



Rice flakes produced from commercial wild rice: Chemical compositions, vitamin B compounds, mineral and trace element contents and their dietary intake evaluation



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ABSTRACT

Non-traditional wild rice flakes were analysed for chemical composition, vitamin B compounds, α -tocopherol, mineral and trace elements. Dietary intakes of vitamins, minerals and trace elements were evaluated using FAO/WHO and Institute of Medicine regulations. Wild rice flakes proved to be significant contributors of pyridoxine, pantothenic and folic acids, niacin, thiamine, chromium, magnesium, manganese, phosphorus, zinc, copper, molybdenum and iron to essential dietary intakes values. Toxic dietary intake values for aluminium, cadmium, tin and mercury were less than 33%, which complies the limits for adults set by FAO/WHO for toxic elements intake related to the body weight of 65 kg for females and 80 kg for males taking 100 g of flakes as a portion. However, concentrations of Hg reaching between 3.67 and 12.20 $\mu\text{g}/100\text{ g}$ in flakes exceeded the average Hg value of 0.27–1.90 $\mu\text{g}/100\text{ g}$ in cereals consumed in the EU. It has to be respected in the future.

1. Introduction

Wild rice (*Zizania aquatica* L.) has been reported to be a health-promoting cereal, particularly due to its cholesterol-lowering and antioxidant properties and its ability to participate in the prevention of atherogenesis and diabetes type II (Surendiran, Alsaif, Kapourchali, & Moghadasian, 2014). Wild rice is not commonly refined and it has been recognized as a whole grain by the US Food and Drug Administration in 2006 (FDA, 2006). *Zizania aquatica* L. is a cereal originally coming from the eastern and south-eastern regions of the USA, Canada and Asia (Nriagu & Lin, 1995; Zhai, Tang, Jang, & Lorenz, 1996). Newly, wild rice is grown and harvested in Hungary and Greece providing new possible food sources (Bunzel, Allerdings, Sinwell, Ralph, & Steinhart, 2002; Przybylski, Klensporf-Pawlik, Anwar, & Rudzinska, 2009). Furthermore, it is gluten-free so there has been a serious interest in adding it to a variety of food to enhance its nutritional profile, such as a hydrothermally processed flakes.

Wild rice grains contain significant amounts of proteins, contents of vitamin B compounds, minerals, phenolics and are low in fat (Zhai, Lu, Zhang, Sun, & Lorenz, 2001; Sumczynski, Kotásková, Orsavová, & Valášek, 2017). In more detail, vitamin B compounds could be used as a treatment for different forms of neuropathies and act as neuroprotective

agents, their deficiency may cause hyperhomocysteinemia and increase an oxidative stress (Chen, Yang, Hsiao, Huang, & Huang, 2016; Haughey et al., 2012). To date, literature data about vitamin B composition of wild rice flakes has been lacking. In addition, potential accumulation of toxic and trace elements in wild rice grains may represent a potential health hazard. Data devoted to wild rice flakes contribution to the RDA (Recommended dietary allowance) and AI (Adequate intake) for vitamins and minerals, the PTWI (Provisional tolerable weekly intake) and PTMI (Provisional tolerable monthly intake) for trace elements has been insufficient. That is why, this study has targeted on wild rice flakes prepared and processed by hydrothermal treatment to determine its dry matter, ash, starch, protein and lipid contents, crude fibre (CF), and neutral-detergent fibre (NDF). Furthermore, concentrations of vitamin B compounds and tocopherol and forty-four minerals and trace elements were assessed together with the evaluation of their appropriate contributions to the RDA, AI, PTWI and PTMI.

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2. Materials and methods

2.1. Material's section

Eight different raw brand wild rice imported from four different countries were purchased from the local markets in the Czech Republic in the amount of five packages of 200–250 g for each sample. Wild rice samples, originated from Canada, Cambodia, Greece and Hungary, were obtained in 2016 and 2017. Wild rice grains were not ground, but directly cooked in the amount of 5×0.2 kg of each sample in a water bath with the volume of 0.4 L equipped with a thermometer (95 °C, 15 min). Cooking time corresponded to the conditions suitable for the consumption. Afterwards, grains were left at room temperature for 5 min and non-traditional wild rice flakes were immediately prepared by a Combi-Star mill grinder (Waldner Biotech, Lienz, Austria) equipped with a flake roller set to the thickness of 0.60–0.70 mm. Flakes were re-dried for 1 h at 70 °C in the laboratory oven and stored in non-transparent plastic bottles at laboratory temperature with a storage period limited to 1 week.

2.2. Chemicals

Trifluoroacetic acid, acetonitrile and methanol were obtained from Penta (Prague, Czech Republic) and neutral detergent solution package (containing sodium lauryl sulphate, EDTA disodium, sodium borate, sodium phosphate dibasic together with triethylene glycol) was purchased from Ankom Technology (NY, USA). Tiamine-hydrochlorid, riboflavin, nicotinic acid, calcium-pantothenat, pyridoxine-hydrochlorid, tetrahydrofolic acid and D,L- α -tocopherol standards were purchased from Carl Roth (Karlsruhe, Germany). ICP-MS STD 15 standard series (As, B, Ca, Cd, Cr, Fe, Hg, K, P, S, Na, Pb, Se, Sn and Ti), ICP-MS STD 28 standard series (Be, Zn, Cu, Ni, Al, Ga, Ge, Mg, Co, Li, Sc, Ag, Mn, Sr, Ba, Tl, Bi, Zr, Mo, Sb, Ce, Cs, Ho, V, Ta, Tb, U, Y), ICP-MS INT Rh standard, Analpure ultra H₂O₂ and 67% Analpure ultra HNO₃ were purchased from Analytika (Prague, Czech Republic). Helium and argon were provided from Linde Gas (Zlín, Czech Republic) and ultrapure water was supplied by Purelab Classic Elga water system (Labwater/VWS Ltd., UK).

2.3. Chemical methods

Moisture and ash contents were determined using Association of Official Analytical Chemists (AOAC, 2007) and American Association of Cereal Chemists (AACC, 1995) methods. Ewers' polarimetric method was employed to determine starch values (ISO, 1997). Total nitrogen was determined using Kjeldahl method. Acquired values were multiplied by 6.25 and expressed as crude protein. Lipid content was determined using Soxhlet method with hexane as an extracting agent. Crude fibre (CF – cellulose and lignin complex) and neutral-detergent fibre (NDF – complex of cellulose, lignin and insoluble hemicelluloses) were assessed according to study by Sumczynski, Bubelová, and Fišera (2015). Both determinations of CF and NDF were performed using an Ankom²²⁰ fibre analyser (Ankom Technology, NY, USA).

2.4. Determination of vitamin B compounds and α -tocopherol using HPLC-DAD

Vitamin B compounds profile and α -tocopherol concentrations were determined by HPLC analysis system (Thermo Scientific Dionex Ultimate 3000; MA, USA) consisting of Thermo Scientific Dionex UltiMate 3000 Diode Array Detector type DAD-3000RS according to Sumczynski, Koubová, Sneyd, Erb-Weber, and Orsavová (2018). Vitamin B compounds were separated using Zorbax Eclipse XDB C18 (150 $\times$ 4.6 mm; 3.5 μ m) column (Agilent Technologies, CA, USA) and eluted under the gradient conditions with 0.025% trifluoroacetic acid and acetonitrile. In α -tocopherol assessment, Discovery C18

(250 $\times$ 4.6 mm; 5 μ m) column (Supelco, USA) was used and α -tocopherol was eluted under the isocratic elution conditions with the mobile phase consisting of methanol and redistilled water (95:5).

2.5. Determination of minerals and trace elements in ICP-MS equipment

2.5.1. Sample preparation

High purity 18.2 M Ω cm water was obtained from Purelab Classic Elga system. Five mL of 67% HNO₃ and 1 mL of H₂O₂ were added to each sample weighing 1.0 g and they were decomposed by microwave system (Milestone Ethos One, Sorisole, Italy) with the parameters set as follows: 500 W for 10 min, 1500 W for 15 min and 500 W for 15 min. The samples were in acidic solutions that contain no more than 5% of HNO₃ (the samples were in liquid form). Each sample was prepared in three replicates. Two sets of calibration standard series were prepared to be matched with the expected concentration ranges in the samples: ICP-MS STD 28 standard series at the concentrations of 3–35 μ g/L and ICP-MS STD 15 standard series at the concentrations of 0.5–1.0 μ g/L. Rhodium (¹⁰³Rh) at the concentration of 100 μ g/L was used as an internal standard. Reference materials of green algae Metranal®8 and NIST Rice flour 1568b from the National Institute of Standards and Technology (both bought via Analytica Ltd., Prague, Czech Republic) were applied to assess the measurement accuracy (see Supplementary Table 1).

2.5.2. ICP-MS instrumentation

Analyses were performed using quadrupole-based Thermo Scientific iCAP Qc inductively coupled plasma-mass spectrometer (ICP-MS) (Thermo Scientific, MA, USA). Collision cell (QCell) containing helium was applied to remove undesirable molecule ions by distinguishing their kinetic energies (CCT and KED mode). Specific working parameters were set as follows: 1550-W RF power, 5-mm sampling depth, 14.0 L/min cool gas flow rate, 0.8 L/min auxiliary gas flow rate, 1.015 L/min nebulizer gas flow rate, 4.1 mL/min He flow rate, 40.00-rpm nebulizer pump speed and 2.7 °C chamber temperature. Samples were analysed five times in total.

2.6. Evaluation of the contribution of vitamins, minerals and trace elements to the RDA, AI, PTWI and PTMI

Dietary intake levels for vitamins, minerals and essential trace elements from wild rice flakes have been evaluated and compared with the appropriate RDA or AI values (if the RDA has not been set) as recommended by the Institute of Medicine (IOM, 1997, 1998, 2000, 2001, 2005). Intake levels of toxic elements have also been evaluated and compared with the PTWI or PTMI (if the PTWI has not been defined) as suggested by the FAO/WHO (2006, 2011a, 2011b, 2013). Intake levels have been determined for adults aged between 31 and 50, both males with the average weight of 80 kg and females weighing 65 kg. Since there is no recommendation for daily intake of wild rice flakes, serving size of flakes has been set to 100 g.

2.7. Statistical analysis

All analyses were replicated 5 times. Results were reported as mean $\pm$ standard deviation in fresh weight statistically evaluated using one-way analysis of variance (ANOVA). Subsequently, Tukey's test was applied to identify the differences among means. The level of probability for significance was 5%.

3. Results and discussion

3.1. Chemical properties

As can be seen in Table 1, moisture content varied between 7.1 and 11.5%. According to the applicable Czech regulation (Reg. No. 333,

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