Naturally occurring radioactive nuclides from cereal grains, legumes and some foodstuffs consumed in Saudi Arabia

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Abstract: Twenty samples of different types of Legumes, cereal grains and foodstuffs were collected from the local markets in Saudi Arabia (Jeddah City). The average activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K radionuclides were measured using gamma spectrometry .These twenty samples fall under five food groups. The annual ingestion dose "D" for ^{226}Ra, ^{232}Th and ^{40}K ranged from 2.85(Coffee beans) to 168.78µSv/y (Cereal grains), 2.05(Coffee beans) to 145.13µSv/y (Vegetables) and 1.99(Coffee beans) to 95.31µSv/y (Cereal grains) respectively. The corresponding mean values of the three nuclides ^{226}Ra, ^{232}Th and ^{40}K are 81.47, 58.31 and 47.14µSv/y. These values are less than the recommended limit. The total annual ingestion dose "D_T" were varied from 6.88 (Coffee beans) to 369.02µSv/y(Vegetables) with an average value of 219.57µSv/y. The mean of the total annual ingestion dose for all food groups were within the global value (290 µSv/y). The calculated values of cancer risk "R" for the total annual ingested dose for the five food groups were 1.22×10^{-3}, 2.076×10^{-4}, 2.409×10^{-5}, 1.29×10^{-3} and 5.27×10^{-4} respectively. The results show that the calculated mean of the cancer risk "R" was 6.54×10^{-4}. This calculated value was less than the ICRP value by a factor of 5.4, so our studied food groups pose no significant risk to general public's health.

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1. Introduction:

Naturally occurring radionuclides are present in the environments; earth crust, soil, water, air, plants. These natural radionuclides originating in uranium and thorium series and potassium-40. The human body digests, inhales or absorbs radiations and sometimes confuses certain radioactive elements with minerals the body is lacking. ^{226}Ra is chemically similar to calcium and absorbed through the plants from soil and enters the human's body [1]. Potassium has a chemical composition similar to a radioactive by product substance called Cesium 137. Because of this similarity, the body will absorb any available Radium-226 or Cesium-137. Also, the excessive use of nuclear energy in all branches of life increase the problem. The radionuclide radioactivity is cumulative and its effects devastating, both in the short and long-term. This is the cause of allergic response and unexplained illnesses. Agricultural plants absorb radiations from the soil, which in turn transferred to each living organism [2]. The majority of people around the world depend on cereals grains, legumes and foodstuffs in their nutrition. It is necessary to estimate the natural radioactivity concentrations in our daily food. However, a study of natural radioactivity concentration in foodstuff have been performed in several countries [3-5]. This study will investigate the natural radioactivity concentration of Uranium, Thorium series and Potasium-40 in cereals grains, legumes and some foodstuffs collected from the local market in Saudi Arabia (Jeddah City) . The total annual effective ingestion dose and cancer risk to the consumers will be estimated. This will provide a base line to investigate food security and suitability to human beings.

Sample Collections and Measurements:

Twenty samples of different types of Legumes, cereal grains and foodstuffs were collected from the local markets in Saudi Arabia (Jeddah City). Food groups and samples names are listed in Table (1). The samples were dried in an oven at 80°C for 6 h and then stored in tight plastic containers with a constant weight ranged from 60 to 233g for four weeks to allow radioactive equilibrium to be reached between parents and their daughter radionuclides [6]. The samples measurement of the radionuclides were carried out by gamma ray spectrometer using a NaI (TI) detector 3x3 inch with a 1024-channel computer analyzer. The detector has a peak efficiency of 1.2×10^{-5} at 1332.5Kev Co-60 and an energy resolution (FWHM) of 7.5% for 662kev [7]. Samples were counted for 15 hours, the activity concentration of ^{214}Pb (352Kev) and ^{214}Bi (609 Kev, 1120Kev) were chosen to provide an estimate of ^{226}Ra. While that of the daughter radionuclides ^{208}Ti (2651Kev), ^{212}Pb (239Kev) and ^{228}Ac (911Kev) were chosen as indicator of ^{232}Th. The single photo peak at 1460 Kev was directly measured for ^{40}K. An empty beaker was also counted under the same conditions to determine the background calculations.

The activity concentrations "A_s" for the natural radionuclides of the samples were computed by the following equation [8].

$$A_s\ (Bq/kg) = C_r / \varepsilon\ P_\gamma\ M_s \qquad (1)$$

where C_r is the net counting rate of γ-ray (counts per second), ε is the detector efficiency of the specific γ-ray, P_γ is the absolute transition probability of γ-decay and M_s is the mass of the sample (kg). The counting system was calibrated using standard sources and the same geometry were followed for the studied samples.

Annual effective ingestion dose and cancer risk calculations:

The annual effective dose due to the ingestion of natural radionuclides in foods can be calculated from the Formula given by [9] :

$$D = A_s\ I\ E \qquad (2)$$

D is the annual effective dose (Sv/y) to an individual due to the ingestion of radionuclides , A_s the Average activity concentration of radionuclides in the ingested sample (Bq/Kg), I the annual intake of the studied samples (Kg/y) and E the ingested dose conversion factor for radionuclides (Sv/Bq) for adults . The conversion factor 'E' is equal to 0.28µSv/Bq for ^{226}Ra, 0.23µSv/Bq for ^{232}Th and 0.0062µSv/Bq for ^{40}K for adults [10].

The cancer risk "R" can be estimated from:

$$R = D_T \times L \times RF \qquad (3)$$

The dose contributed from the three radionuclides ^{226}Ra, ^{232}Th and ^{40}K were summed to obtain the total dose, D_T. The life-span of an average individual, L, is about 70 years. The cancer risk factor for low doses, RF is 5×10^{-5} (1/mSv), [11].

3. Results and Discussions

Food samples (20 in total) were gathered to five groups: Cereal grains, Legumes, Coffee beans, Vegetables and Meat. Measured activity concentration of the natural radionuclides ^{226}Ra, ^{232}Th and ^{40}K in the food samples are shown in **Table (1).** For cereal grains, the activity concentration for ^{226}Ra, ^{232}Th and ^{40}K ranged from 2.60-10.63 Bq/kg with an average value of 5.53 Bq/kg, 1.50-6.33 Bq/kg with an average value of 3.38Bq/kg and 99.30-178.31 Bq/kg with an average value of 141.03Bq/kg respectively. For legumes, the activity concentration for ^{226}Ra, ^{232}Th and ^{40}K ranged from 2.91-7.53Bq/kg with an average value of 4.04 Bq/kg, 1.53-3.05 Bq/kg with an average value of 2.34 Bq/kg and 107.83-177.30 Bq/kg with an average value of 146.61 Bq/kg respectively. The results for coffee beans were 3.39, 2.97, 106.73 Bq/kg of ^{226}Ra, ^{232}Th and ^{40}K respectively. For vegetables, the activity concentration for ^{226}Ra, ^{232}Th and ^{40}K ranged from 2.25-8.28 with an average value of 5.27Bq/Kg, 4.31-8.30 Bq/kg with an average value of 6.31Bq/kg and 117.34-128.89 Bq/kg with an average value of 123.12Bq/kg respectively. The results for meat ranged from 3.30-6.37 Bq/kg with an average value of 4.44Bq/kg, 2.48-6.49 with an average value of 4.11Bq/kg and 104.86-166.47 Bq/kg with an average value of 132.80 Bq/kg for ^{226}Ra, ^{232}Th and ^{40}K respectively. From **Table 1** , it can be seen that , the highest measured radionuclide concentration was that of ^{40}K activity concentration for all foods group. The present results agree with the world range reported by [12] for ^{40}K concentration range from 40 to 240 Bq/kg. Also, the obtained results show that the specific activity of ^{226}Ra, ^{232}Th and ^{40}K in all food samples appeared lower than the standard recommended limit for foodstuffs ingestion [13].

The annual ingestion dose "D" for each radionuclide of foods group were presented in **Table (2)** and shown graphically in **Fig(1)** . The annual ingestion dose for ^{226}Ra, ranged from 2.85 (Coffee beans) to 168.78µSv/y (Cereal grains), for ^{232}Th ranged from 2.05(Coffee beans) to 145.13 µSv/y (Vegetables) and for ^{40}K ranged from 1.99(Coffee beans) to 95.31µSv/y (Cereal grains) respectively. It is clear from **Fig(1)** that ^{226}Ra,^{232}Th ingestion doses for cereal grains and vegetables, both of them above the world average values (120 µSv/y) reported by UNSCEAR (2000). This increase of ^{226}Ra, ^{232}Th ingestion doses for cereal grains and vegetables attributed to fertilizer . The other radionuclide ingestion doses for the food groups were less than the world average. **Table (2)** shows that the total annual ingested dose of the three radionuclides "D_T" were varied from 6.88 (Coffee beans) to 369.02µSv/y (Vegetables) with an average value of 219.57µSv/y. Again, the total annual ingested doses for cereal grains and vegetables were above the world average (290µSv/y) reported by UNSCEAR (2000) . These doses are still lower than the ICRP recommended limit of 1.0 mSv. Therefore, consumption of the studied food samples in Saudi Arabia are radiological safe in the presence of investigating radionuclides.

The cancer risk factor "RF" states the probability of a person dying of cancer increases by 5% for a total dose of 1Sv received during his life time [14]. The ICRP cancer risk is 3.5×10^{-3} based on total annual ingestion dose of 1mSv and life span of 70 year to general public. Our calculated mean value of cancer risk (6.54×10^{-4}) for all food groups as shown in **Table (2)**, were less than the ICRP value by a factor of 5.4. So, our studied food groups pose no significant risk to general public's health.

Table (1): Average Activity concentration (Bq/Kg) of 226Ra, 232Th and 40K in food samples.

Foods Group	Sample Name	Activity concentration (Bq/kg)		
		^{226}Ra	^{232}Th	^{40}K
Cereal grains	Saudi wheat	3.91±0.1967	3.20±0.1951	139.26±11.9792
	U.S wheat	2.60±0.1303	1.50±0.0928	99.30±8.5425
	Saudi Millet	4.97±0.2491	2.48±0.1557	147.25±12.6668
	Yemeni barley	10.63±0.6489	6.33±0.3855	178.31±15.3385
Range		2.60-10.63	1.50-6.33	99.30-178.31
Average		5.53	3.38	141.03
Legumes	Chickpeas	3.58±0.1824	1.53±0.0935	170.47±14.6641
	Egyptian bean	3.87±0.1951	2.54±0.1549	177.30 ±15.2517
	English bean	3.57±0.1812	2.64±0.1697	160.93±13.8436
	Small black lentils	3.45±0.1729	1.73±0.1057	107.83±9.2759
	Large black lentils	3.55±0.2224	2.41±0.1472	144.08±12.3943
	Tiny red lentil	4.34±0.2160	3.05±0.1891	129.13±11.1083
	Big red lentils	3.56±0.1788	2.59±0.1668	146.83±12.6306
	White beans	7.53±0.3784	2.54±0.1566	129.86±11.1706
	Lupine	2.91±0.1478	2.04±0.1243	153.09±13.1685
Range		2.91-7.53	1.53-3.05	107.83-177.30
Average		4.04	2.34	146.61
coffee beans	Ethiopian coffee beans	3.39±0.1495	2.97±0.1811	106.73±9.1810
Vegetables	Leafy Vegetable	8.28±0.3616	8.30 ±0.5057	117.34±10.0940
	Vegetable	2.25±0.1201	4.31±0.2624	128.89±11.0871
Range		2.25-8.28	4.31-8.30	117.34-128.89
Average		5.27	6.31	123.12
Meat	Cattle meat1	6.37±0.2793	6.49±0.3980	145.27±12.4963
	Cattle meat2	4.53±0.1985	3.47±0.2156	104.86±9.0201
	Poultry meat1	3.56±0.2221	3.98±0.2494	166.47±14.3202
	Poultry meat2	3.30±0.1651	2.48±0.1567	114.58±9.8562
Range		3.30-6.37	2.48-6.49	104.86-166.47
Average		4.44	4.11	132.80

Table (2) Calculated ingestion dose (D) from the intake of ^{226}Ra, ^{232}Th and ^{40}K, the annual intake (I), the total Ingestion dose (D_T) and the cancer risk (R) in the Food groups for adults .

Food groups	Annual intake I^* (Kg/y)	Ingestion dose "D" (µSv/y)			Total dose D_T (µSv/y)	cancer risk R $X10^{-3}$
		^{226}Ra	^{232}Th	^{40}K		
Cereal grains	109	168.78	84.74	95.31	348.83	1.22
Legumes	23	26.02	12.38	20.91	59.31	0.2076
Coffee beans	3	2.85	2.05	1.99	6.88	0.02409
Vegetables	100	147.56	145.13	76.33	369.02	1.29
Meats	50	62.16	47.27	41.17	150.60	0.527
Range		2.85-168.78	2.05-145.13	1.99-95.31	6.88-369.02	0.02409-1.29
Mean	-	81.47	58.31	47.14	219.57	0.654
World Average		120		170	290	3.5

*I(Ref. [15-17])

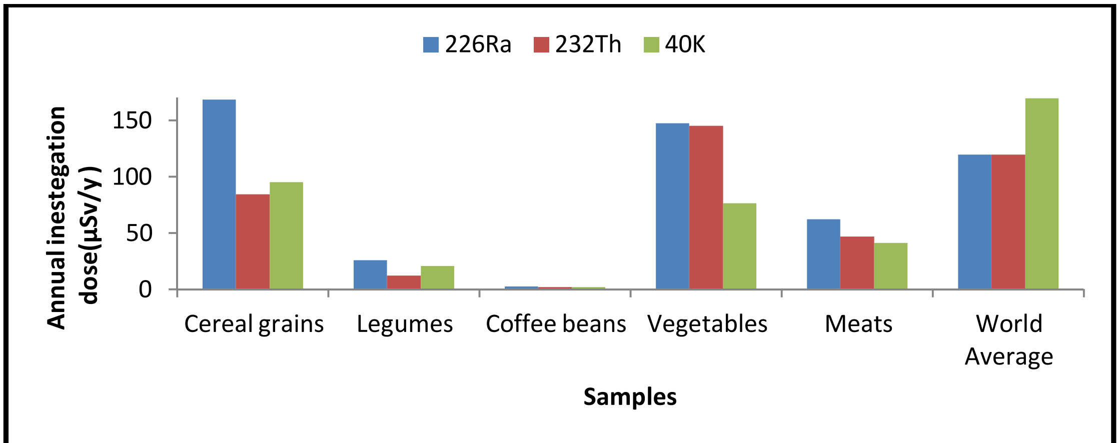

Fig (1) The annual ingestion dose (D) from the ^{226}Ra, ^{232}Th and ^{40}K of the food groups as indicated in table(2).

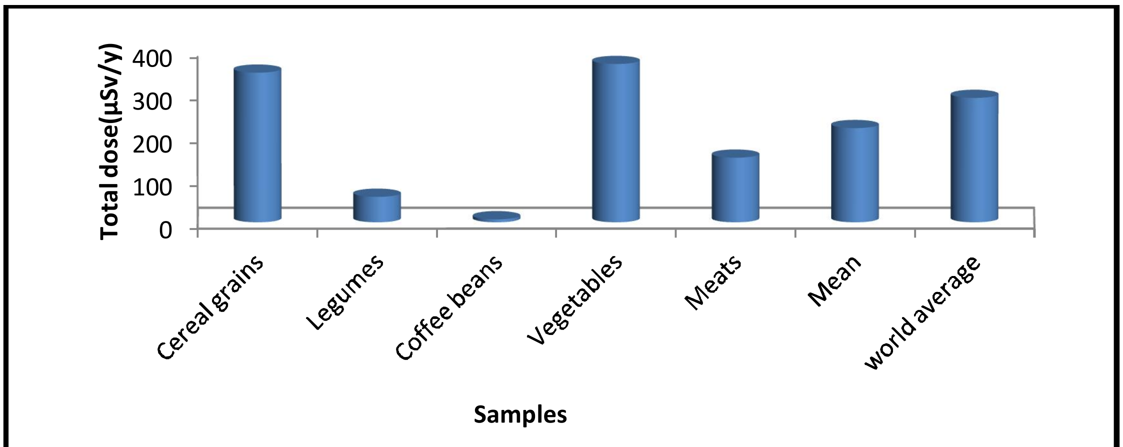

Fig (2) Comparison of the total does (µSv/y) due to the intake of natural radionuclides of ^{226}Ra, ^{232}Th and ^{40}K from the foodstuffs with the world average.

Conclusions

Twenty different samples collected from local market and measured using gamma ray spectrometer with a NaI(TI) detector . The results show that the mean calculated cancer risk "R" were 6.54×10^{-4} based on the mean of the total annual ingestion dose for all measured food groups (219.57µSv/y) and life span of 70 year to general public. It is clear that the calculated cancer risk less than The ICRP value by a factor of 5.4. So our studied samples are safe for consumptions to general public. It is known that Saudi Arabia import most of its nutritional needs from all over the world . So, all of the imported foodstuff should subject to radioactivity inspection and make sure that they have no health risk to population . This kind of researches build up a wide data base for researchers and help laying down the rules and regulations govern the quality and safety of the imported foodstuff.

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