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Metals in food products with rising consumption (brewer's yeast, wheat bran, oat bran, sesame seeds, flaxseeds, chia seed). A nutritional and toxicological evaluation

Carmen Rubio[a,*], Dailos González-Weller[a,b], José M. Caballero[a], Ana R. Romano[c], Soraya Paz[a], Arturo Hardisson[a], Ángel J. Gutiérrez[a], Consuelo Revert[a]

[a] *Área de Toxicología, Universidad de La Laguna, 38071 La Laguna, Tenerife, Spain*
[b] *Servicio de Inspección Sanitaria y Laboratorio, Servicio Canario de la Salud, 38006 Santa Cruz de Tenerife, Tenerife, Spain*
[c] *Faculdade de Farmácia da, Universidade de Lisboa, Av. Prof. Gama Pinto, 1649-003 Lisboa, Portugal*

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ABSTRACT

Brewer's yeast, sesame seeds, wheat bran, oat bran, flaxseeds and chia seeds have gained popularity. Twenty metals were determined by ICP-OES for a nutritional and toxicological evaluation of the metal content of these foods. K is the most abundant macroelement in brewer's yeast (4959 mg/kg), followed by Ca in sesame seeds (4349 mg/kg). Regarding the micronutrients, the Zn level in brewer's yeast (132 mg/kg) is the highest, followed by Fe in wheat bran (56.8 mg/kg). Al is found in larger quantities in sesame seeds (14.1 mg/kg). These novel foods contribute notably to the dietary intake of Zn and Fe. The intake of Mn and Mo is nearly 100% of the daily reference intake. Regulations on the maximum limits of these elements should be implemented. The analyzed foods seem to offer higher contributions to the RDIs when it comes to micronutrients, rather than macronutrients. The metal contents pose no health risk.

1. Introduction

The generalized interest in health food is leading to a higher consumption of novel foods like brewer's yeast, wheat bran, oat, sesame, flax and chia. The notably increasing consumption is due to the health benefits to the human rather than the nutritional value.

Brewer's yeast consists of the dried, pulverized cells of *Saccharomyces cerevisiae* and is easily digested as well as having a high nutrient content. In general, brewer's yeast tends to be a rich source of the B-complex vitamins (thiamin, biotin, riboflavin, pantothenic acid, niacin, folic acid and pyridoxine), all essential amino acids and minerals, particularly Se, Cu, Fe, K, Mg, Zn and Cr. Some studies show that brewer's yeast helps to lower LDL and raises HDL cholesterol levels, while others show it is also an effective treatment for acne (Talbot and Hughes, 2007; UMMC, 2011a). In addition, brewer's yeast consumption is arising due to their antioxidative activity (Jilani, Cilla, Barberá, & Hamdi, 2015; Meng, Zhang, Li, Ho, & Zhao, 2017). Brans have been characterized to possess a wealth of health-promoting ingredients, they have been validated to impart antilipaemic, antiatherogenic, antihypertensive and hypoglycaemic properties and they have been verified to combat oxidative stress, attenuate insulin resistance, avert obesity risk by inducing satiety and alleviate cardiovascular complications (Prückler et al., 2014; Patel, 2015; Luthria, Lu, & Maria John, 2015). Bran fractions of wheat (*Triticum* spp.) are rich in fiber, minerals, vitamin B6, thiamine, folate and vitamin E and some phytochemicals, in particular antioxidants such as phenolic compounds (Ziegler et al., 2016). Epidemiological and experimental evidence is accumulating to show that wheat bran, due to its high content in fiber, may reduce the risk of certain chronic diseases, in particular cardiovascular disease, metabolic syndrome, type 2 diabetes and certain cancers (Stevenson, Phillips, O'Sullivan, & Walton, 2012). Based on Article 13(1) of Regulation (EC) No 1924/2006, the EFSA (European Food Safety Authority) has approved a health claim related to wheat bran fiber and an increase in fecal bulk, a decrease in intestinal transit time and a contribution to the maintenance of a normal body weight (EFSA, 2010a).

Oats (*Avena sativa*) are distinct among cereals due to their multifunctional characteristics and nutritional profile. Oats consumption is increasing regarding to their notably health properties as antioxidant or anticarcinogenic (Xiao et al., 2015). Oat bran is a good source of B-complex vitamins, protein, fat, minerals and beta-glucan. Beta-glucan is a soluble fiber with notable functional properties and is of great importance in human nutrition. These physiological effects of beta-glucan

* Corresponding author at: Área de Toxicología, Universidad de La Laguna, 38071 La Laguna, Tenerife, Spain.
E-mail address: crubio@ull.edu.es (C. Rubio).

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are related to its viscosity, attenuation of postprandial plasma glucose and insulin responses, high transport of bile acids towards lower parts of the intestinal tract and high excretion of bile acids thereby lowering serum cholesterol levels. Moreover, it is helpful against celiac disease (Zhang, Luo, & Zhang, 2017).

Sesame (*Sesamum indicum* L.) is widely naturalized in tropical regions around the world and is cultivated for its edible seeds, which grow in pods (derived from a capsule) (EC, 2013a). Sesame seeds are rich in oil and contain vital minerals such as Mn, Fe, Ca, Fe and Mg, vitamins (thiamine and tocopherol) and phytosterol. Sesame seeds have several properties such as emollients, demulcents, emmenagogues, laxatives, diuretic and fattening qualities. The seeds contain a lignin called sesamin that can act as a phytoestrogen and has bactericide and insecticide activities as well as antioxidant activity and health-promoting benefits (Miyamoto, Fujii, Komiya, Terasaki, & Mutoh, 2016). Sesame seeds are recognized as having cholesterol-lowering effects and can reduce inflammation and pain associated with rheumatoid arthritis. In addition, sesame seeds are useful for treating respiratory and skin disorders. Moreover, sesame seed consumption is reported to enhance plasma gamma-tocopherol and vitamin E activity, which can prevent cancer and heart disease (Paliyath et al., 2011).

Flax (*Linum usitatissimum*) is an erect annual plant whose oil seed is called flaxseed or linseed (EC, 2013b). In addition to having one of the largest amounts of omega-3 fatty acid, among the major seed oils, flaxseed is an essential source of high quality protein and soluble fiber (Nandi and Ghosh, 2015), and has considerable potential as a source of phenolic compounds, especially flavonoids, phenolic acids and lignans, and is the richest source of mammalian lignin precursors. The preventive and therapeutic potential of flaxseed has been receiving increasing scientific attention due to evidence of beneficial biological effects in reducing the risk of degenerative diseases (Oomah and Mazza, 2000). Flaxseed may also improve the adverse effects of the lack of oestrogens (Mora Aguilar, Tomaz Sant'Ana, Vasconcelos Costa, Silva, & Brunoro Costa, 2017).

Chia (*Salvia hispanica*) is currently not grown on a large scale, but because of the universal applicability of its seeds it deserves attention. Chia has been shown to be an excellent source of polyunsaturated fatty acids, fiber, protein and antioxidants and its omega-3 fatty acid content is even higher when compared to flax (Ayerza, 2013; Martínez-Cruz and Paredes-López, 2014), accounting for 75% of the total oil content (Muñoz, Cobos, Diaz, & Aguilera, 2013). Although there are not many published studies on the health benefits of consuming chia seeds, and much of the available information is based on animal studies or human studies with a small number of research participants, there is evidence that it improves cardiovascular risk factors such as lowering cholesterol, triglycerides and blood pressure (Muñoz et al., 2013). Sierra et al. (2015) reported that dietary chia oil could protect vascular function under hypercholesterolaemia serving as a true functional food. Another study conducted in obese rats, which were feed with chia seed and oil, have shown an antioxidant protective effect (Marineli, Lenquiste, Moraes, & Maróstica, 2015).

However, these novel foods could be a source of essential and toxic metals (Rubio et al., 2012). Therefore, assuming that food consumption is the main route of exposure of the general population to metals, that brewer's yeast, wheat bran, oat bran, sesame seeds, flaxseeds and chia seeds are novel foods with increasing popularity, and that there is still a shortage of data on their mineral content, the need of this nutritional and toxicological metal evaluation is justified. The objectives of this work were to determine the concentrations of macrominerals (Na, K, Ca and Mg), trace elements (B, Ba, Co, Cr, Cu, Fe, Li, Mn, Mo, Ni, Sr, V and Zn) and toxic metals (Al, Cd and Pb), and to compare the metal content between organic and non-organic samples.

2. Materials and Methods

2.1. Sampling

A total of 112 organic and non-organic food samples were analyzed. The sample set consisted of:

- 72 non-organic samples (18 samples of brewer's yeast, 10 samples of wheat bran, 9 samples of sesame seeds, 9 samples of flaxseeds, 18 samples of chia seeds, 10 samples of oat bran).
- 38 organic samples (10 samples of wheat bran, 9 samples of sesame seeds, 9 samples of flaxseeds, 10 samples of oat bran).

The samples were collected between January and April 2015 in different hypermarkets, supermarkets and local herbalist stores in Spain, Portugal and France.

2.2. Treatment and Analysis

Before sample preparation, all laboratory materials were washed with Acationox laboratory cleaning agent (Merck, Darmstadt, Germany) to prevent contamination and eliminate any possible trace of metals. They were then kept in 5% nitric acid for 24 h and subsequently washed with Milli-Q (Millipore, Milford, MA) quality water.

After collection and classification, the food samples were homogenized, preserved at -18° C and analyzed within 2 months.

In previously weighed porcelain capsules on PB153-S/FACT scales (Mettler Toledo, Switzerland), 10 g of each raw sample was weighed in duplicate. The capsules with the samples were then subjected to drying in an oven (Selecta, Spain) at 60–70 °C for 12–14 h. Afterwards, the samples were placed in a muffle furnace (Nabertherm®, Germany) and the temperature was gradually increased (50 °C/h) until it reached 425 ± 15 °C, this temperature was maintained for 18–24 h to destroy the organic matter in the sample. The final white ashes were dissolved in 1.5% HNO_3 and completed to a volume of 50 mL. The diluted samples were transferred to pre-numbered polypropylene containers and stored at room temperature in the dark until metal determination (Rubio et al., 2012).

Metal contents were analyzed by Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-OES) using a Thermo Scientific iCAP 6000 series (Waltham, MA, USA) spectrometer (Rubio et al., 2012). Conditions were as follows: approximate RF power, 1.2 kW; gas flow (nebulizer flow; auxiliary flow), 0.5 L/min; pump rate, 50 rpm; stabilization time 0 s. All analyzes were performed in duplicate.

The quality controls were established by the average recovery obtained with reference materials under reproducible conditions. The reference materials (SRM) of the National Institute of Standards and Technology (NIST): SRM 1567a Wheat Flour, SRM 1515 Apple Leaves, SRM 1568a Rice Flour were used. All the recovery percentages obtained with the reference materials were higher than 93% (Table 1) (Rubio et al., 2012). Instrumental detection and quantification limits in terms of reproducibility were calculated as three and ten times the standard deviation (SD) resulting from the analysis of 15 targets of acid digest (IUPAC, 1995).

Table 2 shows the wavelengths (nm), the detection and quantification limits (mg/L) of the metals analyzed.

2.3. Statistical analysis

Two different criteria were considered for the statistical analysis, the type of food (brewer's yeast, oat bran, wheat bran, chia seeds, flaxseeds or sesame seeds) and the cultivation method (organic or non-organic). Statistical analysis was performed using the IBM SPSS Statistics 21.0 statistical package. The main parameters for the descriptive statistics that have been used to characterize the samples were the arithmetical mean, the standard deviation, and the maximum and