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Assessing Bulk Hydrogen in Cyanogenic Food Plants Using Neutrons for Routine Quality Control

Keziah Garba

Centre for Energy Research and Training, Nigeria, Ahmadu Bello University, Nigeria

Abstract

- The challenges of food safety affect over 820 million people globally.
- Certain foods such as cocoyam and sorghum contain cyanogenic glycosides which are toxic and can cause long-term health issues if improperly processed.
- This study employed neutron reflection—a rapid, environmentally sustainable, and non-destructive technique to determine the hydrogen content of various food samples.
- The alkaline picrate method allowed us to measure the cyanide content in the food samples.
- Overall, the results showed an inverse relationship between the hydrogen content and cyanide concentrations, indicating a trend that can be used to assess cyanogenic food plants.

Introduction

- Cyanogenic foods contain glycosides that yield cyanide upon enzymatic breakdown.
- Examples include cocoyam, cassava, sorghum, and lima beans.
- Cyanide is toxic and can lead to detrimental health problems in humans and livestock when consumed. They are contained in sorghum and cocoyam.

Fig 1. Sorghum

Fig. 2 Colocasia esculenta

Fig 3. Red Sorghum

Fig. 4 Xanthosoma sagitifolium

- Due to the neutral nature of neutron, they can be used to easily deep-profile agricultural and geological samples.
- Thermal neutron reflection involves the use of thermalized neutrons to assess the elemental content of substances.

Aim

- The aim of this research is to investigate the bulk hydrogen content of sorghum and cocoyam in relation to their cyanide content using neutrons for routine quality control

Objectives

- To determine the hydrogen content of sorghum and cocoyam
- To evaluate the cyanide content of sorghum and cocoyam
- To assess the use of total hydrogen content in sorghum and cocoyam as a quality control indicator of starch content in them

Methodology

Sample Collection and preparation

- Four different varieties of sorghum and cocoyam were collected from retail outlets in Nigeria, washed clean and dried in an oven at 80ºC.

Neutron reflection for Hydrogen assessment

- Liquid hydrocarbons were assessed to obtain a standard calibration curve for the hydrogen content.
- 400ml of each sample was measured into the sample holder and exposed to thermalized neutrons from an Am-Be source.

- $^{4}_{2}\alpha + {}^{9}_{4}Be \rightarrow {}^{12}_{6}C + {}^{1}_{0}n$

Eqn 1. Neutron source equation

- $^{3}He + \ n \rightarrow \ p + {}^{3}H$

Eqn 2. Neutron detection equation

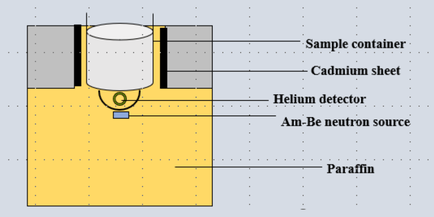
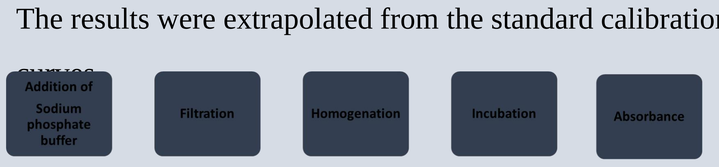


Fig 5 Schematic diagram of a neutron reflection facility

- As a function of the hydrogen atoms present in the samples, the attenuated neutrons are detected by the ^{3}He detector.
- The counts are measured by a neutron counter/timer.

Alkaline Picrate Method for Cyanide analysis

- Varying concentrations of potassium cyanide were analyzed to obtain a calibration curve for the cyanide content.
- The results were extrapolated from the standard calibration



Results

- The following equation was used to obtain the neutron attenuation coefficients, ŋ of the hydrogen standards and samples:

$$\eta = \frac{1}{\rho}\frac{I - I_0}{I_0}$$

ρ = density
I_0 = initial count rate
I_s = samples' count rate
H (wt)% = Hydrogen content

Eqn. 3 Neutron attenuation coefficient

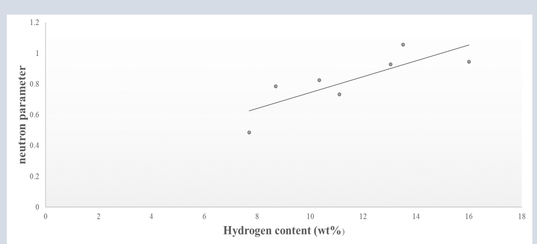
Sample ID	Mean sample counts (I)	ŋ ($g^{-1}cm^{3}$)
Red Sorghum	1366.2	0.5446 ± 0.10
Cocoyam (Type 1)	1231.0	0.5613 ± 0.07
Yellow Sorghum	1406.0	0.6562 ± 0.09
Cocoyam (Type 2)	1339.8	0.6580 ± 0.10

Table 1. Neutron attenuation coefficient

Standard	I_s	ŋ	H (wt%)
Benzene	1451.6	0.485 ± 0.104	7.692
Toluene	1710.6	0.786 ± 0.076	8.696
Acetone	1684.0	0.826 ± 0.059	10.344
n-Butyl alcohol	1866.2	1.056 ± 0.045	13.514
n-Heptane	1675.6	0.944 ± 0.061	16.000
Ethanol	1764.4	0.928 ± 0.041	13.043
Water	1765.4	0.734 ± 0.030	11.110

Table 2. Neutron counts and neutron reflection parameter of samples

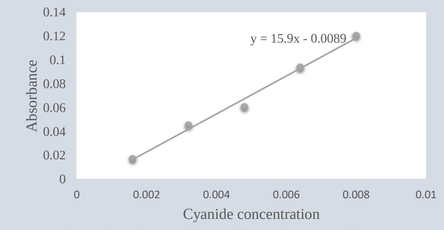
- The hydrogen content of the food samples were obtained via extrapolation from the standard hydrogen calibration



Standard Hydrogen calibration graph

- The total hydrogen weight percent (H wt%) range from 6.083±1.10 to 8.2854±0.10

Results contd.



Standard cyanide calibration graph

Sample	Absorbance	Cyanide concentration (g/litre)
Yellow sorghum	0.0523	0.00384
Fresh cocoyam	0.0910	0.00628

Table 3. Cyanide content

- The cyanide content range for the samples is from 0.00384±0.00009 to 0.00628±0.0004.

Discussion

- For the neutron attenuation coefficient, ŋ the individual densities of the samples were used to balance the excess count rate.
- The variation of neutron reflection coefficient as a function of the total H (wt)% was fitted by a linear equation y = 0.0515x + 0.2313 to calculate the total H (wt)%.
- Red sorghum has the minimum reflection parameter while cocoyam flour has the maximum reflection.
- This results confirm that the reflection parameter is a function of the sample's total hydrogen content.

Conclusion

- Samples having low hydrogen content are generally rich in cyanide, indicating an inverse relationship.
- This implies that the neutron reflection facility can be adapted for the direct determination of hydrogen content using food plants of known cyanide content.
- This method is fast and non-destructive, making it an attractive option for the determination of H (wt)% and routine quality control of cyanogenic food plants.

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Contact Details

Email: keziahgarba@gmail.com
Phone: +2348067860856

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