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The effects of milling on corn flour using instrumental neutron activation analyses: a case study of three selected corn millers within Accra metropolis, Ghana

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ABSTRACT

Most Ghanaian foods are made from maize. Unfortunately, certain diets made from the cereal cannot be produced without processing the maize into flour. The corn mill has been the most efficient and often used tool for grinding legumes, cereals, nuts and spices. Maize is milled either dried or soaked. Dry maize is usually milled over and over again for about four times to retain a smooth texture. It is used to prepare many delicacies in different parts of Ghana. However, soaked maize is milled only once and it is ready for use. The work was conducted to find the levels of Cd, Al, Ni, Cu, Mg and Zn in the processed flour using instrumental neutron activation analyses at the Ghana Research reactor-1 Facility. As the grinding plates of the corn mills rub against each other, there is friction as well as wear and tear. This could introduce toxic metals into the corn flour. Results showed that the corn mills had no negative effects on the corn flour as the level of the elements recorded were below the required limits. Al values in the sample ranged from 1.8 ± 0.27 mg/kg to 5.40 ± 0.81 mg/kg. Cu, Cd, Zn and Mn also recorded concentration values of ranges 0.70 ± 0.11 mg/kg to 1.50 ± 0.23 mg/kg, 4.80 ± 0.72 mg/kg to 6.40 ± 0.96 mg/kg, 0.52 ± 0.08 µg/kg and 0.90 ± 1.35 mg/kg to 4.10 ± 0.62 mg/kg respectively. No particular process recorded consistent peak value concentrations for the heavy metals. Ni recorded concentrations within the range 26.18 ± 3.23 mg/kg to 46.42±2.53 mg/kg. However, continuous consumption could lead to accumulation of these elements that could affect the body adversely.

Introduction

Maize is an important staple food grown in many parts of the tropics which serves as food for many people and animals. In Ghana, it is the most popular of all grain crops and it is grown all over the country. Maize is processed into corn flour which is used in the preparation of many local foods such as kenkey, banku, tuo zaafi, akple, porridge, abolo etc. (Lokko et al, 2004). The corn mill is the machine used to process cereals, legume, nuts, and spices into flour. It is an indispensible tool in the flour production industry. It can be found in cities, towns and villages across the country due to the dependence on cereal food products by the country folks. It has a pair of circular grinding plates which are made of cast iron. Cast iron is normally used for machinery parts to resist wear and tear. Iron is alloyed with nickel, chromium, copper, molybdenum and silicon to increase the tensile strength (Johnson, 1977). Both surfaces of the plates have small ridges running from edge to center. Grinding is done by power rotating one mobile plate against a stationary plate. In the process, grains that pass between the plates are crushed to powder. The sliding process of the plates generates friction which leads to wear and tear. A casual observation of maize processing indicates that worn out metals are been processed into corn flour.

Heavy metals often have direct physiological toxic effects. Some are stored in living tissues, sometimes permanently. According to Kwofie (2006), three different samples of locally manufactured grinding plates were selected from the same manufacturer and tested for chemical composition as well as hardness and wear. Although results showed that chemical composition were similar, the hardness and wear resistance of the samples were significantly different suggesting that samples were of different heats. Since the grinding plates were from the same production shop and meant for the same purpose, these differences in hardness and wear resistance indicated non-reproducibility of products.

There are two locally manufacturing industries in Ghana, Tema and Kumasi. Other foreign grinding plates used by the corn mill operators are radget, amuda, rex, premier, bin and bamford. The higher the quality of the grinding plates the longer it takes to wear out and the safer it is because there would be less worn out metals in the corn flour.

The plate type, the location of the mill as well as the method of grinding (whether milled with a corn mill or milled with pestle and mortar which are all made from timber) can affect the results.

Timber is a natural solid wood from a tree which has been sawn into sizes suitable for building and construction purposes (Sackey et al, 2004).

The objective of this work was to determine the concentration of heavy metals in corn flour ground by corn mills. It was also aimed at discovering which of the grinding plate materials produces the best levels of heavy metals. Figure 1 and 2 show examples of the wooden mortar and pestle and the corn mill respectively.

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Fig 1: A photograph of a typical mortar and pestle

Fig 2: A picture of a typical corn mill in Ghana

Materials and methods

Instrumentation

Sample irradiations for neutron activation analysis were carried out in the 30 kW Miniature neutron source reactor (MNSR) at a neutron flux of 5 x 10^{11} neutrons cm^{-2} s^{-1}. The reactor is situated at the Ghana Atomic Energy Commission, Kwabenya, Accra, Ghana.

Study Design

The sampling of the corn flour occurred in March, 2011. Maize cobs were collected from maize plants on farms in the Akuapim South district in the Eastern region as well as the Wenchi district in the Brong Ahafo region, all in Ghana. The cobs were dehusked, shelled and dried to constant weight. Three maize samples were soaked in water for three days. Samples of soaked and dried maize each of mass 2500g were ground by one corn miller. In all three corn mills each at Nungua, Newtown and Madina, all in different parts of the Accra metropolis, Ghana were used for the grinding. Also, one sample of soaked dried maize each of mass 2500g were also ground using a wooden pestle and mortar. These were used as controls. In all eight samples were taken.

Sample preparation

The corn flour was sent to the Neutron Activation Analysis Laboratory of the Ghana Research Reactor-1. The samples were placed in petri dishes and sent into the freeze dryer for 10 to15 hours. After freeze-drying process, the samples were grounded and homogenized in an industrial blender into fine powder. The sample preparation was done in a dry, dust-free environment. The samples were weighed in three fold with each weighing 100mg on the metiler balance. The sample was wrapped in a clean polythene film using a pair of forceps. Prior to packaging the samples, the polyethylene capsules were soaked in trioxontic (V) acid (HNO_3) of 1:1 for three days, washed with deionised water and dried. The samples were then packed into the polyethylene irradiation capsules. The capsule was heat-sealed. Standard reference material Wheat Flour 1567 (200mg) and reference material 8435 Whole Milk Powder (200mg) were then prepared in the same manner as the corn flour samples. The two standard reference materials with certified values were used to validate the INAA method. The large capsules containing the samples and standards have a diameter of 1.6cm and a height of 5.5cm. The values are represented in table 1.

Sample irradiation and counting

Samples and standards were transferred into the reactor via the pneumatic transfer system at a pressure of 0.6 mPa. The corn flour samples were irradiated for 2mins, 1hour and 4hours for short, medium and long irradiations respectively. At the end of the irradiation, the samples and standards were removed from the reactor and allowed to decay for 24 hours and 1 week for medium and long irradiations respectively. The short was allowed to decay for less than 2 mins. The large irradiation vial containing the radioactive corn flour sample was placed on the coaxial high purity germanium (HPGe) semi-conductor γ-ray detector (Canberra) and the γ-activity of the induced radioisotopes. Measurement time depended on the activities of the induced radioisotopes. This was followed by the measurement of the γ-activity of the induced radioisotopes in the standard reference materials on the same coaxial HPGe γ -ray detector and at the same source-detector distance. A plexiglass source support was mounted on the detector during the measurement in order to ensure easy and reproducible source positioning (De Corte, 1987). The ORTEC MAESTRO-32 γ-spectroscopy software was used for γ -spectrum acquisition.

Results and Discussion

Table 1 shows the analytical results obtained for Aluminium, Cadmium, Zinc, Manganese, Copper and Nickel at GHARR-1 laboratory for the reference materials compared with the experimental samples. The values obtained compared favourably well with the recommended values. The experimental samples were within ±5% of the recommended values. The measurement precision specified by the relative standard deviation was within ±4%. The error margins are standard deviations.

Table 2 shows the concentrations of Aluminium, copper, manganese, zinc and cadmium in the corn flour samples. Eight corn flour samples were obtained using eight different milling methods (corn mills with different grinding plate constituents and mortar and pestle). Generally, the concentrations of all the heavy metals were below the toxic level. Al values in the sample ranged from 1.8 ± 0.27 mg/kg to 5.40 ± 0.81 mg/kg. Cu, Cd, Zn and Mn also recorded concentration values of ranges 0.70 ± 0.11 mg/kg to 1.50 ± 0.23 mg/kg, 4.80 ± 0.72 mg/kg to 6.40 ± 0.96 mg/kg, 0.52 ± 0.08 µg/kg and 0.90 ± 1.35 mg/kg to 4.10 ± 0.62 mg/kg respectively. No particular process recorded consistent peak value concentrations for the heavy metals. Ni recorded concentrations within the range 26.18 ± 3.23 mg/kg to 46.42±2.53 mg/kg.

High concentrations of these elements in the human body are undoubtedly injurious to the human body. Al decreases the absorption of a number of inorganic elements including iron, fluorides and phosphorus and forms insoluble compounds in these elements. Al toxicity inhibits enzymes into the brain. It blocks the electrical discharge of the nerve cells which reduces nervous system activity. Kidney dialysis related to aluminium toxicity causes memory loss, disorientation, loss of coordination and confusion (FAO, 2006).

Whole blood contains about 1 mg/L of copper. The levels can vary considerably especially in women. During pregnancy and after the intake of oral contraceptives, copper can rise to 2 or more mg/L in blood (Insaidoo, 1999).

Human beings require manganese for the maintenance of normal health. Humans have a body pool between 12 mg and 20mg (Phillips, 1976). It is essential in cellular metabolism (some enzymes require manganese to function). The liver maintains the normal adult body pool of 20mg with excess manganese excreted into the intestines via the bile. The normal urinary level of manganese averages about 2.75 µg/L with a range of about 1-8 µg/L. Urinary levels over 10 µg/L are indicative of manganese exposure (Stokinger, 1981). The National Research Council (NRC, 1989) recommends a dietary allowance of 2 to 5 mg/day for a safe and adequate intake of manganese. The Recommended dietary allowance (RDA) for Mn is 2.3mg (RDA, 1989) indicating that the Mn in the mortar and pestle processed flour were below this value. However, the flour processed by the corn mills recorded slightly higher values.

Estimated ranges of daily dietary intake of total Zn are 5.60 – 10 mg/days for infants and children aged up to 11 years, 12.30 -13.0 mg/day for children aged 12 – 19 years, and 8.80 – 14.40 mg/day for adults aged 20 – 50 years. Mean Zn intake for drinking water is estimated to be less than 0.2 mg/day (WHO, 1996). However, a single or short term exposure to Zn could lead to gastrointestinal distress, nausea and diarrhoea.

Cadmium inhibits essential enzymes in the Krebs energy cycle. It directly damages nerve cells. Accumulation in the kidney results in high blood pressure and kidney disease. Cd can replace Zn in the arteries which contributes to the arteries being brittle and inflexible (FAO, 2006).

The various forms of nickel differ in physiochemical properties and biological effects. However, if inhaled at concentrations high enough to induce chronic lung inflammation. These compounds could enhance carcinogenic risks associated with inhalation exposure to other substances.

It was expected that the concentration of the metals in the dry processed flour would be lower than that of the wet processed flour due to concomitant milling process in order to obtain very fine smooth flour. As expected, the results, showed that the concentration of the elements in the wet processed flour in all the samples were higher than the dry processed flour. The tap water used to soak portions of the maize contains different kinds of metals and minerals. This disparity could be caused by the metals in the tap water which was added to the samples of the processed flour resulting in the increase in the concentration of the metals in the wet flour.

The composition of the grinding plates could also affect the concentration of the metals in the flour. Premier grinding plate was used for grinding at Madina, local grinding plates was used at Newtown and Rex Plate was used at Nungua. Generally, the concentrations of the metals in the flour processed at Newtown was highest followed by that of Madina and Nungua in that order. However the Al concentration wet corn flour was highest for all of the flour this could be due to the fact that there was an Al smelting plant in the vicinity of the corn mill (particulate Al in the atmosphere could be carried to the corn mill site and this could be the cause of high Al value). Both premier and Rex plates are foreign plates and takes about three days to wear out. Kumasi plate, which is locally manufactured, takes 1 or 2 days to wear out. The foreign plates are considered to be of better quality in terms of hardness than the local plates. The corn flour processed using the Rex plates had lower concentration of the metal than was recorded in the corn flour processed using the premier plates. This indicates that the Rex plate is of a better quality.

Furthermore, the mortar and pestle processed flour recorded lower concentration of metals compared to the flour processed with grinding plates. This is indicative of the fact that the metals are not entirely of grinding plate origin. The level of metals in the flour processed by the pestle and mortar are the true levels of metals in the maize. The pestle and mortar are made of wood which has cellulose and fibre components. Therefore, it does not contribute to the level of metal in the flour and even if present through the absorption of roots, it would be marginal.

Smoothness of flour required can also affect the concentration of the metals in the samples. Smoothness is achieved by adjusting the mobile parts of the corn mill. When the wheel is adjusted, the two plates are pressed together tightly causing more friction and wear. This could results in the variation in the concentrations in the samples.

Conclusion

The results of recorded indicated that the effect of the corn mill on the corn flour was minimal. The concentration of Al, Cu, Mn, Zn, Cd and Ni were all below the recommended levels. However, more could be done to make the process more refined. For example, even though the tap water used in soaking the maize cobs is not toxic, the maize cobs could be soaked with deionised water instead of tap water to reduce or eliminate heavy metal concentration. From the results obtained the Rex plate was the best grinding plate for processing corn flour.Also, more research work could be conducted so that the material used for the grinding plates would consist of more non toxic metals elements. The corn mills should be operated in clean and safe environment to prevent particulate heavy metals in the atmosphere to come into contact with the corn flour during and after processing which could increase the concentration of the heavy metal in the flour.

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Table 1: Results of standard reference material wheat flour 1567 & reference material 8435 whole milk powder showing reported and measured values used for validation.

ELEMENT	Reported value (Wheat Flour)	Measured value (Wheat Flour)	Reported value (Whole Milk Powder)	Measured value (Whole Milk Powder)
Aluminum (Al)	-	-	$^{+}$0.90	0.92 ± 0.138
Zinc (Zn)	$^{@}$10.6 ± 1.0	10.62 ± 1.21	$^{\#}$28.0 ± 3.1	27.96 ± 2.71
Manganese (Mn)	$^{@}$8.5 ±0.5	8.54 ± 0.67	$^{\#}$0.17 ±0.05	0.175 ± 0.061
Cadmium (Cd)	$^{@}$0.032 ± 0.007	0.029 ± 0.004	$^{+}$0.0002	0.00028 ± 0.00003
Copper (Cu)	$^{@}$2.0 ± 0.3	2.12 ± 0.41	$^{\#}$0.46 ± 0.08	0.52 ± 0.12
Nickel (Ni)	* 0.18	0.2 ± 0.03	$^{+}$0.01	0.012 ± 0.0018

TABLE 2: MEAN VALUES (3 values each) OF ELEMENTAL CONCENTRATION IN mg/kg RECORDED IN THE CORN FLOUR SAMPLES

Elements	Sample ID							
	MOWF (Conc. in mg/kg)	MODF (Conc. in mg/kg)	MAWF (Conc. in mg/kg)	MADF (Conc. in mg/kg)	NEWF (Conc. in mg/kg)	NEDF (Conc. in mg/kg)	NUWF (Conc. in mg/kg)	NUDF (Conc. in mg/kg)
Aluminium	2.20±0.33	1.80±0.27	5.40±0.81	5.30±0.80	5.20±0.75	4.60±0.69	3.80±0.57	2.90±0.44
Copper	1.20±0.18	0.90±0.14	1.00±0.15	0.76±0.12	1.50±0.23	1.10±0.23	1.20±0.17	0.70±0.11
Manganese	1.81±0.75	0.90±1.35	2.30±3.5	2.60±0.39	3.40±0.51	3.40±0.51	3.10±0.47	2.20±0.33
Zinc	5.10±0.77	4.50±0.68	5.50±0.83	5.9±0.89	5.40±0.81	4.80±0.72	6.40±0.96	5.30±0.80
Cadmium	0.85±0.13	0.74±0.11	0.74±0.11	0.63±0.95	1.40±2.10	0.90±0.14	0.64±0.95	0.52±0.08
Nickel	46.42±2.53	39.24±3.11	43.58±1.35	32.21±1.05	41.96±1.67	37.05±2.33	33.49±2.20	26.18±3.23

Data are presented as mean ± standard deviation of three replicate measurements; MOWF- MORTAR AND PESTLE WET FLOUR; MODF- MORTAR AND PESTLE DRY FLOUR; MAWF- MADINA WET FLOUR; MADF- MADINA DRY FLOUR; NEWF- NEWTOWN WET FLOUR; NEDF- NEWTOWN DRY FLOUR; NUWF- NUNGUA WET FLOUR; NUDF- NUNGUA DRY FLOUR