckwheat grains (CDH) containing 840 mg catechin/100 g DW. It is known that buckwheat grain phenolics are accumulated mainly in hulls and that the total phenolic content of buckwheat hulls is 434–525 mg/100 g and is higher than that of dehulled grains [37,38]. With this in mind, the lack of differences in total phenolic content of beverages from whole and dehulled grains found in our study may be due to the poor extractability of phenolics with water from hulls. The phenolic compounds of the hulls remained in the cakes, hence the higher total phenolic content in cakes from whole grain processing compared to cakes from dehulled grain.

Table 1. Total phenolic content, antiradical capacity towards $ABTS^{\bullet+}$ and $DPPH^{\bullet}$, and ferric-reducing antioxidant power (FRAP) of the beverage and cake from buckwheat whole grains (BWG and CWG, respectively) and beverage and cake from dehulled buckwheat grains (BDH and CDH, respectively).

Sample	Total Phenolic Content	ABTS Assay	FRAP	DPPH Assay
	[mg catechin/100 mL]	[mmol Trolox/100 mL]	[mmol Fe^{2+}/100 mL]	[mmol Trolox/100 mL]
BDH	44.7 ± 7.0	0.349 ± 0.049	418 ± 52	0.162 ± 0.029
BWG	43.7 ± 2.9	0.331 ± 0.029	385 ± 61	0.148 ± 0.018
	[mg catechin/100 g DW]	[mmol Trolox/100 g DW]	[mmol Fe^{2+}/100 g DW]	[mmol Trolox/100 g DW]
CDH	681 ± 83 *	5.70 ± 0.79	6591 ± 964 *	1.349 ± 0.105 *
CWG	840 ± 47 *	5.30 ± 0.34	8157 ± 494 *	1.915 ± 0.187 *

Values marked with * for BDH versus BWG and CDH versus CWG separately for each parameter differ significantly with $p < 0.05$. DW—dry weight.

The beverages prepared from dehulled and whole grains, as well as from cakes after beverages production, were subjected to RP-HPLC-DAD analysis in order to obtain information about their phenolic profile. Figure 1 depicts typical phenolic fingerprints of extracts obtained from cakes and beverages. Of the peaks in the chromatograms, 22 were identified as corresponding to phenolic compounds. A list of those compounds is shown in Table 2, in which the contents of individual phenolics in beverages and cakes are also provided. Ten phenolic acids and 12 flavonoids were detected. Most of the compounds were identified by comparing the chromatographic data with those for the standards. However, compounds 3–5, 7, 9, 11, 16, 17, 20 and 21 were only tentatively assigned to certain classes of phenolics based on their UV-DAD spectra. Compounds 3, 4, 7 and 11 exhibited maxima typical for phenolic acids [39]. Spectra of compounds 5, 16, 17, 20 and 21 were closely related to flavonoids [40], and among them, those of compounds 5 and 21 were characteristic of flavanols [40]. All phenolic acids and flavonoids with recognized structure in our study were previously reported in buckwheat grains [38,41–43].

Individual phenolic acids, with the exception of protocatechuic acid, were identified in all beverages and cake extracts (Figure 1, Table 2). Flavonoids differentiated the quality profile of beverages and cakes to a greater extent. The most diverse flavonoid profile, with the presence of all detected compounds of this class, was identified in the cakes obtained by processing whole buckwheat grains. Orientin, homoorientin, hyperoside and flavonoid (20) were detected only in CWG. In turn, two other flavonoids (16 and 17) were not present in BDH and CDH. The absence of orientin, homoorientin and hyperoside, as well as protocatechuic acid in dehulled grain products (BDH and CDH), was not surprising, considering the literature reports indicating that these compounds were identified in buckwheat hull, but not in buckwheat groats [38,44]. In turn, the lack of orientin, homoorientin and hyperoside in BWG was probably related to their poor extractability from hulls with water, which we mentioned when discussing the total phenolic content.

The quantitative profile of phenolic compounds also differentiated both beverages and cakes from each other, as well as products obtained from whole and dehulled grains (Table 2). Overall, the content of flavonoids was significantly higher than that of phenolic acids in cakes (2.5 times in CDH and 6.8 times in CWG). In the case of beverages, flavonoids only slightly exceeded the content of phenolic acids in BDH, and their content in BWG was even lower (1.69 g/100 mL) than the content of phenolic acids (2.93 g/100 mL). However, when comparing the proportions of content of compounds of each class in terms of the type of grains used to obtain beverages and cake, the use of whole grains resulted in a lower proportion of phenolic acid contents and higher proportion of flavonoid contents than for dehulled grains. The dominant phenolics of CDH were flavanol (21), rutin, (–)-epicatechin and (+)-catechin. The contents of the last two was significantly higher ($p < 0.05$) in CDH (15.80 and 6.05 mg/g DW, respectively) than in CWG (7.71 and 1.48 mg/g DW, respectively). This relationship was consistent with literature data on the higher abundance of these compounds in groats or flour from dehulled grains than in hulls [38,41]. Dziadek

et al. [37] even reported that among phenolics of dehulled grains, no flavonoids other than derivatives of flavan-3-ols were found. In turn, in our study, rutin—which in many reports was mentioned as the main phenolic compound of buckwheat seeds [43,45,46]—was present in significant amounts in both CDH (10.40 mg/g DW) and CWG (7.72 mg/g DW), but its contribution to the profile of phenolic compounds of beverages was low. This was quite surprising, as one would expect that rutin, which contains diglycoside residue in its chemical structure, should be easily extractable into water. Probably interactions of rutin with other matrix compounds hindered its extraction. The beverages were dominated by (–)-epicatechin, flavonoid (21), (+)-catechin and quercetin among flavonoids and the content of these compounds was significantly higher ($p < 0.05$) in BHD than in BWG (Table 2). However, as mentioned above, the contribution of phenolic acids was significant in the profile of phenolic compounds of beverages, and the contents of most of them were comparable or higher than the contents of main flavonoids.

Table 2. Phenolic contents in beverage and cake from buckwheat whole grains (BWG and CWG, respectively) and beverage and cake from dehulled buckwheat grains (BDH and CDH, respectively).

No.	Compound	BDH	BWG	CDH	CWG
		[mg/100 mL]		[mg/g DW]	
1	Gallic acid	0.153 ± 0.026	0.148 ± 0.033	1.57 ± 0.32 *	2.4 ± 0.14 *
2	Protocatechuic acid	-	0.317 ± 0.110	-	3.62 ± 0.62
3	Phenolic acid [1]	0.333 ± 0.054	0.280 ± 0.008	2.84 ± 0.62 **	1.14 ± 0.11 **
4	Phenolic acid [1]	0.655 ± 0.120	0.558 ± 0.069	5.88 ± 1.1 **	2.29 ± 0.30 *
5	Flavanol [2]	0.386 ± 0.065	0.428 ± 0.069	5.37 ± 0.91 ***	12.1 ± 0.89 ***
6	*p*-Hydroxybenzoic acid	0.032 ± 0.007 *	0.0837 ± 0.024 *	0.29 ± 0.09 **	0.534 ± 0.051 **
7	Phenolic acid [1]	0.106 ± 0.020 **	0.299 ± 0.063 **	0.61 ± 0.09	0.612 ± 0.16
8	(+)-Catechin	0.503 ± 0.083 *	0.309 ± 0.065 *	6.05 ± 1.36 **	1.48 ± 0.198 **
9	Phenolic acid [1]	0.522 ± 0.103 *	0.311 ± 0.030 *	4.75 ± 0.88 **	1.48 ± 0.24 **
10	Caffeic acid	0.062 ± 0.007 *	0.379 ± 0.166 *	0.47 ± 0.26	0.72 ± 0.26
11	Phenolic acid [1]	0.447 ± 0.076	0.472 ± 0.090	3.26 ± 0.88 *	1.15 ± 0.18 *
12	(–)-Epicatechin	1.001 ± 0.149 **	0.354 ± 0.173 **	15.80 ± 2.65 **	7.71 ± 0.18 **
13	*p*-Coumaric acid	0.037 ± 0.006 *	0.085 ± 0.023 *	0.40 ± 0.10	0.32 ± 0.09
14	Homoorientin	-	-	-	2.86 ± 0.13
15	Orientin	-	-	-	2.83 ± 0.027
16	Flavonoid [3]	-	0.091 ± 0.019	-	11.30 ± 0.20
17	Flavonoid [3]	-	0.076 ± 0.012	-	11.21 ± 0.44
18	Rutin	0.082 ± 0.018	0.043 ± 0.004	10.40 ± 1.53 *	7.72 ± 0.82 *
19	Hyperoside	-	-	-	19.02 ± 2.38
20	Flavonoid [3]	-	-	-	1.83 ± 0.22
21	Flavanol [2]	0.656 ± 0.0987 **	0.209 ± 0.059 **	11.3 ± 0.63	12.5 ± 0.96
22	Quercetin	0.463 ± 0.071 **	0.179 ± 0.07 **	1.14 ± 0.33 ***	6.66 ± 0.18 ***
	Sum of phenolic acids	2.35	2.93	20.1	14.3
	Sum of flavonoids	3.09	1.69	50.1	97.2

[1] Expressed as caffeic acid equivalent. [2] Expressed as (+)-catechin equivalent. [3] Expressed as quercetin equivalent. No. corresponds to peak numbers. Values for BDH versus BWG and CDH versus CWG separately for each compound differ significantly with $p < 0.05$ (*), $p < 0.01$ (**) or $p < 0.001$ (***). DW—dry weight.

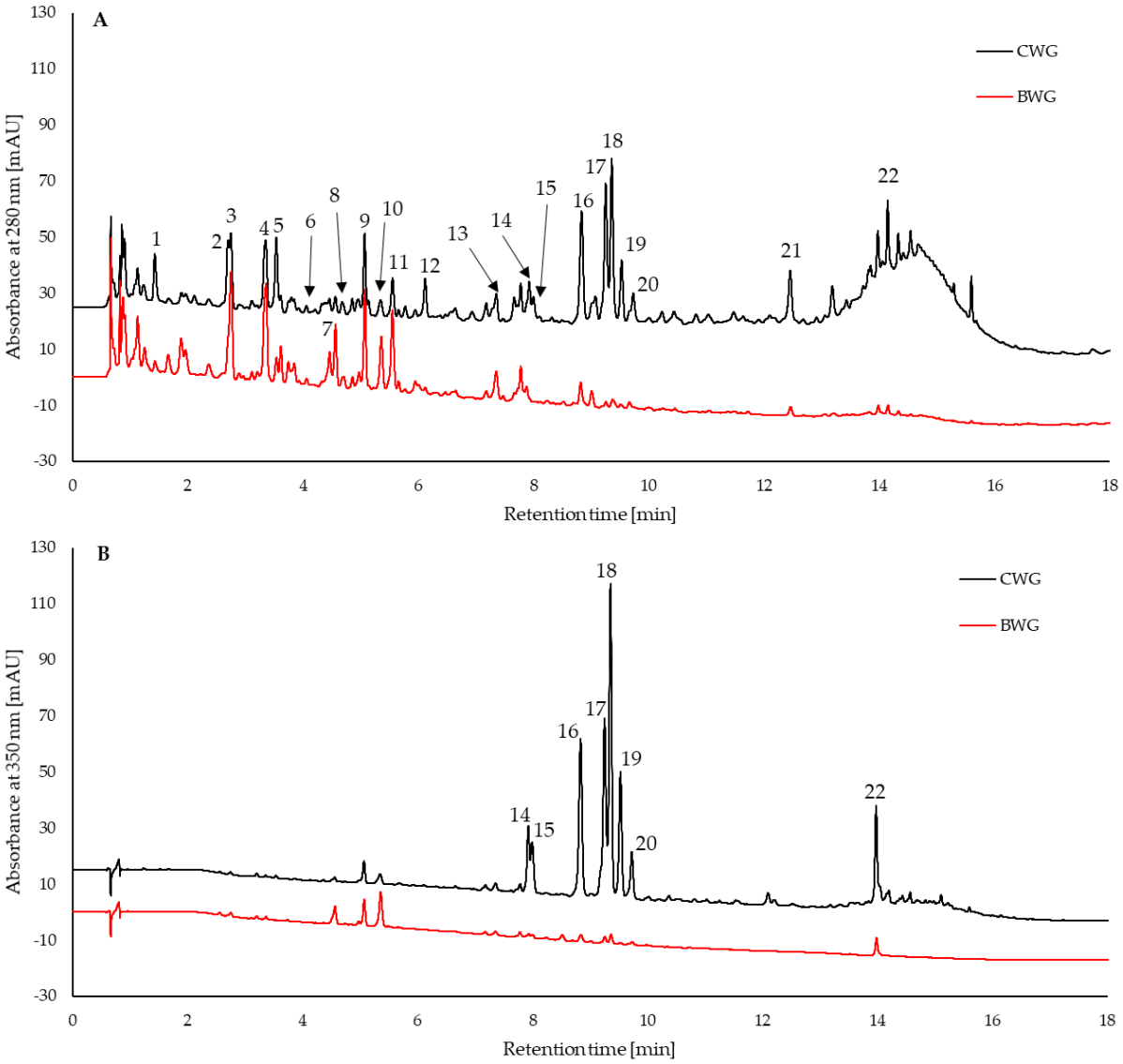

Figure 1. Typical chromatograms of extracts obtained from buckwheat beverage (BWG) and cake (CWG) recorded at λ = 280 nm (**A**) and λ = 350 nm (**B**) using RP-HPLC-DAD.

The results regarding the antioxidant capacity of beverages and cakes obtained after their production from whole and dehulled buckwheat grains are shown in Table 1. The ferric-reducing antioxidant power of beverages produced from both types of material did not differ significantly ($p \geq 0.05$). Similarly, the antiradical capacity towards $ABTS^{\bullet+}$ and $DPPH^{\bullet}$ of beverages prepared using whole grains was not significantly different ($p \geq 0.05$) compared to that of beverages made from dehulled grains. For by-products obtained from beverage production, significantly higher ($p < 0.05$) FRAP and $DPPH^{\bullet}$ scavenging capacity of CWG than CDH was determined. However, the antioxidant capacity of both cake samples in the ABTS assay was at the same level ($p \geq 0.05$). Direct comparison of the obtained values with literature data is difficult due to the limitations of such data. To the best of our knowledge, this research is the first to demonstrate the antioxidant potential of a by-product after the creation of buckwheat drinks. Nevertheless, the results of all antioxidant assays for beverages and the DPPH and FRAP assays for cakes correlated with the total phenolic content in beverages and cakes. This confirms that the phenolic compounds of products were responsible for the detected antioxidant activity. According to literature data, rutin as a major phenolic compound, together with other flavonoids, strongly contributed to the antioxidant capacity of buckwheat grains in FRAP, DPPH and

ABTS assays [43]. In our research, flavonoids may play a significant role as antioxidants only in cakes. In beverages, due to the lower content of flavonoids, it seems that phenolic acids may be more important in inducing antioxidant potential. In turn, the stronger antioxidant potential of CWG than CDH can be attributed to the higher content of flavonoids and their greater diversity in cake from whole grain. Hyperoside, quercetin, orientin and homoorientin, which predominate in CWG, are known for their high antiradical activity and reducing power [41,47]. Furthermore, other compounds than those listed in Table 2 may have been present in the extracts of beverage and cake from whole grains. In the chromatograms of these products, a "hump" at a retention time of 14–15 min is shown (Figure 1). This is characteristic of proanthocyanins [43]. The presence of compounds of this class in whole buckwheat gains and hulls was reported previously [16,48]. Buckwheat seed proanthocyanins are capable of scavenging free radicals and have a reducing power greater than that of simple phenolic compounds [49]. Interestingly, Cui et al. found that cytoprotective activities of flavonoid monomers from buckwheat are closely related to their antioxidant activity, indicating that buckwheat extracts could serve as cytoprotective agents [50]. Overall, using buckwheat whole grain for the production of dairy alternatives (BWG) from one side resulted in a product with an antioxidant potential similar to that of products prepared with dehulled grains (BDH) but with a greater variety of phenolic compounds. From the other hand using whole grains resulted with a residue that was more differentiated in terms of its phenolic profile, especially its flavonoid profile, and more potent in terms of antioxidant activity. It can be successfully used as a side stream that can be valorized to obtain added-value products, e.g., extracts rich in certain phenolic class.

Concerning that, the beverage is water-based and extracts obtained are lipid insoluble, the antioxidant activity under lipid autoxidation conditions has been studied only for extracts from the by-product, i.e., the cake. Kinetic curves of lipid hydroperoxides accumulation during autoxidation of a lipid substrate at 80 °C in the presence of CDH and CWG are given on Figure 2.

The kinetic parameters obtained after processing the curves are summarized in Table 3. Conclusions can be drawn not only on the basis of the parameters obtained for CWG and CDH within this model system, but also by comparing the results for both cakes' extracts from different model systems (Tables 1 and 3).

The chain-breaking antioxidant activity of the studied buckwheat extracts obtained from the cake depends on their concentration in the oxidizable substrate. The highest activity has been observed for CWG at concentrations of 0.16 wt% and 0.20 wt% (Figure 2, Table 3). Increasing the concentration of CWG from 0.12 wt% to 0.16 wt% leads to an increase in the induction period IP_A of more than 10 h, and the initial oxidation rate R_A decreases almost twice (Table 3). An increase in activity was also observed for CDH, for the same concentration range, but to a lesser extent. A further increase in concentration from 0.16 wt% to 0.20 wt% did not result in a significant change in the parameters (Table 3). The sum of flavonoids is almost twice as high in the cake when whole grains are used as raw material (CWG), but phenolic acids are more abundant in CDH (Table 2). Furthermore, only half of the flavonoids expressed as mg per 1 g dry weight of CWG in Table 2 are found in CDH. The main structural features of the radical scavenging capability of flavonoids are the presence of a catechol fragment in ring B, which possesses excellent electron-donating properties; an OH-group at position 3 in ring C; and a 2,3-double bond conjugated with the 4-oxo group responsible for the electron delocalization [51,52]. Quercetin meets all the requirements exhibiting the highest activity. CWG contains a six-fold higher amount of quercetin compared to CDH but four- and two-fold lower content of catechin and epicatechin, respectively. Glycosides show a decrease in the inhibitory effect compared to aglycones, and even the appearance of a pro-oxidant effect under lipid autoxidation conditions [45,52,53]. A lack of correlation between rutin contents and antioxidant activity of buckwheat was reported by Oomah et al. [45]. According to Kancheva et al. [54], the effect of the glycoside depends on its concentration and on the nature and position of the sugar. Thus, the activity of the studied extracts can be a result of overlapping antioxidant

and/or pro-oxidant effect of the phenolic compounds, especially flavonoids. Possible synergistic or antagonistic interactions between the phenolic acids and/or flavonoids may also explain the results obtained [54,55].

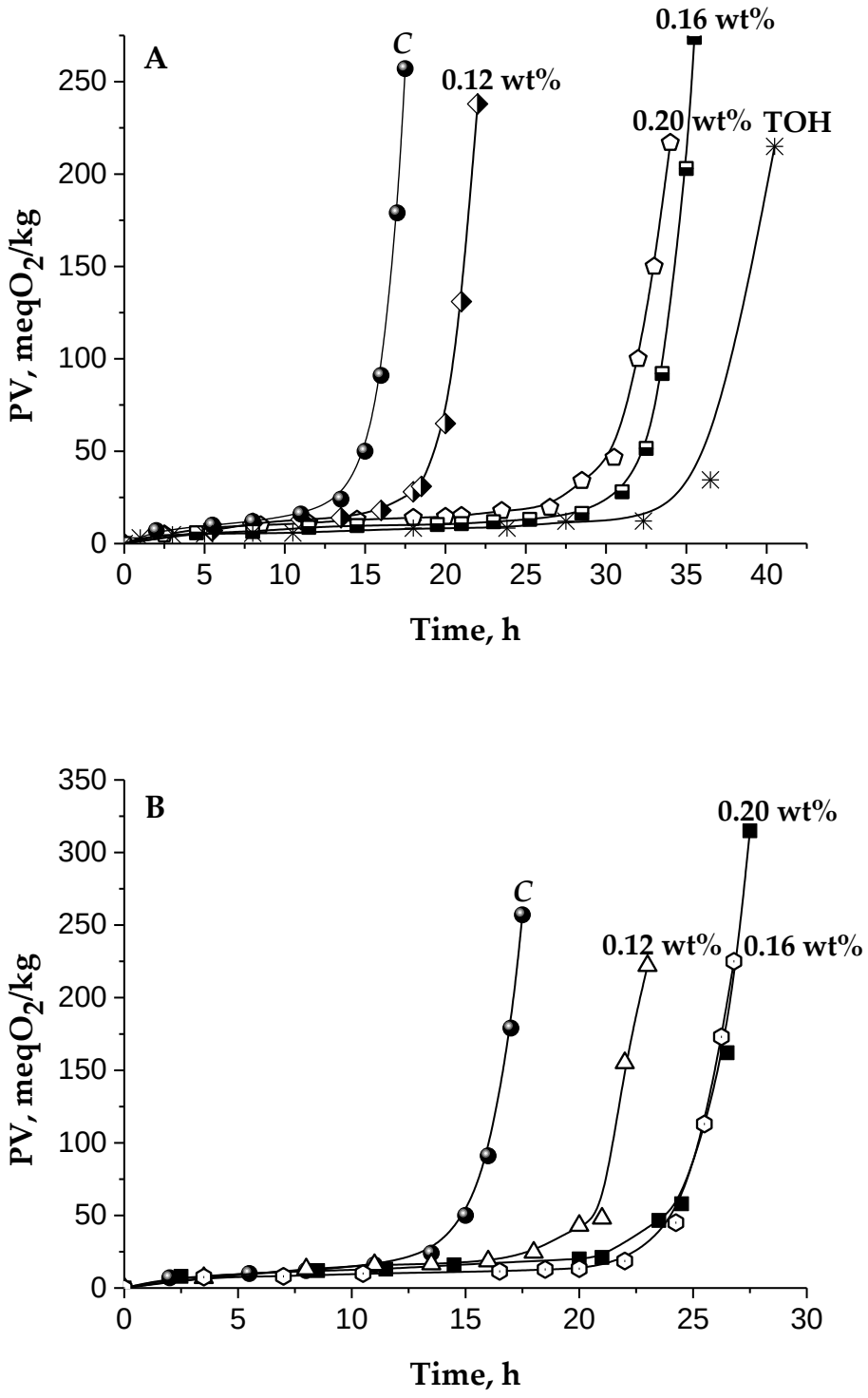

Figure 2. Kinetic curves of accumulation of lipid hydroperoxides during lipid autoxidation at 80 °C in the presence of 0.12 wt%, 0.16 wt% and 0.20 wt% of the obtained cake extracts CWG (**A**) and CDH (**B**).

Table 3. Kinetic parameters characterizing autoxidation at 80 °C in the presence of extracts from the cake obtained after filtration of the milky-like buckwheat beverage.

Cake Extracts		The Main Kinetic Parameters during TGSO Autoxidation			
Abbr.	**Concentr. wt%**	**IP_A h**	**PF -**	**R_A, 10^{-7} Ms^{-1}**	**ID -**
CDH	0.12	20.5 ± 1.5	1.2	1.56 ± 0.08	0.9
	0.16	24.7 ± 1.5	1.5	0.97 ± 0.06	1.4
	0.2	25.5 ± 1.5	1.5	1.21 ± 0.09	1.1
CWG	0.12	20.0 ± 1.5	1.2	1.49 ± 0.09	0.9
	0.16	33.0 ± 2.0	1.9	0.76 ± 0.04	1.8
	0.2	32.0 ± 2.0	1.9	0.69 ± 0.06	2

Control sample parameters: IP_C = 17 ± 1.5 h; R_C = 1.36, 10^{-7} Ms^{-1}.

4. Conclusions and Future Outlook

The antioxidant capacity of beverages obtained from dehulled or whole buckwheat grains, which was measured by applying ABTS and FRAP assays, revealed similar outcomes. Buckwheat dairy alternatives from whole grains exhibit a total phenolic content and an antioxidant potential similar to those prepared with dehulled grains but were characterized by greater flavonoid variety. On the other hand, cake obtained as a by-product from whole grains processing was more differentiated in terms of its phenolic profile and more potent in terms of antioxidant activity than the target beverage. Cakes from dehulled and whole grains exhibited differences within total phenolic content, FRAP, antiradical activity towards $DPPH^{\bullet}$ and under lipid autoxidation conditions. The chain-breaking antioxidant activity of the buckwheat extracts obtained from the cake depended on their concentrations in the oxidizable lipid substrate. The highest activity has been observed for CWG at concentrations 0.16 wt% and 0.20 wt%. An interesting opportunity to increase the content of extractable polyphenols from buckwheat by-products is the use of pectolitic enzymes and cellulases. The phenolic profile after enzymatic hydrolysis needs to be further investigated, as starch may comprise up to 70% of buckwheat's dry weight [56], which could cause problems during thermal processes applied to extend the microbial shelf life of the product [1,3,57]. Amylase family enzymes are often used for starch liquefaction and to achieve the desired viscosity. Due to their high amount of oligosaccharides, i.e., fermentable sugars [58], buckwheat-based milk alternatives have promising applications in fermentation and in the production of dairy free yoghurt-type products. Furthermore, due to their nutritional composition and pH, they are a suitable food matrix for incorporation of probiotics. In addition, buckwheat by-products CWG and CDH could be used for the fortification of food formulations with phenolic compounds and dietary fiber [59].

Author Contributions: Conceptualization, M.A.J. and A.S.-K.; methodology, M.A.J., M.K. and A.S.-K.; validation, M.K., R.A. and P.D.; formal analysis, M.A.J., K.S. and A.S.-K.; investigation, M.A.J., K.S. and A.S.-K.; resources, M.K. and R.A.; data curation, M.A.J., M.K., P.D. and A.S.-K.; writing—original draft preparation, M.A.J. and A.S.-K.; writing—review and editing, M.K., R.A. and P.D.; visualization, M.K., R.A., P.D. and A.S.-K.; supervision, M.K., R.A. and P.D.; project administration, M.A.J. and A.S.-K.; funding acquisition, M.A.J. and A.S.-K. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Bulgarian Academy of Sciences (BAS) and Polish Academy of Sciences (PAS) under Contract IC-PL/06/2022-2023.

Data Availability Statement: Data are contained within the article.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Reyes-Jurado, F.; Soto-Reyes, N.; Dávila-Rodríguez, M.; Lorenzo-Leal, A.C.; Jiménez-Munguía, M.T.; Mani-López, E.; López-Malo, A. Plant-based milk alternatives: Types, processes, benefits, and characteristics. *Food Rev. Int.* **2023**, *39*, 2320–2351. [CrossRef]
2. Pieczyńska, K.; Rzymski, P. Health Benefits of Vegetarian and Mediterranean Diets: Narrative Review. *Pol. J. Food Nutr. Sci.* **2022**, *72*, 327–346. [CrossRef]
3. Sethi, S.; Tyagi, S.K.; Anurag, R.K. Plant-based milk alternatives an emerging segment of functional beverages: A review. *J. Food Sci. Technol.* **2016**, *53*, 3408–3423. [CrossRef] [PubMed]
4. Vakima, H.; Kaleda, A.; Rosend, J.; Rosenvald, S. Market mapping of plant-based milk alternatives by using sensory (RATA) and GS analysis. *Future Food* **2021**, *4*, 100049. [CrossRef]
5. Jeske, S.; Zannini, E.; Arendt, E.K. Evaluation of physicochemical and glycaemic properties of commercial plant-based milk substitutes. *Plant Foods Hum. Nutr.* **2017**, *72*, 26–33. [CrossRef] [PubMed]
6. Jeske, S.; Zannini, E.; Arendt, E.K. Past, present and future: The strength of plant-based dairy substitutes based on gluten-free raw materials. *Food Res. Int.* **2018**, *110*, 42–51. [CrossRef] [PubMed]
7. Silva, A.R.A.; Silva, M.M.N.; Ribeiro, B.D. Health issues and technological aspects of plant-based alternative milk. *Food Res. Int.* **2020**, *131*, 108972. [CrossRef]
8. Aydar, E.F.; Tutuncu, S.; Ozcelik, B. Plant-based milk substitutes: Bioactive compounds, conventional and novel processes, bioavailability studies, and health effects. *J. Func. Food* **2020**, *70*, 103975. [CrossRef]
9. Galanakis, C. Recovery of high-added value components from food wastes: Conventional, emerging technologies and commercialized applications. *Trends Food Sci. Technol.* **2012**, *26*, 68–87. [CrossRef]
10. Balasundram, N.; Sundram, K.; Samman, S. Phenolic compounds in plants and agri-industrial by-products: Antioxidant activity, occurrence, and potential uses. *Food Chem.* **2006**, *99*, 191–203. [CrossRef]
11. Oleszek, M.; Kowalska, I.; Bertuzzi, T.; Oleszek, W. Phytochemicals derived from agricultural residues and their valuable properties and applications. *Molecules* **2023**, *28*, 342. [CrossRef] [PubMed]
12. Jimenez-Lopez, C.; Fraga-Corral, M.; Carpena, M.; García-Oliveira, P.; Echave, J.; Pereira, A.G.; Lourenço-Lopes, C.; Prieto, M.A.; Simal-Gandara, J. Agriculture waste valorisation as a source of antioxidant phenolic compounds within a circular and sustainable bioeconomy. *Food Funct.* **2020**, *11*, 4853–4877. [CrossRef]
13. Farooq, S.; Rehman, R.; Pirzadah, T.B.; Malik, B.; Dar, F.A.; Tahir, I. Cultivation, agronomic practices, and growth performance of buckwheat. In *Molecular Breeding and Nutritional Aspects of Buckwheat*; Zhou, M., Kreft, I., Woo, S.-H., Chrungoo, N., Wieslander, G., Eds.; Elsevier: Amsterdam, The Netherlands, 2016; pp. 299–313.
14. Christa, K.; Soral-Śmietana, M. Buckwheat grains and buckwheat products-Nutritional and prophylactic value of their components—A review. *Czech J. Food Sci.* **2008**, *6*, 153–162. [CrossRef]
15. Cai, Y.Z.; Corke, H.; Li, W.D. Buckwheat. In *Encyclopedia of Grain Science*; Wrigley, C., Corke, H., Walker, C.E., Eds.; Elsevier: Amsterdam, The Netherlands, 2004; pp. 120–128.
16. Watanabe, M.; Ohshita, Y.; Tsushida, T. Antioxidant compounds from buckwheat (*Fagopyrum esculentum Moench*) hulls. *J. Agric. Food Chem.* **1997**, *45*, 1039–1044. [CrossRef]
17. Holasova, M.; Fiedlerova, V.; Smrcinova, H.; Orsak, M.; Lachman, J.; Vavreinova, S. Buckwheat–the source of antioxidant activity in functional foods. *Food Res. Int.* **2002**, *35*, 207–211. [CrossRef]
18. Podolska, G.; Gujska, E.; Klepacka, J.; Aleksandrowicz, E. Bioactive compounds in different buckwheat species. *Plants* **2021**, *10*, 961. [CrossRef]
19. Govindhaswamy Krishnaswamy, G.; Parameshwari, S. A concise review on buckwheat materials based ready to serve and ready to eat food products. *Mater. Today-Proc.* **2022**, *66*, 783–788. [CrossRef]
20. Fernandez, C.G.; Sonawake, S.K.; Arya, S.S. Cereal based functional beverages. *J. Microbiol. Biotechnol. Food Sci.* **2019**, *8*, 914–919. [CrossRef]
21. Mousavi, M.-H.; Gharekhani, M.; Aliirezalu, K.; Roufegarinejad, L.; Azadmard-Damirchi, S. Production and characterization of nondairy gluten-free fermented beverage based on buckwheat and lentil. *Food Sci. Nutr.* **2023**, *11*, 2197–2210. [CrossRef] [PubMed]
22. Kowalska, E.; Ziarno, M. Characterization of buckwheat beverages fermented with lactic acid bacterial cultures and bifidobacterial. *Foods* **2020**, *9*, 1771. [CrossRef] [PubMed]
23. Tanashkina, T.V.; Peregoedova, A.A.; Semenyuta, A.A.; Boyarova, M.D. Gluten-free buckwheat kvass with aromatic raw materials. *Food Process Tech. Technol.* **2020**, *50*, 70–78. [CrossRef]
24. Kokwar, A.; Arya, S.S.; Bhat, M.S. A cereal-based nondairy probiotic functional beverage: An insight into the improvement in quality characteristics, sensory profile, and shelf-life. *J. Food Process Pres.* **2022**, *46*, e16147. [CrossRef]
25. Paul, A.A.; Kumar, S.; Kumar, V.; Sharma, R. Milk Analog: Plant based alternatives to conventional milk, production, potential and health concerns. *Crit. Rev. Food Sci.* **2020**, *60*, 3005–3023. [CrossRef]
26. Ogrodowczyk, A.M.; Drabińska, N. Crossroad of tradition and innovation—The application of lactic acid fermentation to increase the nutritional and health-promoting potential of plant-based food products—A Review. *Pol. J. Food Nutr. Sci.* **2021**, *71*, 107–134. [CrossRef]
27. Xiao, C.W. Functional soy products. In *Functional Foods*, 2nd ed.; Saarela, M., Ed.; Woodhead Publishing: Sawston, UK, 2011; pp. 534–556. [CrossRef]

28. Janas, K.M.; Amarowicz, R.; Zielińska-Tomaszewska, J.; Kosińska, A.; Posmyk, M.M. Induction of phenolic compounds in two dark-grown lentil cultivars with different tolerance to copper ions. *Acta Physiol. Plant.* **2009**, *31*, 587–595. [CrossRef]
29. Sulewska, K.; Rybarczyk-Płońska, A.; Karamać, M. Antioxidant capacity of lentil flour hydrolysates obtained with pancreatin. *Pol. J. Food Nutr. Sci.* **2022**, *72*, 381–391. [CrossRef]
30. Gai, F.; Janiak, M.A.; Sulewska, K.; Peiretti, P.G.; Karamać, M. Phenolic compound profile and antioxidant capacity of flax (*Linum usitatissimum* L.) harvested at different growth stages. *Molecules* **2023**, *28*, 1807. [CrossRef]
31. Herman, M.; Janiak, M.A.; Sadlik, J.K.; Piekoszewski, W.; Amarowicz, R. Iron, zinc, copper, manganese and chromium in green teas, their transfer to extracts and correlations between contents of elements and bioactive compounds. *Pol. J. Food Nutr. Sci.* **2022**, *72*, 421–429. [CrossRef]
32. Re, R.; Pellegrini, N.; Proteggente, A.; Pannala, A.; Yang, M.; Rice-Evans, C. Antioxidant activity applying an improved ABTS radical cation decolorization assay. *Free Rad. Biol. Med.* **1999**, *26*, 1231–1237. [CrossRef]
33. Benzie, I.F.; Strain, J.J. The ferric reducing ability of plasma (FRAP) as a measure of "antioxidant power": The FRAP assay. *Anal. Biochem.* **1999**, *239*, 70–76. [CrossRef] [PubMed]
34. Brand-Williams, W.; Cuvelier, M.E.; Berset, C. Use of a free radical method to evaluate antioxidant activity. *LWT Food Sci. Technol.* **1995**, *28*, 25–30. [CrossRef]
35. Slavova-Kazakova, A.; Karamac, M.; Kancheva, V.; Amarowicz, R. Antioxidant activity of flaxseed extracts in lipid systems. *Molecules* **2016**, *21*, 17. [CrossRef]
36. Yanishlieva, N.; Popov, A.; Marinova, E. Eine modifizierte jodometrische methode zur bestimmung der peroxidzahl in kleinen lipidproben. *Comptes Rend. Acad. Bulg. Sci.* **1978**, *31*, 869–871.
37. Dziadek, K.; Kopeć, A.; Pastucha, E.; Piątkowska, E.; Leszczyńska, T.; Pisulewska, E.; Witkowicz, R.; Francik, R. Basic chemical composition and bioactive compounds content in selected cultivars of buckwheat whole seeds, dehulled seeds and hulls. *J. Cereal Sci.* **2016**, *69*, 1–8. [CrossRef]
38. Kalinová, J.P.; Vrchotová, N.; Tříska, J. Phenolics levels in different parts of common buckwheat (*Fagopyrum esculentum*) achenes. *J. Cereal Sci.* **2019**, *85*, 243–248. [CrossRef]
39. Janiak, M.A.; Slavova-Kazakova, A.; Kancheva, V.D.; Ivanova, M.; Tsrunchev, T.; Karamać, M. Effects of γ-irradiation of wild thyme (*Thymus serpyllum* L.) on the phenolic compounds profile of its ethanolic extract. *Pol. J. Food Nutr. Sci.* **2017**, *67*, 309–315. [CrossRef]
40. Taniguchi, M.; LaRocca, C.A.; Bernat, J.D.; Lindsey, J.S. Digital database of absorption spectra of diverse flavonoids enables structural comparisons and quantitative evaluations. *J. Nat. Prod.* **2023**, *86*, 1087–1119. [CrossRef]
41. Quettier-Deleu, C. Phenolic compounds and antioxidant activities of buckwheat (*Fagopyrum esculentum* Möench) hulls and flour. *J. Ethnopharmacol.* **2000**, *72*, 35–42. [CrossRef] [PubMed]
42. Przybylski, R.; Lee, Y.C.; Eskin, N.A.M. Antioxidant and radical-scavenging activities of buckwheat seed components. *J. Am. Oil Chem. Soc.* **1998**, *75*, 1595–1601. [CrossRef]
43. Karamać, M.; Biskup, I.; Kulczyk, A. Fractionation of buckwheat seed phenolics and analysis of their antioxidant activity. *Pol. J. Food Nutr. Sci.* **2015**, *65*, 243–249. [CrossRef]
44. Dietrych-Szostak, D.; Oleszek, W. Effect of processing on the flavonoid content in buckwheat (*Fagopyrum esculentum* Möench) grain. *J. Agric. Food Chem.* **1999**, *47*, 4384–4387. [CrossRef] [PubMed]
45. Oomah, B.D.; Mazza, G. Flavonoids and antioxidative activities in buckwheat. *J. Agric. Food Chem.* **1996**, *44*, 1746–1750. [CrossRef]
46. Vollmannová, A.; Musilová, J.; Lidiková, J.; Árvay, J.; Šnirc, M.; Tóth, T.; Bojňanská, T.; Čičová, I.; Kreft, I.; Germ, M. Concentrations of phenolic acids are differently genetically determined in leaves, flowers, and grain of common buckwheat (*Fagopyrum esculentum* Moench). *Plants* **2021**, *10*, 1142. [CrossRef] [PubMed]
47. Zielińska, D.; Zieliński, H. Antioxidant activity of flavone C-glucosides determined by updated analytical strategies. *Food Chem.* **2011**, *124*, 672–678. [CrossRef]
48. Verardo, V.; Arráez-Román, D.; Segura-Carretero, A.; Marconi, E.; Fernández-Gutiérrez, A.; Caboni, M.F. Identification of buckwheat phenolic compounds by reverse phase high performance liquid chromatography–electrospray ionization-time of flight-mass spectrometry (RP-HPLC–ESI-TOF-MS). *J. Cereal Sci.* **2010**, *52*, 170–176. [CrossRef]
49. Karamać, M. Antioxidant activity of tannin fractions isolated from buckwheat seeds and groats. *J. Am. Oil Chem. Soc.* **2010**, *87*, 559–566. [CrossRef]
50. Cui, Y.; Zhao, Z.; Liu, Z.; Liu, J.; Piao, C.; Liu, D. Purification and identification of buckwheat hull flavonoids and its comparative evaluation on antioxidant and cytoprotective activity in vitro. *Food Sci. Nutr.* **2020**, *8*, 3882–3892. [CrossRef]
51. Bors, W.; Heller, W.; Michel, C.; Saran, M. Flavonoids as antioxidants: Determination of radical-scavenging efficiencies. *Methods Enzymol.* **1990**, *186*, 343–354. [CrossRef]
52. Pietta, P.-G. Flavonoids as antioxidants. *J. Nat. Prod.* **2000**, *63*, 1035–1042. [CrossRef]
53. Xiao, Y.; Yang, C.; Xu, H.; Zhang, J.; Zhang, L. Study on the change of flavonoid glycosides to aglycones during the process of steamed bread containing Tartary buckwheat flour and and antioxidant, α-glucosidase inhibitory activities evaluation in vitro. *LWT-Food Sci. Technol.* **2021**, *145*, 111527. [CrossRef]
54. Kancheva, V.; Taskova, R.; Totseva, I.; Hanjieva, N. Antioxidant activity of extracts, fractions and flavonoid constituents from *Carthamus lanatus* L. *Riv. Ital. Sostanze Gr.* **2007**, *84*, 77–86.

55. Rúa, J.; de Arriaga, D.; García-Armesto, R.M.; Busto, F.; del Valle, P. Binary combinations of natural phenolic compounds with gallic acid or with its alkyl esters: An approach to understand the antioxidant interactions. *Eur. Food Res. Technol.* **2017**, *243*, 1211–1217. [CrossRef]
56. Arslan, A.; Haros, C.M.; Yalçın, E.; Güneş, A. Wet milling of buckwheat cultivars and some quality properties of the fractions. *Food Sci. Technol. Int.* **2022**, *28*, 320–330. [CrossRef] [PubMed]
57. Mäkinen, O.E.; Wanhalinna, V.; Zannini, E.; Arendt, E.K. Foods for Special Dietary Needs: Non-Dairy Plant Based Milk Substitutes and Fermented Dairy Type Products. *Crit. Rev. Food Sci. Nutr.* **2016**, *56*, 339–349. [CrossRef]
58. Streimikyte, P.; Balciunaitiene, A.; Liapman, T.D.; Streimikyte-Mockeliune, Z.; Puzeryte, V.; Borkertas, S.; Viskelis, P.; Viskelis, J. Enzymatically Hydrolysed Common Buckwheat (*Fagopyrum esculentum* M.) as a Fermentable Source of Oligosaccharides and Sugars. *Appl. Sci.* **2022**, *12*, 8210. [CrossRef]
59. Znamirowska, A.; Sajnar, K.; Kowalczyk, M.; Kluz, M.; Buniowska, M. Effect of addition of spelt and buckwheat hull on selected properties of yoghurt. *JMBFS* **2020**, *10*, 296–300. [CrossRef]

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.