Concentrations of $^{238}$U in selected Thai spices and the related dose assessment

P Nochit*, W Kulsawat and J Khunsamut
Thailand Institute of Nuclear Technology (Public Organization),
9/9 Moo 7, Ongkharak District, Nakhon-Nayok 26120, Thailand

*E-mail: phatchada@tint.or.th

Abstract. Finger root, galangal, turmeric, and lemon grass are commonly used in Thai cuisine as spices and herbs. The radionuclide uranium accumulates in human diet can has toxic effects in human health such as kidney damage and neurological disorders. In this study, the concentrations of $^{238}$U in some selected spices commonly used in Thailand were determined and the annual effective doses (AED) were assessed. Four spices consisted of galangal, turmeric, lemon grass and finger root were sampling from Bang Krathum district, Phitsanulok during 2017-2018. The radioactivity of $^{238}$U in these spice samples were varied from 0.015 (below detection limit) to 2.79 Bq/kg fresh. The highest activity was recorded in finger root ($2.79 \pm 0.14$) while the lowest was lemon grass ($0.34 \pm 0.06$). The estimated AED determined in this study due to consumption of spices ranges from 0.004 to 0.781 µSv/y and the total value for all four spices was 1.934 µSv/y. It was found that AED in this study is far below the International standard of average radiation dose of 290 µSv/y received per person worldwide due to intake of natural radionuclides in food. The results revealed insignificant radiological health hazard to the public due to the consumption of spices via foods. Based on these results, the spices samples from the studied area are considered radiological safe for human consumption. The results provide baseline values which may be useful in establishing rules and regulations relating to radiation protection.

1. Introduction
Thai cuisine is recognized as a healthy and functional diet. The remarkable of Thai food is its full-flavored dishes which is a harmony tastes of salty, sweet, sour, bitter, and spicy. Spices are always present in Thai dishes. It is a common experience that the distinct aroma of spices stimulates the appetite. These ingredients are rich in nutrients with medicinal properties. The common spices used in Thai cuisine are finger root, galangal, turmeric and lemon grass [1-2]. However, there is little information available about the safety of these spices with respect to naturally occurring radionuclides contamination.

Uranium-238 ($^{238}$U), thorium-232 ($^{232}$Th) and potassium-40 ($^{40}$K) are the radioactive elements in the earth’s crust and the discrete sources of natural radiation. They may be quantified in soil, plants, and animals. Although potassium (including $^{40}$K) is an essential nutrient for plant growth, radioactive $^{40}$K comprises a very small fraction (about 0.012 %) of naturally occurring potassium. The biological half-life (excretion time decay) of $^{40}$K is 30 days with most of it being excreted in urine. While $^{238}$U and $^{232}$Th are eliminated from the bone with a biological half-life of 22 years with the general potential for subsequent cancer induction [3]. Thus, $^{238}$U and $^{232}$Th will be much concerned on health hazard in terms of biological half-life than $^{40}$K. The level of plant uptake of $^{238}$U and $^{232}$Th illustrated by data values of the relative number of the ratio of the activity concentration of radionuclide in the plant to
that in the soil (Fv) for $^{238}\text{U}$ and $^{232}\text{Th}$. Thorium is known to be relatively immobile and Fv (0.0035 for all crops) is typically an order of magnitude lower than that observed for uranium (0.023 for all crops) [4]. These data indicated preferential uptake of $^{238}\text{U}$ rather than $^{232}\text{Th}$ in plants species.

Therefore, the presented study focused on the activity concentrations of $^{238}\text{U}$ in four Thai spices. Determining the levels of $^{238}\text{U}$ toxicity in spices would help ascertain the health impact of taking these spices, and provide relevant data on spices in the country [5]. $^{238}\text{U}$ has a very long physical half live of $4.47\times10^9$y. It is characterized by both radiotoxicity and chemical toxicity. The health hazard associated with $^{238}\text{U}$ results from its ability to accumulate in human tissues. Uranium accumulates in human lungs and kidney tissues. Depositions of large quantities of this radionuclide in particular organs produce radiation damages, biochemical and morphological changes. This results in weakening of immune systems and has toxic effects in human health such as kidney damage, neurological disorders, development of various types of diseases, cancers and increase in mortality rate [6-8].

Bang Krathum district, Phitsanulok province covers most of the agricultural area such as banana plantation, paddy fields, sugar cane, and spices cultivations. Spices are primarily grown for home consumption; however, they are proof to be soil improver and household economic strengthening. Therefore, abandoned land converting to spices cultivation is a good option and widespread shifting. Spices including chilly, ginger, finger root, galangal, turmeric and lemon grass are now grown to be sold not for merely eaten within families. Spices are easily grown and do not require much care. The most important thing is spices farming costs less than growing any other crops [1, 9]. Spice is not only a seasoning food ingredient but also an invaluable medicinal crop which led to an increased demand. The growth in spice consumption reflects a trend toward the used of spices to compensate for less salt and lower fat levels in food [1].

The objectives of this study were: (1) to establish a base line of $^{238}\text{U}$ concentrations in common four Thai spices including finger root, galangal, turmeric, and lemon grass for Bang Krathum district, Phitsanulok province by measuring the $^{238}\text{U}$ in the study area; (2) to estimate the annual effective dose of $^{238}\text{U}$ via these spices consumption.

2. Method
2.1. Study area
Bang Krathum District situated in the administrative area of Phitsanulok Province. The area lies between latitude 16°34′30″N and longitude 100°17′60″E (see figure 1). Most of Bang Krathum lies within the Nan Basin, although a narrow strip of land on the west side of the district lies within the Yom Basin. Both basins are part of the Chao Phraya Watershed. The Nan, Wang Thong and Wat Ta Yom Rivers flow through Bang Krathum, and the Yom River forms part of the border between Bang Krathum and Phichit province. Most of the habitats have agricultural occupation.

Regarding the weather, there are an average temperature of 27.9°C, relative humidity of 73.2% and precipitation falls annually of1, 324 mm/y. Total area of Bang Krathum district is 447 km$^2$ and its topography consists of flat, fertile lowlands. The Köppen-Geiger climate classification is Aw. The majority of agricultural is holdings which equal to 94.6% [9].

![Figure 1. Study area in Bang Krathum district, Phitsanulok province Thailand [9].](image-url)
2.2. Sample collection and preparation
Four dominant spices in a study area namely finger root, galangal, turmeric and lemon grass were collected from the cultivated field during 2017-2018. Upon return to the laboratory, the biological samples of finger root, galangal, turmeric and lemon grass were washed and then rinsed with Milli-Q distilled water and were immediately frozen at -20°C until freeze-dried. Wet weight and dry weight were recorded. Aliquot of the dried, ground and homogenized spice samples were kept in zip lock plastic bag ready for $^{238}$U determination.

2.3. Uranium-$^{238}$ isotope analysis
After preparation step, radiochemical analysis was performed. The purpose of chemical separation is to enhance the sensitive, accurate, and precise determination of $^{238}$U in biological material and to eliminate nonspecific and isobaric interferences from the intended $^{238}$U. For that purpose, freeze dried of 3 g was spiked with a known amount of $^{236}$U tracer (app. 20-30 mBq) then digested through the sequential step of HNO$_3$, HClO$_4$, HF and HCl which was performed on a hotplate at atmospheric pressure. The following steps are purification and conversion of $^{238}$U to a chemical form that is appropriate with the requirements of the deposition method. The uranium isotopes were electrodeposited onto a stainless steel disc for alpha spectrometry. The disc was measured using high-resolution Ion-implanted Silicon Charged-Particle detectors: 450 mm$^2$ active area (ORTEC Model: Octete Plus).

The accuracy and precision of the radiochemical method were evaluated using IAEA reference material (IAEA-330 Spinach).

2.4. The annual committed effective dose (AED)
The estimated AED for individuals as a result of radionuclide intake was derived from measured concentrations in sample using the appropriate ingestion dose conversion factors (DCF) for adults recommended by ICRP [10]. The dose was calculated as follows:

$$C_0 = A_i \times D_F \times E_F \times IG$$

where $C_0$ is the AED in $\mu$Sv/y, $A_i$ is the activity intake (Bq/kg ww), $D_F$ is the DCF ($0.045 \, \mu$Sv/Bq for $^{238}$U), $E_F$ is the exposure frequency (y), $IG$ = consumption rate (assume 1 kg/y).

2.5. Statistical analysis
One-way analysis of variance (ANOVA) was applied to determine the differences in $^{238}$U among spice samples at the level of 95%. Statistical analyses were performed using GraphPad Prism V.8 (GraphPad Software, Inc., La Jolla, California, USA). A probability of 0.05 ($p < 0.05$) was considered as significant in testing the null hypothesis of no differences in $^{238}$U.

3. Results and discussion
The natural spices considered in the study were finger root, galangal, turmeric, and lemon grass. Samples were collected from the cultivated field in Bang Krathum district, Phitsanulok province, Thailand. They were classified according to their scientific name, Thai names, the used part of the plant and medicinal property as shown in table 1.

3.1. Activity concentrations of $^{238}$U
The activity concentrations range of $^{238}$U measured in finger root, galangal, turmeric and lemon grass collected from Bang Krathum district, Phitsanulok province, Thailand are given in table 2.

Data on UNSCEAR reported in different countries for annual intake range from 5.5 to 6.2 Bq in countries of North America, 3.2 to 57 Bq from Asian countries, and 4.4 to 16 Bq from countries in Europe. The highest value presented in this study (2.793 Bq) is not exceed the reported values. The daily ingestion of the $^{238}$U has been reported to be 1.9 $\mu$g for ICRP Reference man whereas proposed United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) values for the entire world (global average) populations are 15.6 mBq (1.3 $\mu$g) for $^{238}$U [10-12].
Table 1. Information of spices in this study.

| Spices     | Thai name | Scientific name       | Part of the plant used | Medicinal property                                                                 |
|------------|-----------|-----------------------|------------------------|-------------------------------------------------------------------------------------|
| Finger root| Kra chai  | Boesenbergia rotunda  | root                   | anti-allergic, anti-bacterial, anti-inflammatory, anti-oxidant, anti-ulcer and wound healing |
| Galangal   | Khaa      | Alpinia galangaal     | rhizome                | anorexia, indigestion (dyspepsia), colic and stomach ache                           |
| Turmeric   | KhaMin    | Curcuma longa         | rhizome                | anti-inflammatory, improved brain function and a lower risk of brain diseases.       |
| Lemon grass| DhaKhrai  | Cymbopogon citratus   | stem                   | alleviate colds and congestion                                                     |

Table 2. Range of $^{238}\text{U}$ values (Bq/kg ww) in spice types from Bang Krathum district, Thailand.

| Spices     | $^{238}\text{U}$ values (Bq/kg ww) |
|------------|-----------------------------------|
| Finger root| 0.015 – 2.793                     |
| Galangal   | 0.015 – 2.136                     |
| Turmeric   | 0.015 – 1.652                     |
| Lemon grass| 0.015 – 0.349                     |

The variation of the activity concentrations of $^{238}\text{U}$ in the different spice plant samples depend significantly on the plant species and plant parts. Some plant species were $^{238}\text{U}$ phyto-extraction from soils. Previous experiment indicated that roots prevent penetration of large amounts of $^{238}\text{U}$ to upper plant parts. In addition, uptake of $^{238}\text{U}$ is likely to be influenced by the type of the plant roots. It was reported that $^{238}\text{U}$ content in root samples was consistently higher for fine roots than for bigger roots. The root and rhizome (modified underground stem) barks including periderm and living phloem were shown to contribute greatly to the $^{238}\text{U}$ accumulation in roots and rhizome [13]. Shahandeh and Hossner [14] reported that $^{238}\text{U}$ concentration in roots of different plants collected from the same site was 30–50 times higher than $^{238}\text{U}$ concentration in shoots.

In this study, the $^{238}\text{U}$ concentrations revealed the highest level in finger root $>$ turmeric (a thick bark rhizome) $>$ galangal (a thin bark rhizome). The lowest value was in lemon grass (an above ground stem).

3.2. The annual committed effective dose (AED)

Annual committed effective dose due to the ingestion of $^{238}\text{U}$ via individual spice samples was calculated and is shown in figure 2. The average amount consumption of each spice for adult member of Thailand was assumed to 1 kg/y.

The annual effective dose (µSv/y) from $^{238}\text{U}$ in food spices were estimated to be finger root (0.781) $>$ turmeric (0.596) $>$ galangal (0.462) $>$ lemon grass (0.095). The total effective dose of all studied spices is 1.934 µSv/y. These values are much less than the safe dose value of 290 µSv/y [12]. Upon considering the finding results, the sampled spices (finger root, galangal, turmeric, and lemon grass) for Bang Krathum district, Phitsanulok province were considered safe for human consumption. There is no risk from the daily use of the above mentioned spices.
4. Conclusion
The scale of the annual intake (1 kg/y) was used in this study in terms of worst case scenario. Although, human needs for spices is very few grams per day. The highest annual effective ingestion doses due to intake of $^{238}$U varied from 0.095 in lemon grass, 0.462 in galangal, and 0.596 in turmeric $\mu$Sv/y to 6.13 $\mu$Sv/y in finger root. The results showed that there were far below the average radiation dose of the 290 $\mu$Sv/y received per head worldwide. Therefore the radiological hazard associated with intake of the natural $^{238}$U radionuclides in the spice plants is insignificant. In conclusion, the spice crops samples from Bang Kratham district, Phitsanulok province are considered safe in terms of the intake of the natural dose of $\mu$Sv/doses due to intake of $^{238}$U.

The highest annual effective ingestion doses due to intake of $^{238}$U varied from 0.095 in lemon grass, 0.462 in galangal, and 0.596 in turmeric $\mu$Sv/y to 6.13 $\mu$Sv/y in finger root.

Figure 2. $^{238}$U and AED plot of four spices.

Table 3. U-238 Activity (Bq/kg) and Effective Dose (µSv/y) for four spices

| Spices        | U-238 Activity (Bq/kg) | Effective Dose (µSv/y) |
|---------------|------------------------|------------------------|
| Lemon Grass   | 0.462                  | 1.65                   |
| Galangal      | 0.596                  | 2.13                   |
| Turmeric      | 0.781                  | 2.79                   |
| Finger root   | 0.34                   | 0.781                  |

References
[1] Kaefer C M and Milner J A 2008 J. Nutr. Biochem. 19(6) 347
[2] Khanthapok P and Sukrong S 2019 J. Food Health Bioenviron. Sci. 12(1) 54
[3] Mitchell N, Perez-Sanchez D and Thorne M C 2013 J. Rad. Proct. 33(2) 17
[4] IAEA2010 Handbook of Parameter Values for the Prediction of Radionuclide Transfer in Terrestrial and Freshwater Environments (IAEA Technical Report Series No. 472) (Vienna: IAEA)
[5] Elsaman R, Ali G A M, Uosif M A M, El-Taher A and Chong K F 2020 Int. J. Radiat. Res. 18(1) 157
[6] Szymariska K, Strumiriska-Parulska D and Falandysz J 2020 Chemosphere 250 126242 Online: https://doi.org/10.1016/j.chemosphere.2020.126242
[7] Van T T, Bat L T, Nhan D D, Quang N H, Cam B D and Hung L V 2019 J. Environ. Manage. 63 444
[8] Tettey-Larbi L, Darko E O, Schandorf C and Appiah A A 2013 SpringerPlus 2 157
[9] Wikipedia 2020 Bang Kratham District Online: https://en.wikipedia.org/wiki/Bang_Kratum_District
[10] UNSCEAR 2000 Sources and Effects of Ionizing Radiation (UNSCER 2000 report to the general Assembly, with Scientific Annexes Vol. I) (New York: UNSCEAR)
[11] ICRP 1997 Individual Monitoring for Internal Exposure of Workers (ICRP Publication No. 78) (Oxford: Pergamon Press)
[12] Jha S K, Gothankar S, Longwai P S, Kharbuli B, War S A and Puranik V D 2012 J. Environ. Radioact. 103 1
[13] Shtangeeva I 2008 Chapter 14 Uranium and Thorium Accumulation in Cultivated Plants in Trace Elements as Contaminants and Nutrients: Consequences in Ecosystems and Human Health Ed M N V Prasad 2008 John Wiley & Sons, Inc. p 344
[14] Shahandeh H and Hossner L R 2002 Water Air Soil Pollut. 141 165