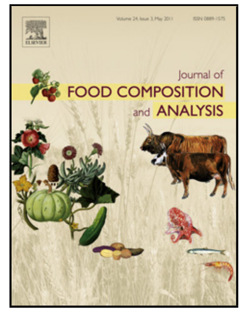
Journal Pre-proof



^{137}Caesium, ^{40}Potassium and potassium in raw and deep-oil stir-fried mushroom meals from Yunnan in China

Jerzy Falandysz (Conceptualization) (Resources) (Methodology) (Funding acquisition) (Formal analysis) (Data curation) (Writing - original draft) (Writing - review and editing), Yuanzhong Wang (Conceptualization) (Resources) (Methodology) (Funding acquisition) (Investigation), Michał Saniewski (Funding acquisition) (Formal analysis) (Data curation) (Investigation), Alwyn Fernandes (Conceptualization) (Resources) (Formal analysis) (Data curation) (Investigation) (Writing - review and editing)

PII: S0889-1575(19)31519-4

DOI: https://doi.org/10.1016/j.jfca.2020.103538

Reference: YJFCA 103538

To appear in: *Journal of Food Composition and Analysis*

Received Date: 10 October 2019

Revised Date: 13 May 2020

Accepted Date: 18 May 2020

Please cite this article as: { doi: https://doi.org/

^{137}Caesium, ^{40}Potassium and Potassium in raw and deep-oil stir-fried mushroom meals from Yunnan in China

Jerzy Falandysz[1,2,3], Yuanzhong Wang[3], Michał Saniewski[4] Alwyn Fernandes[5]

[1]University of Gdańsk, Environmental Chemistry and Ecotoxicology, 63 Wita Stwosza Street, 80-308 Gdańsk, Poland

[2]Environmental and Computational Chemistry Group, School of Pharmaceutical Sciences, Zaragocilla Campus, University of Cartagena, Cartagena, Colombia[+]

[3]Medicinal Plants Research Institute, Yunnan Academy of Agricultural Sciences, Kunming 650200, China[+]

[4]Institute of Meteorology and Water Management – Maritime Branch, National Research Institute, 42 Waszyngtona Av., 81-342 Gdynia, Poland

[5]School of Environmental Sciences, University of East Anglia, Norwich NR4 7TJ, UK

[*]Correspondence:

e-mail: jerzy.falandysz@ug.edu.pl, jerzy.falandysz@gmail.com; [+]Visiting professor (JF)

Graphical abstract

Mushrooms stir-fried in deep oil in a wok

Highlights

- Stir-fried mushrooms showed greater contamination with ^{137}Cs than fresh
- Stir-fried mushrooms on a whole weight were enriched in ^{137}C
- Stir-fried mushrooms on a whole weight were also enriched in K and ^{40}K
- A single 100 g meal provide K at 9.8 to 22 mg per kg of body mass

Abstract

A number of wild, edible mushroom species (*Baorangia bicolor*, *Boletus calopus*, *Boletus obsclereumbrinus*, *Butyriboletus roseoflavus*, *Rubroboletus sinicus*, *Rugiboletus extremiorientalis* and *Xerocomus* sp.) were collected in 2017, from Yunnan (Yuxi prefecture) in SW China. Samples of raw and stir-fried pools of these specimens were analysed for radioisotopes ^{137}Cs (caesium) and ^{40}K (potassium), and for total K concentrations. On a whole (wet) weight (ww) basis, ^{137}Cs activity ranged from < 0.10 to 0.75 Bq kg^{-1} for raw, and from 0.5 to 4.4 Bq kg^{-1} in stir-fried mushrooms. Radiopotassium (^{40}K) activity ranged from 57 to 96

Bq kg^{-1} ww for raw, and 170 to 370 Bq kg^{-1} ww for stir-fried mushrooms, while the corresponding concentration ranges for total K were 2100 to 3400 mg kg^{-1} ww (mean: 2800 ± 3900 mg kg^{-1} ww), and 6000 to 13000 mg kg^{-1} ww) mean: 8700 ± 2100 mg kg^{-1} ww), respectively. This data indicates that mushrooms from this region show negligible ^{137}Cs contamination with evidently higher activity levels of ^{40}K. The deep oil stir-frying process results in enrichment in the resulting meals for all three determinants. 100 g meal portions showed ^{137}Cs activity in the range < 0.08 to 0.44 Bq 100 g^{-1} ww (mean 0.15 ± 0.12 Bq 100 g^{-1} ww), and ^{40}K activity from 16 to 37 Bq 100 g^{-1} ww (mean 24 ± 6 Bq 100 g^{-1} ww). The consequent exposure from ^{40}K contained in a single 100 g serving and weekly (100 g x7) servings was equivalent to radiation doses in the range of 0.099 to 0.23 μSv and 0.68 to 1.6 μSv per capita (means 0.15 ± 0.04 and 1.1 ± 0.3 μSv). This is equivalent to doses in the range of 0.0017 to 0.0038 μSv kg^{-1} bm day^{-1} and 0.011 to 0.027 μSv kg^{-1} bm week^{-1} respectively (mean values of 0.0025 ± 0.006 μSv kg^{-1} bm day^{-1}and 0.018 ± 0.004 μSv kg^{-1} bm week^{-1}). Analogically to the annual ^{137}Cs radiation exposure resulting from high rates of annual consumption (20 to 24 kg *per capita*), the estimated annual dose of radiation from ^{40}K would range from 0.34 up to 0.92 μSv kg^{-1} bm (mean 0.60 μSv kg^{-1} bm). Thus in practice, high annual consumption rates of wild, stir-fried mushrooms as seen in Yunnan, would result in negligible internal doses from decay of artificial ^{137}Cs, relative to that from natural ^{40}K. The 100 g servings also contained between 590 to 1300 mg of K making this local food one of the top dietary sources of nutritionally important potassium for local consumers.

Key words: Human exposure, Foodstuffs, Fungi, Macromycetes, Nutritional content

Introduction

Mushrooms are considered as a beneficial source of human dietary intake of essential inorganic macro-nutrients including potassium (K) and phosphorous (P), and micro-nutrients e.g. zinc (Zn), copper (Cu), selenium (Se) and others, but can occasionally also be a source of some geochemical or environmental radioactive contaminants. For example, mushrooms were known as a potentially significant source of human dietary intake of radiocaesium (^{137}Cs) (Kiefer et al., 1965), long before the accident at the Chernobyl nuclear power plant made this contamination more widely known and led to focused studies on this pathway to human exposure (Falandysz and Borovička, 2013; Stijve and Poretti, 1990). Apart from the global atmospheric radioactive fallout from nuclear testing and the two bombs in the 1940s, major nuclear power plant disasters such as Chernobyl and Fukushima Dai-ichi in Japan also result in widespread or near-global impacts (Steinhauser et al., 2014). Recent research shows that mushrooms from all over the Chernobyl fallout zones, both proximate and more distant areas, continue to bio-accumulate ^{137}Cs, many years after the accident (Betti et al., 2017; Cocchi et al., 2017; Falandysz et al., 2015a, 2016, 2019a; Orita et al., 2017; Türkekul et al., 2018; Vinichuk et al., 2010). The later Fukushima Daiichi incident in 2011, also caused ^{137}Cs contamination of foods, specifically mushrooms and game animals, in the Fukushima prefecture of Japan (Chatterjee et al., 2017; Prand-Stritzko and Steinhauser, 2018), but its impact on wild mushrooms in SW China - the Yunnan and Sichuan provinces - is minor, apart from a few exceptions, possibly due to the regional climate and local weather conditions in the period following the incident (Falandysz et al., 2018; Tuo et al., 2017).

Macrofungi including the large edible species that grow in the wild, are foraged in many parts of the world and are considered to be an important source of food for local populations.

Some species such as *Boletus edulis* and related species, *Cantharellus cibarius*, *Tricholoma matsutake*, etc., are particularly prized and are much sought after by mushroom hunters, either as a valued addition to their cuisine, or as a seasonal source of income. However, knowledge on the mineral composition of many types of edible mushrooms after culinary processing and the resulting effects on human exposure is insufficient to provide a view on this contamination pathway. This dearth of knowledge is particularly acute for certain areas, such as those that show natural geochemical soil anomalies or have suffered from particular environmental problems (Beneš et al., 2018; Borovička et al., 2007 and 2014; Chiaravalle et al., 2018; Falandysz and Borovička, 2013; Falandysz et al., 2017a, 2019b and 2019c). The Yunnan province in China is a natural habitat to more than a thousand wild mushroom species with high local consumption of the edible species. Yunnan is also the main centre in China for the trading of these mushrooms collected from the wild. Thus, mushrooms may constitute a significant source of mineral macronutrients including K but, when contaminated, a potential source of dietary radiocaesium for locals who consume them regularly.

Certain local, domestic preparation procedures, e.g., washing and boiling (blanching, parboiling) but also commercial conserving procedures (pickling and canning) can substantially reduce the ^{137}Cs contamination levels in mushrooms. Simultaneously, these procedures can also reduce the contents of other toxic, as well as nutritionally beneficial compounds and minerals. (Barnett et al., 1999; Beresford et al., 1999; Consiglio et al., 1990; Daillant et al., 2013; Drewnowska et al., 2017; Pankavec et al., 2019; Skibniewska and Smoczyński, 1998; Stijve, 1994). The reduction of ^{137}Cs (or any other contaminant) contents in edible fungi by cooking is thus a significant route to limiting the human intake of this radionuclide, both for mycophilous consumers as well as others who may be inadvertently exposed to contaminated fungi which form minor flavoring ingredients in mixed meals (e.g. soups, fish and meat stews).

The stir-frying of mushrooms with or without initial blanching (parboiling) is typical method of cooking fresh mushrooms in China. The proportion of vegetable oil used per volume of fried mushrooms can vary depending on the particular species or on local customs or recipes.

Nevertheless, it should be mentioned that this is a huge biodiversity of edible mushrooms, as well as cooking methods and recipes (Bhatt et al., 2018; Nnorom et al., 2019; Santiago et al., 2016; Wu et al., 2019). Freshly harvested mushrooms are also eaten boiled, e.g. *Macrocybe gigantea*, *C. cibarius* and other in prepared as a soup, but are rarely eaten raw. An exceptions is freshly sliced or chipped Matsutake *Tricholoma matsutake*. The black Cloud ear Auricularia auricula-judae, is available dried, and is soaked before consumption, but without any thermal treatment. A large variety of dried mushrooms are available all year round in China.

When blanched (or parboiled), mushrooms are known to release to varying degree, numerous organic and inorganic compounds that are highly water soluble, such as l-ascorbic acid (vitamin C), soluble proteins, soluble sugars, some colloidal constituents and metallic elements including ^{137}Cs and metalloids, in the usually discarded water that they are cooked in (Biekman et al., 1996; Consiglio et al., 1990; Daillant et al., 2013). Additionally, when blanched or boiled, as in a soup, mushrooms also lose their juices and dehydrate, but can simultaneously absorb the water used for cooking. Thus, immaterial to whether results are expressed on a dry biomass basis or on a whole (wet) weight basis, blanched mushrooms lose radiocesium during this cooking procedure. At the normal boiling temperature of 100 °C, the percentage loss is dependent on the blanching time, the degree of defragmentation of the fruiting bodies and possibly on the level of pre-washing (Stijve, 1994).

Mushroom preparation and cooking techniques vary but frying in oil is a popular method in many parts of the world. Stir-frying of foods using hot vegetable oil in a wok is a popular cooking method in Yunnan and elsewhere in Asia with many regional variations on the exact techniques (Qiu, 2003). There is however very little information on the effects of this mode of cooking on ^{137}Cs and other mineral contents of the prepared meals (Falandysz et al., 2019b and 2019c).

A partial leakage of ^{137}Cs into the oil fraction has been noted when mushrooms are fried in a pan or in a flat type of vessel (Steinhauser and Steinhauser, 2016). Beresford et al. (1999) have compiled data showing that activity levels resulting from ^{137}Cs in fried mushrooms decrease by 50% relative to the fresh product. An earlier study reported an even higher (70%) rate of ^{137}Cs loss during frying (Kenigsberg et al., 1996), but it is unclear in both these reports as to whether the data were calculated on a whole (wet) weight or dry biomass basis. Clarification is necessary because frying in hot oil dehydrates foodstuffs, reducing the whole weight, while simultaneously preserving the mineral and contaminant contents. This often results in an apparent increase in their content in the prepared food due to the effect of concentration (Bordin et al., 2013). This study investigated the fate of ^{137}Cs and in parallel that of ^{40}K and total K, on mushrooms that were collected in the wild in the Yunnan province in China and were cooked by stir-frying using deep oil in a wok.

Materials and Methods

Collection of mushrooms

Edible mushroom species were collected from the forests of the Yuxi prefecture in the central region of Yunnan province in July 2017 and were separated within each species into two pools of raw and stir-fried samples. All mushrooms in this study were relatively young specimens (but did not include immature or 'baby' fruiting bodies) that were selected randomly from several batches that were available on the same day in different local markets. The mushrooms were considered suitable for cuisine by local consumers, and were cooked (processed fresh) in the afternoon of the day of collection. All mushrooms within a particular species (either for the raw pool or stir-fried pool were collected at the same time and in the same location as follows: *Baorangia bicolor* (Kuntze) G. Wu, Halling & Zhu L. Yang, 11specimens for drying (biomass 391 g) and 22 specimens (biomass 579 g) for frying were collected from Shihe in Jiangchuan (coordinates: 24°17′25″ N, 102°45′8″ E; and 16 specimens (343 g) and 18 specimens 604 g respectively, were collected from Luohe in Dayingjie (24°20′25″ N, 102°29′32″ E). For *Boletus calopus* Fr., 22 specimens for drying (biomass 408 g) and 36 (biomass 607 g) for frying were collected from Anhua in Jiangchuan (24°24′59″ N, 102°39′51″ E). In the case of *Boletus flammans* Dick & Snell, 15 specimens for drying (biomass 402 g) and 7 for frying (biomass 636 g) were collected from Lingxiu in Hongta (24°19′41″ N, 102°34′49″ E). For *Boletus obsclereumbrinus* Hongo. from Shihe in Jiangchuan; - 13 specimens for drying (biomass 400 g) and 23 for frying (biomass 600 g), and for *Butyriboletus roseoflavus* Forst., from the same location, 10 specimens for drying (biomass 382 g) and 22 for frying (biomass 604 g) were collected. For *Rubroboletus sinicus* (W.F. Chiu) Kuan Zhao & Zhu L. Yang7 specimens for drying (biomass 406 g) and 11 for frying (biomass 628 g), were collected from Huangcaoba in Hongta (24°26′8″N, 102°26′39″ E). For *Rugiboletus extremiorientalis* (Lj.N. Vassiljeva) G. Wu & Zhu L. Yang, from Luohe in Dayingjie, 5 specimens were collected for drying (biomass 517 g) and 13 for frying (biomass 600 g) and from Anhua in Jiangchuan 15 specimens were collected for drying (biomass 517 g) and 9 for frying (biomass 600 g). Pools were also collected of an unidentified *Xerocomus* sp., from Luohe in Dayingjie with 10 specimens collected for drying (biomass 482 g) and 18 for frying (biomass 653 g).

Before processing and cooking by drying and stir-frying, each collected specimen within a pool was individually cleaned by removing any soil particles or other debris and the cap was separated from the stipe. The specimens that were not stir-fried were sliced and dried at 65 ºC in a food dehydrator (Ultra FD1000, Ezidri, Australia) and ground to a fine powder using a clean porcelain mortar and pestle and stored dry in sealed polyethylene bags until analysis.. The moisture contents of each species pool was determined by drying subsamples in an electrically heated oven for 24 h to a constant mass at 105 °C.

Mushrooms stir-fried in deep oil

As mentioned earlier, mushrooms that were randomly selected for stir-frying pools were collected at the same time and location as the raw counterpart pools. The individuals were similarly sliced and pooled (both caps and stipes) and stir-fried in deep oil (200 mL) for 10 min in a Chinese type wok pan. After cooking, the excess oil was drained away and the fried products were cooled and transferred into unused polyethylene containers (screw capped jars, 0.5 L), weighed, deep frozen (- 20 ºC), lyophilised and then kept refrigerated in sealed jars until analysis. Immediately prior to instrumental analysis, the fungal materials were deep frozen with a final lyophilisation for 72 h (Labconco Freeze Dry System, Kansas City, MO, USA), then reweighed (to calculate moisture content) and further homogenised using a blender with ceramic blades so that the activity levels of radionuclides would be determined in fully dehydrated materials.

Analysis

20 to 25 g (dry weight) average biomass of the prepared samples was weighed out in cylindrical dishes (diameter 40 mm). The activities of ^{40}K and ^{137}Cs in each sample were determined using a gamma spectrometer with a coaxial high purity germanium (HPGe) detector (Falandysz et al., 2018 and 2019d) with a relative efficiency of 18 % and a resolution of 1.9 keV at 1.332 MeV. Quantitation was carried out using the equation:

$$A_i = \frac{N_i}{t\,\varepsilon(E)\,y} \qquad (1)$$

where: N_i – number of counts after background correction,

$\varepsilon(E)$ – detector efficiency for photons with energy E

y – quantum efficiency

t - measurement time in seconds.

The Minimum Detectable Activity (MDA) was determined by the Curie method. This method is based on two basic parameters: (i) critical level (LC), which is defined as a level, below which the detection signal cannot be reliably recognized and (ii) limit of detection (LD) specifying the smallest signal that can be considered as quantitatively reliable.

$$MDA = \frac{L_D}{t\,\varepsilon(E)\,y} \qquad (2)$$

The LD was calculated using the formula:

$$L_D = 0{,}276 + 1{,}05\sigma \quad (3)$$

Where:

aL_D – detection limit in impulses.

σ – standard deviation of the background.

All measurements of the fungal materials were preceded by a background measurement (time 80,000 s or 250,000 s), and background counts were subtracted (using the GENIE 2000 program). The lower limit of detection was at 0.10 Bq kg^{-1} dry biomass (db). The equipment was calibrated using a multi-isotope standard and the method was fully validated. The reference material ‘Standard solution of gamma emitting isotopes, code BW/Z-62/27/07’ produced at the

IBJ-Świerk near Otwock in Poland was used for preparing reference samples for equipment calibration. The radionuclides used in the reference solution during equipment calibration were ^{241}Am, 1,2%; ^{109}Cd, 2,1%; ^{57}Co, 0,80%; ^{51}Cr, 1,55; ^{113}Sn, 2,0%; ^{85}Sr, 1,2%; ^{137}Cs, 1,5%; ^{54}Mn, 1,55; ^{65}Zn, 1,2%; ^{60}Co 0,8% , with an approximation error level at 3-5%.

The same geometry of cylindrical dishes with 40 mm diameter (as used for the measurement of collected samples) was used for reference samples during equipment calibration. Calibration was carried out using standards with a density of approximately 1 g cm^{3}(liquid) with different heights: 3, 6, 9, 15, 25 mm, which allows the selection of the appropriate calibration for samples of different thickness layer.

All numerical data obtained were adjusted for dehydrated (at 105 ^{o}C) fungal materials and the exact date of mushroom collection (Tables 1 - 3). Potassium (K) content was calculated using the activity concentration of ^{40}K in natural K which is in the range 27.33 to 31.31 Bq g^{-1} of K (Samat et al., 1997). The ^{137}Cs, ^{40}K and K contents respectively in the whole fruiting bodies or separately in the caps and stems (dried and fresh), were calculated based on the original measurement data and taking into account the mean share of the biomass of the caps and stems (percentage by mass) in the whole fruiting bodies - both fresh and dehydrated.

The estimated intake values of ^{137}Cs and ^{40}K and the corresponding radiation doses for an adult person *per capita* and per kg body mass (Asian person, body mass 60 kg) based on the consumption of a single 100 g stir-fried mushroom meal and a weekly consumption of seven meals (100 g x 7). The free Social Science Statistics software (www.socscistatistics.com) was used for statistical data analysis.

Results and Discussion

^{137}Cs, ^{40}K and K in dehydrated raw mushrooms and stir-fried in deep oil

Radioactive caesium (^{137}Cs) activity concentrations determined for the mushroom samples in this study were normalised to dry biomass (db). For unprocessed mushrooms (the whole fruiting bodies) concentrations ranged from < 2.2 to 7.4 ± 0.9 Bq kg^{-1} db (mean: 4.5 ± 1.6 Bq kg^{-1} db), while for stir-fried mushrooms, the range was < 1.1 to 9.3 ± 1.1 kg^{-1} db (mean: 3.3 ± 2.7 Bq kg^{-1} db) (Table 1). The distribution ratio of ^{137}Cs activity concentration between caps and stems of the fruiting bodies for the majority of the species was close to unity, with a mean value of 0.96 ± 0.23. ^{137}Cs activity concentrations observed in fresh mushrooms showed negligible contamination and were within the reported concentration range for many of the species foraged across the Yunnan province since the early 2010s (Falandysz et al., 2015a, 2015b, 2016, 2017, 2018 and 2019; Tuo et al., 2017; Wang et al., 2015).

The ^{40}K activity concentrations in the whole fruiting bodies were in the range 620 to 960 Bq kg^{-1} db (mean: 800 ± 120 Bq kg^{-1} db), and total K concentrations ranged from 22000 to 34000 mg kg^{-1} db (mean: 29000 ± 4100 mg kg^{-1} db) (Tables 2 and 3). Unlike ^{137}Cs, the caps showed around 1.5-fold greater ^{40}K activity ($p < 0.05$; Mann Whitney U test) than the stipes (mean $Q_{C/S}$ ratio: 1.4 ± 0.4) (Table 2). Stir-fried mushrooms showed ^{40}K activity concentrations in the range 370 ± 41 to 860 ± 75 Bq kg^{-1} db (mean: 560 ± 140 Bq kg^{-1} db) and total K from 13000 ± 1500 to 31000 ± 2700 kg^{-1} db (mean: 20000 ± 5200 kg^{-1} db) (Tables 2 and 3).

^{137}Cs, ^{40}K and K in the whole (wet) weight raw mushrooms and stir-fried in deep oil

The ^{137}Cs activity concentrations in raw mushrooms expressed on a whole (fresh) weight (ww) basis were in the range < 0.10 to 0.75 Bq kg^{-1} ww (mean: 0.41 ± 0.18 Bq kg^{-1} ww). Stir-fried mushroom meals showed greater contamination ($p < 0.05$; Mann Whitney U test) with ^{137}Cs, with activities in the range of 0.5 to 4.4 Bq kg^{-1} ww (mean: 1.5 ± 1.2 Bq kg^{-1} ww) (Table 4).

In this study ^{40}K was in the range of 57 to 96 Bq kg^{-1} ww (mean: 74 ± 12 Bq kg^{-1} ww) for raw mushrooms, and 170 to 370 Bq kg^{-1} ww (mean: 240 ± 62 Bq kg^{-1} ww) in stir-fried mushroom meals. The total K contents in raw fresh mushrooms was in the range 2100 to 3400 mg kg^{-1} ww (mean: 2800 ± 3900 mg kg^{-1} ww) and 6000 to 13000 mg kg^{-1} ww (mean: 8700 ± 2100 mg kg^{-1} ww) in stir-fried mushroom meals (Table 4). Clearly, if expressed on a whole weight basis, the stir-fried mushrooms were enriched in potassium, and also in ^{137}Cs, but this radionuclide was a very minor constituent due to the low levels of earlier radioactive fallout in the Yunnan province (Falandysz et al., 2018). The ^{40}K activity concentrations in mushrooms collected in the regions not directly affected by ^{137}Cs radioactive depositions are of natural origins due to high content of potassium, which is the major metallic element in mushrooms (Karadeniz and Yaprak, 2010).

Intake of ^{137}Cs, ^{40}K and K from stir-fried mushroom meals and internal exposure dose from the radionuclides

Mushrooms that are stir-fried in deep oil are served after draining off the oil residue, which is discarded. A significant proportion of the oil is usually absorbed by mushrooms (from 24 to 32 % when stir-fried with a small volume of oil) (Falandysz et al., 2019b), and this contributes substantially to the hidden calorific content of the meal. The residual oil contains compounds that leach out of the partially dehydrated flesh of the mushroom, e.g. ^{137}Cs (Steinhauser and Steinhauser, 2016). If the oily residue is discarded or simply not eaten, a proportion of these compounds is excluded from the meal, reducing dietary exposure. In other cases, condiments such as salt and powdered spices, along with sliced vegetables are sometimes added to the stir-fried mushroom dish, enhancing the taste of the fatty residue. It is known that this residue (sometimes butter is used instead of vegetable oil) is often eaten with bread or topped (with the mushrooms) on a bowl of boiled rice. In these cases, there is no reduction of the dietary intake of radiocaesium from the mushroom meal. Due to the weight loss from dehydration during stir-frying, the dose of radioactivity from radionuclide decay received from a stir-fried mushrooms meal (whole weight basis) can be substantially higher than that originally contained in the same mass of raw mushrooms.

The contents and intake rates of ^{137}Cs, ^{40}K and K and the corresponding radiation doses from ^{137}Cs and ^{40}K decay, estimated for an adult person based on the consumption of a single 100 g stir-fried mushroom meal and weekly consumption (100 g x 7), are presented in Table 5. Thus a single stir-fried mushroom meal would represent a ^{137}Cs activity in the range < 0.08 to 0.44 Bq per 100 g, or < 0.56 to 3.1 Bq, if the meal was consumed every day for a week. The respective mean activities would be 0.15 ± 0.12 Bq and 1.0 ± 0.9 Bq. The corresponding values for ^{40}K were much higher when compared to ^{137}Cs, i.e. from 16 to 37 Bq per 100 g and 110 to 260 Bq for a week's consumption, with means of 24 ± 6 Bq and 170 ± 47 Bq, respectively.

Mushrooms are generally consumed throughout the growing season by foragers and their families but the quantities depend on the abundance of growth in a particular season. So for example, depending on availability, an annual consumption of up to 20-24 kg of wild mushrooms per capita among the Yi (Nuosuo) people in SW China has been reported (Zhang et al., 2010). On the basis of this level of consumption, the estimated ^{137}Cs radiation exposure would range from < 2.2×10^{-3} to up to 22.8×10^{-3} µSv kg^{-1} body mass (mean 7.92×10^{-3} µSv kg^{-1} bm).

Similarly, exposure from ^{40}K contained in a single 100 g serving and weekly (100 g x7) servings was equivalent to radiation doses per capita, in the range 0.099 to 0.23 µSv and 0.68 to 1.6 µSv (means 0.15 ± 0.04 and 1.1 ± 0.3 µSv). This is equivalent to doses in the range of 0.0017 to 0.0038 µSv kg^{-1} bm day^{-1} and 0.011 to 0.027 µSv kg^{-1} bm week^{-1} respectively (mean values of 0.0025 ± 0.006 µSv kg^{-1} bm day^{-1}and 0.018 ± 0.004 µSv kg^{-1} bm week^{-1}). Analogically to the annual ^{137}Cs radiation exposure resulting from a high rate of annual consumption (20 to

24 kg *per capita*), the estimated annual dose of radiation from ^{40}K would range from 0.34 up to 0.92 µSv kg^{-1} bm (mean 0.60 µSv kg^{-1} bm).

The assessment from this study is that high annual consumption rates of wild, stir-fried mushrooms as seen in Yunnan in 2018, would result in negligible internal doses from decay of artificial ^{137}Cs, relative to exposure from other foods, drinks and inhaled matter under normal condition from natural nuclides, i.e. ^{40}K and radiocarbon.

The potassium (total K) intake associated with these mushroom meals was in the range of 590 to 1300 mg per 100 g and 4100 to 9100 mg for weekly consumption, with mean values of 870 ± 220 mg and 6100 ± 1600 mg respectively. The corresponding intake rates of K for a 60 kg adult expressed per kg of body mass were in the range 9.8 to 22 mg for a single 100 g meal and 68 to 152 mg for weekly consumption, with mean values of 14 and 102 mg.

Potassium is a nutritional requirement and the adequate daily intake for an adult is set as 4700 mg (NIH, 2019). A 100 g serving of stir-fried mushrooms containing between 590 to 1300 mg of K (assuming that absorption rate by body is 85 to 90%) would make this mushroom meal one of the top dietary sources of potassium (NIH, 2019). However, this would be more relevant to foraged wild mushrooms as industrially processed mushrooms (blanched and blanched/pickled or conserved) are much poorer in numerous mineral constituents (Pankavec et al., 2019; Vetter, 2003). When conserved in brine or pickled, mushrooms tend to leach out their soluble constituents, resulting in relatively low mineral contents (including potassium), relative to fresh mushrooms (Pankavec et al., 2019; Vetter, 2003). Button mushrooms (*Agaricus bisporus*) conserved in brine were reported with concentrations of 450 mg kg^{-1} db of K (whole) and 1300 mg kg^{-1} db of K (sliced), relative to the fresh fruiting bodies with concentrations of 38000 and 40000 mg kg^{-1} db (Vetter, 2003), showing a tremendous mineral loss through processing.

Conclusions

Stir-frying of foraged mushrooms results in potassium enrichment in the resulting meals (expressed on a whole weight basis). A 100 g serving of stir-fried mushrooms containing between 590 to 1300 mg of K (assuming that absorption rate by body is 85 to 90%) would make this mushroom meal one of the top dietary sources of potassium. Unfortunately, this cooking method also increases the ^{137}Cs activity in the same meals, but in the Yunnan province in China which shows low levels of earlier radioactive fallout, this radionuclide represents a relatively low average ^{137}Cs dose of 7.92×10^{-3} μSv kg^{-1} bm for the maximum reported consumption rates.

Statement

Jerzy Falandysz: Conceptualization, Resources, Methodology, Funding acquisition, Formal analysis, Data curation, Writing - original draft, Writing - review & editing. **Yuanzhong Wang**: Conceptualization, Resources, Methodology, Funding acquisition, Investigation. **Michał Saniewski**: Funding acquisition, Analysis, Data curation, Investigation. **Alwyn R. Fernandes**: Conceptualization, Resources, Formal analysis, Data curation, Investigation, Writing - review & editing.

Conflict of interes
The authors declare no conflict of interest

Acknowledgement

A study granted in part by National Natural Science Foundation of China - project no. 21667031.

References

Barnett CL, Beresford NA, Frankland JC, Self PL, Howard BJ, Marriott JVR (1999) Radiocaesium activity concentrations in the fruit-bodies of macrofungi in Great Britain and an assessment of dietary intake habits. Sci Total Environ 231:67-83

Beneš V, Leonhardt T, Sácký J, Kotrba P (2018) Two P1B-1-ATPases of *Amanita strobiliformis* with distinct properties in Cu/Ag transport. Front. Microbiol. 9:747. doi: 10.3389/fmicb.2018.00747

Beresford NA, Howard BJ, Barnett CL, Voigt G, Semiochkina N, Ratnikov A, Travnikova I, Gillett AG, Mehli H, Skuterud L (1999) Reducing the consumption of ^{137}Cs via forest fungi - provision of 'self-help' advice. *In* Contaminated Forests. I Linkov, WR Schell (Eds) pp 359-368. Kluwer Academic Publishers

Betti L, Palego L, Lucacchini A, Giannaccini G (2017) ^{137}Caesium in samples of wild-grown *Boletus edulis* Bull. from Lucca province (Tuscany, Italy) and other Italian and European geographical areas. Food Addit Contam A 34:49-55

Bhatt RP, Singh U, Uniyal P (2018) Healing mushrooms of Uttarakhand Himalaya, India. Current Research in Environmental & Applied Mycology 8:1–23. doi 10.5943/cream/8/1/1.

Biekman, E. S. A., Kroese-Hoedeman, H. I., Schijven, H. P. H. M. (1996). Loss of solutes during blanching of mushrooms (*Agaricus bisporus*) as a result of shrinkage and extraction. J Food Eng 28:139-152

Bordin K, Kunitake MT, Aracava KK, Trindade CS (2013) Changes in food caused by deep fat frying - a review. Arch Latinoam Nutr 63:5-13

Borovička J, Mihaljevič M, Gryndler M, Kubrová J, Žigová A. Hršelová H. Řanda Z (2014) Lead isotopic signatures of saprotrophic macrofungi of various origins: Tracing for lead sources and possible applications in geomycology. Appl Geochem 43:114-120

Chiaravalle AE, Mangiacotti M, Marchesani G, Bortone N, Tomaiuolo M, Trotta G (2018) A ten-year survey of radiocontamination of edible Balkan mushrooms: Cs-137 activity levels and assessed dose to the population. Food Control 94:263-267

Cocchi L, Kluza K, Zalewska T, Apanel A, Falandysz J (2017) Radioactive caesium (^{134}Cs and ^{137}Cs) in mushrooms of the genus *Boletus* from the Reggio Emilia in Italy and Pomerania in Poland. Isotopes Environ Health Stud 53:620-627

Daillant O, Boilley D, Josset M, Hettwig B, Fischer HW (2013) Evaluation of radiocaesium contamination in mushrooms and influence of treatment after collection. J Radioanal Nucl Chem 297:437-441

Drewnowska M, Falandysz J, Chudzińska M, Hanć A, Saba M, Barałkiewicz D (2017) Leaching of arsenic and sixteen metallic elements from *Amanita fulva* mushrooms after food processing. LWT - Food Sci Technol 84:861-866

Falandysz J, Borovička J (2013) Macro and trace mineral constituents and radionuclides in mushrooms: health benefits and risks. Appl Microbiol Biotechnol 97:477-501

Falandysz J, Zalewska T, Krasińska G, Apanel A, Wang Y, Pankavec S (2015) Evaluation of the radioactive contamination in Fungi genus *Boletus* in the region of Europe and Yunnan Province in China. Appl Microbiol Biotechnol 99:8217-8224

Falandysz J, Zalewska T, Apanel A, Drewnowska N, Kluza K (2016) Evaluation of the activity concentrations of ^{137}Cs and ^{40}K in some Chanterelle mushrooms from Poland and China. Environ Sci Poll Res 23:20039-20048

Falandysz J, Zhang J, Wiejak A, Barałkiewicz D, Hanć A (2017a) Metallic elements and metalloids in *Boletus luridus*, *B. magnificus* and *B. tomentipes* mushrooms from polymetallic soils from SW China. Ecotox Environ Safe 142:497-502

Falandysz J, Zhang J, Zalewska T (2017b) Radioactive artificial ^{137}Cs and natural ^{40}K activity in 21 edible mushrooms of the genus *Boletus* species from SW China. Environ Sci Poll Res 24:8189–8199

Falandysz J, Saniewski M, Zhang J, Zalewska T, Liu H, Kluza K (2018) Artificial ^{137}Cs and natural ^{40}K in mushrooms from the subalpine region of the Minya Konka summit and Yunnan Province in China. Environ Sci Poll Res 25:615–627

Falandysz J, Saniewski M, Zalewska T, Zhang J (2019a) Pollution by radiocaesium of fly agaric *Amanita muscaria* in fruiting bodies decrease with a developmental stage. Isotopes Environ Health Stud 55: 317–324

Falandysz J, Zhang J, Mędyk M, Zhang X (2019b) Mercury in stir-fried and raw mushrooms from the *Boletaceae* family from the geochemically anomalous region in the Midu county, China. Food Control 102:17–21

Falandysz J, Dryżałowska A, Zhang J, Wang Y (2019c) Mercury in raw mushrooms and mushrooms stir-fried in deep oil. J Food Comp Anal 82:103239

Falandysz J, Zalewska T, Fernandes A (2019d) ^{137}Cs and ^{40}K in *Cortinarius caperatus* mushrooms (1996–2016) in Poland - bioconcentration and estimated intake: ^{137}Cs in *Cortinarius* spp. from the Northern Hemisphere from 1974–2016. Environ Pollut. 255:113208.

Fuji K, Ikeda S, Akama A, Komatsu M, Takahashi M, Kaneko S (2014) Vertical migration of radiocesium and clay mineral composition in five forest soils contaminated by the Fukushima nuclear accident. Soil Sci Plant Nutr 60:751-764

Karadeniz Ö, Yaprak G (2010) ^{137}Cs, ^{40}K, alkali–alkaline earth element and heavy metal concentrations in wild mushrooms from Turkey. J Radioanal Nucl Chem 285:611–619

Kenigsberg J, Belli M, Tikhomirov F, Buglovaa E, Shevchuk V, Renaudd Ph, Maubertd H, Bruke G, Shutov V (1996) Exposures from consumption of forest produce. pp. 271-181. The radiological consequences of the Chernobyl accident. European Commission and the Belarus, Russian and Ukrainian Ministers on Chernobyl Affairs, Emergency Situations and Health (eds) Karaoglou A, Desmet G, Kelly GN, Menzel HG. Brussel, EUR 16544 EN

Kiefer H, Maushart R, Ernho Khter R (1965) Elevated Cs-137 content in the human body after mushroom ingestion. Atompraxis: Direct Information, p. 15 (in German).

Klán J, Řanda Z, Benada J, Horyna J (1988) Investigation of non-radioactive Rb, Cs, and radiocaesium in higher fungi. Česká Mykologie, 42:158–169

NIH (2019) National Institute of Health; https://ods.od.nih.gov/factsheets/Potassium-HealthProfessional/; retrieved on January 30, 2019.

Nnorom IC, Eze SO, Ukaogo PO (2019) Mineral contents of three wild-grown edible mushrooms collected from forests of south eastern Nigeria: An evaluation of bioaccumulation potentials and dietary intake risks. Scientific African, e00163.

Orita M, Kimura Y, Tiara Y, Fukuda T, Takahashi J, Gutevych O, Chornyi S, Kudo T, Yamashita S, Takamura N (2017) Activities concentration of radiocesium in wild mushroom collected in Ukraine 30 years after the Chernobyl power plant accident. PeerJ 6:e4222; DOI 10.7717/peerj.4222

Pankavec S, Hanć A, Barałkiewicz D, Dryżałowska A, Zhang J, Falandysz J (2019) Mineral constituents of conserved white button mushrooms: Similarities and differences. Roczn Państw Zakł Hig (Ann Nat Inst Hyg) 71:15–25

Prand-Stritzko B, Steinhauser G (2018) Characteristics of radiocesium contaminations in mushrooms after the Fukushima nuclear accident: evaluation of the food monitoring data from March 2011 to March 2016. Environ Sci Pollut Res 25:2409-2416

Qiu PT (2003) An argument about the origin of cooking method - frying. Culinary Science Journal of Yangzhou University. 20:1-6 (in Chinese with English abstract)

Samat SB, Green S, Beddoe AH (1997). The ^{40}K activity of one gram of potassium. Phys Med Biol. 42:407-13

Santiago FH, Moreno JP, Cázares BX, Suárez JJA, Trejo EO, Montes de Oca, GM, Aguilar ID (2016) Traditional knowledge and use of wild mushrooms by Mixtecs or Ñuu savi, the people of the rain, from Southeastern Mexico. J Ethnobiol Ethnomed 12, 35. doi. 10.1186/s13002-016-0108-9

Skibniewska KA, Smoczyński S (1999) Wpływ obróbki kulinarnej na poziom radiocezu w grzybach. Roczn Państw Zakł Hig (Ann Nat Inst Hyg) 50:157-167

Steinhauser G, Brandl A, Johnson TE (2014) Comparison of the Chernobyl and Fukushima nuclear accidents: A review of the environmental impacts. Sci Total Environ 470-471:800-817

Steinhauser G, Steinhauser V (2016) A simple and rapid method for reducing radiocesium concentrations in wild mushrooms (*Cantharellus* and *Boletus*) in the course of cooking. J Food Prot 79:1995-1999

Stijve T (1994) Extraction of radiocesium from contaminated mushrooms. Observ Mycol (Bull. de l'Observatoire Mycologique) 6:2–9

Stijve T, Poretti M (1990) Radiocesium levels in wild-growing mushrooms from various locations (some species accumulate it, some exclude it). Mushroom the Journal, Summer 1990:5-9

Tuo F, Zhang J, Li W, Yao S, Zhou Q, Li Z (2017) Radionuclides in mushrooms and soil-to-mushroom transfer factors in certain areas of China. J Env Rad 180:59-64

Türkekul I, Yeşilkanat CM, Cirişc A, Kölemend U, Çevikc U (2018) Interpolated mapping and investigation of environmental radioactivity levels in soils and mushrooms in the Middle Black Sea Region of Turkey. Isotopes Environ Health Stud 54:262–273

Vetter J (2003) Chemical composition of fresh and conserved *Agaricus bisporus* mushroom. Eur Food Res Technol 217:10–12

Vinichuk M, Taylor AFS, Rosén K, Johanson KJ (2010) Accumulation of potassium, rubidium and caesium (^{133}Cs and ^{137}Cs) in various fractions of soil and fungi in a Swedish forest. Sci Total Environ 408:2543-2548

Wang Y, Zalewska T, Apanel A, Zhang J, Wiejak A, Falandysz J (2015) ^{137}Cs, ^{134}Cs and natural ^{40}K in sclerotia of *Wolfiporia extensa* fungus collected across of the Yunnan land in China. J Environ Sci Health Part B 50:654-658

Wu X, Zhou L, Yang Z, Bau T, Li T, Dai Y (2019) Resource diversity of Chinese macrofungi: edible, medicinal and poisonous species. Fungal Diversity 98:1-76.

Zhang D, Frankowska A, Jarzyńska G, Kojta AK, Drewnowska M, Wydmańska D, Bielawski L, Wang J, Falandysz J (2010) Metals of King Bolete (*Boletus edulis*) collected at the same site over two years. African J Agric Res 5:3050-3055

Table 1. Values of ^{137}Cs activity concentration (Bq kg^{-1} dry biomass) in raw mushrooms and stir-fried in deep oil

Species and localization in Yuxi prefecture	Raw mushrooms				Fried mushrooms
	Caps	Stems	Whole fruiting bodies	$^{*}Q_{C/S}$	Whole fruiting bodies
Baorangia bicolor, Jiangchuan, Shihe	6.4 ± 1.9	< 3.1	4.4$^{\#}$	WD	< 1.4
Baorangia bicolor, Dayingjie, Luohe	< 2.2	< 2.2	< 2.2	WD	2.2 ± 0.6
Boletus calopus, Jiangchuan, Anhua	3.9 ± 1.0	3.7 ± 1.0	3.8 ± 1.0	1.1	< 1.1
Boletus flammans, Hongta, Lingxiu	4.5 ± 1.2	4.8 ± 1.0	4.6 ± 1,1	0.94	5.6 ± 0.8
Boletus obscureumbrinus, Jiangchuan, Shihe	< 2.9	7.2 ± 1.4	4.1$^{\#}$	WD	< 2.5
Butyriboletus roseoflavus, Jiangchuan, Shihe	< 3.3	5.5 ± 1.1	3.5$^{\#}$	WD	< 1.9
Rubroboletus sinicus, Hongta, Huangcaoba	4.7 ± 1.3	4.8 ± 1.1	4.7 ± 1.2	0.98	2.8 ± 0.7
Rugiboletus extremiorientalis, Dayingjie, Luohe	6.7 ± 1.2	6.4 ± 1.0	6.5 ± 1.1	1.1	9.3 ± 1.3
Rugiboletus extremiorientalis, Jiangchuan, Anhua	7.6 ± 0.8	7.2 ± 1.0	7.4 ± 0.9	1.1	3.4 ± 0.6
Xerocomus sp., Dayingjie, Luohe	3.4 ± 3.0	6.7 ± 1.1	4.9 ± 2.0	0.51	5.8 ± 0.8
Mean ± S.D.	4.1 ± 2.2	4.9 ± 2.1	4.5 ± 1.6	0.96 ± 0.23	3.3 ± 2.7

Notes: $^{*}Q_{C/S}$ (quotient from activity concentration of ^{137}Cs in caps and stems); $^{\#}$ If activity was < LOQ in a sample a half
of the LOQ value was used to estimate the activity level in a whole fruiting bodies; WD (without data)

Table 2. Values of ^{40}K activity concentration (Bq kg^{-1} dry biomass) in raw mushrooms and stir-fried in deep oil

Species and localization in Yuxi prefecture	Raw mushrooms				Fried mushrooms
	Caps	Stems	Whole fruiting bodies	$^{*}Q_{C/S}$	Whole fruiting bodies
Baorangia bicolor, Jiangchuan, Shihe	1200 ± 190	590 ± 81	940 ± 120	2.0	550 ± 54
Baorangia bicolor, Dayingjie, Luohe	840 ± 82	410 ± 40	770 ± 76	2.0	420 ± 39
Boletus calopus, Jiangchuan, Anhua	1100 ± 100	790 ± 79	960 ± 88	1.4	560 ± 55
Boletus flammans, Hongta, Lingxiu	800 ± 85	660 ± 78	740 ± 77	1.2	380 ± 47
Boletus obscureumbrinus, Jiangchuan, Shihe	890 ± 94	890 ± 97	890 ± 94	1.0	860 ± 75
Butyriboletus roseoflavus, Jiangchuan, Shihe	920 ± 110	550 ± 87	740 ± 76	1.7	560 ± 55
Rubroboletus sinicus, Hongta, Huangcaoba	930 ± 100	750 ± 83	840 ± 86	1.2	730 ± 55
Rugiboletus extremiorientalis, Dayingjie, Luohe	750 ± 86	550 ± 61	620 ± 63	1.4	580 ± 84
Rugiboletus extremiorientalis, Jiangchuan, Anhua	650 ± 74	480 ± 54	620 ± 71	1.4	370 ± 41
Xerocomus sp., Dayingjie, Luohe	1000 ± 110	850 ± 79	930 ± 87	1.2	600 ± 53
Mean ± S.D.	910 ± 150	650 ± 150	800 ± 120	1.4 ± 0.4	560 ± 140

Table 3. Potassium concentration (mg kg^{-1} dry biomass) in raw mushrooms and stir-fried in deep oil

Species and localization in Yuxi prefecture	Raw mushrooms			Fried mushrooms
	Caps	Stems	Whole fruiting bodies	Whole fruiting bodies
Baorangia bicolor, Jiangchuan, Shihe	43000 ± 6800	21000 ± 2900	34000 ± 4800	20000 ± 1900
Baorangia bicolor, Dayingjie, Luohe	31000 ± 3600	15000 ± 2400	28000 ± 3000	15000 ± 1400
Boletus calopus, Jiangchuan, Anhua	39000 ± 3600	28000 ± 2800	34000 ± 3200	20000 ± 2000
Boletus flammans, Hongta, Lingxiu	29000 ± 3000	24000 ± 2800	27000 ± 2900	14000 ± 1700
Boletus obscureumbrinus, Jiangchuan, Shihe	32000 ± 3400	32000 ± 3500	32000 ± 3500	31000 ± 2700
Butyriboletus roseoflavus, Jiangchuan, Shihe	33000 ± 4000	20000 ± 3100	33000 ± 3500	20000 ± 2000
Rubroboletus sinicus, Hongta, Huangcaoba	33000 ± 3600	27000 ± 3000	31000 ± 3300	26000 ± 2000
Rugiboletus extremiorientalis, Dayingjie, Luohe	27000 ± 3100	20000 ± 2200	24000 ± 2600	21000 ± 3000
Rugiboletus extremiorientalis, Jiangchuan, Anhua	24000 ± 2800	18000 ± 3200	22000 ± 3000	13000 ± 1500
Xerocomus sp., Dayingjie, Luohe	36000 ± 3900	30000 ± 2800	33000 ± 3300	21000 ± 1900
Mean ± S.D.	29000 ± 5300	23000 ± 5300	29000 ± 4100	20000 ± 5200

Table 4. Estimated values of ^{137}Cs and ^{40}K activity concentrations (Bq kg^{-1} whole weight) and K content (mg kg^{-1} whole weight) in raw mushrooms and stir-fried in deep oil (whole fruiting bodies)

Species and localization in Yuxi prefecture	Whole fruiting bodies (raw)			Whole fruiting bodies (stir-fried)		
	^{137}Cs	^{40}K	K	^{137}Cs	^{40}K	K
Baorangia bicolor, Jiangchuan, Shihe	0.43#	87 ± 12	3100 ± 430	< 0.8	230 ± 22	8400 ± 790
Baorangia bicolor, Dayingjie, Luohe	< 0.10	75 ± 7	2700 ± 320	1.2 ± 0.3	180 ± 16	6500 ± 600
Boletus calopus, Jiangchuan, Anhua	0.34 ± 0.09	87 ± 8	3100 ± 290	< 0.5	240 ± 23	8600 ± 860
Boletus flammans, Hongta, Lingxiu	0.35 ± 0.08	57 ± 6	2100 ± 220	2.4 ± 0.3	160 ± 19	5900 ± 710
Boletus obscureumbrinus, Jiangchuan, Shihe	0.34#	75 ± 8	2700 ± 290	< 1.1	370 ± 32	13000 ± 1100
Butyriboletus roseoflavus, Jiangchuan, Shihe	0.32#	68 ± 7	3100 ± 320	< 0.8	240 ± 23	8600 ± 860
Rubroboletus sinicus, Hongta, Huangcaoba	0.43 ± 0.10	78 ± 8	2900 ± 300	1.2 ± 0.3	310 ± 23	11000 ± 850
Rugiboletus extremiorientalis, Dayingjie, Luohe	0.62 ± 0.10	59 ± 6	2300 ± 240	4.4 ± 0.6	270 ± 39	9800 ± 1400
Rugiboletus extremiorientalis, Jiangchuan, Anhua	0.75 ± 0.09	63 ± 7	2500 ± 340	1.6 ± 0.3	170 ± 19	6000 ± 690
Xerocomus sp., Dayingjie, Luohe	0.50 ± 0.20	96 ± 9	3400 ± 340	2.5 ± 0.3	260 ± 22	9100 ± 820
Mean ± S.D.	0.41 ± 0.18	74 ± 12	2800 ± 390	1.5 ± 1.2	240 ± 62	8700 ± 2100

Table 5. Content and estimated intake of ^{137}Cs, ^{40}K and K in mushrooms stir-fried in deep oil and estimated radiation doses from ^{137}Cs and ^{40}K decay for adult person*

Species and localization in Yuxi prefecture	^{137}Cs content (Bq) in 100 g×1 // 100 g×7 fried mushrooms	^{40}K content (Bq) in 100 g×1 // 100 g×7 fried mushrooms	K content (mg) in 100 g×1 // 100 g×7 fried mushrooms	^{137}Cs exposure (μSv) per capita from 100 g×1 // 100 g×7 fried mushrooms	^{40}K exposure (μSv) per capita from 100 g×1 // 100 g×7 fried mushrooms	^{137}Cs exposure (μSv) per kg^{-1} bm from 100 g×1 // 100 g×7 fried mushrooms	^{40}K exposure (μSv) per kg^{-1} bm from 100 g×1 // 100 g×7 fried mushrooms
Baorangia bicolor Jiangchuan, Shihe	< 0.08 // < 0.56	23 // 160	840 // 5900	< 1.0×10^{-3} // < 7.3×10^{-3}	0.14 // 0.99	< 0.017×10^{-3} // < 0.12×10^{-3}	0.0023 // 0.017
Baorangia bicolor Dayingjie, Luohe	0.12 // 0.84	18 // 125	650 // 4500	1.6×10^{-3} // 11×10^{-3}	0.11 // 0.78	0.026×10^{-3} // 0.18×10^{-3}	0.0019 // 0.013
Boletus calopus Jiangchuan, Anhua	< 0.05 // < 0.35	24 // 160	860 // 6000	< 0.65×10^{-3} // < 4.6×10^{-3}	0.15 // 0.99	< 0.011×10^{-3} // < 0.076 ×10^{-3}	0.0025 // 0.017
Boletus flammans Hongta, Lingxiu	0.24 // 1.7	16 // 110	590 // 4100	3.1×10^{-3} // 22×10^{-3}	0.099 // 0.68	0.052×10^{-3} // 0.37×10^{-3}	0.0017 // 0.011
Boletus obscureumbrinus Jiangchuan, Shihe	< 0.11 // < 0.77	37 // 260	1300 // 9100	< 1.4×10^{-3} // < 10×10^{-3}	0.23 // 1.6	< 0.023×10^{-3} // < 0.17×10^{-3}	0.0038 // 0.027
Butyriboletus roseoflavus Jiangchuan, Shihe	< 0.08 // < 0.56	24 // 170	860 // 6000	< 1.0×10^{-3} // < 7.3×10^{-3}	0.15 // 1.1	< 0.017×10^{-3} // < 0.12×10^{-3}	0.0025 // 0.018
Rubroboletus sinicus Hongta, Huangcaoba	0.12 // 0.84	31 // 220	1100 // 7700	1.6×10^{-3} // 11×10^{-3}	0.19 // 1.4	0.026×10^{-3} // 0.18×10^{-3}	0.0032 // 0.023
Rugiboletus extremiorientalis Dayingjie, Luohe	0.44 // 3.1	27 // 190	980 // 6900	5.7×10^{-3} // 40×10^{-3}	0.17 // 1.2	0.095×10^{-3} // 0.67×10^{-3}	0.0028 // 0.020
Rugiboletus extremiorientalis Jiangchuan, Anhua	0.16 // 1.1	17 // 120	600 // 4200	2.1×10^{-3} // 14×10^{-3}	0.11 // 0.74	0.034×10^{-3} // 0.24×10^{-3}	0.0018 // 0.012
Xerocomus sp. Dayingjie, Luohe	0.25 // 1.7	26 // 190	910 // 6400	3.3×10^{-3} // 22×10^{-3}	0.16 // 1.2	0.054×10^{-3} // 0.37×10^{-3}	0.0027 // 0.020
Mean ± S.D.	0.15 ± 0.12 // 1.0 ± 0.9	24 ± 6 // 170 ± 47	870 ± 220 // 6100 ± 1600	1.9×10^{-3} ± 1.5 ×10^{-3} // 13×10^{-3} ± 11×10^{-3}	0.15 ± 0.04 // 1.1 ± 0.3	0.033×10^{-3} ± 0.027 ×10^{-3} // 0.22×10^{-3} ± 0.19 ×10^{-3}	0.0025 ± 0.006 // 0.018 ± 0.004

Notes: *Adult of 60 kg body mass