POTASSIUM CONCENTRATIONS AND ANNUAL EFFECTIVE DOSE OF THE MOST CUSTOMARY- CONSUMED FOODSTUFFS IN MEXICO AS A CULTURAL HERITAGE

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1. Introduction

Food and drinks are known to contain natural and artificial radionuclides that, after ingestion, contribute to an effective internal dose. It has been estimated that a large portion, at least one-eight, of the mean annual effective dose due to natural sources is caused by the intake of foods [1]. Measurement of the concentration of radionuclides present in foodstuffs permits the assessment of the dose caused by the intake of foods products [2] and additionally this type of work allows establishing baseline values for comparison with future measurements. Beside of this, from the trace elements in foodstuffs, K is one of the most important and it is a well-known essential element; it occurs all over the earth. Potassium has three main isotopes: two stable (^{39}K, 93.26%, and ^{41}K, 6.73%) and one radioactive (^{40}K, 0.011%). In the human body, ^{40}K is the most abundant radioactive substance. Its concentration in foods varies widely, so its intake is quite dependent on diet. Dietary Reference Intake of K varies between 1.56 g.d^{-1}and 5.0 g.d^{-1} (40 mEq.d^{-1}and 128 mEq.d^{-1}) [3]. However, variation in diet seems to have little effect on the body content. ^{40}K decays to ^{40}Ca emitting a βeta negative particle (89%), and it decays also to gas ^{40}Ar by electron capture with emission of an energetic gamma-ray (11%, 1460.8 keV). Besides of this, after the Chernobyl Nuclear accident it is mandatory to verify possible radioactive contamination by gamma fission products in fallout such as ^{137}Cs.

Objectives

Aims of this work were: to determine ^{40}K activity and the derived annual effective dose; and to determine potassium percentage in three of the most traditionally consumed foodstuff, as a cultural heritage from pre-Hispanic times in Mexico: beans, chili and corn (maize), paste (or "masa", yet to make "tortillas"); and to verify the non radioactive contamination by gamma-fission products found in fallout.

2. Experimental

All samples are cultivated, distributed, manufactured and available in the Mexican market and were randomly purchased in local grocery stores. They were chosen different varieties of each one of the foodstuff types. For common beans (Phaseolus Vulgaris) in Spanish "frijoles": black; bayo, peruano (also called Canary and native from Mexico, despite the name) examples of yellow beans type; vaquita (mottled skin with black), and ayocote.
For chili they were chosen four varieties of dried chili, morita, pasilla, guajillo, piquin and two varieties of green chili, jalapeño or cuaresmeño and poblano, all of them from the specie capsicum annuum.
In the case of the corn paste, masa (yellow and purple), the samples were randomly purchased in Mexico City and Xalapa, Veracruz, in tortilla factories and another one (yellow) made in house; three samples are of industrialized dried powder "masa nixtamalizada" (ready to reconstitute with hot water to make masa); one of them was a mix (trade mark: Maseca and Minsa); two samples were masa nixtamalizada purple, one of them Minsa and the other Maseca. Every sample was dried in an oven, ground (to enhance the sample final density to 0.5 g. mL^{-1}), weighed to 250 g (dry weight) and placed in a clean Marinelli beaker of 500 mL.

Clasificación científica
Plantae
Magnoliophyta
Magnoliopsida
Asteridae
Solanales
Solanaceae
Capsicum
C. annuum
Nombre binomial
Capsicum annuum

Plant with immature fruit
Scientific classification
Kingdom: Plantae
Division: Magnoliophyta
Class: Magnoliopsida
Order: Fabales
Family: Fabaceae
Subfamily: Faboideae
Tribe: Phaseoleae
Genus: Phaseolus
Species: P. vulgaris
Binomial name
Phaseolus vulgaris

Scientific classification
Kingdom: Plantae
Division: Magnoliophyta
Class: Liliopsida
Order: Poales
Family: Poaceae
Genus: Zea
Species: Z. mays
Binomial name
Zea mays

Quality Control Program includes equipment calibration and duplicate measurements [4,5]. Precision and accuracy were evaluated by RSD (Relative standard deviation) or Variation Coefficient, a percent relative mean deviation, %RMD of duplicate measurements and relative standard error (RSE).

Once the non-radioactive contamination by gamma-emitters was verified and reported as non-detectable activities, the net area under the photopeak of ^{40}K after background correction was used to calculate the activity concentration and percentage of potassium [4,5,6]. Internal radiation dose intakes are obtained from the measured activity (Bq kg^{-1}) and multiplying these by the masses of food consumed [7,8,9] in kg y^{-1}); a dose conversion factor [10, 11, 12] (5.9 x 10^{-9} Sv Bq^{-1}) can be applied to give an estimation of the ingestion dose.

3. Results and discussion

As it can be seen, the mean %K concentration is highest for chili samples in contrast with masa samples (corn meal or maize meal, the main ingredient for tortilla) with the lowest. This type of food has the highest % Coefficient Variation (% CV) 33% , showing the dispersion of values probably due to the influence of different sampling Cities, the nixtamalization process (masa is made from dried field or dent corn boiled with slaked lime, and the mixture known as nixtamal) and different manufacturing process, traditional (hand made) or in modern kitchens and tortilla factories with mechanized grain mills and food processor, or dried and powdered masa that can be easily reconstituted with hot water (masa nixtamalizada). In spite of these factors, the mean specific activity from ^{40}K for the masa is similar to those found in corn (0.1 Bq g^{-1}) from South Bulgaria [13] and equal to the %K reported by the USDA Nutrient database [14], 0.27 %.
Results also show that the mean maximum specific activity of ^{40}K is, for chili, 0.9±0.09 Bq g^{-1}; with a lower %CV, 9.5%, showing lesser dispersion though showing the influence of chili type, (green or dried). The average %K concentration was 2.84±0.027 similar to those reported previously [15].
For common beans, the results for specific activity were similar to those reported for Brazilian beans [16], 0.434 Bq g^{-1} and %K concentration similar to those reported of 1.5% [17]. For this last sample the % CV was lower than 2% showing lesser dispersion of values between different varieties of beans. The total uncertainty associated to counts in samples and background was lower than 5%. Precision evaluated by the % Relative mean standard deviation (%RMSD) between duplicates was in average lower than 1.5% exception made for masa samples, with an average of 7%. The RSE were for masa, chili and bean samples of: 12.6 %, 4 % and 0.5% respectively. The Minimum specific activity and The Minimum Concentration Detectable (MCD) for experimental conditions were 0.1 Bq g-1 of sample and 0.3 % for potassium concentration, respectively.

As it can be seen, masa (corn meal) in spite that it has a lower specific activity, it gives the highest dose due to a high consumption (urban zones); in rural zone the annual consumption for tortillas could be increased to double (219 kg y^{-1}) and consequently duplicating the annual effective dose from this sample to 0.116 mSv y^{-1} and increasing the total annual effective dose from 0.122 to 0.181 mSv y^{-1} representing 54 % and 84 % respectively of those caused by the average intake of 100 Bq d^{-1} of ^{40}K in food [2,19] equivalent to 0.215 mSv y^{-1}.The total % of RDI for potassium, apported for this three foodstuffs cultived and consumed from prehispanic times, and actutally in all economic levels by Mexican population, is 38% in urban zones or 51% in rural zones.

Table 1
Specific activity (Bq g^{-1}) and %K for common bean samples

Bean Sample	A ± σ 1	% K ± σ
Black	0.51 ± 0.02	1.59 ± 0.06
Bayo	0.49 ± 0.02	1.55 ± 0.07
Vaquita	0.51 ± 0.01	1.61 ± 0.04
Peruano	0.52 ± 0.01	1.63 ± 0.03
Ayocote	0.51 ± 0.01	1.62 ± 0.04
Mean	0.51 ± 0.01	1.60 ± 0.04
Median	0.51	1.61
C. V % 2	1.86	1.86

1= Standard Deviation ; 2= % Variation Coefficient

Table 2
Specific activity (Bq g^{-1}) and %K for chili samples

Sample	A ± σ 1	% K ± σ
Morita	0.97 ± 0.02	3.07 ± 0.07
Pasilla	0.94 ± 0.02	2.98 ± 0.06
Guajillo	0.99 ± 0.02	3.11 ± 0.06
Cuaresmeño	0.88 ± 0.02	2.78 ± 0.07
Poblano	0.85 ± 0.04	2.68 ± 0.01
Piquin	0.74 ± 0.02	2.34 ± 0.07
Mean	0.9 ± 0.09	2.84 ± 0.27
Median	0.90	2.95
C. V % 2	9.5	9.5

1= Standard Deviation; 2= % Variation Coefficient

Table 3
Specific activity (Bq g^{-1}) and %K for masa samples

Sample	A ± σ1	% K ± σ
Yellow masa	0.06 ± 0.02	0.188 ± 0.07
Yellow masa (Xalapa)	0.09 ± 0.02	0.271 ± 0.06
Yellow masa (made in house)	0.08 ± 0.02	0.245 ± 0.06
Purple masa (Xalapa)	0.13 ± 0.02	0.418 ± 0.06
Masa nixtamalizada (mix)	0.10 ± 0.06	0.330 ± 0.1
Masa nixtamalizada (Minsa purple)	0.09 ± 0.02	0.287 ± 0.07
Masa nixtamalizada (Maseca purple)	0.05 ± 0.02	0.151 ± 0.05
Mean	0.09 ± 0.03	0.270 ± 0.089
Median	0.09	0.271
C. V %2	33	33

1= Standard Deviation; 2= % Variation Coefficient

Table 4
Calculated mean annual effective dose (μSv y^{-1}) and percent of potassium Dietary Reference Intake for each one of analyzed foodstuffs.

Type of food	MAC[1] (kg y^{-1})	^{40}K MSA[2] (Bq kg^{-1})	MAED[3] (μSv y^{-1})	Potassium MDC4 (g d^{-1})	%DRI[5]
Bean	9.13	510	27.5	0.40	8.0
Chili	7	901	37.2	0.54	10.8
Masa (Corn meal)	109.5	90	58.1	0.81	16.2
Total			122.8	1.75	35.0

1= Mean annual consumption; 2= Mean specific activity; 3=Mean annual effective dose; 4= Potassium mean daily consumption; 5= % of Dietary Reference Intake.

4. Conclusions

The gamma spectrometry technique provide precise (reproducible) and accurate (trueness) data for ^{40}K in analyzed samples.
^{40}K specific activities and % K concentrations measured in analyzed foodstuffs are in the range of those reported in the international literature.
The total mean annual effective dose from the analyzed foodstuffs represents 54 % of the estimated annual effective dose from ^{40}K in composite diets. Tortillas made from masa samples were the food type responsible for the highest contribution to the mean annual effective dose due to large rate of consumption that they have in Mexico
Total % of RDI for potassium, apported for the three foodstuffs consumed from prehispanic times, were 38% in urban zones or 51% in rural zones due also to the same cause above mentioned.