Determination of Radionuclides and Their Radiological Risks in Different Brands of Cooking Oil Samples

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1. INTRODUCTION

Radionuclides such as uranium, radium, and the associated daughters are found in soil, air, water, and plant. Inhalation and ingestion of these radionuclides, beyond the allowable level, are a risk to human health [1]. One of the most important daughters of these radionuclides is radon-222 with a half-life of 3.82 days. It is the product of immediate radioactive decay series of radium (Ra-226), in the decay series of uranium (U-238). Rn-222 becomes an airborne gas before decaying. When airborne gas is inhaled or ingested, an alpha particle is emitted during its decay. Emitted alpha particles deposit all of their energy locally within a small thickness of adjacent tissue. So, Rn outside the body is much less harmful than if it were inhaled or ingested [2]. Radionuclides, in general, may enter the plants through water or air. Therefore, plants that will become substantial food for people are considered a route for radionuclides to travel from the environment to people [3], [4]. It has also been shown that exposure to radon produces lung cancer, while radium accumulation leads to bone tumor, the hazards related to uranium exposure caused by biochemical toxicity, as a heavy metal, are about six times higher than its radioactivity especially on the kidneys. In Saudi Arabia, many brands of oil derived from different plants are being used in cooking food. Therefore, measurement of the concentration of these radionuclides in cooking oils is very important in order to evaluate the ingested dose and to prevent the exposure of consumers to radiation.

The aim of the present work is to determine the concentration of natural radionuclides (U-238, Ra-226, and Rn-222) in different cooking oils derived from different manufacturers in Saudi Arabia by passive (CR-39) technique. In addition, radiological parameters such as the annual ingestion dose and risk of excess cancer per million persons are estimated.

2. MATERIALS AND METHODS

2.1 Samples collection

Eleven samples of different types of cooking oil derived from plants such as Corn, Sunflower and Olive were collected from different markets in Saudi Arabia for radiological analysis. The types of cooking oil samples are listed in Table 1. It was designated according to sample name, sample code, sample type, sample manufacture date, sample expiry date and sample density (Density of oil samples were measured by R.D bottle with a capacity of fifty cubic centimeters at an average temperature of 25 °C.). These types of oils were selected because most people use them.

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Table (1): Name, code, type, expiry, manufacture date, expiry date and density for different brands of Corn, Sunflower and Olive oil samples

<table>
<thead>
<tr>
<th>Name</th>
<th>Code</th>
<th>Type</th>
<th>Manufacture date</th>
<th>Expiry date</th>
<th>Density (g/cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Haley</td>
<td>CH</td>
<td>Corn</td>
<td>16/10/2019</td>
<td>15/10/2020</td>
<td>0.833±0.022</td>
</tr>
<tr>
<td>Afia</td>
<td>CA</td>
<td>Corn</td>
<td>11/2019</td>
<td>10/2021</td>
<td>0.850±0.008</td>
</tr>
<tr>
<td>Panda</td>
<td>CP</td>
<td>Corn</td>
<td>9/2019</td>
<td>8/2021</td>
<td>0.881±0.006</td>
</tr>
<tr>
<td>Noor</td>
<td>SN</td>
<td>Sunflower</td>
<td>2/9/2019</td>
<td>1/9/2020</td>
<td>0.912±0.001</td>
</tr>
<tr>
<td>Shams</td>
<td>SS</td>
<td>Sunflower</td>
<td>5/2019</td>
<td>4/2021</td>
<td>0.913±0.001</td>
</tr>
<tr>
<td>Lite Life</td>
<td>SL</td>
<td>Sunflower</td>
<td>15/12/2019</td>
<td>16/12/2020</td>
<td>0.914±0.001</td>
</tr>
<tr>
<td>Abu Zahra</td>
<td>SA</td>
<td>Sunflower</td>
<td>2/12/2019</td>
<td>1/12/2021</td>
<td>0.918±0.001</td>
</tr>
<tr>
<td>Nadec</td>
<td>ON</td>
<td>Olive (EVOO)</td>
<td>3/11/2019</td>
<td>2/7/2020</td>
<td>0.907±0.001</td>
</tr>
<tr>
<td>Panda</td>
<td>OP</td>
<td>Olive (EVOO)</td>
<td>30/11/2019</td>
<td>30/5/2021</td>
<td>0.908±0.001</td>
</tr>
<tr>
<td>Almarai</td>
<td>OA</td>
<td>Olive (EVOO)</td>
<td>19/11/2019</td>
<td>16/11/2021</td>
<td>0.906±0.002</td>
</tr>
<tr>
<td>Alwazir</td>
<td>OW</td>
<td>Olive (Refined)</td>
<td>5/2/2019</td>
<td>5/8/2020</td>
<td>0.909±0.001</td>
</tr>
</tbody>
</table>

2.2 Passive technique

Passive technique, CR-39 polymer detectors type TASTRAK (Track Analysis System, Ltd, UK) of area 1 cm² were used for measuring alpha particles levels in this study. Each detector was pasted at the bottom of the cover per plastic flask at a distance 10 cm from the surface of the oil sample, and then sealed at room temperature for 90 days exposure time as shown in Fig. (1). One flask was left without oil sample to calculate the background alpha radiation. After 90 days CR-39 detectors were collected from each plastic flask and etched by NaOH solution of concentration 6.25 N for 7 hours at 70 °C with an accuracy of ±1 °C using water bath technique. Next, the detectors were removed from the etching solution and washed and dried. The numbers of alpha tracks were observed by using an optical microscope of magnification 400 X.

The radon concentration, $C_{Rn}$ (Bq/m³), in airspace of flask was calculated using the following equation [5],[6]:

$$C_{Rn} = \frac{\rho}{F t}$$  \hspace{1cm} (1)

where $\rho$ is the track density (tracks.cm⁻²), $t$ is the exposure time of distributed CR-39 detector in (days) and $F$ is the calibration factor which calculated and equal to 0.18±0.002 (tracks.cm⁻².d/Bq.m⁻³) [5]. The effective radium content $C_{Ra}$ (Bq/L) can be calculated from the relation [5], [7]:

$$C_{Ra} = \frac{\rho h A}{F t e M}$$  \hspace{1cm} (2)

where $h$ is the distance between the detector and the surface of the oil sample (in m), $A$ is the area of cross section of the flask (in m²), $M$ is the amount of the oil sample (in L) and $T_e$ is the effective exposure time (in hour) which can be determined using the following equation:

$$T_e = t - \frac{1 - e^{-\lambda_{Rn} t}}{\lambda_{Rn}}$$  \hspace{1cm} (3)

where $t$ is the exposure time, and $\lambda_{Rn}$ (in h⁻¹) is the decay constant for radon. Uranium concentrations $C_u$ (in ppm) of oil samples has been calculated using the following equation [8]:

$$C_u (ppm) = \frac{W_u}{W_s}$$  \hspace{1cm} (4)

where $W_u$ is uranium weight in oil sample and $W_s$ is the weight of oil sample.

2.3 Radiological risk parameters

2.3.1 Annual ingestion dose

The annual dose for ingestion (AED$_{ig}$) was calculated from the experimentally determined value of activity of

Fig. (1): Sealed-can technique of radon measurements

radon concentration ($C_{Rn}^a$) in (Bq/Kg) by using eq. (5) given by [9]:

$$AED_{i_o} = C_{Rn}^a x A_o x EDC$$

(5)

where, $A_o$ is the amount of oil consumed by one person in one year [10] and EDC is the effective dose coefficient of radon ingestion (3.5 nSv/Bq) [11].

2.3.2 Excess lifetime cancer risk

The excess lifetime cancer risk (ELCR) per million persons due to radon ingestion was calculated by the following equation [4]:

$$ELCR = AED_{i_o} x DL x RF$$

(6)

Where DL is the average duration of life (70 years) and RF is risk factor (0.055 Sv$^{-1}$) recommended by the ICRP.

3. RESULTS AND DISCUSSION

4.1 Radiological analysis

Table (2) displays the obtained results of radon, radium and uranium concentrations in vegetable oil samples collected from different markets in Saudi Arabia. The highest concentration of these radionuclides were found 176.227±9.377 Bq/m$^3$, 0.330±0.018 Bq/L and 0.263±0.014 ppm respectively, in sample SN (Noor derived from Sunflower) and the lowest for these radionuclides were found to be 16.86±0.581 Bq/m$^3$, 0.032±0.001 Bq/L, 0.025±0.001 ppm respectively in sample OA (Almarai derived from Olive). It found that the highest value of $^{222}$Rn, $^{226}$Ra and $^{238}$U concentrations were lower than the WHO guideline limit of 100-300 Bq/m$^3$, 10 Bq/L. 11.7 ppm for $^{222}$Rn, $^{226}$Ra and $^{238}$U respectively [9].

Figs (2,3 and 4) illustrate the distribution of radon, radium content and uranium concentration in the oil samples under study. The variation in these radionuclides' concentration may be due to the different sources for oil samples because they were of different plant origin. The plant absorption of radionuclides varies depending on the geological formation of soil crust, the plant itself, and the fertilizer [12]. The pollution by radionuclides may be also directly caused by the absorption of radionuclide from the atmosphere. Consequently, the plant pollution with radionuclides is expected. As seen from Table (2), alpha activities, due to radium and uranium in the cooking oil samples, are lower than those due to radon. This is because radon has less half- life (3.82 d) than radium (1600 y) and uranium (4.47x10$^9$ y) [13]. Figs. (5 and 6) show the relation between radon with radium and uranium with radium, respectively. The results showed that there is a positive correlation between radon and radium, as well as a positive relation between uranium and radium with a good linear correlation coefficient of 0.999 for both in this study. These results provide an indication for the fact that uranium is a good source of radium, and a radium is a good source of radon in all samples.

![Table 2](image_url)

Table (2): Concentration of Rn-222, Ra-226, and U-238 in cooking oil samples

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Sample Code</th>
<th>$C_{Rn}$ (Bq/m$^3$)</th>
<th>$C_{Ra}$ (Bq/L)</th>
<th>$C_{U}$ (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>CH1</td>
<td>70.023</td>
<td>0.131</td>
<td>0.104</td>
</tr>
<tr>
<td>2</td>
<td>CH2</td>
<td>69.767</td>
<td>0.131</td>
<td>0.104</td>
</tr>
<tr>
<td></td>
<td>CH3</td>
<td>72.093</td>
<td>0.135</td>
<td>0.108</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>70.628±1.275</td>
<td>0.132±0.002</td>
<td>0.105±0.002</td>
</tr>
<tr>
<td>3</td>
<td>CA1</td>
<td>109.302</td>
<td>0.205</td>
<td>0.163</td>
</tr>
<tr>
<td></td>
<td>CA2</td>
<td>106.202</td>
<td>0.199</td>
<td>0.158</td>
</tr>
<tr>
<td></td>
<td>CA3</td>
<td>106.783</td>
<td>0.200</td>
<td>0.159</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>107.429±1.648</td>
<td>0.201±0.003</td>
<td>0.160±0.002</td>
</tr>
<tr>
<td>4</td>
<td>CP1</td>
<td>75.581</td>
<td>0.141</td>
<td>0.113</td>
</tr>
<tr>
<td></td>
<td>CP2</td>
<td>78.450</td>
<td>0.147</td>
<td>0.117</td>
</tr>
<tr>
<td></td>
<td>CP3</td>
<td>74.419</td>
<td>0.139</td>
<td>0.111</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>76.150±2.075</td>
<td>0.142±0.004</td>
<td>0.114±0.003</td>
</tr>
<tr>
<td>5</td>
<td>SN1</td>
<td>168.992</td>
<td>0.316</td>
<td>0.252</td>
</tr>
<tr>
<td></td>
<td>SN2</td>
<td>186.822</td>
<td>0.350</td>
<td>0.279</td>
</tr>
<tr>
<td></td>
<td>SN3</td>
<td>172.868</td>
<td>0.323</td>
<td>0.258</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>176.227±9.377</td>
<td>0.330±0.018</td>
<td>0.263±0.014</td>
</tr>
<tr>
<td>6</td>
<td>SL1</td>
<td>29.567</td>
<td>0.055</td>
<td>0.044</td>
</tr>
<tr>
<td></td>
<td>SL2</td>
<td>30.491</td>
<td>0.057</td>
<td>0.045</td>
</tr>
<tr>
<td></td>
<td>SL3</td>
<td>28.876</td>
<td>0.054</td>
<td>0.043</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>29.645±0.810</td>
<td>0.055±0.002</td>
<td>0.044±0.001</td>
</tr>
<tr>
<td>7</td>
<td>SA1</td>
<td>157.364</td>
<td>0.294</td>
<td>0.235</td>
</tr>
<tr>
<td></td>
<td>SA2</td>
<td>153.488</td>
<td>0.287</td>
<td>0.229</td>
</tr>
<tr>
<td></td>
<td>SA3</td>
<td>157.106</td>
<td>0.294</td>
<td>0.234</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>155.986±2.167</td>
<td>0.292±0.004</td>
<td>0.233±0.003</td>
</tr>
<tr>
<td>8</td>
<td>ON1</td>
<td>29.264</td>
<td>0.055</td>
<td>0.044</td>
</tr>
<tr>
<td></td>
<td>ON2</td>
<td>30.233</td>
<td>0.057</td>
<td>0.045</td>
</tr>
<tr>
<td></td>
<td>ON3</td>
<td>28.165</td>
<td>0.053</td>
<td>0.042</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>29.220±1.034</td>
<td>0.055±0.002</td>
<td>0.044±0.002</td>
</tr>
<tr>
<td>9</td>
<td>OP1</td>
<td>58.140</td>
<td>0.109</td>
<td>0.087</td>
</tr>
<tr>
<td></td>
<td>OP2</td>
<td>53.488</td>
<td>0.100</td>
<td>0.080</td>
</tr>
<tr>
<td></td>
<td>OP3</td>
<td>62.791</td>
<td>0.117</td>
<td>0.094</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>58.140±4.651</td>
<td>0.109±0.009</td>
<td>0.087±0.007</td>
</tr>
<tr>
<td>10</td>
<td>OA1</td>
<td>16.860</td>
<td>0.032</td>
<td>0.025</td>
</tr>
<tr>
<td></td>
<td>OA2</td>
<td>17.442</td>
<td>0.033</td>
<td>0.026</td>
</tr>
<tr>
<td></td>
<td>OA3</td>
<td>16.279</td>
<td>0.030</td>
<td>0.024</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>16.860±0.581</td>
<td>0.032±0.001</td>
<td>0.025±0.001</td>
</tr>
<tr>
<td>11</td>
<td>OW1</td>
<td>69.767</td>
<td>0.131</td>
<td>0.104</td>
</tr>
<tr>
<td></td>
<td>OW2</td>
<td>72.351</td>
<td>0.135</td>
<td>0.108</td>
</tr>
<tr>
<td></td>
<td>OW3</td>
<td>68.798</td>
<td>0.129</td>
<td>0.103</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>70.306±1.836</td>
<td>0.132±0.003</td>
<td>0.105±0.003</td>
</tr>
</tbody>
</table>

4.2 Radiation hazard indices

Table 3 shows the annual ingestion dose and ELCR per million persons due to radon ingestion in the cooking oil samples under study. It is observed that the average of the annual ingestion dose in oil samples varies from 12.657±0.436 in sample OA (Almarai derived from Olive) to 131.417±6.933 nSv/y in sample SN (Noor derived from Sunflower). The maximum value of annual ingestion dose is less than the limit of the recommended range (3-10 mSv/y) recommended by International Commission on Radiological Protection and the action level of 0.29 mSv/y recommended by UNSCEAR for the ingestion exposure caused by natural sources [9]. Additionally, the ELCR per million persons in all oil samples was found to range from 0.049±0.002 to 0.506±0.027. The maximum value was 0.506 per million
persons in sample SN (Noor derived from Sunflower). This value was less than the lower limit of the range (170-230) per million person recommended by International Commission on Radiological Protection [14]. Therefore, the values of ELCR are very low, so, the risk of cancer is negligible. This low value is related to low value of radon concentrations. In addition, the lower value of radon in the oil samples may be due to low moisture content that may reduce the radon level in the cooking oil sample [15], [16]. That means that the radon concentration in the cooking oil samples under study does not generate any sort of radiological health risk.

Table (3): Annual ingestion dose (nSv/y), ELCR per million persons due to ingestion of Rn-222 in cooking oil samples

<table>
<thead>
<tr>
<th>Sample Code</th>
<th>Sample Name</th>
<th>Annual ingestion dose (nSv/y)</th>
<th>ELCR per million persons</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH1</td>
<td></td>
<td>57.239</td>
<td>0.220</td>
</tr>
<tr>
<td>CH2</td>
<td></td>
<td>57.030</td>
<td>0.220</td>
</tr>
<tr>
<td>CH3</td>
<td></td>
<td>58.931</td>
<td>0.227</td>
</tr>
<tr>
<td>mean</td>
<td></td>
<td>57.733±1.042</td>
<td>0.222±0.004</td>
</tr>
<tr>
<td>CA1</td>
<td></td>
<td>87.455</td>
<td>0.337</td>
</tr>
<tr>
<td>CA2</td>
<td></td>
<td>84.974</td>
<td>0.327</td>
</tr>
<tr>
<td>CA3</td>
<td></td>
<td>85.439</td>
<td>0.329</td>
</tr>
<tr>
<td>mean</td>
<td></td>
<td>85.956±1.319</td>
<td>0.331±0.005</td>
</tr>
<tr>
<td>CP1</td>
<td></td>
<td>58.280</td>
<td>0.224</td>
</tr>
<tr>
<td>CP2</td>
<td></td>
<td>60.492</td>
<td>0.233</td>
</tr>
<tr>
<td>CP3</td>
<td></td>
<td>57.383</td>
<td>0.221</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>58.718±1.600</td>
<td>0.226±0.006</td>
</tr>
<tr>
<td>SA1</td>
<td></td>
<td>116.584</td>
<td>0.337</td>
</tr>
<tr>
<td>SA2</td>
<td></td>
<td>113.712</td>
<td>0.327</td>
</tr>
<tr>
<td>SA3</td>
<td></td>
<td>116.392</td>
<td>0.329</td>
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<tr>
<td>mean</td>
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<td>115.563±1.606</td>
<td>0.331±0.005</td>
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<td>SS1</td>
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<td>84.792</td>
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<td>SS2</td>
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<td>98.636</td>
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<tr>
<td>SS3</td>
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<td>95.752</td>
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<tr>
<td>mean</td>
<td></td>
<td>93.060±7.304</td>
<td>0.358±0.028</td>
</tr>
<tr>
<td>SL1</td>
<td></td>
<td>22.001</td>
<td>0.085</td>
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<td>SL2</td>
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<td>SL3</td>
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<tr>
<td>Mean</td>
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<td>22.058±6.03</td>
<td>0.085±0.002</td>
</tr>
<tr>
<td>SN1</td>
<td></td>
<td>126.022</td>
<td>0.485</td>
</tr>
<tr>
<td>SN2</td>
<td></td>
<td>139.318</td>
<td>0.536</td>
</tr>
<tr>
<td>SN3</td>
<td></td>
<td>128.912</td>
<td>0.496</td>
</tr>
<tr>
<td>mean</td>
<td></td>
<td>131.417±6.933</td>
<td>0.506±0.027</td>
</tr>
</tbody>
</table>

CONCLUSION

The concentration of 222Rn, 226Ra and 338U were below the recommended value. Likewise, the annual dose due to ingestion of radon was lower than the limit range (3-10 nSv/y) recommended by ICRP and UNSCEAR. Consequently, the risk of cancer is negligible. The obtained results reveal that all the cooking oil samples are radiologically safe for consumption. This result serves as a baseline radiological data on cooking oil for future studies.

REFERENCES


