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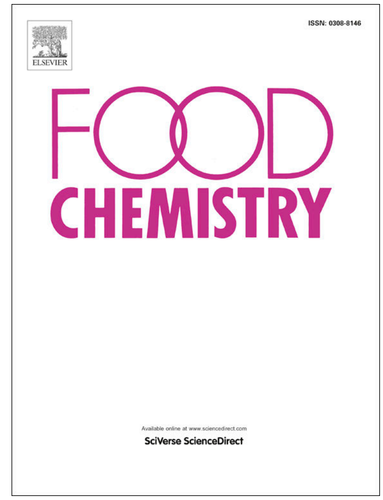

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Milling Fractions Composition of Common (*Fagopyrum esculentum* Moench) and Tartary (*Fagopyrum tataricum* (L.) Gaertn.) Buckwheat

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Abstract

Buckwheat is a pseudocereal with important nutritional qualities and great potential for broad consumption. The study aimed to determine the biochemical composition, antioxidant properties and multi-mineral composition of the whole grains, hulls, bran, and the light flour of common (*Fagopyrum esculentum* Moench) and Tartary (*Fagopyrum tataricum* (L.) Gaertn.) buckwheat harvested in two consecutive years. Significant differences between fractions of both species were observed. On the other hand, the differences between the production years were not so significant. Biochemical and multi-mineral compositions of common and Tartary buckwheat were comparable, while significant differences between species were observed in antioxidant properties. The antioxidant potential (AOP), total phenolic content (TPC), and total flavonoid content (TFC) were higher in all fractions of Tartary buckwheat compared to individual fractions of common buckwheat. Fourteen minerals were quantified in fractions. Contents of all major minerals and most of the trace minerals were the highest in bran fraction.

Keywords: whole grain; hulls; bran; light flour; bioactive compounds; phenolics

1 Introduction

Two species of buckwheat are among the most extensively produced and consumed around the world: common buckwheat (*Fagopyrum esculentum* Moench) and Tartary buckwheat (*Fagopyrum tataricum* (L.) Gaertn.). Common buckwheat and Tartary buckwheat have been in cultivation for 5000-6000 and 4000 years, respectively. Both species originated in China; however, it is suggested that cultivated buckwheat species may have multiple origins since independent domestication events occurred (Mizuno and Yasui, 2019; Zhang et al., 2021). The major producers of buckwheat are China, Russia, France, Ukraine, and Poland (FAOSTAT, 2018). Both worldwide available traditional foodstuffs are not only a good source of energy and nutrition for maintenance of the body but are also a source of bioactive compounds that are health beneficial (Christa and Soral-Śmietana, 2008). The nutritional value of Tartary buckwheat is much higher than of a common buckwheat. Tartary buckwheat is richer in nutrients, including vitamin B and some antioxidants, such as rutin, and has good medicinal properties (Ruan et al., 2020; Zhao et al., 2018). Both species have a high polyphenol and mineral contents in seeds (Tsai et al., 2012). Previous studies have also shown high levels of antioxidants in buckwheat (Ruan et al., 2020). Since the favorable nutritional composition of protein, lipid, dietary fiber, and minerals, and combination with other health beneficial components, buckwheat can be characterized as a so-called functional food (Giménez-Bastida and Zieliński, 2015; Krkošková and Mrázová, 2005).

The main form of buckwheat for consumption is a grain. The nutrient composition of buckwheat products depends on the milling fraction, which reflects the relative abundance of the seed tissues (Steadman et al., 2001a). Buckwheat seed milling fractions are obtained through the milling process involving the separation of the hulls from buckwheat seeds. The results of further milling are usually light flour, grits/semolina, and bran fractions. The traditional milling process is carried out by using stone mills, which usually have a smaller milling capacity and are appropriate for smaller producers. Milling fractions contain different proportions of central endosperm, embryo, and maternal tissues, each of which can vary in composition. Light flour mainly contains central endosperm, grits are hard chunks of endosperm, while bran contains seed coat and embryo tissues (Steadman et al., 2001a, 2001b). Common buckwheat and Tartary buckwheat yields after milling process with traditional stone mill are similar; approximately 56% of flour, 24% of bran, 17% of husks, and 3% of losses (Bonafaccia et al., 2003).

The main constituents in buckwheat are carbohydrates. Among different fractions, buckwheat flour contains the highest portion of carbohydrates (70-90%) (Huda et al., 2021). Buckwheat bran is the milling fraction with the highest portions of proteins and lipids (Skrabanja et al., 2004; Steadman et al., 2001a). Liu et al. (2018) showed a high impact of milling processes on physicochemical properties of Tartary buckwheat flours due to the proportion of the bran, and degree of damage and size of the particles.

Buckwheat has already been proven to be a good source of antioxidants (Kiprovski et al., 2015; Li et al., 2013). Overall, almost 180 bioactive compounds were identified in buckwheat (Huda et al., 2021). The antioxidant capacity of extracts from different buckwheat seed fractions had different efficiencies (Li et al., 2013; Quettier-Deleu et al., 2000). Total phenolic content was found higher in Tartary buckwheat, compared to common buckwheat (Liu et al., 2019). Buckwheat is also a good source of minerals. Tartary buckwheat is a richer source of minerals than common buckwheat, as well as other cereals and pseudocereals. It contains high levels of trace minerals, especially manganese, copper, and magnesium (Bonafaccia et al., 2003), but also iron and zinc (Krupa-Kozak et al., 2011). A gluten-free diet is often categorized by low contents of some nutritional components, such as proteins and minerals. Therefore, buckwheat flour is a promising gluten-free product enriched in proteins, major and trace minerals (Krupa-Kozak et al., 2011).

The objective of the present study was to analyze the basic chemical composition, multi-mineral contents, and bioactive compounds contents of the whole grains, hulls, bran, and light flour of common and Tartary buckwheat fractions obtained by traditional stone-milling harvested in two consecutive years. Although buckwheat is recognized as nutritionally valuable, a detailed composition of milling fractions is incomplete. Therefore, the aim of the study was to evaluate and compare the properties of individual fractions of the two buckwheat species.

2 Materials and methods

2.1. Materials

Common buckwheat (*Fagopyrum esculentum* Moench; population from Dolenjska region) and Tartary buckwheat (*Fagopyrum tataricum* (L.) Gaertn.; traditional Slovene population) were cultivated as a catch crop in Slovenia in the Posavje region (46°02' N 15°13' E, 194 m above sea level) in a moderate soil and harvested in two consecutive years. Both buckwheat species were grown from the second week of July (sowing time) until the last week of October (harvest time) each year. The average monthly temperature was 17.2 °C in the first year and 17.4 °C in the second year of production. There were little differences in total accumulated rainfall in each growing season, with the peak of rainfall in September. Each species was cultivated on a 400 m^2 plot area each year. After harvest, the grains were dried in a wooden drying chamber with ventilation at ambient temperature. To obtain different milling fractions traditional stone mill (capacity 15 kg h^{-1}) was used for the milling 50 kg of each buckwheat species each year. Clean undamaged whole grains were subjected to successive milling and sieving. Fractions were divided into bran, hulls, and light flour, and were subsequently manually checked to remove residues. The samples were stored at room temperature and low relative humidity in the paper bags until analysis.

2.2. Sample preparation

The whole grains and fractions of buckwheat were homogenized in a laboratory ball mill (Retsch MM400) directly before analysis. The samples used for the determination of antioxidant potential, total phenolic content, and total flavonoid content were extracted with 70% ethanol. Approximately 50 mg of the homogenized sample was weighed in a centrifuge tube and 1300 μL of extraction solvent was added. Samples were thoroughly mixed on vortex, extracted in an ultrasonic bath for 10 min, incubated for 1h in the dark, and mixed again. After extraction, the samples were centrifuged at 13,200 × g for 5 min and filtered through 0.20 μm PTFE syringe filters (Macherey-Nagel) before analyses.

2.3. Basic chemical composition

In all of the samples the chemical composition was determined, i.e. the determination of dry matter content, crude fats, protein content, ash, and crude fiber, and calculation of moisture and total carbohydrates content. Dry matter content was determined by drying samples at 103 °C for 48 h. Crude fats were analyzed with petroleum ether extraction. Five grams of the homogenized sample was transferred to an extraction thimble, placed in an extractor, and extracted for six hours with light petroleum. The petroleum extract was collected in a dry, weighed flask. The solvent was distilled off and the residue was dried in the drying oven till constant weight. For the determination of crude protein content, Kjeldahl method was used (ISO 5983-2, 2009). Ash was determined by weight difference before and after incineration at 550 °C for 4 h. Results of chemical composition are presented as g kg^{-1}. The crude fiber was determined according to ISO 6865:2000. After 1 g of the sample was weighed, 350 mL of 0.13 mol L^{-1} H_2SO_4 was added and heated under the boiling state for 30 min. Then the sample was rinsed with water three times. After adding 350 mL of 0.23 mol L^{-1} KOH, the sample solution was heated under the boiling state for another 30 min. Then the sample was rinsed with boiling water three times, rinsed with acetone, dried for 2 h at 130 °C, weighed and ashed for 2 h at 580 °C. The total carbohydrates content was calculated by the equation: total carbohydrates = 100 – (% protein + % crude fat + % ash + % moisture) (Dziadek et al., 2016).

2.4. DPPH radical-scavenging activity

The antioxidant potential (AOP) of the samples was determined spectrophotometrically, as the 2,2-diphenyl-1-picrylhydrazyl (DPPH; Sigma-Aldrich) free-radical-scavenging capacity, based on the modified method of Brand-Williams et al. (1995). The absorbance was measured after 50 min incubation at room temperature, using a spectrophotometer at 517 nm, against methanol as the blank. Calibration was done through seven-point standard curve of Trolox (Sigma-Aldrich). AOP of the samples was determined in triplicate, and expressed in g kg^{-1} of Trolox equivalents (TE).

2.5. Total phenolic content

Total phenolic content (TPC) was determined according to the Folin-Ciocalteu method described by Singleton and Rossi (1965), with minor modifications. The absorbance was measured after 50 min incubation at room temperature, using a spectrophotometer at 765 nm, against deionised water as the blank. Calibration was done through a seven-point standard curve of gallic acid (Fluka, Buchs, Switzerland). TPC of the samples was determined in triplicate and expressed in g kg^{-1} of gallic acid equivalents (GAE).

2.6. Total flavonoid content

Total flavonoid content (TFC) was determined according to the slightly modified method described by Lin and Tang (2007). The absorbance was measured after 40 min incubation at room temperature, using a spectrophotometer at 415 nm, against deionized water as the blank. Calibration was done through a seven-point standard curve of quercetin (Sigma-Aldrich). TFC of the samples was determined in triplicate and expressed in g kg^{-1} of quercetin equivalents (QE).

2.7. Multi-mineral analyses using ICP-MS

Milestone ETHOS 1600 microwave digestion system was used for sample digestion. The dried, milled, and homogenized samples, 0.250 g, were weighed into polytetrafluoroethylene (PTFE) vessels. Two mL of hydrogen peroxide (30%, v/v; Suprapur, Merck) and 6.0 mL of nitric acid (65%, v/v; Suprapur, Merck) were added into the vessels. Digested samples were cooled to room temperature and diluted to 50 mL with doubly de-ionized water (resistivity of 18.2 MΩ; Millipore). Prior to the analysis the digested samples were diluted by a factor of 20 and consisted of 1% (v/v) nitric acid.

Contents of minerals were determined using an Agilent ICP-MS 7900 (Tokyo, Japan) with a 4^{th} generation collision/reaction cell, the Octopole Reaction System (ORS^4). The sample introduction system consisted of a quartz double-pass spray chamber and a MicroMist nebulizer connected to the peristaltic pump of the spectrometer with Tygon® tubes. Nickel sampler and skimmer cones were used. Helium was used as reaction gas at the flow rate of 5.0 mL min^{-1} in

He mode, and 10.0 mL min^{-1} in HEHe mode. Five major minerals (> 1 g kg^{-1} DW) Mg, P, S, K and Ca, and nine trace minerals (> 1 mg kg^{-1} DW) Na, V, Cr, Mn, Fe, Co, Cu, Zn and Mo were determined. The isotopes monitored were ^{23}Na, ^{24}Mg, ^{31}P, ^{34}S, ^{39}K, ^{43}Ca, ^{51}V, ^{52}Cr, ^{55}Mn, ^{56}Fe, ^{59}Co, ^{63}Cu, ^{66}Zn, and ^{95}Mo. The majority of minerals were measured in He mode, while P, S, and Se were measured in HEHe mode.

The quantitative determinations of minerals were performed using the external calibration method. The calibration curve was prepared using IV-STOCK-50 standard solution (Inorganic Ventures); P and S single standard solutions (Inorganic Ventures) were added separately to the mixture. Internal standards ^{45}Sc, ^{103}Rh, ^{115}In, and ^{175}Lu were added in a concentration of 200 µg L^{-1} (1% (v/v) nitric acid).

For quality control analytical blanks, independent quality control (QC) standards, and standard reference material were used. QC standards were prepared from ICP multi-mineral standard solution VIII (Merck, 109492) and ICP multi-mineral standard solution XVI (Merck, 109487). A certified reference material (NIST SRM 1573a tomato leaves, Gaithersburg, MD, USA) was used. All sample results are quoted on a dry weight basis.

2.8. Data analysis

Statistical analyses were performed using the R commander software (version 3.3.3). To ensure the appropriateness of ANOVA, the variances between fractions were determined using Levene's tests ($\alpha > 0.05$). Further ANOVA was performed with *post-hoc* Tukey's tests; *, $P < 0.05$; **, $P < 0.01$; ***, $P < 0.001$. Significant differences between common and Tartary buckwheat among individual fractions were obtained using a t-test. Pearson product-moment correlation test was performed to evaluate the correlation.

3 Results

The basic chemical composition of whole grain, hulls, bran, and light flour of common and Tartary buckwheat harvested in two consecutive years is presented in Table 1. Significant differences between fractions were observed for all studied parameters, i.e. ash, carbohydrates, fats, fiber, moisture, and protein content. Moreover, differences for all parameters were observed between common and Tartary buckwheat. There were minor differences between production years, however, results were comparable and had no significant effect on further data interpretation. The most pronounced differences between fractions were found for carbohydrate, protein, and fat content. The ash content in common and Tartary buckwheat was the highest in the bran (4.6–5.8%) and the lowest in light flour (1.0–1.3%). Carbohydrate content was the highest in the hulls (81.2–88.1%), followed by light flour (75.6–77.5%), whole grain (72.5–73.6%), and bran (48.4–53.0%). Contrary, fat content was the highest in the bran (4.1–5.2%) and the lowest in hulls (0.4–0.7%). As expected, fiber content was the highest in hulls and represented approximately 50% and the lowest in light flour with less than 1%. Overall the highest difference between fractions was observed in protein content. Protein content for both buckwheat species was highest in bran with over 25%, followed by whole grain with over 10%. The difference between common and Tartary buckwheat was most noticeable for carbohydrate, fiber, and fat content, e.g. carbohydrate and fiber contents were higher in hulls of Tartary buckwheat, while fat content was higher in bran.

The antioxidant potential (AOP), total phenolic content (TPC), and total flavonoid content (TFC) were higher in all fractions of Tartary buckwheat compared to individual fractions of common buckwheat (Table 2). There was a very strong positive correlation between antioxidant potential with total phenolic content (R^2 over 0.9) and total flavonoid content (R^2

over 0.9). In both buckwheat species the highest AOP was in bran and ranged between 9.51 and 12.53 µmol g^{-1} for common buckwheat, and between 72.80 and 102.34 µmol g^{-1} for Tartary buckwheat. AOP in whole grain was approx. 6 µmol g^{-1} for common buckwheat and approx. 35 µmol g^{-1} for Tartary buckwheat.

Fourteen minerals were quantified in whole grains and milling fractions of common and Tartary buckwheat. Minerals can be divided into two groups: the major minerals (> 1 g kg^{-1} DW) Mg, P, S, K and Ca, and trace minerals (> 1 mg kg^{-1} DW) Na, V, Cr, Mn, Fe, Co, Cu, Zn and Mo (Table 3). The order of the minerals from the most to the least abundant (based on mean values) is: K (6.23 g kg^{-1}), P (4.64 g kg^{-1}), Mg (2.71 g kg^{-1}), S (1.74 g kg^{-1}), Ca (1.08 g kg^{-1}), Fe (65.88 mg kg^{-1}), Zn (37.74 mg kg^{-1}), Na (31.03 mg kg^{-1}), Mn (27.50 mg kg^{-1}), Cu (8.75 mg kg^{-1}), Mo (1.35 mg kg^{-1}), Cr (0.30 mg kg^{-1}), V (0.07 mg kg^{-1}) and Co (0.05 mg kg^{-1}). The highest relative difference was observed for P, where bran fraction contained 12-fold, 5-fold, or 3-fold higher concentrations of P than hulls, light flour, or whole grains, respectively. The highest relative difference among trace minerals was observed for Zn. Bran fraction on average contained almost 5-fold, over 3-fold, or 2-fold more Zn than hulls, light flour, or whole grains, respectively.

4 Discussion

Considerable efforts are being made to improve human nutrition and increase the amount of consumed bioactive compounds with a beneficial effect on human health. Pseudocereals, with buckwheat as one of the important species, are interesting for wide human consumption, while they are gluten-free and possess high nutritional value.

Basic chemical composition, multi- mineral contents, and bioactive compounds contents of whole grains and milling fractions of common and Tartary buckwheat were studied. There were significant differences between fractions for all studied parameters. Differences between buckwheat species were also observed, however the year of production had a lower impact on the contents of bioactive compounds. Some differences were observed between the two production years, but results were comparable.

The average protein content of the whole grains was slightly higher than 11%, regardless of the buckwheat species. In literature, the protein content of buckwheat grains ranges between 12.0 and 18.9% (Krkošková and Mrázová, 2005; Steadman et al., 2001a). The protein concentrations were the highest in bran fractions of both buckwheat species and similar to results presented by Steadman et al. (2001a), where protein content of six different bran fractions ranged from 18.6 to 39.3%. Bran fractions that contained hulls had lower protein content, as among fractions hulls contain the least proteins, i.e. about 4% (Pomeranz and Robbins, 1972; Steadman et al., 2001a). Protein contents in common buckwheat fractions were comparable to contents in Tartary buckwheat. Although some differences were observed between both species, they were not pronounced and usually not significant in both years of production. This shows a high effect of the production year and milling process on the chemical composition of fractions. While, Bonafaccia et al. (2003) presented comparable results of protein content in grain and flour of common and Tartary buckwheat, a difference in protein contents in bran fractions was observed. Protein content was higher in Tartary buckwheat bran fraction. However, in our case protein content in bran fractions was higher in both species of buckwheat. Fat contents of buckwheat ranged from 0.4 to 5.2%, regardless of buckwheat species and fractions. Fats in whole grains represent about 2%, which is in agreement with Steadman et al. (2001a), who reported from 1.5

to 4% of total lipids in buckwheat grains. In our study, hulls of both buckwheat species contained less than 1% of fats.

Antioxidant activity of buckwheat grains is up to 10-fold higher than the activity of oat, barley, wheat, or rye (Zieliński and Kozłowska, 2000). Dave Oomah et al. (1996) determined phenolic acid contents in five buckwheat cultivars grown at three locations in Canada for four years and showed that variation in contents was mainly due to cultivar and seasonal effects while growing location had no significant effect. In our research, differences in AOP, TCP, and TFC between both buckwheat species were significant. All three tests showed higher activities in Tartary buckwheat fractions, compared to common buckwheat. Jiang et al. (2007) showed that rutin plays an important role in the antioxidant activity of buckwheat seed, since in all samples rutin content in buckwheat seeds significantly correlated to the antioxidant activity. On the other hand, Morishita et al. (2007) suggested that the contribution of polyphenols to antioxidant activity is different between common and Tartary buckwheat. Not only rutin but also other phenols significantly influence antioxidant activities, since quercetin was not even detected in common buckwheat and epicatechin was not detected in Tartary buckwheat (Morishita et al., 2007). Among three studied buckwheat species (*Fagopyrum esculentum*, *F. tataricum*, and *F. homotropicum*) and in total 11 cultivars/accessions Tartary buckwheat had the highest antioxidant activity and exhibited the most effective inhibition of LDL peroxidation (Jiang et al., 2007). Similar results were presented by Morishita et al. (2007) who found out that Tartary buckwheat grains possess 3-4 times higher antioxidant activity than common buckwheat grains. In a detailed comparison of 83 studies on buckwheat species and cultivars, differences were reported in the case of phenolics, especially flavonoids, tocopherols, β-glucans, and phytosterols (Raguindin et al., 2021). In our study, the lowest AOP was measured in the light flour fraction of both buckwheat species. Although light flour of Tartary buckwheat had the lowest AOP among fractions, it was still comparable or even higher than the AOP of all common buckwheat fractions. Several radical scavenging tests also showed differences between 12 common buckwheat cultivars from 8 countries (Kiprovski et al., 2015) and groats and whole grains of two common buckwheat cultivars (Yıldız et al., 2019). Differences among different buckwheat species and cultivars in total and individual phenolic contents were also reported by Podolska et al. (2021). Interestingly, variation in phenolic content among cultivars of the same buckwheat species can be higher than between different buckwheat species (Li et al., 2013). Overall, bran, especially that of Tartary buckwheat, had the highest TPC, which was also shown in previous studies including both species and different cultivars (Guo et al., 2012; Li et al., 2013). Results indicate that most bioactive compounds with antioxidant properties are located in outer layers of the grain, i.e. bran. Hung and Morita (2008) determined TPC of 16 whole buckwheat grains fractions and found that the outer layers of buckwheat grains had a higher amount of phenolic compounds. Higher TPC along with higher amounts of protein, lipid, ash and dietary fiber are considered to be good materials for cereal-based food processing. The flour milled from the outer layers of buckwheat grains or bran fraction, which consist of outer layers, contains large amounts of phenolic compounds, high antioxidant capacity, and is considered to have significant health benefits (Hung and Morita, 2008).

There were significant differences in major and trace mineral contents between different milling fractions. The highest levels for the four most abundant minerals K, P, Mg, and S were found in the bran of both species of buckwheat, while Ca content was the highest in hulls. Steadman et al. (2001b) reported on eleven milling fractions during the milling process. Contents of all major minerals in three obtained bran fractions were comparable, however higher compared to other fractions (Steadman et al., 2001b). Contents of trace minerals Fe, Zn, Cu, Mo, and Co were also the highest in bran, for both buckwheat species and years of production. On the other hand, contents of trace minerals Na, Mn, Cr, and V were the highest in hulls. Interestingly, there were no pronounced differences in minerals contents between common and Tartary buckwheat. The year of production had a similarly significant impact on the differences between the contents as buckwheat species. Domingos and Bilsborrow (2021) studied two common buckwheat varieties produced at two sowing dates in three consecutive years. They reported similar contents of trace minerals Fe and Zn; however, there were no significant interactions found for any of the study treatments (Domingos and Bilsborrow, 2021).

Although milling fraction, e.g. bran, are somewhat by-product of light flour production, there is a potential for its implementation in a variety of products, such as rutin enriched material made of bran (Cho et al., 2014). Especially, Tartary buckwheat has a high potential for further product development, whilst it shows high nutritional value since it contains beneficial active substances attributed to beneficial properties and medicinal value (Ruan et al., 2020).

5 Conclusions

The present study describes the general nutritional value of two common types of buckwheat. Since buckwheat has immerse potential in the food industry as a rich source of nutrients and bioactive compounds, especially in a gluten-free diet, its composition should be thoroughly studied to reveal its maximum potential. In our study, significant differences in basic chemical composition, antioxidant properties, and multi-mineral composition between whole grains of two buckwheat species, and their milling fractions were found. Significant differences in antioxidant properties were observed between buckwheat species. Tartary buckwheat had higher levels of total phenolics and flavonoids, compared to common buckwheat. On the other hand, there were small differences between the species in the case of multi-mineral composition. All analyses showed significant differences between milling fractions, regardless of buckwheat species. Buckwheat is a novel and healthy food; therefore its consumption should be enhanced. Buckwheat flour products are known and already popular worldwide, however other fractions of the buckwheat milling processes are still considered as by-products or even waste. The purpose of this study was to present the high nutritional value of buckwheat grains and their fractions. Among fractions, bran showed the highest potential, since it contained the highest levels of minerals and proteins and had the highest antioxidant potential. Bran is already used in several products, such as tea, breakfast cereals or bread, but we believe it is not yet used to its full potential.

Conflicts of interests

The authors have declared no conflict of interest.

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Table 1: Basic chemical composition (%) of whole grain, hulls, bran and light flour of common and Tartary buckwheat harvested in two consecutive years (I, II).

Year	Buckwheat species	Fraction	Ash	Carbohydrates	Fats	Fiber	Moisture	Protein	Dry matter
I	Common	Whole grains	2.1 ±0.0 c	73.6 ±0.0 b	2.1 ±0.0 c	12.1 ±0.0 c	10.9 ±0.0 b	11.3 ±0.0 c	89.1 ±0.0 c
		Hulls	2.0 ±0.0 b	81.2 ±0.0 d	0.7 ±0.0 a	48.0 ±0.1 d	10.7 ±0.0 a	5.4 ±0.0 a	89.3 ±0.0 d
		Bran	4.6 ±0.0 d	53.0 ±0.2 a	4.1 ±0.0 d	2.7 ±0.1 b	13.1 ±0.0 c	25.3 ±0.2 d	87.0 ±0.0 b
		Light flour	1.0 ±0.0 a	76.4 ±0.0 c	0.8 ±0.0 b	0.6 ±0.0 a	14.8 ±0.0 d	7.0 ±0.1 b	85.2 ±0.0 a
	Tartary	Whole grains	2.5 ±0.0 c	75.2 ±0.1 b	2.5 ±0.0 c	19.8 ±0.2 c	9.8 ±0.0 b	10.0 ±0.0 c	90.2 ±0.0 c
		Hulls	2.0 ±0.0 b	88.1 ±0.1 d	0.4 ±0.0 a	56.1 ±0.2 d	6.2 ±0.0 a	3.4 ±0.1 a	93.8 ±0.0 d
		Bran	5.8 ±0.0 d	49.2 ±0.0 a	5.2 ±0.0 d	3.8 ±0.1 b	12.2 ±0.0 c	27.7 ±0.1 d	87.8 ±0.0 b
		Light flour	1.3 ±0.0 a	76.3 ±0.0 c	0.6 ±0.0 b	1.1 ±0.1 a	13.4 ±0.0 d	8.3 ±0.0 b	86.6 ±0.0 a
II	Common	Whole grains	2.4 ±0.0 c	72.9 ±0.0 b	2.3 ±0.0 c	14.0 ±0.2 c	10.8 ±0.0 b	11.7 ±0.1 c	89.2 ±0.0 c
		Hulls	2.2 ±0.1 b	83.4 ±0.3 d	0.5 ±0.0 a	51.8 ±0.3 d	9.6 ±0.0 a	4.3 ±0.2 a	90.4 ±0.0 d
		Bran	5.3 ±0.0 d	48.4 ±0.1 a	4.7 ±0.0 d	2.8 ±0.0 b	13.7 ±0.0 c	27.9 ±0.1 d	86.3 ±0.0 b
		Light flour	1.3 ±0.0 a	75.6 ±0.1 c	0.8 ±0.0 b	0.7 ±0.0 a	14.5 ±0.0 d	7.8 ±0.0 b	85.5 ±0.0 a
	Tartary	Whole grains	2.2 ±0.0 c	72.5 ±0.1 b	2.3 ±0.0 c	15.5 ±0.0 c	11.4 ±0.0 b	11.6 ±0.1 c	88.6 ±0.0 c
		Hulls	1.9 ±0.0 b	85.4 ±0.0 d	0.6 ±0.0 a	54.8 ±0.1 d	7.8 ±0.0 a	4.4 ±0.1 a	92.2 ±0.0 d
		Bran	4.7 ±0.0 d	52.0 ±0.1 a	4.9 ±0.0 d	2.0 ±0.1 b	13.2 ±0.0 d	25.2 ±0.1 d	86.8 ±0.0 a
		Light flour	1.0 ±0.0 a	77.5 ±0.0 c	0.9 ±0.0 b	0.8 ±0.0 a	12.6 ±0.0 c	8.0 ±0.0 b	87.4 ±0.0 b
Range			1.0–5.8	48.4–88.1	0.4–5.2	0.6–56.1	6.2–14.8	3.4–27.9	85.2–93.8

Data are means ± SD (n=3). Means with different letters within each buckwheat species are significantly different (*P* <0.05).

Table 2: Antioxidant potential (AOP; µmol g^{-1} TE), total phenolic content (TPC; mg g^{-1} GAE) and total flavonoid content (TFC; mg g^{-1} QE) of whole grain, hulls, bran and light flour of common and Tartary buckwheat harvested in two consecutive years (I, II).

Year	Buckwheat species	Fraction	AOP	TPC	TFC
I	Common	Whole grains	6.04 ±0.04 b,***	3.75 ±0.02 c,***	0.61 ±0.01 c,***
		Hulls	5.91 ±0.08 b,***	2.93 ±0.02 b,***	0.40 ±0.00 b,***
		Bran	9.51 ±0.08 c,***	7.29 ±0.09 d,***	1.20 ±0.00 d,***
		Light flour	2.27 ±0.08 a,***	1.71 ±0.01 a,***	0.20 ±0.00 a,***
	Tartary	Whole grains	37.95 ±0.36 c,***	12.90 ±0.02 c,***	9.12 ±0.05 c,***
		Hulls	20.74 ±0.24 b,***	7.07 ±0.09 a,***	2.50 ±0.01 a,***
		Bran	102.34 ±0.36 d,***	30.73 ±0.09 d,***	27.15 ±0.06 d,***
		Light flour	10.55 ±0.04 a,***	7.86 ±0.04 b,***	5.04 ±0.01 b,***
II	Common	Whole grains	6.58 ±0.12 b,***	3.81 ±0.01 c,***	0.47 ±0.00 c,***
		Hulls	9.79 ±0.04 c,***	3.61 ±0.08 b,***	0.38 ±0.00 b,***
		Bran	12.53 ±0.08 d,***	9.14 ±0.05 d,***	1.86 ±0.03 d,***
		Light flour	3.41 ±0.08 a,***	2.38 ±0.01 a,***	0.28 ±0.01 a,***
	Tartary	Whole grains	32.81 ±0.20 c,***	11.65 ±0.03 c,***	8.77 ±0.05 c,***
		Hulls	12.89 ±0.04 b,***	5.83 ±0.01 b,***	2.76 ±0.01 a,***
		Bran	72.80 ±0.48 d,***	25.61 ±0.05 d,***	20.73 ±0.03 d,***
		Light flour	10.81 ±0.04 a,***	4.95 ±0.05 a,***	3.74 ±0.07 b,***
Range			2.27–102.34	1.71–30.73	0.20–27.15

Data are means ± SD (n=3). Means with different letters within each buckwheat species are significantly different (P <0.05); means with * are significantly different (difference between buckwheat species), with significance indicated as follows: ***, P <0.001; **, P <0.01; *, P <0.05.

Table 3: Major mineral (g kg$^{-1)}$ and trace mineral (mg kg^{-1}) content of whole grain, hulls, bran and light flour of common and Tartary buckwheat harvested in two consecutive years (I, II).

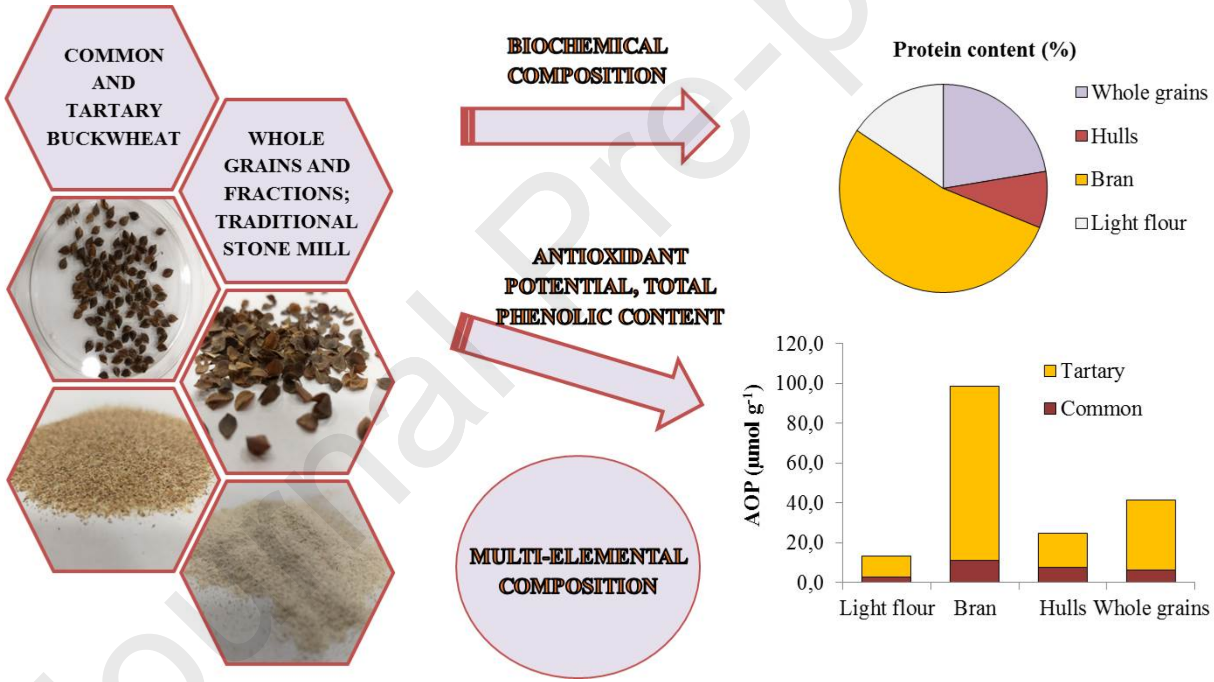
Year	Buckwheat species	Fraction	Major mineral content					Trace mineral content									
			Mg	P	S	K	Ca	Na	V	Cr	Mn	Fe	Co	Cu	Zn	Mo
I	Common	Whole grains	2.42	3.80	1.76	4.87	0.75	29.1	0.06	0.39	18.7	44.5	0.04	6.72	24.5	1.39
		Hulls	2.27	1.32	1.00	4.79	1.84	39.9	0.09	0.41	35.8	51.3	0.04	8.43	17.2	0.82
		Bran	5.42	10.28	3.43	9.80	0.75	37.8	0.06	0.22	28.0	77.9	0.06	10.95	57.6	2.32
		Light flour	1.12	1.90	1.20	2.54	0.48	35.4	0.05	0.28	8.1	33.2	0.05	5.22	21.5	1.20
	Tartary	Whole grains	2.22	3.82	1.52	5.73	1.88	27.7	0.06	0.23	39.4	53.5	0.05	8.73	46.5	3.31
		Hulls	1.37	0.65	0.64	5.28	2.82	34.8	0.05	0.36	55.1	42.0	0.04	7.47	18.7	0.79
		Bran	6.30	13.40	3.53	12.97	1.50	29.8	0.05	0.27	48.1	127.2	0.10	14.66	120.9	2.82
		Light flour	1.26	2.43	1.35	3.10	0.73	25.9	0.05	0.22	14.2	46.6	0.05	13.93	30.4	0.87
II	Common	Whole grains	2.39	3.97	1.62	5.84	0.67	36.5	0.09	0.40	21.5	86.9	0.05	8.30	27.6	0.96
		Hulls	1.40	0.85	0.70	7.05	1.06	31.7	0.10	0.25	34.4	52.1	0.04	6.47	9.1	0.58
		Bran	6.50	12.12	3.73	11.79	0.82	33.5	0.06	0.36	34.9	88.2	0.07	11.61	62.6	1.82
		Light flour	1.36	2.35	1.31	2.90	0.46	29.6	0.08	0.29	10.2	51.9	0.04	5.50	15.0	0.71
	Tartary	Whole grains	2.14	4.06	1.50	5.48	0.84	23.3	0.05	0.20	21.6	69.7	0.04	7.80	33.0	0.86
		Hulls	1.16	0.94	0.74	5.61	1.59	29.9	0.06	0.33	32.2	49.7	0.03	6.15	22.9	0.48
		Bran	5.06	10.42	2.68	9.57	0.55	22.1	0.07	0.20	27.9	102.8	0.06	10.53	70.5	1.84
		Light flour	1.03	1.90	1.15	2.41	0.50	29.5	0.07	0.32	9.9	76.6	0.05	7.47	25.8	0.88
Range			1.03–6.50	0.65–13.40	0.64–3.73	2.41–12.97	0.46–2.82	22.10–39.90	0.05–010	0.20–0.41	8.10–55.10	33.20–127.20	0.03–0.10	5.22–14.66	9.10–120.90	0.48–3.31

CRediT authorship contribution statement

Lovro Sinkovič: Investigation, Conceptualisation, Resources, Writing – Review & Editing. **Doris Kokalj Sinkovič:** Formal analyses, Visualization, Writing - Original Draft. **Vladimir Meglič:** Supervision, Project administration, Funding acquisition, Writing – Review & Editing.

Graphical abstract

Differences between common and tartary buckwheat, and their milling fractions obtained by traditional stone milling.



Highlights:

- Biochemical composition of milling fractions of common and tartary buckwheat was evaluated.
- Significant differences between fractions were observed.
- Antioxidant properties of tartary buckwheat were higher compared to common buckwheat.
- Contents of all macroelements and most of the microelements were the highest in bran fraction.