Assessment of natural radioactivity levels and heavy metals in different types of rice consumed in Qassim, Saudi Arabia

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Abstract: Radionuclides ingested in food and to a lesser extent, water, account for a substantial part of the average radiation doses received by various organs of the human body, especially the skeleton. A study of natural radionuclides in rice consumed in Saudi Arabia was performed. The study targeted the natural radionuclides ^{226}Ra, ^{232}Th, and ^{40}K, in addition to heavy metals (Cd, Zn, Fe,Cr, Pb and V). It was found that rice consumption in Saudi Arabia is radiologically safe for the presence of the investigated radionuclides. The presence of ^{40}K in all samples in higher levels was anticipated due to its natural abundance. The levels of the toxic metals, Lead (pb), Cadmium (cd) were not detected in examined rice samples. The mean values of Iron, zinc and manganese were higher than findings reported by other studies in literature. The present study is the first at the national level to investigate the radioactivity and heavy metals of rice in Saudi Arabia. The findings of this study will help in establishing a baseline of radioactivity and heavy metals for public exposure from foodstuff ingestion.
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1. Introduction

Radioactivity can present in our environment by two different forms as natural occurring and anthropogenic (man-mad) sources (Alrefae & Nageswaran, 2013). Extensive surveys have been conducted in many countries to study the naturally occurring radiation and environmental radioactivity (UNSCEAR, 2000). Exposure to radiation from natural sources is common to humans. There are different sources of radioactive materials such as earth materials, air and food. Small amount of radioactive material presents in everything on earth. Moreover, fruits, vegetables and plants also contain heavy metals and gamma radioactive elements (Chibowski, 2000).

People in general receive about 180 μSv/year from ^{40}K; the essential cellular constituent. Total natural potassium content in an average human body is about 0.14 kg, so ^{40}K is a predominant natural radioactive substance in our bodies. Such natural background is considered as a constant source of radioactivity to humankind therefore, its adverse consequences cannot be ignored (Khan *et al.,* 1995; Wang *et al.,* 1996; Alharbi & El-Taher, 2013). Food consumption is the prime source of radioactive elements to human (Gaso *et al.,* 2000; Chen *et al.,* 2005). Natural radionuclides can transfer from soil to agricultural products including rice. Saeed *et al.* (2012) have studied the natural radionuclides transfer factor (TFs) of soil to rice the major food consumed in Asian meals (about 100 gram/day) The soil to rice TFs values for the radionuclides of (^{226}Ra, ^{232}Th, ^{238}U and ^{40}K) were (8.8×10^{-2}, 14.2×10^{-2}, 5.8×10^{-2} and 6.3×10^{-2}) respectively, Shigeo Uchida *et al.* (2007) reported that the TFs elements of brown rice and white rice were different in both the radionuclide critical paths and critical foods between Japan and European and North American countries due to differences in agricultural products and food customs.

In Saudi Arabia, number of studies have been conducted to measuring radioactivity levels in environmental samples and the health hazard associated with it to the people (El-Taher, 2012; El-Taher and Althoyaib, 2012; Aleissa, *et al.,* 2013; Khater *et al.,* 2014). Most of these studies focused on the level of radioactivity from soil, water and phosphate fertilizers in limited regions of Saudi Arabia. Attributable to the public health hazard analysis, the environmental monitoring program necessitates screening of natural radionuclides in foodstuff. People exposure to largest contributor of the radiation doses are through natural radioactive sources. However, the most important radioactive elements in natural sources include ^{40}K and the member of ^{238}U and ^{232}Th decay series. (Khan *et al.,* 1997). Food samples are one way of people exposure to radiation that present from natural sources or due to discharges of radioactivity from industries, hospitals, research laboratories or from nuclear weapon tests fallout. Consumption of contaminated food with different radionuclides considered as one of the most internal radiation doses received by human beings (Alharbi & El-Taher, 2013). In Saudi Arabia, there is a lack of scientific information on the radioactivity contents of technological enhanced naturally occurring radioactive materials (TENORM) in consumer products. Therefore, it is necessary to carry out accurate assessment of these radionuclides such as ^{226}Ra, ^{232}Th and ^{40}K and heavy metals in different brands of rice consumed in Saudi Arabia in order to ascertain the degree of risk and deleterious effects to the public health. In the present work, thirty different rice samples from different brands that are available in the Saudi market were analyzed for their radioactive and heavy metals contents. All of these brands were imported from various regions around the world such as India, Pakistan, Thailand, Egypt, and USA. The reported data in this study could help in establishing a baseline level of naturally occurring radioactivity and heavy metals as well in rice, which will help to develop guidelines for radiological protection to the public. likewise, heavy metals such as Lead (Pb), Cadmium (Cd), Mercury (Hg) and Copper (Cu) present great danger to mankind health due to environmental pollution that might end up into food. Heavy metals can be transferred from surrounding environment by fruits, vegetables, soil, fertilizers, pesticides, inorganic pollutants and organic wastes. The hazardous of these heavy metals is due to their cumulative poisons with low level intakes. (WHO, 1992; WHO, 1995).

Therefore, the aim of this work was to assess the levels of naturally occurring radionuclides such as ^{226}Ra, ^{232}Th and ^{40}K and to evaluate heavy metals presence in different rice samples consumed in Qassim area, Saudi Arabia.

2. Materials and Methods

2.1 Samples collection and preparation

Representative rice samples from different types consumed in Saudi Arabia were collected from local markets. The Weighed samples were ground, homogenized and sieved to about 100 mesh by a crushing machine. The samples were then placed for drying at 110˚C to ensure that moisture is completely removed. Weighed samples were placed in polyethylene bottles, of 350 cm^3 volume, each. The bottles were completely sealed for more than one month to allow radioactive equilibrium to be reached. This step was necessary to ensure that radon gas is confined within the volume and that the daughters will also remain in the sample.

2.2 Instrumentation and calibration

The gamma ray spectrometer used for measuring the activity concentrations was scintillation detector 3"x 3". It is hermetically sealed assembly which includes a NaI(Tl) crystal, coupled to PC-MCA Canberra Accuspes. The accumulation time of activity or background was 12 h. The background spectra were used to correct the net peak area of gamma rays of measured isotopes. A dedicated software program (Quantum) from PGT has carried out the online analysis of each measured γ-ray spectrum. The efficiency calibration curve was made using different energy peaks covering the range up to ≈2000 keV. Measurements were performed with calibrated source samples, which contain a known activity of one or more gamma-ray emitters of the radionuclides ^{60}Co (1173.2 and 1332.5 keV), ^{133}Ba (356.1keV), ^{137}Cs (661.9 keV) and ^{226}Ra (1764.49 keV). With certified accuracies of < 2 % supplied by PTB Braunschweig, Germany (El-Taher *et al.,* 2003; El-Taher., 2010 a-c; El-Taher and Makhluf., 2010; El-Taher and Madkour. 2011).

2.3 Calculation of activity

Calculations of count rates for each detected photopeak and radiological concentrations (activity per mass unit or specific activity) of detected radionuclides depend on the establishment of secular equilibrium in the samples. The ^{232}Th concentration was determined from the average concentrations of ^{212}Pb (238.6 keV) and ^{228}Ac (911.1keV) in the samples, and that of ^{226}Ra was determined from the average concentrations of the ^{214}Pb (351.9keV) and ^{214}Bi (609.3 and 1764.5 keV) decay products (Hamby & Tynybekov, 2002; El-Taher, 2010 a-d and El-Taher & Makhluf, 2010).

The activity concentration in Bqkg^{-1} (A) in the environmental samples was obtained as follows:

$$A = \frac{N_p}{e \times \eta \times m} \qquad (1)$$

Where Np = net count rate (cps), measured count rate minus background count rate, e is the abundance of the γ-line in a radionuclide, η is the measured efficiency for each gamma-line observed for the same number of channels either for the sample or the calibration source, and m the mass of the sample in kilograms.

2.4. Heavy metals measurement

Determination of the heavy metals in rice samples was conducted using Atomic absorption spectrometry (AAS, Shimadzu Model AA-6200, Kyoto, Japan). The method of the Association of Official Agricultural Chemists (AOAC, 1984) was used to digest the rice samples to prepare it for analysis of Cadmium (cd), zinc (Zn), iron (Fe), manganese (Mn), Chromium (Cr), Lead (pb) and Vanadium (V) by the atomic absorption spectrometry (Varian model analyst AA240FS). Detection limits for of Cd, Zn, Fe, Cr, Pb and V were 0.003, 0.4, 0.1, 0.05 and 1.0 μg/L, respectively (Modaihsh *et al.,* 2004).

The procedures proposed by Kennedy *et al.* (1993) were used for the quality control of the analytical data and later outlined as a standard routine procedure in the FAO Bulletin No. 74 (1998).

3. Results and Discussion

3.1 Activity concentration of ^{226}Ra, ^{232}Th and ^{40}K

Table 1 presents the activity concentrations for ^{226}Ra, ^{232}Th and ^{40}K in the different rice samples consumed in Saudi Arabia. ^{226}Ra was detected in all samples with a maximum value of 2.6 Bq kg^{-1} (a sample from India), a minimum value of 0.1 Bq kg^{-1} (a sample from USA) with average value 0.4 Bq kg^{-1}. As for ^{232}Th, it was detected in all samples with a maximum value of 2.3 Bq kg^{-1} (a sample from India), a minimum value of 0.1 Bq kg^{-1} (a sample from Thailand) with average value 0.2 Bq kg^{-1}. ^{40}K was detected in all samples with a maximum value of 257.2Bq kg^{-1} (a sample from India), a minimum value of 20.9 Bq kg^{-1} (a sample from India) with average value 138 Bq kg^{-1}.

The results from the present study were compared to those reported in the literature. Table 2 shows the values of the activity concentration of the present study agreeing in some cases with those reported in the literature. The variations in the concentrations of the radioactivity in the rice brands of the various locations of the world depend upon the geological and geographical conditions of the area and the extent of fertilizer applied to the agriculture lands (UNSCEAR, 2000).

3.2 Radium equivalent activities (Raeq).

Different indices were used to assess the Gamma-ray radiation hazards as a result of the particular radionuclides Ra, Th and K. The radium equivalent activity (Ra_{eq}) is the most widely used as radiation hazard index (Krieger., 1981; Beretka & Mathew 1985). Based on the estimation that 370 Bq/kg of Ra, 259 Bq/kg of Th and 4810 Bq/kg of K produce the same γ-ray dose rates (Stranden, 1976); the Ra_{eq} is a weighted sum of activities of the above three radionuclides Ra_{eq} that is given by the following equation:

$$R_{aeq} = A_{Ra} + (A_{Th} \times 1.43) + (A_K \times 0.077) \quad (2)$$

A value of 370 $Bqkg^{-1}$ corresponds to 1 mSv y^{-1}. The radium equivalent concept (R_{aeq}) describes the gamma output from different mixtures of uranium, thorium and potassium as a widely used hazard index. The calculated values are varied from 1.7 to 20.2 Bq/kg with an average of 10.93 Bq/kg (Table 1).These values are lower than the permissible maximum value of 370 Bq kg^{-1} (NEA-OECD,1979; UNSCEAR, 1988).

3.3 Absorbed dose rate

The absorbed gamma dose rates D_R (nGh^{-1}) for the uniform distribution of radionuclides were calculated based on guidelines provided by (UNSCEAR, 2000).

$$D_R\,(nG\,h^{-1}) = 0.427C_{Ra} + 0.623C_{Th} + 0.043C_K \quad (3)$$

where C_{Ra}, C_{Th} and C_K are the activity concentrations (Bq kg^{-1}) of ^{226}Ra, ^{232}Th and ^{40}K respectively, in the samples. The absorbed dose rate expresses the received dose in the open air from the radiation emitted from radionuclides concentration in Environmental materials. Also it is the first major step for evaluating the health risk and is expressed in gray (Gy). The calculated total absorbed dose of samples are tabulated in Table 1. It is observed that the absorbed dose rate calculated from activity concentration of ^{226}Ra, ^{232}Th and ^{40}K ranges between 1 to 12 with an average 6.13 Bq kg^{-1}.

3.4. Heavy metals

The values of Lead (pb), Cadmium (cd), iron (Fe), manganese (Mn), zinc (Zn), Chromium (Cr) and Vanadium (V) in some of rice samples collected from Saudi market compared with those reported in other countries were presented in Tables (3). The values for Cd, Pb, Fe, Mn and Zn in some of rice samples of our study compared with those reported in other countries were presented in Tables (4 & 5).

The levels of the toxic metals, Lead (pb), Cadmium (cd) were not detected in rice samples collected from Saudi Market (Table 3). This is similar to the finding reported by Zhang *et al.* (1998) who studied lead and cadmium contents in cereals in North-eastern China. Also, the results of present study is similar to the findings reported by Conti *et al.* (2000) who studied the trace metals in soft and durum wheat from Italy and to the findings of Onianwa *et al.* (1999) who conducted a study on trace heavy metals composition of some Nigerian beverages and food drinks (Table 4). Since ten years ago, all ports in KSA were controlled strongly by the Saudi Food and Drug Authority which have a huge laboratories and advanced equipment's and all of Foodstuff samples must be analyzed according the food quality, safety and standards before allowing circulation and consumption. According to this, the weekly intake of metals from all sources should not exceed 0.05 and 0.075 mg/kg body weight for lead and cadmium, respectively. The toxicological studies reported that Cadmium and lead are the most famous toxic heavy metals for human and animals. Moreover, the increasing curve and ratio of the certain diseases have been associated with the excessive content of these heavy metals in food, water and environment. Due to non-biodegradability and long stay time, some toxic heavy metals such as Pb, Cr and Cd cause pollution to the environment (WHO, 1992; WHO, 1995).

Table 1: Activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K and radiation hazard parameters in rice m m consumed in Saudi Arabia

Sample	Ra-226 Bq/kg	Th-232 Bq/kg	K-40 Bq/kg	Raeq Bq/kg	Dose rate (nGy/h)
Fragrant Jasmine Rice (Uk)	0.6±0.1	0.9±0.2	94.0±4.7	8.5	4.9
Snow White Rice (Australia)	0.5±0.1	0.2±0.0	194.1±9.7	14.4	8.7
Basmati Rice (Tilda) (w)	0.9±0.2	0.4±0.1	180.8±9.0	14.2	8.5
White Basmati Rice (India)	0.3±0.0	1.3±0.3	176.8±8.8	14.6	8.6
Basmati Rice Punjab (India)	0.1±0.0	0.8±0.2	47.1±2.4	3.4	2.1
Basmati Rice (Mayil) India	1.0±0.2	0.9±0.2	45.0±2.2	5.4	2.9
Basmat Parboiled Rice (USA)	2.6±0.3	0.5±0.1	68.2±3.4	8.1	4.4
Basmati Rice (India)	0.9±0.2	0.6±0.1	101.2±5.1	8.8	5.1
Snow White Rice Calrose (Egypt)	0.8±0.2	0.5±0.1	96.1±4.8	8.3	4.9
Sella Basmati Rice (India)	1.5±0.3	2.3±0.3	54.3±2.7	8.7	4.5
Pathumthani Rice (Thailand)	1.7±0.3	0.1±0.0	112.5±5.6	9.6	5.6
Mazza Basmati Rice (India)	0.2±0.0	0.3±0.0	20.9±1.0	1.7	1.0
Kohinoor Basmati Rice(India)	0.1±0.0	0.2±0.0	145.2±7.3	10.6	6.4
Mazza Basmati Rice (India)- K	0.2±0.0	0.4±0.1	139.4±7.0	10.5	6.4
Hadeel Mazza Basmati (India)	0.2±0.0	0.6±0.2	126.4±6.3	9.8	5.9
Radikal Mazza Basmati (India)	1.3± 0.2	1.0±0.2	171.0±8.5	14.7	8.6
MH-Basmati Rice Punjab (India)	0.8±0.1	0.2±0.0	189.5±9.5	14.4	8.6
SH- Mazza Basmati Rice (India)	1.2±0.3	0.5±0.1	188.1±9.4	15.0	8.9
White Basmati Rice (Pakistan)	1.5±0.3	1.0±0.2	195.8±9.8	16.6	9.7
BO- Mazza Basmati Rice (India)	1.2±0.2	0.5±0.1	257.2±12.9	19.2	11.6
OTH-Sella Basmati Rice (India)	0.9±0.2	0.8±0.2	244.2±12.2	19.1	11.4
SH-Basmati Rice Punjab (India)	0.2±0.0	1.4±0.3	256.3±12.8	20.2	12.0
ABUK-Sella Basmati Rice (India)	0.5±0.1	0.9±0.2	227.4±11.4	17.7	10.6
WA- Mazza Basmati Rice (India)	0.4±0.1	0.6±0.2	232.9±11.6	17.6	10.6
WE- Mazza Basmati Rice (India)	0.7±0.1	0.2±0.0	119.2±6.0	9.4	5.6
BABK-White BasmatiRice (India)	1.0±0.2	0.5±0.2	241.6±12.1	18.6	11.2
Jasmine Rice, (Thailad)	1.8±0.3	1.3±0.3	201.2±1.1	8.8	5.1

Table 2: Activity concentrations (Bq kg^{-1}) of ^{226}Ra, ^{232}Th and ^{40}K in rice samples investigated in the present study compared with those reported in the literature as given in (Alrefae et al., 2013).

Origin	^{226}Ra	^{232}Th	^{40}K	Reference
Brazil	----	---	15	Venturini & Sordi (1999)
Egypt	0.77	0.60	36	Alrefae *et al.* (2013)
France	---	0.32	51	Alrefae *et al.* (2013)
Germany	----	0.4-0.5	87-101	Alrefae *et al.* (2013)
Hong Kong	---	----	15	Yu and Mao (1999)
India	0.41-0.91	0.36-0.62	36-81	Alrefae *et al.* (2013)
Iraq	---	---	38	Hosseini *et al.* (2006)
Malaysia	18-25	35-65	65-110	Saeed *et al.* (2011)
Pakistan	--	0.06-0.08	7-50	Hosseini *et al.* (2006)
Pakistan	---	0.43-0.46	33-38	Alrefae *et al.* (2013)
Thailand	----	0.02-0.3	22-23	Hosseini *et al.* (2006)
Saudi Arabia average (range)	0.4 (0.1-2.6)	0.2 (0.1-2.3)	138 (45-257.2)	Present work

Table 3. Concentration of heavy metals in analyzed rice samples with actual names.

Sample	Code	Pb µg/g	Cd µg/g	Fe µg/g	Mn µg/g	Zn µg/g	Cr µg/g	V µg/g
Fragrant Jasmine Rice (Uk)	R-1	-	-	34.1±0.5	11±0.4	10±0.7	-	-
Snow White Rice Calrose (Australia)	R-2	-	-	16.1±0.2	14.8±0.7	3.9±0.1	-	-
Basmati Rice (Tilda) (UAE)	R-3	-	-	13.2±0.6	11.6±.4	8.5±0.2	-	-
White Basmati Rice (India)	R-4	-	-	12.4±0.4	10.3±0.7	4.7±0.1	-	-
Basmati Rice Punjab (India)	R-5	-	-	12.7±0.7	9.2±0.5	7.5±0.3	-	-
Basmati Rice (Mayil) India	R-6	-	-	11.6±0.8	15.6±0.8	6.8±0.4	-	-
Basmat Parboiled Rice (USA)	R-7	-	-	16.9±1.1	10.8±0.2	8.5±0.2	-	-
Basmati Rice (India)	R-8	-	-	21.1±1.3	8.2±0.1	5.3±0.3	-	-
Snow White Rice Calrose (Egypt)	R-9	-	-	7.7±0.6	12.6±0.6	6.8±0.4	-	-
Sella Basmati Rice (India)	R-10	-	-	16.8±0.8	7.3±0.4	8.9±0.7	-	-
Pathumthani Rice (Thailand)	R-11	-	-	8.2±0.4	10.2±0.3	9.2±0.3	-	-
Mazza Basmati Rice (India)	R-12	-	-	8.8±0.5	7.2±0.7	18.8±1.1	-	-
Kohinoor Basmati Rice(India)	R-13	-	-	7.3±0.3	9.3±0.4	9.3±0.8	-	-
Mazza Basmati Rice (India)- K	R-14	-	-	8±0.2	19.2±0.6	9.6±0.6	-	-
Hadeel Mazza Basmati Rice (India)	R-15	-	-	11.9±0.6	6.9±0.2	6.6±0.3	-	-
Radikal Mazza Basmati Rice (India)	R-16	-	-	9.7±0.9	31.9±0.4	2.5±0.1	-	-
MH-Basmati Rice Punjab (India)	R-17	-	-	9±0.7	15±0.2	3.2±0.2	-	-
SH- Mazza Basmati Rice (India)	R-18	-	-	7.6±0.4	6.7±0.3	4±0.2	-	-
White Basmati Rice (Pakistan)	R-19	-	-	9.7±0.6	9.5±0.5	3.5±0.1	-	-
BO- Mazza Basmati Rice (India)	R-20	-	-	16.2±0.4	6.1±0.7	1.3±0.1	-	-
OTH-Sella Basmati Rice (India)	R-21	-	-	13.5±0.4	10.2±0.2	2.6±0.1	-	-
SH-Basmati Rice Punjab (India)	R-21	-	-	18.1±0.6	10.1±0.4	2.1±0.2	-	-
ABUK-Sella Basmati Rice (India)	R-23	-	-	6.7±0.3	6.2±0.1	2.8±0.1	-	-
WA- Mazza Basmati Rice (India)	R-24	-	-	6.8±0.4	6.3±0.3	2±0.1	-	-
WE- Mazza Basmati Rice (India)	R-25	-	-	6.3±0.2	5.0±.1	2.7±0.1	-	-
BABK-White Basmati Rice (India)	R-26	-	-	5.4±0.4	7.7±0.7	6±0.6	-	-
BABH-White Basmati Rice (India)	R-27	-	-	17.2±0.9	9.7±0.2	7±0.4	-	-
Premium Jasmine rice (Thailand)	R-28	-	-	2.1±0.1	7.8±0.4	8±0.8	-	-
ABUF-White Basmati Rice (Pakistan)	R-29	-	-	3.6±0.3	6.3±0.3	6.7±0.5	-	-
OTH-White Basmati Rice (Pakistan)	R-30	-	-	2.6±0.1	7.2±0.2	2.8±0.2	-	-
-:not detected								

Table 4. Levels of lead and cadmium in some rice sample from our study compared with those report

Country	Unit	lead	cadmium	References
Saudi Arabia	mg/Kg	-	-	Present work
China	mg/Kg	-	-	Zhang *et al.* (1998)
Italy	mg/Kg	-	-	Zhang *et al.* (1998)
Nigeria	mg/Kg	-	-	Onianwa *et al.* (1999)
Greece	mg/Kg	0.0062	0.0052	Karavoltsos *et al.* (2002)
Egypt	mg/Kg	0.239	0.091	Salama & Radwan (2005)
Saudi	mg/Kg	0.032 -0.021	Not reported	Al Othman (2010)
Saudi	mg/Kg	0.02 -0.01	Not reported	Al Othman (2010)
Pakistan	mg/Kg	0.17	0.29	Shabbir *et al.* (2013)
Pakistan	mg/Kg	0.23	0.35	Shabbir *et al.* (2013)
Iran	mg/Kg	0.122	0.274	Chamannejadian *et al.* (2013)
Saudi	mg/Kg	0.135	0.02	Al-Saleh and Shinwari (2001)
Japan	mg/Kg	0.002	0.05	Shimbo *et al.* (2001)
USA	mg/Kg	0.250	0.016	Bennett *et al.* (2000)

The mean values of Fe, Zn and Mn in some of rice samples collected from Saudi market compared with those reported in other countries are presented in Table (7). The mean values of Fe, Zn and Mn were 11.376, 6.053 and 10.33 mg/kg respectively. The mean values of Iron and zinc were lowered (11.73 and 6.053 mg/kg) than values reported by (Jenga *et al.*, 2012; Jorhem *et al.*, 2008) who reported mean levels of (28.10 & 14) for iron and (15.36 & 21) for Zinc respectively in Taiwan, Brown rice in Sweden market and Brown Indian rice respectively. The mean values of Mn of rice samples collected from Saudi market is similar to finding reported by Pennington et al. (1995) who reported Mn mean levels of 10.35

mg/kg while the mean Mn mean values of our study is 10.33 mg/kg. in the other hand, The mean values of Iron, zinc and manganese were higher than finding reported by (Ogbodo, 2013; Olivares *et al.*, 2004) who reported mean levels in Nigerian and Chilean Rice (Table 7).

Table 5. Levels of iron, zinc and manganese in some rice sample from our study compared with those report in literature.

Country	Unit	Fe	Zn	Mn	References
Saudi Arabia	mg/Kg	11.376	6.053	10.33	Present study
Santiago, Chile	mg/Kg	5.90	1.035	-	Olivares *et al.* (2004)
Nigeria	mg/Kg	1.89	0.22		Ogbodo (2013)
Egypt	mg/Kg	-	4.893	-	Salama & Radwan (2005)
Italy	mg/Kg	-	-	-	Conti *et al.* (2000)
Nigeria	mg/Kg		4.93		Onianwa *et al.* (2001)
Taiwan	mg/Kg	28.10	15.36	7.28	Jenga *et al.* (2012)
East Asia	mg/Kg	-	15	-	Wu Leung & Butrum (1972)
USA	mg/Kg	-	5.7	10.35	Pennington *et al.* (1995)
FDA	mg/Kg	124	62	13.1	FDA (2007)
FDA	mg/Kg	250.5	14.8	12.9	FDA (2010)
India (Brown)	mg/Kg	14	21	45	Jorhem *et al.* (2008)
Pakistan (white)	mg/Kg	3.8	17	9.0	Jorhem *et al.* (2008)
USA (Brown)	mg/Kg	8.7	18	40	Jorhem *et al.* (2008)
Thailand	mg/Kg	1.9	15	12	Jorhem *et al.* (2008)
Pakistan(white)	mg/Kg	3.8	17	9	Jorhem *et al.* (2008)
USA(white)	mg/Kg	5.2	12	13	Jorhem *et al.* (2008)
Italy(white)	mg/Kg	2.2	9.5	7.8	Jorhem *et al.* (2008)
Brown rice, Sweden Market)	mg/Kg	14	18	42	Jorhem *et al.* (2008)
White rice, Sweden Market)	mg/Kg	4.1	6.6	7	Jorhem *et al.* (2008)

4. Conclusion

Long-lived gamma emitters and heavy metals (Cd, Zn, Mn, Fe, Cr, Pb and V) in rice samples consumed in Saudi Arabia were investigated. The study targeted three radionuclides, namely ^{226}Ra, ^{232}Th and ^{40}K. the finding of this study reveal that rice consumption in Saudi Arabia is radiologically safe for the presence of the investigated radionuclides. On the other hand, levels of the toxic metals, Lead (pb), Cadmium (cd) in the tested samples were not detected. The mean values of Iron, zinc and manganese were higher than reported findings by other studies in literature. The present study is the first investigation of the radioactivity in rice samples from Saudi Arabian market. Data collected in this investigation could be useful in establishing a baseline of radioactivity and heavy metals exposure to public interim of foodstuff safety intake.

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