ARTICLE IN PRESS

Applied Radiation and Isotopes xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Applied Radiation and Isotopes

journal homepage: www.elsevier.com/locate/apradiso

Computational Approaches on Photon-Attenuation and Coincidence-summing Corrections for the detection of gamma-emitting radionuclides IN foods

Clarence Rolle*, Zhichao Lin, Stephanie Healey

Winchester Engineering and Analytical Center, Food and Drug Administration, 109 Holton Street, Winchester, MA 01890 USA

A R T I C L E I N F O

Keywords:
Gamma spectroscopy
Efficiency
Monte Carlo
Density corrections

A B S T R A C T

Source-based calibration methods used for photon attenuation and coincidence summing corrections are time consuming and require multiple certified standards that match sample geometry with varying densities. Three programs which are capable of simulating a variety of sample geometries, matrix compositions, and sample densities have been examined as alternatives. LabSOCS, ANGLE 3 and GESPECOR are effective at generating efficiency curves for food matrices with a range with different densities. The curves generated have been successfully used to determine activity in food samples.

1. Introduction

The risk of food being tainted with radioactive materials due to accidents at nuclear facilities, proliferation of nuclear war or deliberate contamination by terroristic threats, is of critical concern to the U.S. Food and Drug Administration (FDA). In order to prepare for these potential radiological threats, significant efforts are needed to develop radioanalytical capabilities for emergency response situations. Even though there are methods for detecting radionuclides in a large number of food samples (Lin et al., 2016), improvements must be made that allow for rapid and high-throughput detection. The radionuclides of greatest concern for food safety and public health have been previously categorized with respect to their principal emissions, many of which are radionuclides with gamma radiation as the principal emission (Lin et al., 2016).

In order to effectively respond to a large-scale nuclear or radiological emergency, the method of detection must be quick, simple, and capable of high-throughput applications. Gamma-ray spectroscopy is an advantageous technique to use because it allows for the identification and quantification of gamma-emitting radionuclides without extensive sample preparation (Debertin and Helmer, 1988; Knoll, 2010). A high resolution sample gamma spectrum, which exhibits energies and intensities of different gamma radionuclides, can be used to identify and quantify unknown radionuclides present in a food sample.

Although gamma spectroscopy is a powerful technique that is very useful for characterizing and quantifying radioactive material, applying this method for rapid quantification of radionuclides in food faces several challenges. A major issue that affects the speed in which measurements are taken in emergency response operation is the calibration of the instrument. Traditionally, calibration of gamma ray spectrometer requires use of a physical standard comprised of mixed gamma sources. The matrix of the standard sample must match that of the unknown in order to replicate its composition and density and the radioactive material within the sample must be dispersed homogeneously. These requirements of having a physical calibration standard match each unknown sample is difficult to meet quickly. There are very limited food-based gamma standards available for purchase and they are high in cost. Preparing unique gamma food standards that are accurate and stable is challenging and generates radioactive waste which is difficult to dispose of. In addition, these standards also have limited useful shelf life due to radionuclides of interest being short lived. Coincidence-summing that leads loss or addition of a count from summed-out or summed-in photons must also be accounted for in order to ensure the accuracy of efficiency curve, which is used to ultimately derive the amount of unknown in the sample.

The ability to develop a simple and practical approach to emulate physical and chemical properties of the sample, compute counting efficiency, and correct coincidence summing effects is critically needed to achieve rapid instrument calibration for high throughput sample analysis. This work focused on examining computational methods as a way to address the issues and challenges related to instrument calibration and sample analysis.

* Corresponding author.
E-mail address: Clarence.Rolle@fda.hhs.gov (C. Rolle).

http://dx.doi.org/10.1016/j.apradiso.2017.02.034
Received 16 August 2016; Received in revised form 16 February 2017; Accepted 21 February 2017
0969-8043/ Published by Elsevier Ltd.

Table 1
Detector and geometry parameters used for calculations.

Detector parameters	Value used in computation (mm)	Geometry parameters	Value used in computation (mm)	Uncertainty ($k=2$)
Crystal Diameter	62	Shape	Cylinder	
Crystal Length	58.3	Material	Polypropylene	
Crystal Core Hole Diameter	7.5	Diameter	99.2	± 1.40
Crystal Core Hole Length	43.5	Wall Thickness	1.3	± 0.16
End to Cap Crystal Distance	5	Bottom Thickness	0.9	± 0.23
Window Thickness	0.6	Sample Height	51.41	± 2.34
Dead Layer Top Face	0.1	Spacer Material	Polypropylene	
Dead Layer Side Face	0.1	Spacer Width	3.25	± 0.19
End Cap diameter	76			
Windows Thickness	0.5			

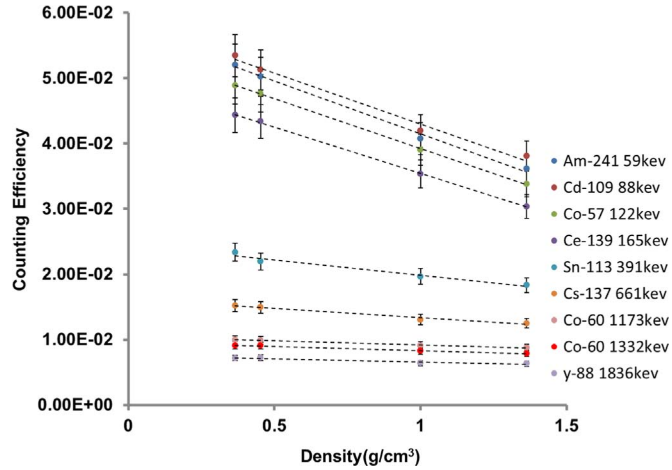

Fig. 2. The effect of different densities on the counting efficiency for various radionuclides. Typical uncertainty values were found to be on the order of 6% in this study.

2. Materials and methods

This study compares the activities calculated for food samples spiked with known radioactivity, based on both traditional multi-line efficiency calibration and detection efficiencies from calculation methods. Mathematical calibration software has been previously used across the nuclear measurement industry (Bell et al., 2012; Długosz-Lisiecka and Ziomek, 2015; Done et al., 2016). Three software packages evaluated are LabSOCS by Canberra (Canberra, 2013), ANGLE 3 (Jovanovic et al., 2010; Jovanović et al., 1997) and GESPECOR (Sima et al., 2001). Each software package uses different methods for calculations and has unique user interfaces and adjustable parameters

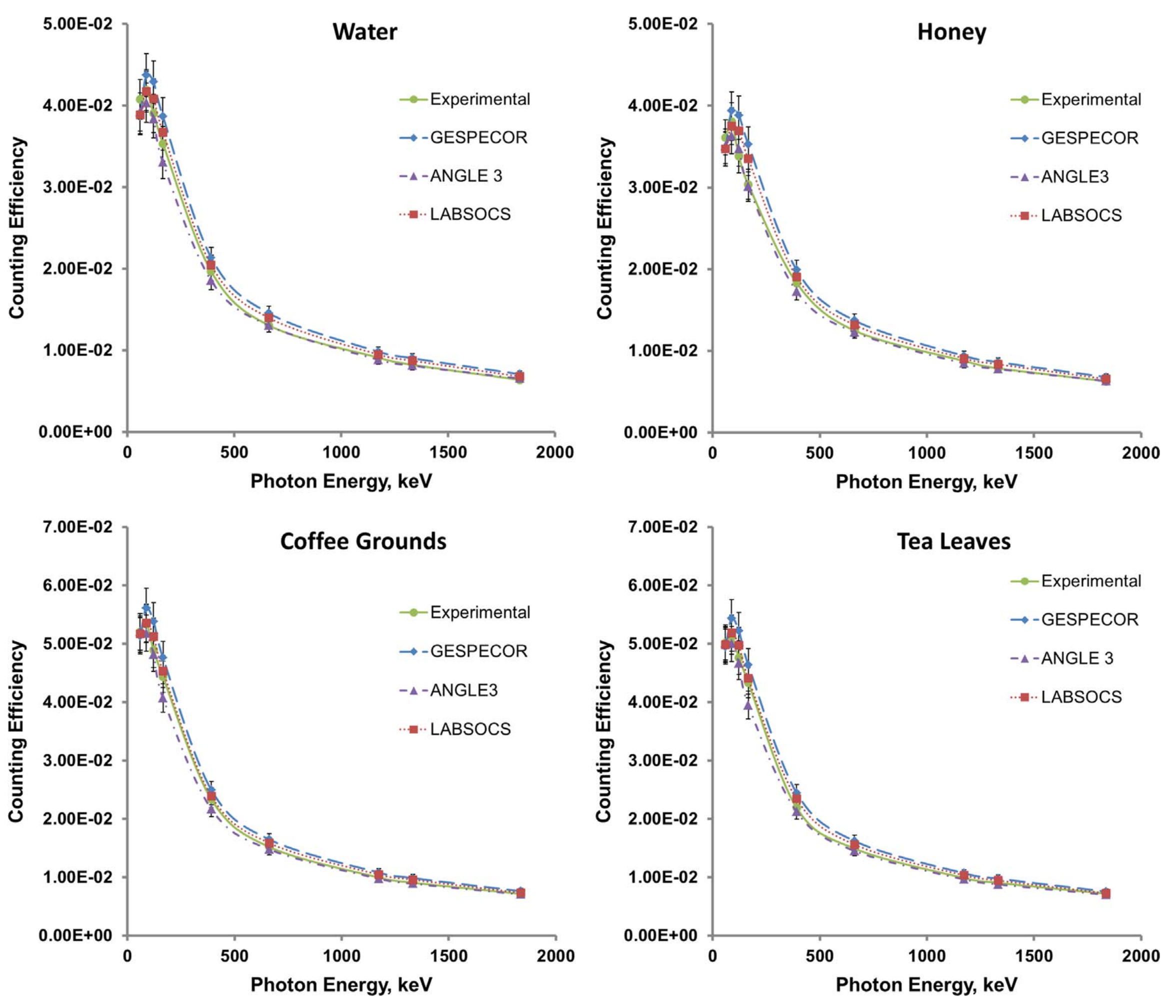

Fig. 1. A comparison of the measured efficiency curve to the computer generated efficiency curves with LabSOCS, ANGLE3 and GESPECOR for different types of foods with different densities. Our regulatory programs require a measurement accuracy to be within ± 10%. Efficiency computations with a 2% uncertainty assigned to each of the detector and sample parameters showed that a combined effect on counting efficiencies from all uncertainty components is on the order of 6%.