10.7251/AGRENG1601151N
UDC 636.4:539.16(497.7)

DETERMINATION OF NATURAL RADIONUCLIDE IN PIG PRODUCTION CHAIN IN MACEDONIA BY GAMMA SPECTROMETRY

Dimitar NAKOV[1*], Metodija TRAJCHEV[1], Aleksandra ANGJELESKA[2], Katerina BELICHOVSKA[1], Nikola PACINOVSKI[3]

[1]Faculty of Agricultural Sciences and Food, Institute of Animal Biotechnology, University „St. Cyril and Methodius“, Skopje, Republic of Macedonia
[2]Faculty of Veterinary Medicine, University „St. Cyril and Methodius“, Skopje, Republic of Macedonia
[3]Institute of Animal Science, University „St. Cyril and Methodius“, Skopje, Republic of Macedonia
*Corresponding author: nakovd@fznh.ukim.edu.mk

ABSTRACT

Exposure of animals to ionizing irradiation may be a important pathway for transfer of radionuclides to human food chain, thereby adding to the exposure burden. Therefore, radiation control of animal feeds and animal products will reduce risk for radioactive hazards to human health. The study was carried out in order to detect the natural radioactivity in edible parts of pigs, excrements and feeds in one commercial pig breeding farm in Macedonia. Therefore, ^{40}K, ^{212}Pb, ^{214}Pb, ^{228}Ac, ^{235}U, ^{241}Am, ^{212}Bi, ^{214}Bi, ^{232}Th, ^{7}Be and ^{226}Ra were measured using gamma spectrometry. Gamma spectrometer Canberra Packard with a high-purity germanium detector and Marinelli beakers (1 l capacity) were used for the samples measurement. The most prominent gamma energies observed in the spectra belonged to the naturally occurring radionuclides ^{40}K, ^{235}U and ^{232}Th. Other nuclides if present occurred infrequently at low levels. The result show that ^{40}K made the largest contribution to the specific radioactivity in all the samples. The mean activity concentration of the ^{40}K in edible organs (kidney and liver), muscle, excrements and feeds was: 73.39±9.109 Bq/kg; 111.26±3.88 Bq/kg; 298.80±38.51 Bq/kg; 83.60±10.279 Bq/kg, respectively. The ^{235}U and ^{232}Th were detectible only in feed samples (0.53±0.293 Bq/kg; 163.69±23.791 Bq/kg, respectively) and samples from excrements (0.25±0.021 Bq/kg; 58.17±1.062 Bq/kg, respectively). The other radionuclides were detected only in few samples and the measured activities were below the detection limit. If we take in consideration the activity concentration of the most frequently occurred ^{40}K found in all samples, than there was statistical significant difference between radioactivity concentration in organs, muscle, excrements and feeds ($p<0.001$).

Key words: *gamma spectrometry, pig production, radioactivity*.

INTRODUCTION

Numerous sources of ionizing radiation can lead to human exposure: natural sources, nuclear explosions, nuclear power generation, use of radiation in medical industrial and research purposes, and radiation-emitting consumer products. Before assessing the radiation dose to the population one requires a precise knowledge of the activity of a number of radionuclides. In different amounts, natural radioactivity has great contributions in ionizing radiations to the world population due to its natural presences in environment (Rahman and Faheem, 2008). Environmental pollution is a global problem arising from rapid industrialisation and modern technological practices. Human activities such as agricultural practices and livestock production are among the leading factors that enhance increased environmental pollution.

Radionuclides are present in the environment either naturally or artificially due to atmospheric nuclear weapon testing and to a series of nuclear accidents. Therefore, radionuclides which can be found in the environment can be divided into three groups: naturally occurring nuclides of very long half-life, naturally occurring nuclides which have short half-lives and radionuclides released into the environment owing to man's activity and accidents. As radioactive materials transfer from the environment to agricultural, livestock and fishery products, radioactive contamination of foods and its health effects have become great concerns for the people (Ramasany et al., 2006; Kaplan et al., 2011).

Plants, in general, may accumulate radionuclides depending on many factors including species, tissue type, soil-water-plant relationships, soil type, and the chemical nature of the radionuclide in the soil. Based on study by Arogunjo et. al. (2005) contamination of the food chain is resulting from direct deposition of these radionuclides on plant leaves, root uptake from contaminated soil or water and animals that ingesting contaminated plants, soil or water. In any accidental releases of radioactivity cases into the environment, a potential of widespread and long-term contamination on the agricultural land need to be suspected and consequently a potential long-lasting impact on food. This situation required the development of the monitoring network in the agricultural field especially in the contaminated area to maintain a safe food produced. A method that describes this accumulation in a plant is called the "*concentration ratio*" (CR) (Mortvedt, 1994).

Consumption of food is usually the most important route by which natural and artificial radionuclides can enter the human body. The foods of animal origin are largely represented in the human diet and the key transfer pathway to animals is ingestion of contaminated feed. Fortunately, the gastro-intestinal tract of humans and animals excludes 80% or more of radionuclides (Roessler et al., 1991). Within animals and humans, certain tissues tend to accumulate selected radionuclides. This information can help with dietary choices (e.g. avoiding the consumption of animal organs that accumulate radionuclides) and as in the calculation of dose, as well.

Recently, there has been a growing concern about the effect of low level radioactivity on human health. There is a current lack of information on activity concentrations in animal feed and edible tissues from pig body. Additionally, analyzing the animal excrements is giving an opportunity to determinate the circulation of natural radionuclides in environment.

MATERIAL AND METHODS

In order to measure the specific activity of natural radionuclides in edible tissues of pigs body (kidney, liver and muscle) and moreover excrements and feeds in pig production chain, there was performed a survey in one commercial pig breeding farm in the eastern part of Macedonia. The samples were collected from died animals on-farm and from feed used on farm. The fresh pig manure from the farm was collected for analyzing the activity concentration of natural radionuclides. The collected samples were weighed individually (weight 1 kg) and the measurement of radioactivity was done on fresh samples in Marinelli-beakers containers from 1 liter. A total of 23 samples were analyzed.

The spectral analysis of the radionuclides of these samples was conducted by applying a γ-ray spectrometer with high purity germanium (HPGe) detector with 30% relative efficiency and energy resolution (FWHM) of 1.8 keV for 1.33 MeV reference passage of ^{60}Co (Verdoya et al., 2009).

The detector was protected with 9 cm-thick lead with an internal line with a 0.5 cm-thin copper panel covered by 1 mm aluminum in order to absorb the x-rays from the lead and the copper. The internal size of the cavity of the shell was 30 x 30 x 30 cm. The detector was given a high voltage through a preamplifier which was then connected to an amplifier with a computer based channel analyzer through an ADC (analogue to digital converter). The software used for obtaining the data is Canberra software package Genie-2000, including search of maximum value and modules for identification of nuclides. The system was regularly calibrated for energy and efficiency. The prepared Marinelli glasses (samples) were placed on a final detector at a distance of approximately 10 mm. Every sample was measured within a period of around 62000s in order to get good statistics and the constant time was lower than 10%. The measurements with an empty Marinelli glass, in identical conditions were also conducted in order to determine the basic recounts. Then they were deducted from the measured spectrums of every sample in order to obtain the net activities of the radionuclides.

The data were grouped according to the type of sample and redionuclide (each sample for similar edible tissue, feed or excrements represent separate group). Statistical analysis was carried out using descriptive methods and ANOVA.

RESULTS AND DISCUSSION

The results of the natural radioactivity measurements on the above samples are given in Table 1. All the concentrations are reported in Bq/kg for the samples from the different edible tissues of pigs (kidney, liver and muscle) and moreover the samples from the excrements and feeds for determination of natural radionuclides distribution. The concentration activity is reported as arithmetical mean and the relevant standard deviation.

Table 1. Activity concentration of natural radionuclides (Bq/kg)

	time (sec)	^{40}K	^{235}U	^{232}Th	^{212}Pb	^{214}Pb	^{228}Ac	^{241}Am	^{212}Bi	^{214}Bi	^{7}Be	^{226}Ra
Liver and kidney	64288.67± 10339.291	73.39± 9.109			4.441				1.700			
Muscle	80146.00± 10343.168	111.26± 3.88										
Excrement	78231.65± 4867.182	83.60± 10.279	0.25± 0.021	58.17± 1.062	0.512	0.400	1.043			0.486	2.200	
Feeds	41587.86± 27268.966	298.80± 38.51	0.53± 0.293	163.69± 23.791	0.632	0.56± 0.883	1.321	0.283	1.372	0.585	1.498	8.957
Total	61872.94± 21957.474	148.71± 104.411	0.45± 0.275	121.48± 60.195	1.86± 2.235	0.50± 0.109	1.18± 0.196	0.283	1.54± 0.231	0.54± 0.070	1.84± 0.496	8.957

In all examined samples, the ^{40}K made the largest contribution to the specific radioactivity. Their activity concentration ranged from 73.39±9.109 in liver and kidney up to 298.80±38.51 in feeds. Similar fundings were published by Ban-nai et al. (1997), Ventiru and Sordi (1999) and Badran et al. (2003). Akinloye et al. (1999) reported that the pork meat has the highest mean activity concentration of ^{40}K in comparison with beef and poultry meat. The same authors reported that the highest mean activity concentration of ^{226}Ra was recorded in goat meat while wasn't detectible in pork and beef meat. Further, certain animal organs do not accumulate radium (Ra-226) or lead (Pb-210) (e.g. kidney and muscle), while other tissue may (e.g. bone). Thus, humans consuming pig muscle tissue (pork) will be exposed to lowered concentrations of radionuclides than actually ingested by the pig simply because the radionuclides accumulated in the bone.

Recent research published by Meli et al. (2013) reported that the mean ^{40}K activity concentration was 415±55.9 Bq/kg and ranged from 207±12.4 Bq/kg (pig) to 578±34.7 Bq/kg (deer). ^{214}Pb and ^{214}Bi, indicators of ^{226}Ra, have been detectable in the 33.1% of examined samples. The ^{235}U and ^{232}Th were detectible in feed samples and activity concentration was 0.53±0.293 Bq/kg; 163.69±23.791 Bq/kg, respectively. The activity concentration of ^{235}U and ^{232}Th in excrement samples was 0.25±0.021 Bq/kg and 58.17±1.062 Bq/kg, respectively. The other radionuclides detected only in few feed samples, has the following measured activity: 0.632 Bq/kg for ^{212}Pb, 0.619 Bq/kg for ^{214}Pb, 1.321 Bq/kg for ^{228}Ac, 0.283 Bq/kg for ^{241}Am, 1.372 Bq/kg for ^{212}Bi, 0.585 Bq/kg for ^{214}Bi, 1.498 Bq/kg for ^{7}Be and 8.957 Bq/kg for ^{226}Ra. The measured activity concentration of the other radionuclide found in excrements sample was: 0.512 Bq/kg for ^{212}Pb, 0.400 Bq/kg for ^{214}Pb, 1.043 Bq/kg for ^{228}Ac, 0.486 Bq/kg for ^{214}Bi and 2.200 Bq/kg for ^{7}Be. If the activity concentration of the most frequently occurred ^{40}K that is found in all samples is taken into account, it can be concluded there is statistical significant difference between radioactivity concentration in organs, muscle, excrements and feeds ($p<0.001$). The highest statistically significant difference in activity concentration of ^{40}K was found between excrements samples and other examined samples (Table 2).

Table 2. Bonferoni test for difference in mean values of activity concentration of ^{40}K in samples

	Muscle	Feeds	Excrement
Liver and kidney	37.874	225.416*	10.210
Muscle		187.542*	27.663
Feeds			215.205*

The figure 1 represents the chart of activity concentration of radionuclides in samples.

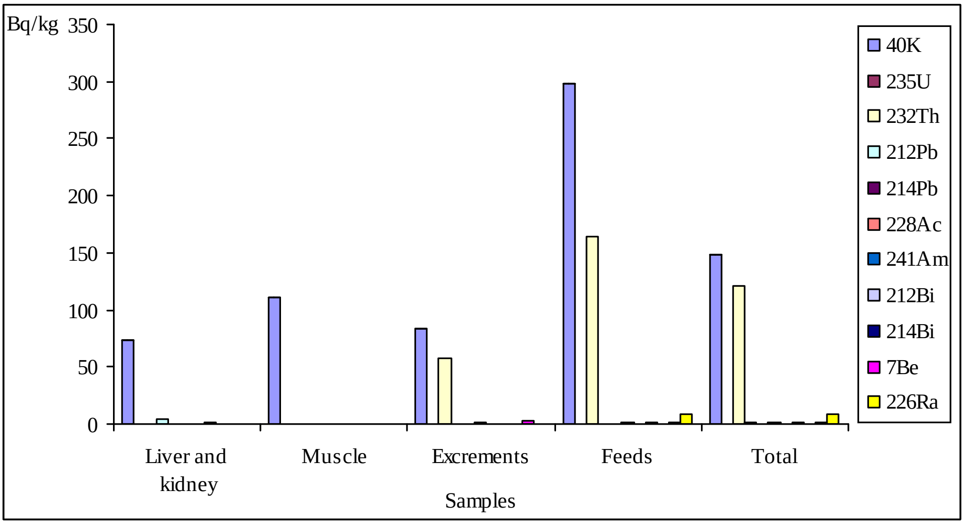

Figure 1. Activity concentration of naturally occurred radionuclides in pig production chain

Recently, more attentions have been focusing on the concept of “from farm to fork” adapted into researches as an effort to reduce the contamination of foods by concentrating on source-directed measures. Preventing contaminated raw materials from entering the food chain are more effective to ensure the food safety compared to conventional market control. In a radiation situation, the availability of uncontaminated food and food raw materials to consumers and to the entire production chain is a challenge, especially during the growing season (Rantavaara et al. 2005).

CONCLUSION

Radiometric control of products involved in the food chain is an important part of ongoing quality control of products related to food and feed. The data obtained from our analyses provide information on the background activity concentration of natural radionuclides in pig production chain. The ^{40}K made the largest contribution to the specific radioactivity in the pig production chain. The other radionuclides, ^{212}Pb, ^{214}Pb, ^{228}Ac, ^{241}Am, ^{226}Ra ^{214}Bi, ^{7}Be ^{212}Bi, were detected only in few feed samples. The radionuclide found in excrement samples were ^{212}Pb, ^{214}Pb, ^{228}Ac, ^{214}Bi and ^{7}Be.

REFERENCES

Akinloye, M.K., Olomo, J.B., Olubunmi, P.A. (1999). Meat and poultry consumption contribution to the natural radionuclide intake of the inhabitants of the Obafemi Awolowo University, Ile-Ife, Nigeria Nuclear Instruments and Methods in Physics Research A 422: 795-800.

Arogunjo, A.M., Ofuga, E.E. and Afolabi, M.A. (2005). Levels of natural radionuclides in some Nigerian cereals and tubers, Journal of Environmental Radioactivity, 82, 1-6.

Badran, H.M., Sharshar, T. and Elnimer, T. (2003). Levels of 137Cs and 40K in edible parts of some vegetables consumed in Egypt. J. Environ. Radioactivity 67, 181-190.

Ban-nai, T., Muramatsu, Y. and Yoshida, S. (1997). Concentrations of 137Cs and 40K in edible mushrooms collected in Japan and radiation dose due to their consumption. Health Phys. 72, 384-389.

Kaplan, O., Yildirim, N.C., Yildirim, N. and Cimen, M. (2011). Toxic element in animal products and environmental health. Asian', Journal of Animal Veterinary Advances, 6: 228–232.

Meli, M.A., Cantaluppi, C., Desideri, D., Benedetti, C., Feduzi, L., Ceccotto, F., Fasson, A. (2013). Radioactivity measurements and dosimetric evaluation inmeat ofwild and bred animals in central Italy, Food Control 30: 272–279.

Mortvedt, J.J. (1994). Plant and soil relationships of uranium and thorium decay series radionuclides--A review. J. Environ. Qual. 23:643-650.

Rahman, S. and Faheem, M. (2008). Natural radioactivity measurements in Pakistandan overview. Journal of Radiological Protection, 28(4), 443.

Ramasany, V., Murugesan, S. and Mullainathan, S. (2006). Natural activity concentration and radiological hazards of Palar river sediment Tamilnadu, India. The Indian Meteorologist, 40, 9–23.

Rantavaara, A., Wallin, H., Hasunen, K., Härmälä, K., Kulmala, H., Latvio, E., Liskola, K., Mustonen, I., Nieminen, I. and Tainio, R. (2005). Finnish stakeholder engagement in the restoration of a radioactively contaminated food supply chain, Journal of Environmental Radioactivity, 83, 305-317.

Roessler, C.E., Bolch, W.E., Birky, B. and Roessler. G.S. (1991). Dose estimation and risk assessment for naturally occurring radionuclides in agricultural products. p. 194-212. In Hanlon, E.A. (ed.) 1991.

Venturi, L. and Sordi, G.A.A. (1999). Radioactivity in and committed effective dose from some Brazilian foodstuffs. Health Phys. 76, 311-313.

Verdoya, M., Chiozzi, P., De Felice, P., Pasquale, V., Bochiolo, M., Genovesi, I. (2009). Natural gamma-ray spectrometry as a tool for radiation dose and radonhazard modelling. App. Rad. Isot., 67(5), 964-968.