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Determination of essential nutrients and cadmium in the white quinoa and amaranth seeds

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ABSTRACT

Micronutrients are trace elements required in very small amounts in the diet. Metals such as copper (Cu), iron (Fe), and zinc (Zn) are essential nutrients that are required for various biochemical and physiological functions. Cadmium, which is considered as systemic toxicant that is known to induce multiple organ damage, even at lower levels of exposure, has been also determined. Therefore, in this paper the concentrations of Cu, Fe, Zn and Cd have been determined in the white quinoa and amaranth by ICP-MS analysis. Concentrations of all examined metals were higher in the amaranth. This research has shown that amaranth and white quinoa could be good sources of essential micronutrients. The concentration of cadmium in amaranth was very close to maximum permitted concentration in food.

Introduction

Food is composed of a wide distribution of nutrients, which have very specific metabolic effects on the human body. While some nutrients are essential, others are considered as non-essential. Essential are the nutrients that the human body is not capable to synthesize and therefore they are provided with food. Vitamins, minerals, amino acids, fatty acids and some carbohydrates that provide energy are essential. Non-essential nutrients are those that the body can synthesize from other ingredients, as well as to provide with food. Nutrients are generally divided into two categories: macronutrients and micronutrients.

Macronutrients are nutrients that are decomposed to provide energy to the body. Carbohydrates, dietary fiber, fat, fatty acids, cholesterol, proteins and amino acids belong to the group of macronutrients. Micronutrients are trace elements required in very small amounts in the diet. Heavy metals are defined as metallic elements that have a relatively high density compared to water (Fergusson, 1990.). Their toxicity depends on several factors including the dose, route of exposure, and chemical species, as well as the age, gender, genetics and nutritional status of exposed individuals. However, heavy metals are indestructible and therefore can concentrate in the food chain and eventually accumulate in the human body (Ayangbenro et al., 2017; Grabowska, 2011).

Elements such as copper (Cu), iron (Fe) and Zn are known as micronutrients that are essentially necessary for plant physiological processes in trace quantities, while cadmium (Cd) is an element that can be assessed as trace element and potentially harmful contaminants. However, increased presence of trace elements in the environment and particularly in soils can affect plant development as well as influence the elemental composition of harvested crops and, in case of food or feed plants, lead to contamination of the food chain (Vincevica-Gaile and Klavins, 2012).

Cadmium (Cd)

Cadmium is a heavy metal of considerable environmental and occupational concern. It is widely distributed in the earth's crust at an average concentration of about 0.1 mg/kg. The main routes of exposure to cadmium are via inhalation or cigarette smoke and ingestion of food. Human exposure to cadmium is

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possible through a number of several sources including employment in primary metal industries, eating contaminated food, smoking cigarettes, and working in cadmium-contaminated work places, with smoking being a major contributor (IARC, Monographs – Cadmium., 1993; Paschal et al. 2000). Cadmium is also present in trace amounts in certain foods such as leafy vegetables, potatoes, grains and seeds, liver and kidney, and crustaceans and mollusks (Satarug, 2003). Cadmium compounds are classified as human carcinogens by several regulatory agencies. The International Agency for Research on Cancer and the U.S. National Toxicology Program has concluded that there is adequate evidence that cadmium is a human carcinogen (Ayangbenro et al., 2017).

Copper (Cu)

The bioavailability of copper in food depends on the amount of copper present. If the copper is needed in higher amount, it will be more absorbed, and if too much copper is taken, it will absorb less (Silverberg, 2012). Other nutrients present in foods may affect copper absorption. Increased intake of zinc, vitamin C and iron reduces copper absorption due to competitive binding for a common carrier. Copper can be found in seafood, nuts, beans, cacao, dried fruit, spinach, cereals and seeds. It can also be supplied via water. The content is reduced by the processing of food. Removing the outer layer of grains significantly reduces copper content as well as cooking at high temperatures for a longer period of time. Vegetarian diet allows sufficient copper intake (Ma and Betts, 2000). The daily requirement is about 2-5 mg of which 50% is absorbed from the gastrointestinal tract (Walravens, 1980).

Zinc (Zn)

Zinc is an essential micronutrient that contributes to the optimal functioning of the immune system and the resistance of the anti-infective organism. It should be consumed regularly because it can not be stored in the body.

Iron (Fe)

Iron is necessary for a range of processes in the human body. For instance, it is an essential component of haemoglobin, the compound that carries oxygen in our blood. Maintaining adequate levels of iron is essential for health.

María Reguera and co-workers highlight that different agro-ecological conditions could significantly alter the agronomical and nutritional properties of quinoa what impacts the seed quality. In their research they concluded that both the variety and location determined the mineral composition, the amino acid profile, the protein content and the antioxidant capacity of the quinoa seeds (Reguera et al., 2018). Iron is introduced into the body by food and its absorption depends on a number of factors, so the intake needs to exceed daily needs. Absorption of iron is enhanced by ascorbic acid which acts as a reducer. The food contains two forms of iron, iron in the hem and non-hem. Iron in the hem is found in foods of animal origin and is better absorbed by iron that is not in the hem and it is found in foods of plant origin. Hem iron sources are meat (kidneys and livers) and fish. It is almost completely absorbed and not influenced by other nutritional factors. Non-hem iron is a form that is mostly consumed by food but also by supplements and is found in fruit, vegetables, grains and cereals and is less absorbed depending on the presence of other nutrients that can increase or decrease its absorption. The non-hem iron is in the feri and in order to be able to resorb it, it has to be transformed into a fero form (Demaeyer et al., 1989).

The old RDIs and new RDIs are given in the table 1. (https://en.wikipedia.org/wiki/Reference_Daily_Intake, 15.01.2019.)

Ancient grains

Quinoa and other ancient grains, such as amaranth and chia are rapidly growing in popularity because of their wide array of health benefits. Ancient grains are referred to as such because they have remained largely unchanged for hundreds or even thousands of years. Quinoa was known to the Incas as "the mother of all grains" and was first cultivated over 5.000 years ago.

Table 1. The old and new RDI.

Nutrient	RDI		
	Old RDI (mg/day)	New RDI (mg/day)	
		Male, age 19-30	Female, age 19-30
Copper	2	0.9	0.9
Iron	18	8	18
Zinc	15	11	8

Quinoa

Botanically, quinoa is not classified as a grain. It is an ancient grain (pseudocereal). This means it is a non-grassy plant used in much the same way as cereals and grains with a similar nutritional profile. The most common colour of quinoa is white. Quinoa is a complex carbohydrate with a low glycaemic index, but it also contains all 9 amino acids, making it a complete protein. It is rich in monounsaturated fats, has small amounts of omega-3 fats and is high in anti-inflammatory phytonutrients, as well as iron, calcium, phosphorus, selenium, and vitamins B and E. Whole grains, such as quinoa, provide essential vitamins, minerals, and fibre . These help regulate the digestive system and keep you fuller and more satisfied. Quinoa is naturally gluten-free. About 25 percent of quinoa's fatty acids come in the form of oleic acid, a heart-healthy monounsaturated fat, and about 8 percent comes in the form of alpha-linolenic acid (ALA), the omega-3 fatty acid most commonly found in plants. It is one of only a few plant foods that are considered a complete protein, containing all nine essential amino acids - these are the amino acids that our bodies cannot produce and, therefore, need to consume. This makes quinoa a great dietary choice for vegetarians and vegans. Because of quinoa's high fibre content compared with other grains, it helps reduce the risk of a number of health conditions. These conditions include constipation, heart disease (by lowering blood pressure and reducing cholesterol), and haemorrhoids (piles). High-fibre diets have been shown to help improve blood sugar control. This can be beneficial for individuals with diabetes or prediabetes. Also, diets rich in fiber tend to promote a healthy weight because fiber helps you feel fuller for longer period of time, potentially reducing the overall food intake. Quinoa provides a higher amount of antioxidants than other common grains used in a gluten-free diet. Most gluten-free products consist of corn, rice, or potato flour and lack the nutrients that products incorporating quinoa can provide. Quinoa has a potential protective effect against kidney stones. This is because quinoa helps manage potassium levels (https://www.medicalnewstoday.com/articles/274745 .php; 31.12.2018.).

Amaranth

Amaranthus, collectively known as amaranth is a cosmopolitan genus of annual or short-lived perennial plants. Some amaranth species are cultivated as leaf vegetables, ancient grains, and ornamental plants. Most of the *Amaranthus* species are summer annual weeds and are commonly referred to as pigweed (*Bensch et al., 2003.).* The grains of these species are rich in nutrients and provide a complete diet of amino acids (Singh, 2017). They contain significant amounts of minerals, nutrients, vitamins and amino acids. Beside antidiabetic and antioxidant activities, they also have high levels of iron, selenium, phosphorus and low levels of toxic substances (Barcellos Xarvier et al., 2018). Several studies have shown that amaranth seed or oil may be beneficial for those with hypertension and cardiovascular disease. Regular consumption reduces blood pressure and cholesterol levels, while improving antioxidant status and some immune parameters. Vegetable amaranths are recommended as a good food with medicinal properties for young children, lactating mothers and for patients with constipation, fever, hemorrhage, anaemia or kidney complaints. (Achigan-Dako et al., 2014.).

Material and methods

The sample for the analysis was purchased at the store in Bosnia and Herzegovina. In Figure 1 The samples are shown in Figure 1

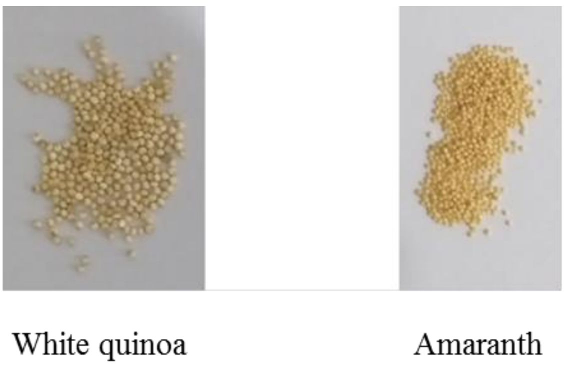

Fig. 1. The view of the samples for the analysis

Method

The standard method for determination of trace elements in food, pressure digestion BASEN 13805:2014 was used. The sample for ICP-MS analysis has been prepared by using microwave digestion. 1 g of each sample has been dispersed in 11 ml of nitric acid and 1 ml of hydrogen peroxide and then exposed under microwave digestion for 30 minutes in 3 steps. The first step at 130 °C for 10 minutes, the second step at 150 °C for 5 minutes and the third step at 190°C for 15 minutes has been done. The power used depends on the number of digestion vessels in microwave oven. In our experiment the power was set up at 400 W during all three microwave digestion steps.

Chemicals

Nitric acid (suprapur) 67-69% produced by Carlo Erba and hydrogen peroxide (suprapur) 30% produced by Fluka. Multielement standard solution, Agilent technologies, 10 μg/ml.

Instruments

Following instruments have been used in this paper: ICP-MS, Agilent Technologies, 7700X for determination of metals as well as microwave digestion/extraction workstation Sineo Jupiter-B for digestion for the preparation of samples.

Results

The concentrations of iron, copper, zinc, and cadmium in amaranth and white quinoa seeds are given in Table 2 and Diagram 1. The concentrations of trace elements in seeds have been determined by standard BASEN 13805:2014 method.

Discussion

From these data analyses we can see that the concentrations of all examined metals are the highest in amaranth. We can see also that the concentration of iron is 1.6 and for zinc is 1.9 times higher in amaranth than in white quinoa, while the concentrations of copper are comparable. The concentration of cadmium is very high in amaranth and is 3.85 times higher than in white quinoa. The concentration of cadmium in amaranth is very close to maximal permitted concentration in food.

Table 2. The concentrations of iron, copper, zinc and cadmium in amaranth and white quinoa seeds

Seed	Concentration (mg/kg)			
	Fe	Cu	Zn	Cd
Amaranth	47.34	3.69	37.36	0.1
White quinoa	29.66	3.75	19.74	0.026

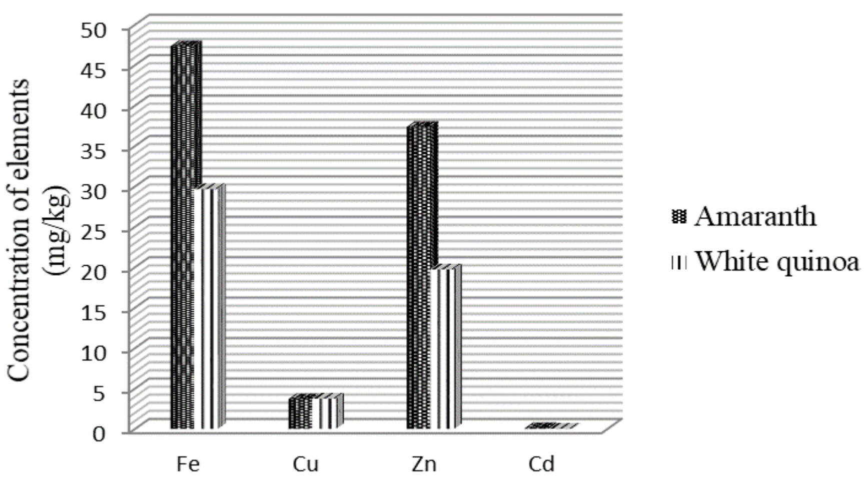

Fig. 1 Determined concentrations of iron, copper, zinc, and cadmium in amaranth and white quinoa seeds

Conclusions

The determination of concentration of cadmium, copper, zinc and iron in amaranth and white quinoa have been done by ICP-MS analysis. This research has shown that amaranth and white quinoa could be a good sources of essential micronutrients. The highest content of iron and zinc were detected in amaranth sample, then follow copper and cadmium. It was found that in amaranth, cadmium accumulation was detected in significantly higher amount than in white quinoa. All the concentrations found in examined seeds were in a range of permitted concentrations in food. The obtained results are useful for both sides, first one understands the source of useful micronutrients and the other is overall understanding of possible contamination of food plants with potentially toxic metals.

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