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Radioactivity measurements and dosimetric evaluation in meat of wild and bred animals in central Italy

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ABSTRACT

This research was dedicated to the study of the background activity concentration of natural radionuclides and ^{137}Cs in meat of wild and farm animals from central Italy. This meat is largely consumed by the local population and also exported to different countries. ^{40}K, ^{210}Pb, ^{214}Pb, ^{214}Bi and ^{137}Cs were determined by gamma spectrometry, ^{210}Po by alpha spectrometry. The mean ^{40}K activity concentration resulted 415 ± 56 Bq kg^{-1} dw. In all samples, ^{210}Pb was below the detection limit (<18.9 Bq kg^{-1} dw). The ^{214}Pb and ^{214}Bi activity concentration was detectable in only 33.1% of samples with a mean value of 3.5 ± 1.2 Bq kg^{-1} dw. The ^{210}Po activity concentration ranged between 0.02 ± 0.002 Bq kg^{-1} dw (pig) and 3.13 ± 0.31 Bq kg^{-1} dw (deer) with a mean value of 0.48 ± 0.42 Bq kg^{-1} dw. A significant difference can be noticed between the ^{210}Po concentration in the meat of wild specimens and the ^{210}Po concentration in those reared. Instead, no difference can be observed between male and female species and between adult and young species. The ^{137}Cs activity concentration resulted or not detectable or near to detection limit except in a few samples of boar and roe deer. The effective dose from ^{210}Po ingested by eating bovine, and pig and wild animal meat accounts only for 0.03–0.11% of the natural radiation exposure in Italy.

1. Introduction

The major contribution to the radiation exposure received by humans comes from natural sources. These include external sources such as cosmic rays and radiation from primordial radionuclides (^{238}U and ^{232}Th) and their decay products in the environment. Information on the levels of naturally occurring radionuclides is important as they contribute to a substantial fraction of the radiation dose to the natural ecosystems.

In this study, among the natural radionuclides, ^{40}K, and some radionuclides of the ^{238}U family (^{214}Pb, ^{214}Bi, ^{210}Pb, ^{210}Po) were taken into account.

^{40}K is a natural radioisotope present in soil and as the element K, an essential plant nutrient, enters in the plant roots via ion channels or specific transporters.

^{210}Po and his grandfather ^{210}Pb belong to ^{238}U series. Their presence in the terrestrial environment arises from ^{222}Rn, which once produced, may remain in soil interstitial air spaces, decay within the mineral matrix of soil or be released to the atmosphere. Globally, radon exhalation from soil accounts for about 22 PBq year^{-1} of ^{210}Pb and ^{210}Po (Cothern & Smith, 1987). At the present the approximated average atmospheric concentrations of ^{210}Pb and ^{210}Po in northern temperate latitudes are 0.5 and 0.05 mBq m^{-3}, respectively (UNSCEAR, 1993). ^{210}Pb and ^{210}Po return to the earth's surface via both wet and dry deposition (Brown et al., 2011; Burton & Stewart, 1960; Peirson, Cambray, & Spicer, 1966; Persson & Holm, 2011), and their presence in all terrestrial foodstuffs is inevitable. It is also known that natural levels of ^{210}Pb and ^{210}Po in the environment can locally be increased by anthropogenic activities like phosphate ore processing, coal-fired power stations, coal mining, metal smelting, etc. which produce enhanced levels of ^{210}Pb and ^{210}Po (Kather & Bakr, 2011).

About 18% of the average internal dose of the population is due to ingestion of ^{210}Po along with its precursor ^{210}Pb (Cherry & Heyraud, 1981, 1982; Cherry & Shannon, 1974). Among the alpha emitters, ^{210}Po is estimated to contribute about 7% of the effective dose equivalent to human from ingested natural radionuclides (UNSCEAR, 1988).

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^{210}Po, in fact, causes considerable radiation risk even at minimal intake due to its high linear energy transfer (LET). The ^{210}Po toxicity is comparable to ^{239}Pu and about 5 times greater than ^{226}Ra (NRC, 1988; Salahel Din, 2011).

In mammals ^{210}Po accumulates mainly in soft tissues such as liver and kidney. It is also observed at high concentration in bone, because it is generated by the decay of ^{210}Pb, but 20% ^{210}Po derived from ^{210}Pb decay is transferred to soft tissues (Skwarzec & Prucnal, 2007).

It is well known that radionuclides are present in the environment either naturally or artificially; ^{137}Cs is an artificial radioelement, released in the past by atmospheric nuclear weapon testing (1945–1963) and by the Chernobyl accident (1986). Both contributions are found in soils of Central Italy. However, the distribution patterns are different. Weapon test fallout can be considered nearly homogeneously distributed, as it occurred during a wide temporal range, whereas Chernobyl fallout depended on the rainfall in the few days after the nuclear power accident, so it is often found at "hot-spots"with very different inventories also at short distances. In Central Italy 137Cs weapon tests distribution provided for about 5 kBq m^{-2} (UNSCEAR, 1982), whereas Chernobyl accident provided from 2 to 40 kBq m^{-2} (De Cort et al., 1998). 137Cs is mobile in the environment and accumulatesd in foodstuffs, mainly in animal products (Fasenko et al., 2007).

As far as the animal products are concerned, the key transfer pathways to animals are ingestion of contaminated feed and in some cases of soil (Howard, Beresford, Barnett, & Fesenko, 2009).

Consumption of food is usually the most important route by which natural and artificial radionuclides can enter the human body and an assessment of radionuclide levels in different foods and diets is therefore important to estimate the intake of these radionuclides by man.

Natural and artificial radioactivity has been measured in foodstuffs (Desideri, Roselli, & Meli, 2010; Meli, Desideri, Roselli, & Feduzi, 2008) and in different kind of meat from different countries (Bunzl, Kracke, & Kreuzer, 1979; Holtzmann, 1980; Ladinskaya, Parfenov, Popov, & Fedorova, 1973; Morse & Welford, 1971) but there are few data for meat samples from Italy. Meat is a very important food: it is part of a balanced diet contributing valuable nutrients that are beneficial to health; it contains high levels of protein, vitamins, minerals and micronutrients which are essential for growth and development.

In this study the determination of natural radionuclides such as ^{214}Pb, ^{214}Bi (two radionuclides coming from the ^{226}Ra decay) ^{210}Pb, ^{210}Po and ^{40}K, and of the artificial ^{137}Cs was carried out in the muscle of wild animals (deer and wild boar) of central Italy. Wild animals seem to be, in fact, good bioindicators of environmental contamination; areas covered by trees are traps for contaminants transported by air and radionuclides deposited persist much longer in forest ecosystem than in agriculture land (Strebl, Gerzabek, Karg, & Tataruch, 1996).

This survey was extended to animals "physiologically similar" bred on farms in the area, pigs and cattle, which differ substantially in the type of feeding, the most important means of introduction of radionuclides in animals.

The purposes of the present study were: a) to provide information on the background activity concentration of natural radionuclides such as ^{214}Pb, ^{214}Bi, ^{210}Pb, ^{210}Po and ^{40}K to obtain useful background reading and contributing to the creation of databases on natural radioactivity; b) to determine the ^{137}Cs content in meat to evaluate the residual impact of nuclear weapon testing and the Chernobyl accident on the central Italy; c) to calculate the committed effective doses from ^{210}Po for the individual local public through ingestion of meat.

2. Materials and methods

2.1. The study area and samples

2.1.1. Study area

Samples of meat (muscle) were collected from 148 animals slaughtered in autumn and winter 2011 in a region of the central Italy (Marche) and furnished by the local Health Agency (ASUR 2). Fig. 1 shows the sampling area.

2.1.2. Samples

The 148 samples analyzed were accompanied by a sheet in which the data of the species, provenance, age (young up to 12 month and adult) and sex were indicated.

78 were wild animals: 49 wild boars of which 22 adults and 27 youngs, 25 males and 24 females; 23 roe deer of which 14 adults and 9 youngs, 10 males and 13 females; 5 fallow deers (2 adults and 3 youngs, 1 female and 4 males) and 1 deer (adult, female).

70 were farm animals: 52 cattles of which 44 adult and 8 young, 23 males and 29 females and 18 pigs (6 young and 11 adults, 11 males and 5 females).

2.2. Sample pre-treatment

After careful cleaning and grinding of meat, a suitable amount (50 g for ^{210}Po determination and 100 g for ^{137}Cs, ^{40}K, ^{214}Bi and ^{210,214}Pb) was weighed, frozen at −20 °C and the next day, freeze-dried for 24 h using a freeze dryer module EDWARDS; the dehydrated sample was weighed and homogenized. The mean ratio between the dry weight (dw) and fresh weight (fw) resulted 0.27 ± 0.03.

2.3. Analytical method

The radionuclides determination was carried out by two different techniques: a) high resolution gamma spectrometry with high purity germanium detectors for ^{210}Pb, ^{214}Pb, ^{214}Bi, ^{40}K and ^{137}Cs; b) radiochemical methods for ^{210}Po.

2.3.1. Gamma spectrometry

It is possible to determine simultaneously many radionuclides by a direct γ-spectrometry of the sample without any specific pretreatment of this.

Samples were put and counted in 50 ml cylindrical beakers for 86,400 s. All the measurements were performed with a low background configuration calibration; the efficiency and energy calibration were obtained by means of gamma–ray certified reference standards of mixed radionuclides (QCY48 and QCYB40 from Amersham). The accuracy of the efficiency calibration of the measuring system was periodically checked through interlaboratory and intercalibration control tests planned by National Physical Laboratory of Teddington (UK). The correction for the self-attenuation of gamma rays in the sample matrix respect to the calibration solution was done with the method reported in Degetto and Cantaluppi (2003).

2.3.2. Radiochemical methods

^{210}Po cannot be determined by gamma spectrometry because it is not a gamma emitter, it emits only alpha particles at 5.407 MeV. It is not possible to use the gamma emission of other members of ^{238}U series because a secular equilibrium for all members of the series cannot be assumed (Desideri et al., 2007). So ^{210}Po was determined through a radiochemical method.

A radiochemical method is a destructive technique; it consists in the measurements of the radionuclides after their separation (by extraction chromatography, precipitation, electrodeposition etc.)