Journal of Scientific Research & Reports
3(3): 419-426, 2014; Article no. JSRR.2014.003

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Instrumental Neutron Activation Analysis of Honey Samples from Lokoja and Suleija North Central Nigeria

S. A. Agaja[1*]

[1]Industrial Safety and Environmental Technology, Petroleum Training Institute, Effurun, Delta State, Nigeria.

Author's contribution

This work was carried out and written by the author, there is no conflict of interest. The author read and approved the final manuscript.

Original Research Article

Received 4th July 2013
Accepted 9th October 2013
Published 26th November 2013

ABSTRACT

Instrumental Neutron Activation Analysis (INAA) using Ghana Research Reactor (GHARR-1) at the Ghana Atomic Energy Commission (GHAEC) operating at 15kW at a thermal flux of 5 x10^{11}n $cm^{-2}s^{-1}$ was used to determine nine elements in honey samples from Lokoja and Suleija North Central Nigeria. The elements were; Al, Br, Ca, Cl, K, Mg, Mn, Na, and V. The concentration of the elements varied in the different samples ranging from few ppm to few percentages.

Keywords: INAA; Honey; Nigeria; Lokoja; Suleija; GHAEC.

1. INTRODUCTION

Honey is a natural product obtained from plants and elaborated by honey bees. Honey [1] is a sweet viscous liquid food, dark amber in colour, produced by bees from the nectar of flower and plant. Honey contains water (13-20%) two major sugars, fructose (40-50%) and glucose (32-37%) small amount of sucrose (<2%) and mineral constituents (ash less than 0.1%). Honey also contains numerous enzymes, vitamins in small amount free acids, various plant colouring internal and trace element. Honey is one of the most easily

**Corresponding author: E-mail: silaagaja@yahoo.com;*

assimilated foods almost the only source of sugar available to the ancients and was valued for its medicinal benefits.

Several authors have written that bees and their products may be used as biological indicators of environmental pollution present in the area where they fly [2,3,4] indicates that there is no correlation between the content of some element (Ag, Cd and Pb) present in the soil and honey. Therefore, honey is not the most sensitive tool to evaluate environmental contamination with pollutants due to metallic concentration present in this product and the great variability caused by factor like origin, source, floral density, season of the year, rainfall and others. Honey may be used as a bio-indicator of air or ground pollution.

The type of equipment (s) used to produce honey as well as the quality of the equipment used to store honey after harvesting are possible sources of honey contamination with trace metals. For example storing honey in galvanize containers can be a major source of zinc contamination [5].

The information about honey samples in Nigerian have been reported in literature [6] [7]. The aim of this work is to determine trace elemental contents of honey samples from North central Nigeria which is a major honey producing area in Nigeria and to compare the results with what other workers have published in Nigeria and elsewhere in the world [6,7,8].

Instrumental Neutron Activation Analysis in combination with a high-resolution gamma-ray spectrometry was used as analytical technique. This method has several advantages which include; high sensitivity, high precision and accuracy, little or no elaborate sample preparation, non-destructive and give multi-element capability [9,10,11,12].

2. MATERIALS AND METHODS

2.1 Honey Collection Sites

The honey samples were bought from honey sellers in Lokoja (7^{o} 49^{1}N 6^{o} 45^{1} E) the confluence town of Niger and Benue River and Suleija (9^{o} 11^{1} N 7^{o} 11^{1} E) a satellite town of Nigerian federal capital city of Abuja. The honey samples were stored in glass bottles and no further sample preparations were carried out on the samples to avoid contamination.

2.1.1 Sample irradiation and counting

2.1.1.1 Technique

Instrumental Neutron Activation Analysis has been employed for the determination of the concentration of elements in the samples provided [9,10,11].

2.1.1.2 Sample preparation

Two honey samples (1 liter bottle) were bought from Suleija and Lokoja North central Nigeria. Samples were prepared by weighing 200mg on polyethylene films. They were then wrapped with forceps with the sample identities on them. Samples were then parked into polyethylene capsule of diameter 1.6cm (Rabbit capsule) and heat sealed.

Standard reference material Orchard Leaves 1571 from the National Institute of Standards and Technology (NIST) were equally weighed as the test samples.

2.1.1.3 Sample irradiation and counting

Samples and controls were irradiated in the Ghana Research Reactor (GHARR-1) at the Ghana Atomic Energy Commission, operating at 15 kW at a thermal flux of $5x10^{11}$ $n.cm^{-2}.s^{-1.}$ Samples were transferred into irradiation sites via pneumatic transfer system at a pressure of 0.60 Mpa. The irradiation was categorized according to the half-life of the element of interest as shown in the irradiation scheme in Table 1.

Table 1. Short and Medium Irradiation Schemes

	Element	Isotopes	Half Life	Gamma Ray Energies (keV)	Irradiation Time	Counting Time
	Al	^{28}Al	2.24 min	1778.9		
	Br	^{82}Br	35.3 h	554.3,776.5		
	Ca	^{49}Ca	8.7 min	3084.4		
	Cl		37.3	1642.2		
Short		^{38}Cl	min	2167.5		
Lived	K	^{42}K	12.36 h	1524.7		
Radio-	Mg	^{27}Mg	9.45	843.8		
nuclides			min	1014.4	120 s	600 s
	Mn	^{56}Mn	2.58 h	846.7,1810.7,		
Medium				2112		
Lived	Na	^{24}Na	15.02 h	1368.6,		
Radio-				2754.1		
nuclides	V	^{52}V	3.76	1434.1		
			min		3600 s	600 s

After the irradiation, radioactivity measurement of induced radionuclide was performed by a PC-based gamma-ray spectrometry set-up. It consists of an n-type HPGe detector coupled to a computer based multi-channel analyzer|(MCA) via electronic modules. The relative efficiency of detector is $25^{0}/_{0}$ and its energy resolution of 1.8 keV at gamma-ray energy of 1332 keV of ^{60}Co. Through appropriate choice of cooling-time, detector's dead time was controlled to be less than $10^{0}/_{0.}$ Identification of gamma-ray product radionuclide was identified through the energies and quantitative analysis of the concentration was by converting the counts as area under the photo peak by the comparator method. Both analyses were done using the gamma-ray spectrum analysis software, ORTEC MEASTRO-32.

Validation of the technique for the experimental set up was done by irradiating a standard reference material (Orchard leaves 1571) for the same period of time as the sample in the same location within the reactor. The analysis of the standard reference material in Table 2, shows good agreement of measured values with the certified ones.

2.1.2 Determination of elements concentrations in the samples

The calculation of trace elements concentrations in the samples was carried out by the comparator method using the same geometry, equal weights of both sample and standard with the same irradiation, decay and counting times, the concentration of the elements in the samples was determined by the expression [11].

$$C_{sample} = C_{std}\left[\frac{A_{sample}}{A_{std}}\right]$$

Where;

C_{sample} = Unknown concentration of the element in the sample.
C_{std} = Known concentration of the element in the standard.
A_{sample} = Activity of the sample.
A_{std} = Activity *of* the standard.

3. RESULTS AND DISCUSSION

The results of the INAA technique discussed in section 2.2, were shown in table 2 and table 3 respectively, Table 2 is the result for the standard reference material 1571 Orchard Leaves used for the validation of this work. Table 3, is showing the concentration of nine trace elements obtained from the two irradiation schemes short lived and medium lived radionuclide.

The results of trace element concentration obtained by other workers in Nigeria and in Europe were shown in tables (4,5 and 6).

The results of trace element concentration obtained in this work were compared with the results obtained by other previous workers. [6,7,8]

Table 2. Irradiation of standard reference material 1571 Orchard Leaves used for validation

Element	No. of Irradiation	Reported Values $mgkg^{-1}$	This work $mgkg^{-1}$
Al	3	Not Reported	12
Br	3	10	12
Ca	3	2.09	2.11
Cl	3	700	698
K	3	1.47wt%	1.40wt%
Mg	3	0.62wt%	0.64wt%
Mn	3	91	91
Na	3	82	81
V	3	Not Reported	37

Table 3. Trace elements concentration in Honey Samples from Lokoja and Suleija.

Element	Concentration (μgg^{-1})	Location
Al	7 ± 1	Lokoja
	25 ± 4	Suleija
Br	65 ± 10	Lokoja
	84 ± 13	Suleija
Ca	86 ± 13	Lokoja
	14 ± 2	Suleija
Cl	45 ± 7	Lokoja
	485 ± 73	Suleija
K	3.2 ± 0.2	Lokoja
	216 ± 32	Suleija
Mg	21 ± 3	Lokoja
	30 ± 5	Suleija
Mn	35 ± 5	Lokoja
	10 ± 1	Suleija
Na	8 ± 1	Lokoja
	12 ± 2	Suleija
V	13 ± 2	Lokoja
	4 ± 1	Suleija

Source: Present study.

Table 4. Reported Concentration of Trace Elements in Nigeria Honey

Element	Concentration Range (μgg^{-1})	Mean (μgg^{-1})
Br	0.5-4	2.4
Ca	152-265	249
Cr	5-17	11.2
Cu	10-35	21
Fe	136-407	220.6
K	1100-21600	10520
Mn	1-5	3
Ni	3.7-28	13.14
Rb	2.2-6	4.12
Se	2.1-13	4.98
Tl	30-80	51.4
Zn	31-106	63.4

Source: Adebiyi et al., 2004 [6].
Analytical method: Total Reflection X-ray Florescence (TXRF) Spectrometer.

Table 5. Trace element in Nigeria Honey and New Zealand

Element	Concentration mgL^{-1}	Manuka Honey (New Zealand) mgL^{-1}
Ca	0.136–78.73	17.4587
Cr	BDL	
Cu	0.005 – 0.693	0.2073
Fe	0 – 104.14	4.1733
K	0.487– 1705	376.723
Pb	BDL	
Zn	0 – 4.173	1.5177

Source: Agbagwa et al., 2007 [7].
Analytical Method: Atomic Absorption Spectrometry (AAS).
BDL: Below Detection Limit.

Table 6. Reported trace element in honey samples from Warsaw Poland

Element	Concentration (μgg^{-1})	Analytical Method
Br	0.7 (42) – 0.3(50)	PIXE
Ca	49(14) – 165 (15)	TXRF
	36 (30) – 214 (27)	PIXE
Cr	1.2(17) – 3.7(17)	TXRF
	0 – 6.1(35)	PIXE
Cu	0.8(28) – 2.5(21)	TXRF
	0.7(34) – 3.2(25)	PIXE
Fe	0 – 16.8(18)	TXRF
	0 -18.6	PIXE
K	442 (14) – 2675 (13)	TXRF
	435 (25) – 2694(25)	PIXE
Mn	0.4(25) – 4.3 (20)	TXRF
	1.3(28) – 5.4(28)	PIXE
Zn	2.0(27) – 14.1(25)	TXRF
	0 – 16.3(20)	PIXE

Source: Braziewicz et al., 2002 [8]
Note: PIXE (Proton Induced X-ray Emission)
TXRF (Total Reflection X-ray Fluorescence)
Values in parentheses are the errors in percentage.

Aluminum: The concentration of Al in honey samples from Suleija were almost four times higher than the concentration obtained for honey samples from Lokoja. The reasons for this variation may be related to the medium and container used by the bee farmers to process the honey before they were sold in the market. Al in honey was not reported by other workers [6,7,8].

Bromine: The concentration of Br in the samples from Suleija was about 25% higher than Lokoja honey samples. This could be due to the nature of soil and plant available to the bees during honey production. The Br concentrations reported in this work ranged between 27 to 35 times higher than the mean value reported by [6] somewhere else in Nigeria. The Br concentrations reported in this work were about 100% higher than the values reported in honey samples from Poland [8].

Calcium: The Ca concentration in the honey Samples in Lokoja honey where about six times higher than values obtained for honey samples from Suleija. This variation may due to the geographical and botanical conditions of the two locations. However, other workers reported the presence of Ca in their work [6] reported a mean value 246 μgg^{-1}. This value is about 6 to 17 times more than the mean concentration reported in this work. The concentration reported for Ca in this work is also, within the range reported by [7] in their work. This is also within the range from honey samples reported by [8].

Chlorine: The concentration of chlorine in honey samples from Suleija was ten times higher than the reported concentration in honey samples from Lokoja. This variation may be due to nature of plants absorption available to the bees in the two locations. Chlorine in honey samples was not reported by other previous workers in honey samples around Nigeria. Also possible dilution of the honey with chlorinated water could be responsible for the higher concentration of chlorine in honey samples from Suleija [6,7].

Potassium: The potassium concentrations in honey samples from Suleija were about seventy times higher than the reported concentration from Lokoja. This very wide variation may be due to the nature of soil available to the plant which the bees used during honey production. [8] reported much higher values in their work [more than 100%]. The concentrations reported by [7] were much lower than the reported concentration in this work. But the K, concentration reported by [7] for New Zealand honey samples was two times higher.

Magnesium: The variation in Mg, from the two locations studied was less than ten percent variation. The concentration of Mg, was not reported for honey samples within and outside Nigeria by other workers whose work were compared with this study.

Manganese: The concentration of Mn in Lokoja honey samples, were three times higher above the observed concentration in honey samples from Suleija. However, concentration of Mn reported in this study were between three and ten times higher than the reported mean value for honey samples in Nigeria by [6] and still much higher than the Mn concentration reported for Poland honey samples by [8].

Sodium: The variation of Na concentration in honey samples from Suleija and Lokoja was less than 15%. Sodium concentration was not reported in honey samples from elsewhere in Nigeria as reported by [6] and [7].

Vanadium: The concentration of V in honey samples from Lokoja was three times higher than the concentration reported for Suleija honey samples. This variation could be due to geographical and botanical factors. Vanadium in honey was not reported by other workers [6,7,8].

4. CONCLUSION

The INAA measurements of honey samples from Lokoja and Suleija in North Central Nigeria were carried out. Concentration of nine elements were determined in the honey samples; Al, Br, Ca, Cl, K, Mg, Mn, Na and V.

There are variations in the measured concentration of the honey samples from Lokoja and Suleija. The concentrations of the following trace element were dominantly higher in honey samples collected from Lokoja; Ca, Mn and V, they were between three to seven times higher than honey samples from Suleija. Also, the concentration of the following elements; Al, Cl, K, Mg, Na, were about two to seven times higher than in Lokoja honey Samples. This variation may be due to several factors like, soil, plant available, species of bees, environmental, geographical and the tools used during extraction and storage of the honey samples potassium was abundantly present especially in Suleija honey samples. This is in agreement with other previous workers result within Nigeria and in Europe.

ACKNOWLEDGEMENTS

The author acknowledges Mr. Nicholas Opata and the GHAEC Authority for their contributions and the privilege to have this work done in their centre. The comments and suggestions of the independent reviewers helped to improve this paper, they are all appreciated.

COMPETING INTERESTS

The author has declared that no competing Interests.

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Peer-review history:
The peer review history for this paper can be accessed here:
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