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Original Research

Heavy Metals Content in Imported Basmati Rice into Jordan

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Abstract

Rice is one of the main ingredients used in most of the daily popular dishes in Jordan. Like many developing countries, Jordan relies on ineffective detection procedures for heavy metals in rice; thus, the main objective of this study is to analyze and determine heavy metal contaminants and define a procedure of control. Given the concern for food safety, this study assessed the contents of As, Pb, Cr, Ni, Zn, Cd, U, and Th in Basmati rice imported from different sources to Jordan. The levels of toxic metals Cd(II), Co(II), Pb(II), U(VI), and Th(IV) were not detected in Basmati rice samples of this study. The mean concentration of Cr(III, VI) in Basmati rice samples from different origins was (0.41 mg/kg), Cu(II) (2.39 mg/kg), Mn(II) (3.94 mg/kg), Ni(II) (0.90 mg/kg), Zn(II) (8.89 mg/kg) and Fe(II) (11.54 mg/kg). The highest Cr(III, VI) concentration was found in Basmati rice samples of Pakistani origin while the highest Cu(II) and Fe(II) concentrations were found in those of Indian origin.

To the best of our knowledge, this is the only work dealing with the assessment of such heavy metals for imported rice grains in Jordan, and it can be a reference for the public and related institutions.

Keywords: heavy metals, rice, EDS spectroscopy, ICP-AES

Introduction

Rice is the second most prevalent cereal crop in the world with an annual global production of approximately 600 million tons. It is the staple food for most Asian countries, with a daily consumption per capita of between 200 and 400 g [1]. In Jordan, rice is one of the main ingredients used in most of the daily popular dishes and a significant amount of this product is imported from different countries. One of the most popular varieties of rice consumed globally is the "Basmati" brand imported from India, Thailand, and Pakistan because of its distinct properties. However, high levels of heavy metals have been reported in these countries' soil and groundwater, indicating pollution. Still, the Basmati brand continues to have robust growth in the Arab markets, especially in Jordan.

Several studies have indicated that rice grown in heavy-metals-contaminated soils has a higher concentration of heavy metals than that grown in uncontaminated soils [2]. Although trace elements have a

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role in biochemical functions and reactions in the human body, they could be harmful if taken in excess amounts. The high Cadmium (Cd) intake through contaminated food or water can cause stomach irritation, vomiting, and diarrhea, while the long-term intake of low levels of Cd can cause kidney disease and bone fragility [3]. Chromium (Cr) and Zinc (Zn) have non-carcinogenic hazardous effects on human health when the exposures to these elements exceed the tolerable reference dose [4], whereas Nickel (Ni) has been reported to cause a significant decrease in helper T cells and an increased level of suppressor T cells [5]. Moreover, humans exposed to Arsenic (As) may develop skin lesions, neuropathy, gastrointestinal diseases, cardiovascular diseases, cancer, and other ailments, while Lead (Pb) exposure may cause changes in the neurologic system, leading to a loss of neurological function [3]. On the other hand, Uranium (U) is characterized by both radiotoxicity and chemical toxicity, whereas Thorium (Th) is the only radiotoxic element. The health hazards associated with these radionuclides stem from their ability to accumulate in human tissues. During the nuclear transformation processes, the radionuclides emit gamma rays as well as high-LET charged particles, thereby causing intensive damage to the tissues they are localized in and, to a lesser extent, to the neighboring organs [1].

Given the concern for food safety, this study would assess the contents of As, Pb, Cr, Ni, Zn, Cd, U, and Th in the edible major crops of Basmati rice imported from different sources to Jordan. To the best of our knowledge, this is the only work that deals with the assessment of such heavy metals in Jordan, which is relevant not only for food security purposes but also for commercial and economic aspects. The steady increase in food contamination necessitates the analysis and monitoring of toxic species that could become a serious potential hazard to human health if not controlled. Many research studies on the type, amount, source, and precaution of toxic metals in contaminated foods have been carried out in various countries in recent years.

The purpose of the present study is to determine the concentration of some heavy metals at trace levels in different sources of Basmati rice consumed in Jordan and to compare these levels with (FAO/WHO) international standards.

Materials and Methods

Sample Preparation

Ten samples of 5 kg each of different imported brands of Basmati rice (Crop 2023/2024) were collected from the most popular shopping centers in Amman/Jordan. The rice samples were collected and packed in polyethylene bags weighing from 1 to 2 kg. From each brand, three samples (100 g each) were randomly selected, sealed in a plastic box, labeled with the brand's name, and stored at room temperature until analysis. All analyses were performed in the Environment, Water and Food Laboratory, Royal Scientific Society, Amman, Jordan.

Chemical Analysis

All chemicals and standards required for the analysis of heavy metals were obtained from Merck Co. (Germany). Blank samples and replicate analysis were implemented. The mean blank value was deducted from the readings before the result was calculated.

Table 1. Proximate composition of all rice samples.

Source country	Sample ID	Moisture Content (%)	Ash content (%)	Fat Content (%)	Protein content (%)	Carbohydrates (%)
India	1	$9.40^{c} \pm 0.05$	$9.48^{c} \pm 0.22$	$0.48^{c} \pm 0.36$	$8.67^{b} \pm 0.60$	$71.97^{a} \pm 0.98$
India	2	$10.56^{b} \pm 0.66$	$9.99^{a} \pm 0.34$	$0.95^{a} \pm 0.14$	$8.26^{d} \pm 0.28$	$70.24^{c} \pm 1.75$
India	3	$9.26^{c} \pm 0.32$	$9.88^{b} \pm 0.03$	$0.21^{e} \pm 0.22$	$9.55^{a} \pm 1.12$	$71.10^{b} \pm 0.72$
India	4	$10.32^{b} \pm 0.24$	$10.00^{a} \pm 0.01$	$0.41^{c} \pm 0.12$	$8.44^{c} \pm 0.88$	$70.83^{b} \pm 0.95$
India	5	$10.61^{b} \pm 0.02$	$9.78^{b} \pm 0.85$	$0.48^{c} \pm 0.78$	$8.61^{b} \pm 0.65$	$70.52^{bc} \pm 0.88$
India	6	$8.11^{d} \pm 0.02$	$10.05^{a} \pm 1.05$	$0.71^{b} \pm 0.44$	$8.48^{c} \pm 0.44$	$72.65^{a} \pm 1.72$
Pakistan	7	$11.73^{a} \pm 0.04$	$9.98^{a} \pm 0.05$	$0.34^{d} \pm 0.06$	$8.63^{b} \pm 0.02$	$69.32^{d} \pm 1.65$
Pakistan	8	$11.79^{a} \pm 0.11$	$10.00^{a} \pm 0.06$	$0.52^{c} \pm 0.24$	$8.22^{d} \pm 0.05$	$69.47^{d} \pm 1.22$
Pakistan	9	8.76 ± 0.02	$9.79^{b} \pm 0.02$	$0.73^{b} \pm 0.33$	$8.43^{c} \pm 0.10$	$72.29^{a} \pm 1.34$
Thailand	10	$11.48^{a} \pm 0.16$	$9.96^{a} \pm 0.00$	$0.89^{a} \pm 0.12$	$6.86^{e} \pm 0.10$	$70.81^{b} \pm 1.05$

Note: All values are the means of three replicates ± standard deviation. All values are on an as-is basis. Means with different superscripts are significantly different (P≤0.05) according to the least significant difference test (LSD).

Table 2. Trace element values obtained from the rice samples.

Rice source country	Sample ID	Heavy and trace elements in (mg/kg)										
		Cd (II)	Co (II)	Cr (III, VI)	Cu (II)	Mn (II)	Ni (II)	Pb (II)	Zn (II)	Fe (II)	U (VI)	Th (IV)
India	1	BDL	BDL	0.47^{xy}	3.22^{op}	3.30^{no}	2.39^{pqrst}	BDL	7.48^{g}	33.35^{a}	BDL	BDL
India	2	BDL	BDL	0.32^{y}	2.79^{opq}	2.70^{opqr}	1.67^{tuv}	BDL	7.09^{gh}	15.61^{b}	BDL	BDL
India	3	BDL	BDL	0.72^{wxy}	4.46^{m}	1.58^{tuvw}	0.93^{uvwxy}	BDL	5.59^{kl}	16.23^{b}	BDL	BDL
India	4	BDL	BDL	0.27^{y}	2.35^{pqrst}	2.74^{opqr}	0.84^{vwxy}	BDL	6.29^{hijk}	7.49^{g}	BDL	BDL
India	5	BDL	BDL	0.49^{xy}	4.16^{mn}	2.60^{opqrs}	1.30^{uvwx}	BDL	6.55^{hij}	14.14^{c}	BDL	BDL
India	6	BDL	BDL	0.35^{y}	3.09^{opq}	2.27^{qrst}	0.93^{uvwxy}	BDL	5.73^{jkl}	8.94^{f}	BDL	BDL
Pakistan	7	BDL	BDL	0.47^{xy}	1.83^{rstu}	2.37^{pqrst}	0.57^{xy}	BDL	4.66^{m}	13.06^{d}	BDL	BDL
Pakistan	8	BDL	BDL	0.68^{wxy}	1.78^{stu}	3.17^{opq}	0.50^{xy}	BDL	4.84^{lm}	13.84^{cd}	BDL	BDL
Pakistan	9	BDL	BDL	0.52^{xy}	3.09^{opq}	1.50^{tuvw}	1.49^{tuvw}	BDL	4.64^{m}	11.49^{e}	BDL	BDL
Thailand	10	BDL	BDL	0.22^{y}	1.58^{uvw}	6.77^{ghi}	0.52^{xy}	BDL	15.51^{b}	5.87^{ijk}	BDL	BDL

Note: *BDL: Stands for below detection limits. All results are means of triplicates. Means with different superscripts are significantly different ($P \leq 0.05$) according to the least significant difference test (LSD).

Table 3. The recommended maximum permissible limits of these metals in food [1].

Metal	WHO Recommended Permissible Limit in Food (mg/Kg)
Iron (Fe)	5.0
Lead (Pb)	5.0
Cadmium (Cd)	0.3
Nickel (Ni)	1.5
Copper (Cu)	40
Zinc (Zn)	60
Chromium (Cr)	20

Reagents and Apparatus

The reagents and apparatus used for this experiment are as follows:

- Nitric Acid (HNO_2) of specific gravity of 1.42 g (Assay: 65-68%) (Scharlau, Germany)
- Deionized water (Merck Co., Germany)
- Volumetric flask of 100 ml (ISO LAB, Germany).
- Filter paper (Whatman No. 42)
- Sand bath (Germany)

Characterization Techniques

Metal ions were analyzed using Inductively Coupled Plasma Emission Spectrometer (ICP-AES), SHIMADZU-Japan, Multiple ICP Emission Spectrometer (Model, ICPE-9800), Energy-dispersive X-ray Spectroscopy (SEM-EDS) SEM: FEI Company-Inspect F50/FEG, High vacuum, Eindhoven, Netherlands, EDS: BRUKER QUANTAX EDS systems, Bruker AXS microanalysis GmbH, X Flash Detector 410-M Silicon Drift (SDD), Berlin, Germany.

Procedure

Rice samples were oven-dried at 105°C for 48 h (Memmert, Model UFE500, Schwabach, Germany) after which they were ashed at 550°C in a muffle furnace (Thermolyne™, Model F6010, USA) under a gradual increase in temperature (25°C/h). The ash obtained was then dissolved in a concentrated HNO_3 and digested in a sand bath for 15-20 min until all nitrous oxides were removed. The digested solution was dissolved in 100 ml of deionized water and then filtered using the Whatman filter paper No. 42. The filtered solution was used for the analysis of Cd(II), Co(II), Cr(III, VI), Cu(II), Mn(II), Zn(II), Ni(II), Fe(II), Pb(II), U(VI), and Th(IV) contents by the Inductively Coupled Plasma Emission Spectrometer (ICP-AES) (Shimadzu, ICPE-9800). Concentrations of trace metal in samples were expressed in terms of mg/kg (ppm) on a dry matter basis. The

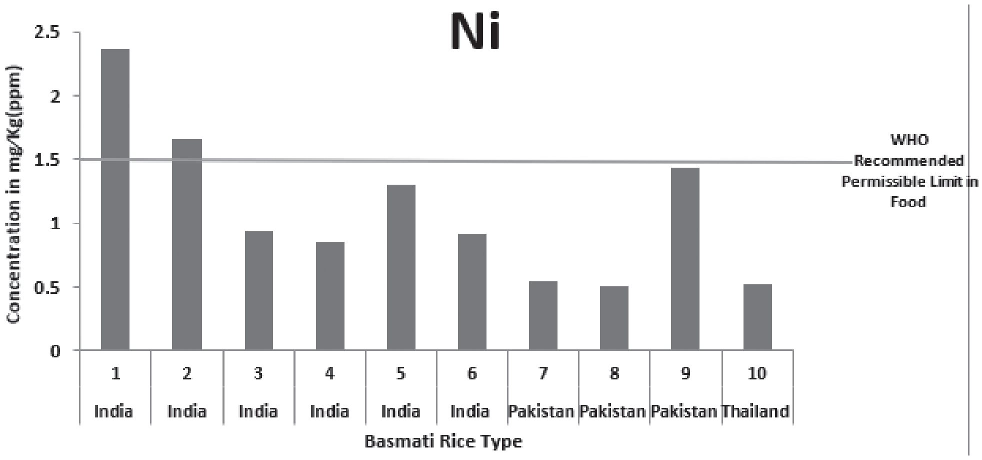

Fig. 1. Nickel content in different Types of Basmati Rice compared to WHO recommended limit in food.

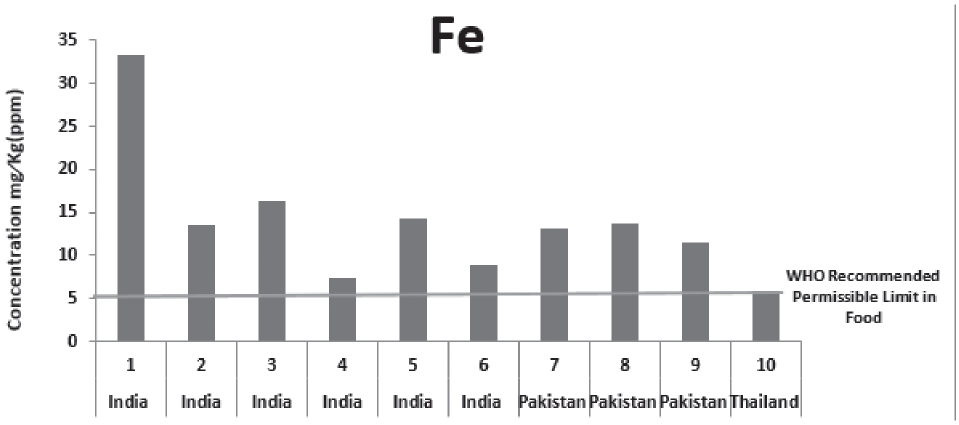

Fig. 2. Iron content in different Types of Basmati Rice compared to WHO recommended limit in food.

calculated detection limits are 0.05 ppm for (Cd(II), Co(II), Cr(III, VI), Cu(II), Mn(II), Zn(II), 0.1 ppm for Ni(II), Fe(II) and Pb(II), 0.5 ppm for U(VI) and 1.5 ppm for Th(IV). Analysis was carried out in triplicates.

Quality Control Procedures

Plastic bottles and vessels were cleaned by soaking in 8% (v/v) HNO_3 for 48 h, rinsed three times with de-ionized water, and dried before use. A rigorous quality control program was implemented, which included reagent blanks, replicate samples, and certified international reference material (Certipur, Merck Germany). The mean blank value was deducted from the readings before the result was calculated. The batch blank was used to decide if the results of the batch were acceptable or not; i.e., if the blank was unacceptably high, then the batch was reanalyzed.

Proximate Analysis

All rice samples were analyzed for their chemical compositions of moisture, fat, protein, ash, and carbohydrates according to the AOAC-approved methods of analysis [6].

Statistical Analysis

Analysis of Variance (ANOVA) was conducted using the Statistical Analysis System (SAS) program [7]. Data were analyzed using the General Linear Model (GLM) procedure of the SAS system. The means of two replicates from each treatment variable were compared for significance at a 5% level of probability using the Least Significant Difference test (LSD).

Results and Discussion

Chemical Composition of Rice Samples from Different Sources

Table 1 shows the proximate analysis of different rice samples from different origins. The moisture content of the rice samples was in the range of 9.26 to 10.61 %, 8.76 to 11.79 %, and around 11.48 % for the Indian, Pakistani, and Thai origins respectively. The Jordanian

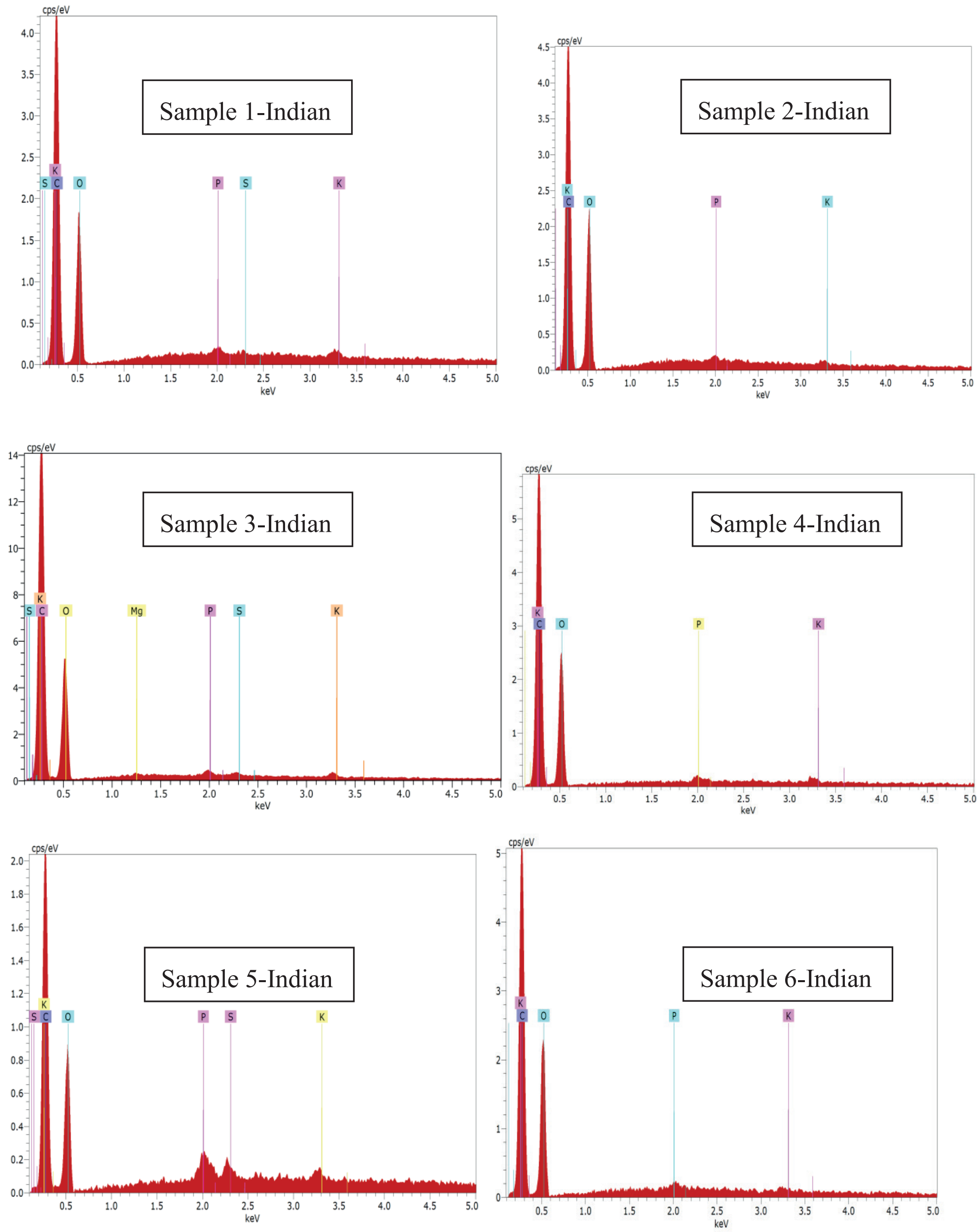

Fig. 3. Scan Electron Microscope Chromatogram for Indian-origin Basmati rice.

standards [8] specify the moisture content for rice not to be higher than 13% which indicates that the rice samples were in line with the Jordanian standards. No significant differences (P>0.05) were obtained for the ash and carbohydrate contents of rice samples from the three different origins. The ash content for Basmati rice reported by Ghazala et al. [9] was in the range of 1.16-2.36%, which is higher than the ash content reported in this study, while Ahmad et al. [10] reported 0.39% for the ash content of white rice, which matches the results for Indian and Pakistani rice samples. The highest fat content was recorded for the Basmati rice samples of Thai origin. The protein content of Indian and Pakistani-origin rice samples was significantly (P≤0.05) higher than that of the Thai samples, which recorded a significantly (P≤0.05) lower protein content of 6.86%. Similar results were obtained in both studies of Ghazala et al. and Ahmad et al. [9, 10]. Carbohydrates of Basmati rice play a key role in regulating body functions. The carbohydrate content of Indian Basmati rice samples ranged from 79.69% to 82.19%, while that of Pakistani-origin samples ranged from 78.80% to 81.62%, and the Thai samples had 80.52%.

Inductively Coupled Plasma Emission Spectrometer (ICP-AES)

Results obtained from the analyses of trace elements from 10 major brands of rice samples consumed in Amman/ Jordan using the ICP instrument are shown in Table 2 and the WHO recommended limits are illustrated in Table 3. All samples were in line with the

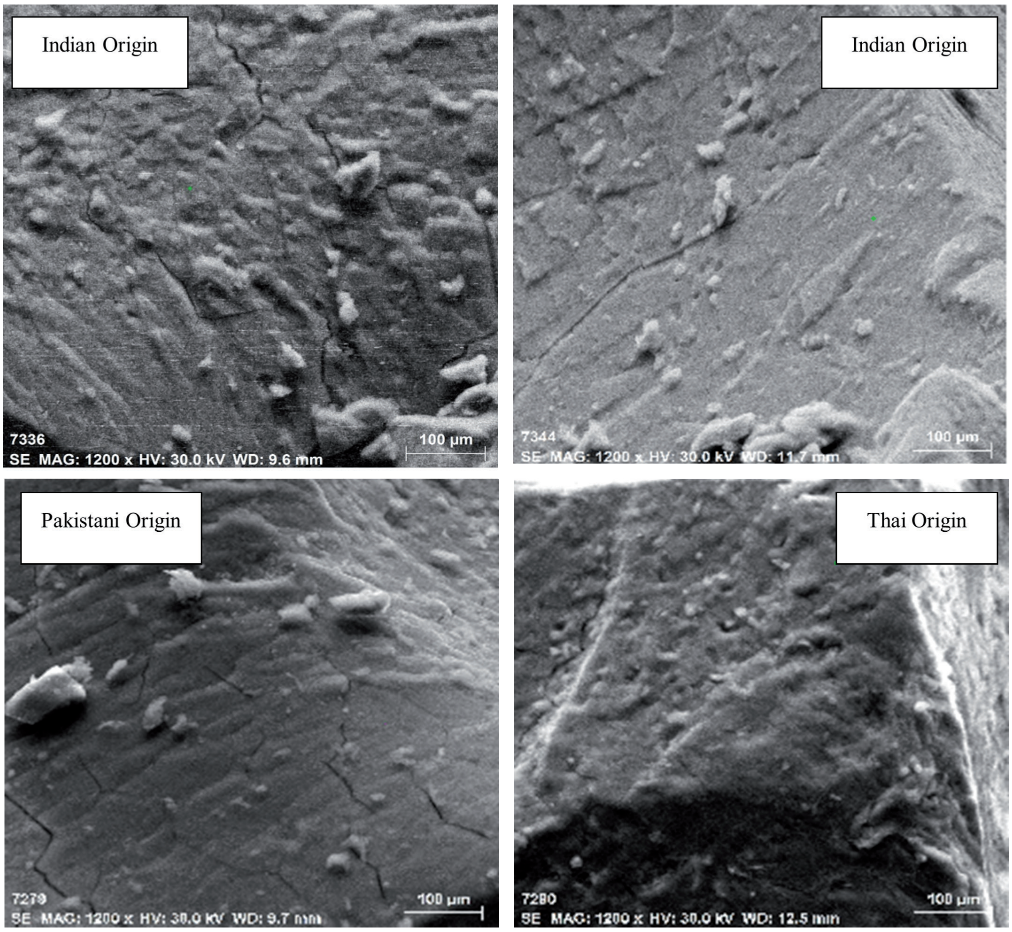

Fig. 4. Scan Electron Microscopy of some rice samples.

WHO recommended trace elements limits except for the Ni (II) and Fe (II) results obtained. Results showed that Ni (II) content was not significantly different (P≤0.05) among Basmati rice samples from different origins (Indian, Pakistani, and Thai); however, Indian rice samples 1 and 2 recorded significantly higher Ni content compared to the WHO limit (1.5 ppm), with values of 2.39 and 1.67 ppm, respectively (Fig. 1). Nickel plays some roles in the human body including enzyme functions, in very trace amounts it may be beneficial to activate some systems, but its toxicity at higher levels is more enzyme-prominent [11]. The mean Ni (II) concentration in Indian Basmati rice samples was found to be higher than the value (0.17 mg/kg) reported by Maryam et al. [2] for rice consumed in Australia and the value (0.29 mg/kg) reported by Lien et al. [12] for rice consumed in Taiwan. The mean concentration of Ni (II) in Basmati rice samples from different origins is 0.90 mg/kg; this is similar to the finding reported by Mehrabi et al. and Ying et al. [13, 14].

The highest Fe (II) concentration in Basmati rice samples analyzed in this study was found in those of Indian origin (15.96 mg/kg) compared to Pakistani and Thai (12.80, 5.87 mg/kg) samples respectively. Significantly (P≤0.05), all samples recorded higher iron results than those recommended by the WHO (5 ppm), except that of the Thai origin, and the highest result was recorded for Indian sample 1, with a value of 33.3 ppm (Fig. 2). The mean Fe (II) concentration in Indian Basmati rice samples was found to be higher than the value (0.08 mg/kg) reported by Omeje et al. [15] for rice consumed in Delta State, Nigeria, and the value (10.33 mg/kg) reported by Osman [16] for rice consumed in Qassim, Saudi Arabia.

Energy-Dispersive X-Ray Spectroscopy (SEM-EDS)

The scan electron microscope chromatograms obtained from the analysis of trace elements in the Indian rice samples using the SEM-EDS instrument are shown in Figs. 3 and 4. The EDS gives the type and weight percent of each element present at the selected point of the sample in the SEM micrographs. It was noticed from the EDS analysis of all Indian-origin Basmati rice samples that traces of magnesium, sulfur, and phosphorus were detected, while the Pakistani-origin samples showed traces of magnesium, sulfur, phosphorus, and aluminum, and the Thai-origin samples showed only traces of sulfur and phosphorus. The EDS could not detect any toxic heavy metals in all samples.

Energy dispersive spectroscopy (EDS) analysis showed that most of the Basmati rice samples contained C, O, K, P, and S. Few samples showed other elements such as Mg and Al (Fig. 4). This analysis indicated that all Basmati rice samples analyzed in this study have no toxic elements.

Conclusions

The concentration of Cr (III, VI) in Basmati rice samples from Pakistan was found to be higher than in samples from India and Thailand. The highest concentration of Cu (II) was observed in Basmati rice from India. The highest concentrations of Mn (II) and Zn (II) were detected in Thai rice, while Indian rice showed the highest Fe (II) concentration, comparable to values reported in the literature.

The levels of heavy metals in the analyzed Basmati rice samples were below the permissible limits set by FAO/WHO [17]. However, regular monitoring of Ni (II) dietary intake is necessary, supported by effective mitigation strategies to reduce toxic element uptake. The toxic metals Cd (II), Co (II), and Pb (II) were below the detection limits of ICP, indicating that rice consumption in Jordanian markets is radiologically safe.

Acknowledgments

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Conflict of Interest

The authors declare no conflict of interest.

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