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ORIGINAL ARTICLE

ACTIVITY OF CESIUM ^{137}Cs AND POTASSIUM CONTENT IN NEW POTATOES IMPORTED TO POLAND

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ABSTRACT

Background. Potatoes are an important component of the human diet. In addition to components which determine the nutrition and dietary values, potato tubers also contain anti-nutritional substances, *inter alia* radioactive elements. Natural and artifical radionuclides are released to the environment as a result of antropogenic activity, in a controlled or uncontrolled manner, and they are transferred to the human body through the food chain.

Objective. The aim of the study was to determine the activity of radioactive cesium ^{137}Cs isotope and potassium content, including the activity of ^{40}K isotope, in new potatoes imported to Poland during the winter period from Mediterranean countries.

Material and methods. The study material included new potatoes imported from Cyprus, Egypt and Israel, purchased in the city of Siedlce from the beginning of February to the end of March 2015. The activity of ^{137}Cs and ^{40}K isotopes in potato tubers was determined. Analyses were performed by γ-spectrometric method. Laboratory tests were performed on a total of 18 samples. Based on the activity of ^{40}K isotope, the total potassium content of potato tubers was calculated, with the assumption that 31.00 Bq ^{40}K is equivalent to 1 g potassium.

Results. The activity of ^{137}Cs in most tested potato samples was below 0.2 Bq kg^{-1} (limit of quantification), and in other samles it was from 0.3 Bq kg^{-1} to 5.4 Bq kg^{-1}. Potatoes of the same variety, originating from the same country, differed in terms of the activity of ^{137}Cs. The highest activity of ^{137}C, determined in potatoes imported from Cyprus, was seven times higher than the lowest value. The activity of ^{40}K changed from 93.3 Bq kg^{-1} to 259.1 Bq kg^{-1}. The average activity of ^{40}K in potatoes imported from Cyprus, Egypt and Israel was at a similar level. The ratio of the activity of ^{137}Cs determined in the tested potatoes to the activity of ^{40}K changed from 0.00242 to 0.04163. The calculated potassium content in imported new potatoes was on average 4.376 g K kg^{-1} of the fresh weight of tubers and ranged from 3.010 g K kg^{-1} to 8.358 g K kg^{-1}.

Conclusions. The activity of the ^{137}Cs cesium isotope in imported new potatoes in most tested samples was at a very low level (below the limit of quantification) and in other samples it did not exceed 5.5 Bq kg^{-1} and posed no threat to human lives. Potatoes originating from the same country differed in terms of the activity of ^{137}Cs. The average activity of ^{40}K in potatoes imported from Cyprus, Egypt and Israel was at a similar level and did not differ from the activity of ^{40}K in domestically produced potatoes. The potassium content in imported new potatoes was determined by the variety.

Key words: *^{137}Cs activity, ^{40}K activity, potassium content, new potatoes*

STRESZCZENIE

Wprowadzenie. Ziemniaki są ważnym składnikiem diety człowieka. Obok składników decydujących o wartości odżywczej i dietetycznej, bulwy ziemniaka zawierają również substancje antyżywieniowe, m in. pierwiastki promieniotwórcze. Naturalne i sztuczne radionuklidy uwalniane są do środowiska na skutek działalności człowieka, w sposób kontrolowany lub niekontrolowany, i poprzez łańcuch pokarmowy przenoszone są do organizmu człowieka.

Cel. Celem było zbadanie i określenie aktywności radioaktywnego izotopu cezu ^{137}Cs oraz zawartości potasu, w tym aktywności izotopu ^{40}K, w młodych ziemniakach importowanych do Polski w okresie zimowym z krajów Basenu Morza Śródziemnego.

Materiał i metody. Materiał do badań stanowiły młode ziemniaki importowane z Cypru, Egiptu i Izraela, zakupione w Siedlcach wokresie od poczatku lutego do końca marca 2015 roku. Oznaczono aktywność izotopów ^{137}Cs i ^{40}K. Analizy wykonano metodą γspektrometryczną. Badania laboratoryjne wykonano w 18 próbkach. Na podstawie aktywności izotopu ^{40}K, wyliczono całkowitą zawartość potasu w bulwach ziemniaka, przyjmując, że 31,00 Bq ^{40}K odpowiada 1 g potasu.

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Wyniki. Aktywność ^{137}Cs w większości badanych próbek ziemniaków była poniżej 0,2 Bq kg^{-1} (poniżej granicy oznaczalności), a w pozostałych próbkach wynosiła od 0,3 Bq kg^{-1} do 5,4 Bq kg^{-1}. Ziemniaki tej samej odmiany, pochodzące z tego samego kraju różniły się pod względem aktywności ^{137}Cs. Najwyższa aktywność ^{137}Cs oznaczona w ziemniakach importowanych z Cypru była siedem razy większa od wartości najniższej. Aktywność ^{40}K zmieniała się od 93,3 Bq kg^{-1} do 259,1 Bq kg^{-1}. Średnia aktywność ^{40}K w ziemniakach importowanych z Cypru, Egiptu i Izraela była na zbliżonym poziomie. Stosunek aktywności ^{137}Cs oznaczonej w badanych próbkach ziemniaków do aktywności ^{40}K zmieniał się od 0,00242 do 0,04163. Wyliczona zawartość potasu w ziemniakach młodych z importu wynosiła średnio 4,376 g K kg^{-1} świeżej masy bulw i wahała się od 3,010 g K kg^{-1} do 8,358 g K kg^{-1}.
Wnioski. Aktywność izotopu cezu ^{137}Cs w ziemniakach młodych z importu w większości badanych próbek była na bardzo niskim poziomie, poniżej granicy oznaczalności, a w pozostałych próbkach nie przekraczała 5,5 Bq kg^{-1} i nie stanowiła zagrożenia dla zdrowia człowieka. Ziemniaki pochodzące z tego samego kraju różniły się pod względem aktywności ^{137}Cs. Średnia aktywność ^{40}K w ziemniakach importowanych z Cypru, Egiptu i Izraela była na zbliżonym poziomie i nie różniła się od aktywności ^{40}K w ziemniakach z produkcji krajowej. Zawartość potasu w badanych ziemniakach młodych z importu zależała od odmiany.

Słowa kluczowe: *aktywność ^{137}Cs, aktywność ^{40}K, zawartość potasu, ziemniaki młode*

INTRODUCTION

Potatoes are an important component of the human diet. They are a source of proteins of high biological value, minerals, vitamins, dietary fibre, phenolic compounds and other health-promoting compounds. In addition to components which determine the nutrition and dietary values, potato tubers also contain anti-nutritional substances (glycoalcaloids, nitrates, heavy metals and radioactive elements). As regards the latter, some of them are either natural components of the tuber or are formed naturally due to metabolic disorders of the plant and others originating from a contaminated environment [1, 10]. Natural and artificial radionuclides are released to the environment as a result of anthropogenic activity, in a controlled or uncontrolled manner. Uncontrolled releases of artificial radioactive isotopes have occurred during experimental nuclear explosions as well as during an accidental release from nuclear facilities, such as the accident at the nuclear power plant in Chernobyl in 1986, or the accident at the nuclear power plant in Fukushima in 2011. The Chernobyl nuclear power plant disaster resulted in the deposition of radioactive cesium over a large area of soils in Europe and countries of the former Soviet Union. Initially, the emission was transferred to the north-west over Poland, the Baltic States, Finland, Sweden and Norway and later spread over Central and Eastern Europe, southern Germany, Italy, and Yugoslavia [15]. The fallout of cesium ^{137}Cs and ^{134}Cs radionuclides in European countries, following the accident at the nuclear power plant in Chernobyl, was at a level of 0.012-190 kBq m^{-2}. The smallest amounts of cesium isotopes were noted in Portugal and the greatest was in Sweden [2]. Soil contamination with a radioactive isotope of cesium ^{137}Cs has a long-term radiological effect. This is determined by its long half-life period ($T_{1/2}$=30.1 years) and high biological availability. This isotope is transferred to the human body through the food chain [26].

The ingestion of agricultural produce contaminated with radioactive cesium is the main route of human exposure to the effects of this radionuclide. The uptake of ^{137}Cs by plants is determined by the level of soil contamination with this radionuclide, biological characteristics of plants, soil properties and climatic conditions and is subject to seasonal changes [5, 7, 11, 14, 16, 26]. A significant relationship has been found between the uptake of ^{137}Cs by plants and the potassium content of soil, including the activity of ^{40}K isotope. Potassium ^{40}K is a natural isotope found in soil ($T_{1/2}$=1.32×10^9 years). Numerous studies have demonstrated that the coefficient of cesium ^{137}Cs transfer from soil to plants was negatively correlated with the ^{40}K content of soil. The coefficient of ^{137}Cs transfer decreased with the increase in the potassium content of the soil [3, 24, 25, 26].

Cesium is very mobile in plants [26]. As regards the content of this radionuclide, a significant difference exists between the above-ground and underground part of plants. For most plants, the values of specific activity of ^{137}Cs in the underground part (mainly in the roots) are from two to five times higher than in the green parts of plants. As regards potatoes, the distribution of ^{137}Cs within the entire biomass of plants is relatively equal [16]. The coefficient of ^{137}Cs transfer in vegetables and cereal grains decreased in the following order: lettuce, cabbage > carrot, potato > cereals, onions [14].

Radioactive elements, even when the soil is heavily contaminated with them, are transferred to potato tubers in small amounts. A study carried out in Austria following the accident at the nuclear power plant in Chernobyl in 1986 demonstrated that the coefficient of ^{137}Cs transfer from soil to potato tubers was 0.0017 [7], while a study carried out in Japan following the accident at the nuclear power plant in Fukushima in 2011 demonstrated that the average coefficient of ^{137}Cs transfer to potato tubers was 0.0057 [13]. In the first year following the Chernobyl accident, the activity of ^{137}Cs in potato tubers, determined in Sweden, was

at a level of 5 Bq kg^{-1} [9]. The activity of radioactive cesium ^{137}Cs in potato tubers in Poland was 1.2 Bq kg^{-1}, and was the lowest for all tested food products [19]. The activity of ^{137}Cs in soil, average for Poland, decreased from the value of 4.64 kBq m^{-2} in 1988 to 1.54 kBq m^{-2} in 2012. This was due to both the radioactive decay of this isotope and the migration processes occurring in the environment, mainly the penetration of cesium into deeper soil layers [6]. The activity of ^{137}Cs in potato tubers, average for Poland, changed during this period from 0.8 to 0.4 Bq kg^{-1}, and in vegetables, from 0.9 to 0.4 Bq kg^{-1}. In the years 2012–2014, a slight increase in the activity of ^{137}Cs was noted in potatoes and vegetables, which was a result of the globally higher concentrations of this radionuclide, recorded following the accident at the nuclear power plant in Fukushima [19].

Most actinides (^{239}Pu, ^{240}Pu, ^{241}Am), as well as ^{90}Sr, mainly accumulate in potato tuber skin and may be removed by peeling, while ^{137}Cs occurs rather uniformly throughout the tuber [8]. In order to ensure radiological security, it is required that the possibilities for the transfer of radioactive isotopes from the environment to the human body be monitored.

The aim of the study was to determine the activity of radioactive cesium ^{137}Cs isotope and potassium content, including the activity of ^{40}K isotope, in new potatoes imported to Poland during the winter period from Mediterranean countries.

MATERIAL AND METHODS

The study material included imported new potatoes purchased in small local fruit and vegetable shops and in supermarkets (Topaz, Stokrotka, Kaufland, Tesco) once a week in the city of Siedlce from the beginning of February to the end of March 2015. The potatoes purchased in February were imported from Cyprus (n=5), and in March, from Cyprus (n=5), Egypt (n=3) and Israel (n=5). Only potatoes imported from Cyprus exhibited the characteristics of new potatoes, consistent with Regulation of the Minister of Agriculture and Rural Development [21] on detailed requirements for the commercial quality of potatoes, i.e. were harvested prior to reaching full maturity, had flaky skins, were not washed and were sold in bulk. The other potatoes introduced to the market as new potatoes were harvested after reaching full maturity, had corky skins and were washed and packed. Each potato sample used in the study weighed approx. 1 kg.

The activity of ^{137}Cs and ^{40}K isotopes in potato tubers was determined. Analyses were performed by γ-spectrometric method using a γ-spectrometer with a NaI scintillation detector. Washed and minced potatoes were transferred to measuring containers of the Marinelli type with a volume of 450 ml. The duration of measurement of the activity of radioactive isotopes in each sample was 80,000 seconds. γ-spectrometric measurements were performed at the Radiation Hygiene Section in Siedlce and at the Provincial Sanitary-Epidemiological Station in Warsaw, Radiation Hygiene Section in Siedlce. Laboratory tests were performed on a total of 18 samples. The test results were expressed in Bq per 1 kg of the fresh weight of potatoes. Based on the activity of ^{40}K isotope, the total potassium content of potato tubers was calculated, with the assumption that 31.00 Bq ^{40}K is equivalent to 1 g potassium [23].

RESULTS AND DISCUSSION

The activity of cesium ^{137}Cs isotope in most tested potato samples (n=11) was negligible, at the level of apparatus background (limit of quantification), i.e. below 0.2 Bq kg^{-1}, and in other samples (n=7) it was from 0.3 Bq kg^{-1} to 5.4 Bq kg^{-1} (Table 1). Potatoes of the same variety, originating from the same country, differed in terms of the activity of ^{137}Cs. The highest activity of ^{137}Cs, determined in tubers of potato of the 'Spunta' variety imported from Cyprus, was seven times higher than the lowest value. At the same time, in half of the analysed samples of this variety, the activity of ^{137}Cs was below the apparatus background (<0.2 Bq kg^{-1}). The activity of ^{137}Cs, determined in 'Spunta' variety potatoes imported from Egypt, was lower than that in potatoes of this variety originating from Cyprus. Particular varieties of potatoes imported from Israel varied. The activity of ^{137}Cs in tubers of 'Nicola' and 'Maris Peer' varieties was below the apparatus background, and in tubers of 'Orchestra' variety, the activity was 2.1 Bq kg^{-1}.

Table 1. ^{137}Cs and ^{40}K activity in potato tuber

Country of origin	Variety	Number of samples	^{137}Cs (Bq kg^{-1} f. w.)	^{40}K (Bq kg^{-1} f. w.)	^{137}Cs : ^{40}K
Cyprus	Spunta	5	0.8 – 5.4	112.6 – 129.7	0.00627-0.04163
Cyprus	Spunta	5	<0.2*	114.7 – 259.1	<0.00174
Egypt	Spunta	1	0.3	123.9	0.00242
Egypt	Spunta	2	<0.2*	115.7 – 125.8	<0.00173
Israel	Nicola	3	<0.2*	93.3 – 118.7	<0.00214
Israel	Maris Peer	1	<0.2*	193.5	<0.00103
Israel	Orchestra	1	2.1	102.5	0.02049

*0,2 Bq kg^{-1} – the limit of quantification

The differences in the activity of ^{137}Cs in potatoes imported from Israel could have been due to the biological characteristics of plants. 'Nicola' and 'Maris Peer' are early varieties, and 'Orchestra' is a medium-early variety. The activity of ^{137}Cs, determined in potato tubers of 'Orchestra' variety imported from Israel, was higher than in potato tubers of 'Spunta' variety originating from Egypt and in most tested samples of this variety originating from Cyprus. The same plant species originating from the same field, but harvested at different times, may differ in the activity of ^{137}Cs in the tissues even by one order of magnitude [19], which is confirmed by this study. In a study by Oshita [13], the activity of ^{137}Cs in tubers, determined 58 days after planting, was 2.4 Bq kg^{-1} and it was not detected 82 days after planting. The uptake of ^{137}Cs by plants is determined by their biological characteristics, the level of soil contamination with this radionuclide, soil properties and climatic conditions [5, 7, 14]. In Cyprus, potato cultivation is concentrated in the south-eastern part of the island in Lixisols, in Egypt in Fluvisols and in Israel in Cambisols. The coefficient of ^{137}Cs transfer to plants from loamy soils is lower than that for the transfer from coarse-grained mineral soils [14]. The coefficient of ^{137}Cs transfer from Calcic Chernozem was higher than for the transfer from Eutric Combisol [7]. Studies by other authors have demonstrated a higher transfer of ^{137}Cs from Chromic Luvisol than from Eutric Fluvisol [5]. In an earlier study by Królak and Karwowska [12], the activity of ^{137}Cs in domestically produced potatoes purchased commercially in the city of Siedlce was 1.44 Bq kg^{-1}.

The average activity of ^{40}K potassium isotope in the tested potato samples (n=18) was 135.6 Bq kg^{-1}, and changed from 93.3 Bq kg^{-1} to 259.1 Bq kg^{-1} (Table 1). The average activity of ^{40}K in potatoes imported from Cyprus, Egypt, and Israel was at a similar level. *Oshita* [13] estimated the natural activity of ^{40}K in potato tubers to be 124.6 Bq kg^{-1}. In the study by *Królak* and *Karwowska* [12], the average activity of ^{40}K, determined in domestically produced potatoes, was at a level of 120.1 Bq kg^{-1}, and in the study by *Oshita* [13], carried out in Japan, it was 151.2 Bq kg^{-1}.

The ^{137}Cs and ^{40}K isotopes represent elements with similar chemical properties, yet they have different sources in the environment. ^{40}K is a natural isotope ($T_{1/2}$=1.32×10^{9} years), and ^{137}Cs is released to the environment as a result of nuclear explosions ($T_{1/2}$=30.1 years). ^{137}Cs is taken up by plants by the same route as potassium. The coefficient of ^{137}Cs transfer decreases with the increase in available potassium content of soil. The selective uptake of cesium and potassium by plants indicates that the cesium and potassium contents in soil do not reflect the content of cesium or the cesium-to-potassium content ratio in plant tissues [18, 25]. The ratio of the activity of ^{137}Cs determined in the tested potato samples (n=7) to the activity of ^{40}K changed from 0.00242 to 0.04163 (Table 1). In a study by *Królak* and *Karwowska* [12], the ratio of the ^{137}Cs activity to ^{40}K activity in potato tubers was 0.01199. The performed studies failed to demonstrate a significant relationship between the activity of ^{137}Cs determined in the tested potato samples (n=7) and the activity of ^{40}K ($r=0.2731$, $p\geq0.05$).

The activity of ^{40}K corresponds to the concentration of potassium in potato tubers [13]. The calculated potassium content of the tested potato samples (n=18) was on average 4.376 g K kg^{-1} of the fresh weight of tubers and ranged from 3.010 to 8.358 g K kg^{-1} (Table 2). *Leszczyński* [10] reports that the potassium content of potato tubers may range from 2 to 9 g K kg^{-1} of fresh weight. The average potassium content of potatoes of the 'Spunta' variety imported from Cyprus was higher than for tubers of the same variety originating from Egypt (Table 2). The potassium content of potatoes of the 'Maris Peer' variety imported from Israel was almost two times higher than in 'Nicola' and 'Orchestra' varieties originating from the same country.

Table 2. Calculated potassium content in potato tuber (g K kg^{-1} f. w.)

Country of origin	Variety	Number of samples	Range min – max	Mean
Cyprus	Spunta	10	3.632 – 8.358	4.720
Egypt	Spunta	3	3.732 – 4.058	3.929
Israel	Nicola	3	3.010 – 3.829	3.414
Israel	Maris Peer	1	6.242	6.242
Israel	Orchestra	1	3.306	3.306

The activity of ^{137}Cs isotope and potassium content in imported new potatoes was similar to the values determined in domestically produced potatoes [12, 20]. The activity of ^{137}Cs isotope was at a very low level which posed no threat to consumer health. The maximum permitted level of radioactive contamination of food with nuclides with a half-life period longer than 10 days, in particular ^{137}Cs ($T_{1/2}$=30.1 years) and ^{134}Cs ($T_{1/2}$=2.06 years) must not exceed 1250 Bq kg^{-1} [4], and the maximum yearly intake of ^{137}Cs isotope by the oral route, equivalent to the annual effective equivalent of the dose of 1 mSv, amounts to 80,000 Bq [22]. Assuming that the daily consumption of potatoes is approx. 200 g, and the duration of consumption of

imported new potatoes is 4 months, the intake of ^{137}Cs isotope by the oral route, at the determined maximum activity of ^{137}Cs of 5.5 Bq kg^{-1}, does not exceed 150 Bq and is below the limit value.

CONCLUSIONS

1. The activity of the ^{137}Cs cesium isotope in imported new potatoes in most tested samples was at a very low level (below the limit of quantification) and in other samples it did not exceed 5.5 Bq kg^{-1} and posed no threat to human health. Potatoes originating from the same country differed in terms of the activity of ^{137}Cs.
2. The average activity of ^{40}K in potatoes imported from Cyprus, Egypt and Israel was at a similar level and did not differ from the activity of ^{40}K in domestically produced potatoes.
3. The potassium content in imported new potatoes was determined by the variety.

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Conflict of interest

The authors declare no conflict of interest.

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