

# Assessment of Nine Micronutrients in Jasmine 85 Rice Grown in Ghana Using Neutron Activation Analysis

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## Abstract

The amount of micronutrients in food is a key factor that determines the health status of a person. The concentrations of nine micronutrients, Sodium (Na), Magnesium (Mg), Chlorine (Cl), Potassium (K), Calcium (Ca), Vanadium (V), Manganese (Mn), Copper (Cu) and Iodine (I), in polished Jasmine 85 rice, locally cultivated in five rice farming areas in Ghana (Afienya, Afife, Dawhenya, Ashaiman and Aveyime), were determined using Neutron Activation Analysis. The standard materials used as reference were the International Atomic Energy Agency (IAEA)-530 Tuna fish homogenate and the National Institute of Standard and Technology (NIST) USA 1566b Oyster Tissue. Recoveries of the elemental concentrations ranged from 88% to 111% of the certified values. Relative standardization method was used in the quantification of the elements. The range of concentrations measured in the rice are: 142.3-188.1 mg/kg for Na, 483.2-875.7 mg/kg for Mg, 465.6-718.0 mg/kg for Cl, 514.6-2949.0 mg/kg for K, 2303.0-2622.0 mg/kg for Ca, 0.0698-0.1925 mg/kg for V, 9.956-14.460 mg/kg for Mn, 0.8728-1.6790 mg/kg for Cu and 0.1181-0.1447 mg/kg for I. Using Hierarchical clustering analysis and Principal Component Analysis to evaluate the intensities of measured concentrations, K was established to be the most abundant, and was used to categorize two distinct clusters; Group 1 farms (Ashaiman, Afienya, and Dawhenya) and Group 2 farms (Aveyime and Afife). Group 2 farms recorded elevated intensities of micronutrients. With Pearson's correlation coefficient, some noteworthy correlations realized were between Na and K ( $r = 0.951$ ), Na and V ( $r = 0.842$ ) and K and V ( $r = 0.812$ ). This indicated the same or similar source inputs for each pair. The calculated mean daily intake of K exceeded the mean Recommended Dietary Allowable and Adequate Intake for all Life Stage Groups. Estimated health risk associated with the consumption of rice was only present for children between the ages of 1 and 3 for Mg. The information on these nine micronutrients content of the rice from these five farming areas would be valuable in rice consumption studies to evaluate the overall availability of micronutrients to the Ghanaian populace and age groups and also in nutrition planning for analysis of nationwide rice supplies, mainly for regions and countries known to be susceptible to deficiencies of these micronutrients. The techniques espoused in this research can be used to accurately determine the concentration of micronutrients in rice and also trace the area where the rice was produced.

**Keywords:** micronutrients, trace elements, Polished Jasmine 85 Rice, neutron activation analysis, recommended daily allowance, GHARR-1

## 1. Introduction

Rice is whole and a broken kernel obtained from the species *Oryza sativa* L and is the second-largest grain produced in the world (Codex, 1996; Abbas, Atiq-ur-Rahman, Manzoor and Farroq, 2015). Polished rice is rice that has been milled to take out the husk, bran, germ, and has diverse amounts of the nutrients contained in them, leaving a starch-rich grain or seed with a bright, white, shiny appearance. This modifies the flavor, quality, and look of the rice, and helps check spoilage and improve its shelf life (Thomas, 2019; White rice, 2019). Jasmine 85 is among the liked, and therefore extensively grown rice type in Ghana (Akintayo, Maalekuu, and Saajah, 2019). After maize, rice is currently the second most essential food staple in Ghana, with its intake increasing because of the growth in population. The nation's value of rice imports has escalated eight-fold in 7 years – from US\$152million in 2007 to a peak of US\$1.2billion in both 2014 and 2015 (Ghana Export Promotion

Authority, 2018). The per capita rice consumption in 2016/17 is estimated at about 35kg/year, with Ghana's population at 28.2 million (Global Agricultural Information Network, 2018).

Rice is the most eaten standard diet in the world supplying over 21% of the calorie intake of the world's populace. It is therefore necessary to know some of the micronutrients in it. A summary of the functions and effects of the nine micronutrients on the human body studied are as shown in Table 1.

Table 1. Functions and effects of the nine micronutrients on the human body

Element	Function	Adverse Effect of Deficiency	Adverse Effect of Excessive Consumption
<b>Na</b>	Major ion of the extra cellular fluid. Assists nerve impulse transmission	Hyponatremia; similar symptoms due to dehydration, and in extreme cases the brain may swell and may cause headaches, seizures, coma and even death	High blood pressure in susceptible people, can lead to an increase in loss of calcium in urine and increases the amount of water the body, thus causing the swelling of the legs and hands
(Health supplements nutritional guide, 2017;The National Academies, 2005; Palsdottir, 2016)			
<b>Mg</b>	Maintains normal nerve and muscle function, supports healthy immune system, keeps heart beat steady, and helps in strong bones, help regulate blood glucose levels and aids in the production of energy and protein.	Anorexia, confusion, delirium, rapid heartbeat, hallucinations, fatigue, insomnia, irritability, muscle twitching, numbness, poor memory, continued muscle contraction	Diarrhoea, abdominal cramping, nausea, stomach upset, vomiting, affects the cardiovascular system, muscle weakness and difficulty in breathing, affects the balance of other minerals in the body, changes in mental status
(Busse, 2015; National Health and Medical Research Council [NHRMC], 2015)			
<b>Cl</b>	Maintains proper blood volume and pressure, keeps amount of fluid in and around cells in balance, critical component of stomach hydrochloric acid, conserves potassium in body	Heavy sweating, congestive heart failure, over-hydration, Addison's disease, certain kidney disorders, most often seen in infants on chloride-deficient formulae	Coughing, symptoms of asthma such as wheezing and tightness of the chest, blurred vision, redness, and blisters on the skin, sensation of burning in the nose, throat, and eyes.
(Nutritional Health Resource, 2017)			
<b>K</b>	Help regulate fluid balance, blood pressure and water retention, nerve signals, and muscle contractions, protect against stroke and prevent osteoporosis and kidney stones.	Muscle weakness	Tiredness or weakness, feel some numbness or tingling, nausea or vomiting, difficulty in breathing, pain in the chest, palpitations or uneven heartbeats.
1 (Raman, 2017)			
<b>Ca</b>	Regulation of heartbeat and blood clotting, building and maintaining bones and teeth, helps body enzymes, help protect against over 10 different	Fainting, heart failure, brittle nails, chest pains, numbness and tingling sensations around the mouth, toes and fingers, wheezing, coarse hair, muscle cramps and weakness, bone fractures	Nausea, vomiting, constipation, muscle weakness, bone pain increased thirst or urination

	types of cancer, the most common being prostate, breast, lung and colorectal, helps in the release of neurotransmitters and contraction of muscles	and tooth decay, fatigue, cataracts, impaired intellectual capacity, seizures, depression, chronic itching, irritability / anxiety	
	(Sharecare, 2019; University Health News, 2019, Davis, 2019)		
<b>V</b>	Controls blood sugar levels, retards tumour growth.	Kidney and heart disease, low blood sugar levels.	Elevation in blood pressure, abdominal cramps, diarrhoea.
	(Murray, 2005; Tracey et al., 2007)		
<b>Mn</b>	Helps bone formation and the action of some enzymes such as those involved in carbohydrate metabolism	Obesity, birth defects, changes of hair colour, abnormal bone cartilage, growth retardation.	Neurotoxicity and elevated blood concentration, high incidence of pneumonia and other upper respiratory infections
	(Lenntech, 2019)		
<b>Cu</b>	Fixes calcium in the bones and to build and repair all connective tissue (tendons, ligaments, skin, hair, nails, arteries, veins).	Low libido in women and. Increases the lipid peroxidation in the heart in 2-folds.	Vomiting, nausea, sleep disorder, abdominal pain, homosexual desire, weakness, menstrual cramps, and metallic taste in the mouth,liver and kidney damage.
	(Nolan, 1983)		
<b>I</b>	Utilized by the thyroid gland for the biosynthesis of the thyroid hormones since every cell in the body depends upon thyroid hormones for its metabolism.	Abortions, Goitre, Stillbirths, Infant Mortality, Mental deficiency, anger, obesity, dwarfism, Congenital anomalies, Psychomotor defects, hypothyroidism.	Thyroid gland inflammation, same symptoms as iodine deficiency, including goitre (an enlarged thyroid gland) and thyroid cancer.
	(Koutras, <i>et. al.</i> , 1985; Delange and Burgi, 1999; U.S. Department of Health & Human Services, 2016)		

In this study, polished Jasmine 85 rice samples collected from five rice farms in five towns in Ghana, (Afienea, Afife, Dawhenya, Ashaiman and Aveyime), have been analyzed for nine elemental micronutrients content (Sodium (Na), Magnesium (Mg), Chlorine (Cl), Potassium (K), Calcium (Ca), Vanadium (V), Manganese (Mn), Copper (Cu) and Iodine (I)). . The technique being used in establishing the concentrations in the rice is Neutron Activation Analysis (NAA). The sources of these elements will also be ascertained by establishing the relationship between them if any.

Neutron Activation Analysis is a nuclear technique applied for determining concentrations of elements and allows for the distinct selection of elements as it discounts the chemical form of the sample and concentrates only on its nucleus. Its strengths are that it needs no chemical preparation, is non-destructive and has very low detection limits for many elements. It can also be used for small sample sizes (1–200 mg) and can be employed to analyze many of elements at the same time. On the order of nano-gram scale, this technique offers sensitivities better than that achieved by other procedures. It has been established as the ‘referee method’ as it is reliable and exact, and used when new procedures are to be developed or when other techniques produce diverse results (Ali, 1999). Comparatively, NAA is less expensive relative to other analytical methods (Vowotor *et al.*, 2012).

## 2. Materials and Methods

### 2.1 Study Area

Rice samples were obtained from different five rice farms in the south-eastern parts of Ghana (Figure 1). These are the main areas in Ghana that grow rice. Ashaiman is located between coordinates 5° 40’ and 5° 43’ N of latitude and longitudes 0° 05’ and 0° 07’ E. It is 26 km North-East of Accra located north of Tema on the northern borders

of Tema community in the Greater Accra region of Ghana. Afife is situated in the Volta Region of Ghana amid latitudes  $6^{\circ} 04'$  and  $6^{\circ} 08'$  and longitudes  $0^{\circ} 45'$  and  $0^{\circ} 55'$  East, 162 km east of Accra. Aveyime is found in the Volta region with a distance of 85 km from Accra. Afienea is a town 41.4 km from Accra in the same longitude with Ashaiman. Finally, Dawhenya, which is 6km from Accra and sharing the latitude with Ashaiman.

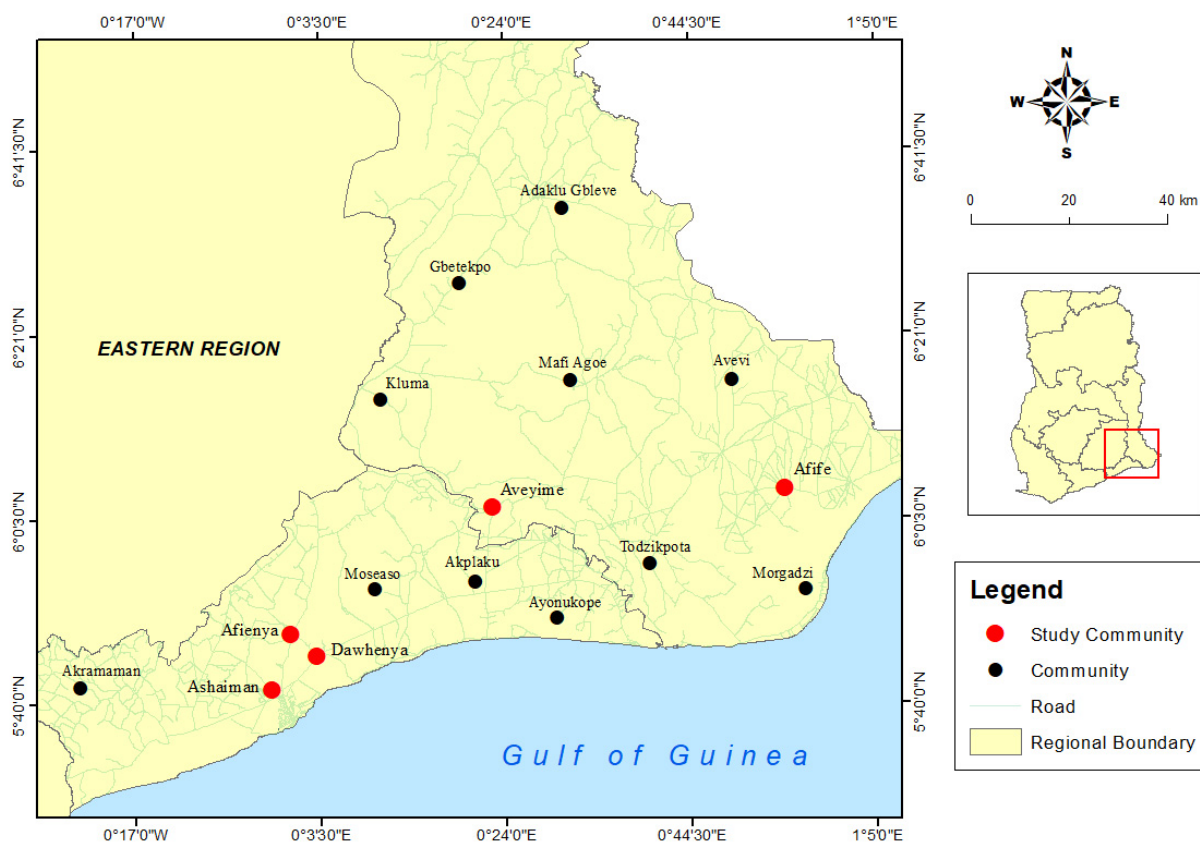


Figure 1. A map of towns in south-eastern Ghana with rice farms

### 2.1.1 Sampling and Sample Collection

The sampling equipment and containers were treated heavy metal-grade acetone before and after use. Additionally, all containers were rinsed with heavy metal-grade hydrochloric acid (HCl) before placing samples in them. Blank determinations were conducted for quality control. Polished Jasmine 85 Rice samples were randomly collected in three different areas within all the farm warehouses. At each farm, the three site-collected samples were put in one bowl and mixed together to form a composite sample. The composite polished Jasmine 85 Rice samples were then put into a plastic container, coded with a permanent marker and placed in a labeled Ziploc bag to avoid cross-contamination. They were then kept in a cool condition and sent to the Ghana Atomic Energy Commission (GAEC) Preparation Laboratory for analyses. During NAA (Figure 2), a neutron interacts with the target nucleus through a non-elastic collision, and a compound nucleus forms in an excited state.

## 2.2 Overview of Neutron Activation Analyses Technique Used

### 2.2.1 Neutron Activation Analysis

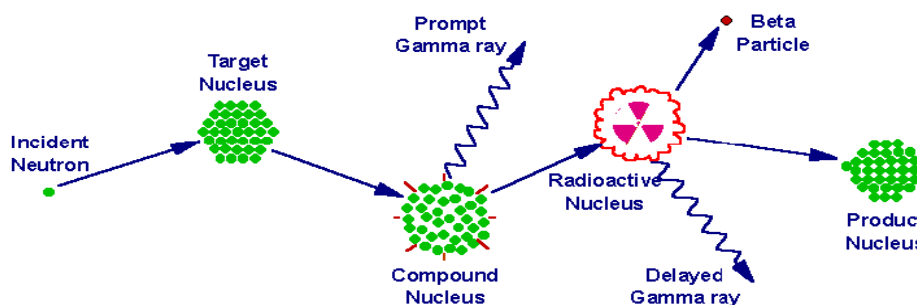


Figure 2. A process of neutron capture then the emission of gamma rays (Glascock, 2003)

The excitation energy of the compound nucleus is as a result of the binding energy of the neutron with the nucleus. The compound nucleus will almost immediately de-excite into a more stable form through the emission of one or more distinctive gamma rays. Most often, this new configuration produces a radioactive nucleus that also decays by the release of one or more typical delayed gamma rays. This is done at a much measured rate according to the half-life of the radioactive nucleus. Depending on the specific radioactive species, half-lives could range from a portion of a second to some years (Ali, 1999).

### 2.2.2 Relative Standardization

In using this method, a chemical standard (index std) of known mass,  $W_{std}$ , of the element is co-irradiated with the sample of unknown mass  $W_{sam}$ . When the samples to be irradiated are short-lived radionuclide, both the standard and sample are irradiated independently under the equal conditions, normally with a monitor of the same neutron fluence rate and both are tallied in the same geometrical arrangements with respect to the gamma-ray energy. The neutron flux, cross-section, irradiation times and all other parameters associated with counting are assumed to be the same for the standard and sample at a particular sample-to-detector geometry. With this assumption, the neutron activation equation then reduces to:

$$\rho_{sam} = \frac{\left[ \frac{(P_A/t_c)}{A} \right]_{sam} [\rho CDW]_{std}}{\left[ \frac{(P_A/t_c)}{A} \right]_{std} [CDW]_{sam}} \quad (1)$$

where  $(P_A/t_c)_{std}$  and  $(P_A/t_c)_{sam}$  are the counting rates for the standard and sample respectively,  $\rho_{std}$  and  $\rho_{sam}$  are the counting concentrations of the standard and the element of interest respectively,  $C_{std}$  and  $C_{sam}$  are the counting factors for standard and sample,  $D_{std}$  and  $D_{sam}$  are the decay factors for the standard and sample respectively.

### 2.3 Experimental Procedure

Fifty (50) mg in 3 replicates for each sample collected at each farm was weighed and packaged in a transparent polyethylene film. The samples were shaken to guarantee consistency before weighing, after which they were encapsulated into irradiation capsules (Rabbit capsule) of diameter 1.6cm and height 5.5cm and heat-sealed for neutron activation (irradiation).

To ensure quality assurance, IAEA-530, Trace element in tuna fish homogenate, Certificate of analysis standard material 1566b Oyster Tissue (National Institute of Standards and Technology) prepared in the same manner as the study samples were included. Recoveries of the elemental concentrations ranged from 88% to 111% of the certified values.

Table 2. Nuclear data of the seven elements

Element	Radioisotope	Gamma Ray Energy (keV)	Half-life	Irradiation Time	Counting Time	DL ( $\mu\text{g/g}$ )
<b>Na</b>	$^{24}\text{Na}$	2754.0	15 hr	10 mim	10 mim	0.001
<b>Mg</b>	$^{27}\text{Mg}$	1014.4	9.46 min	10 mim	10 mim	0.1
<b>Cl</b>	$^{38}\text{Cl}$	1642.4	37.3 min	10 mim	10 mim	0.001
<b>K</b>	$^{42}\text{K}$	1524.6	12.4 hr	10 mim	10 mim	0.01
<b>Ca</b>	$^{49}\text{Ca}$	3084.5	8.72 min	10 mim	10 mim	1.0
<b>V</b>	$^{52}\text{V}$	1434.1	3.76 min	10 mim	10 mim	0.001
<b>Mn</b>	$^{56}\text{Mn}$	1810.7	2.58 hr	10 mim	10 mim	0.0001
<b>Cu</b>	$^{66}\text{Cu}$	1039.2	5.1 min	10 mim	10 mim	0.01
<b>I</b>	$^{128}\text{I}$	440.9	25 min	10 mim	10 mim	0.0001

The samples and reference standards were irradiated in the GHARR-1 facility using light-water as moderator and coolant and operated at 15 kW and at a thermal neutron flux of  $5 \times 10^{11} \text{ ncm}^{-2}\text{s}^{-1}$ . The samples were transferred into the irradiation sites through a pneumatic transfer system at a pressure of 0.6 MPa (Tandoh, Bredwa-Mensah, Dampare, Akaho, and Nyarko, 2009). Irradiation times ranged from 10 s to 1 h depending on the half-lives of the elements of interest. All elements have relatively short half-lives such as Mg, Mn, and V, with half-lives between 2 min and 3h, irradiation time was 10 s and counting time 10 min. The samples were analyzed using irradiation schemes by optimizing irradiation time ( $t_i$ ), decay time ( $t_d$ ) and counting time ( $t_c$ ) based on the half-life of the respective elements. The irradiation scheme was ( $t_i$ :  $t_d$ :  $t_c$  = 0.5-2: 1: 10 min). The nuclear data of elements of interest have been summarized as shown in Table 2.

### 2.3.1 Qualitative and Quantitative Analysis

The qualitative study entails determination of the seven elements in the breast milk samples by the identification of the spectra peaks and assigning corresponding radionuclides and hence the elements present. The quantitative analysis involves the calculation of the areas under the peaks of the identified elements and converting them into concentrations using an appropriate software or equation(s) (Alfassi, 1994). The tallying of the induced radioactivity was carried out by a PC-based  $\gamma$ -ray spectrometry. This is made up of an n-type high purity Germanium (HPGe) detector (model GR2518) connected to a computer-based Multichannel Analyzer through electronic modules and a spectroscopy amplifier (model 2020, Canberra Industries Incorporated). The relative efficiency of the detector is 25% with energy resolution of 1.8 KeV at  $\gamma$ -ray energy of 1332 KeV of  $^{60}\text{Co}$ . The qualitative analysis was achieved by means of ORTEC EMCAPLUS Multichannel Analyzer (MCA) Emulation software. To analyse the spectrum, a Microsoft Window-based software, MAESTRO, was used (Adomako, Nyarko, Dampare, Serfor-Armah, Osae, Fianko, and Akaho, 2008), and was also used to identify the various photo peaks, and calculate the areas under them. The other quantitative measurements were done using the concentration equation (Equation 1) in a Microsoft Excel programme for calculating the elemental concentrations in  $\mu\text{g/g}$ . The detection limit (DL) of the detector for the various elements of interest has also been summarized in Table 2.

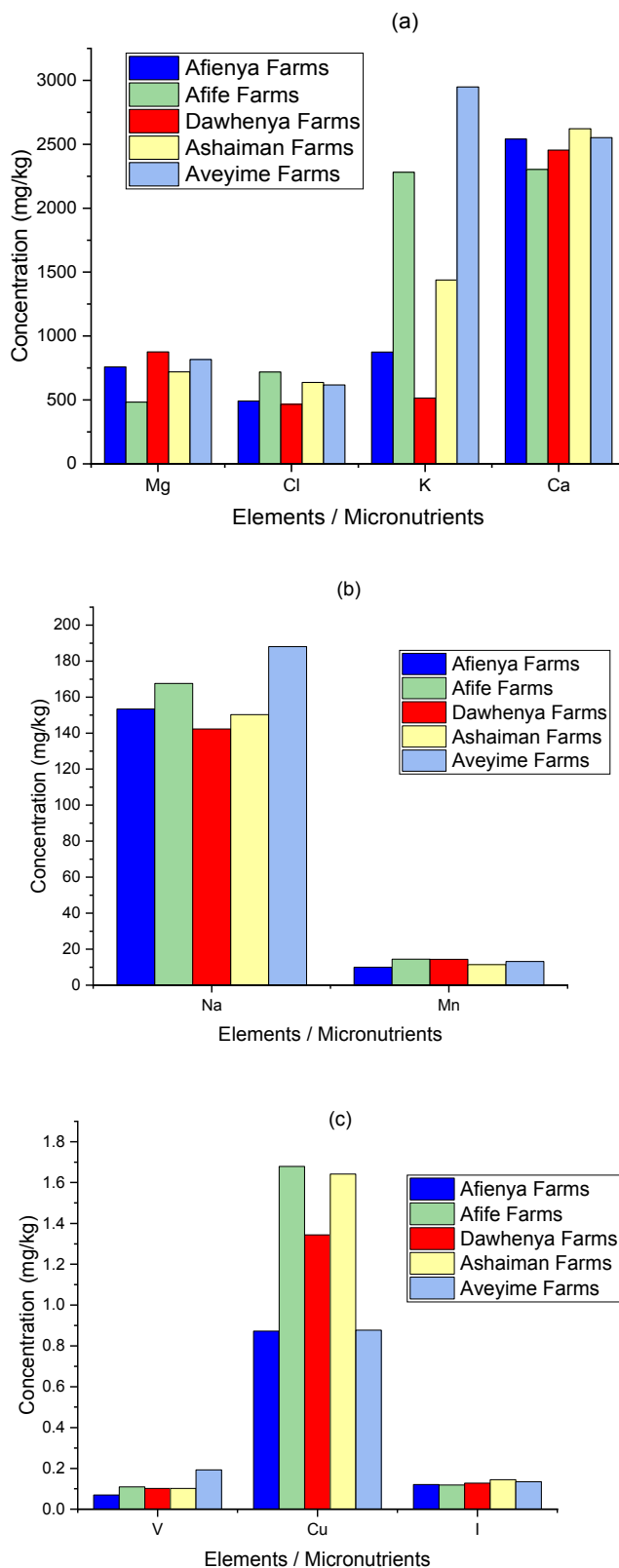


Figure 3. (a) Abundance of the individual elements (Mg, Cl, K and Ca) at the five farms  
 (b) Abundance of the individual elements (Na and Mn) at the five farms  
 (c) Abundance of the individual elements (V, Cu and I) at the five farms

### 3. Results and Discussions

The mean concentrations of Na, Mg, Cl, K, Ca, V, Mn, Cu and I at the five farms are presented in Figure 3.

#### 3.1 Statistical Analyses

The initial descriptive statistics used include mean, standard deviation (SD), and minimum and maximum values. A Pearson correlation analysis was conducted among the 9 micronutrients in the rice. Principal component analysis was also conducted on the basis of the correlation matrix. Based on Dietary Reference Intake, Daily Average Intake was calculated and finally, the Hazard Index was calculated to estimate the daily intake level of the nine micronutrients that is to be expected to be without detrimental effects in a Life Stage Group.

##### 3.1.1 Assessments Carried Out

##### 3.1.2 Assessment According to Micronutrient Concentration

Figure 3 shows the total average mean concentrations of the micronutrients in mg/kg. The elemental composition of a plant reflects the composition of the soil it is found in, or another nutrient medium. Plants are selective in their absorption of elements in a soil (Teherani, 1987), with their growth and maturity being dependent on the availability or otherwise, and the proportions in which micronutrients are present in the soil (Das, 2014). From Figure 3b, Rice from the Aveyime Farm has the highest quantity of Sodium while Dawhenya Farm recorded the least amount of Sodium concentration. On the other hand, Dawhenya had a maximum concentration of Magnesium while Afife had the least amount of Magnesium concentration. Although Afife Farms recorded the maximum amount of Chlorine concentration it also recorded the minimum amount of Calcium. Afife again had the minimum amount of Potassium and Calcium while Aveyime Farms and Ashaiman Farm recorded the highest amount of Potassium and Calcium respectively. The levels of Vanadium, Manganese, Copper, and Iodine were very low. Ghanaian foods have been observed to be very low in Iodine (Nyarko, Serfor-Armah, Akaho, Anim-Sampong, and Maakuu, 2002). Iodine deficiency has been identified as one of the factors that have an adverse effect on child development in developing countries (Walker et al., 2007). These deficiencies manifest as underdeveloped physical and mental growth as well as sterility, lethargy and cognitive injury (Aduand Simpson, 2017).

##### 3.1.3 Multivariate Analysis (Hierarchical Clustering Analysis (HCA))

Hierarchical clustering analysis (HCA) is a multivariate technique which examines the inter point distances between samples and presents the information obtained in a form of a two – dimensional plot called a dendrogram. HCA technique forms clusters (groups) for samples based on the nearest in row spaces (Beebe, Pell, & Seasholtz, 1998; Amuah, Eghan, Anderson, Adueming, & Opoku-Ansah, 2017). The approach initially treat search sample as a cluster and then join the closest cluster together. The process is repeated until only one cluster remains. Figure 4 shows the HCA carried out on the concentration data to determine if any pattern that characterizes or separates the micronutrients at the various farms could be established.

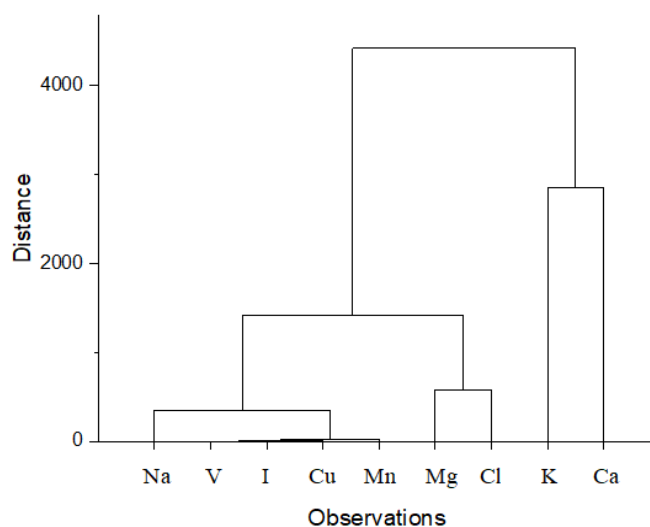


Figure 4. HCA results for the 9 micronutrients on the 5 farms

From Figure 4 two major clusters can be identified; Group 1 (K and Ca) and Group 2 (Na, V, I, Cu, Mn, Mg, and Cl). The inference, therefore, is that there is a common element that differentiates between these two groups. To



know this element, and possibly which of the farms have more or less of it, Principal Component Analysis (PCA) was used (Figure 5).

### 3.1.4 Multivariate Analysis (Principal Component Analysis)

Principal Component Analysis (PCA) is a technique for multivariate analysis in which new ‘axes’ called principal components (PCs) are constructed by forming linear combinations of original variables (measured parameter). The first PC or PC1 contains the maximum variance from the data; followed by PC2 and so forth (Bro & Smilde, 2014).

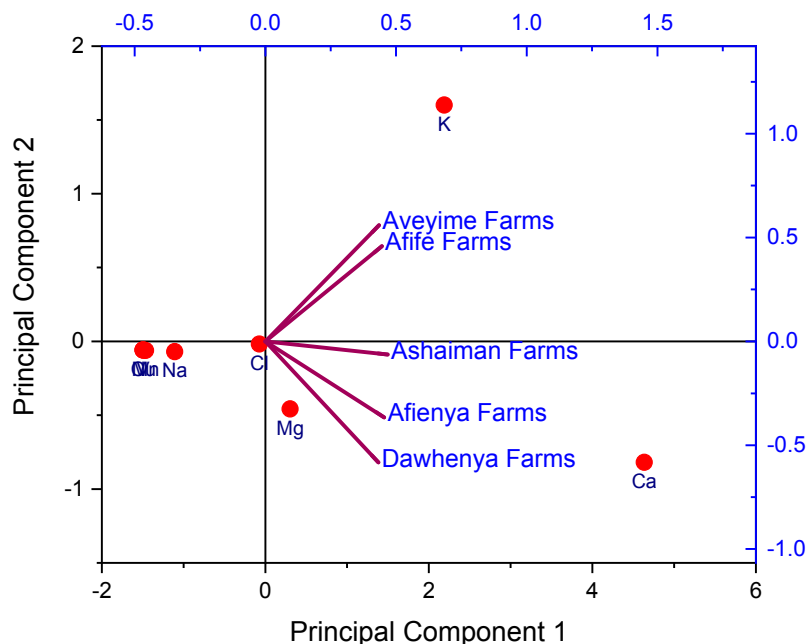


Figure 5. Biplot depicting the relationships between the farms (observations) and how the micronutrients (variables) contributed to the variations or similarities among the farms

A PCA score plot shows the levels of micronutrients are not the same in the rice for all farms. Two groupings can be identified in Figure 5. The first group of farms (Ashaiman, Afienya, and Dawhenya) are to the low or negative axis of the PC2 axis (vertical-axis) while the second group (Aveyime and Afife) are high or on the positive axis. It can be inferred that since the second group of farms is to the high side on the PC2 axis, then the major micronutrient causing the differences between these two groups is more in the second group (to the positive side on the PC2 axis) than the other group of farms to the negative side of the PC2 axis. The responsible micronutrient is K as it exhibits the maximum positive value along the PC2 axis. This is followed by Ca being the second responsible micronutrient exhibiting maximum positive value along the PC2 axis. The contribution of all the other micronutrient can also be inferred as follows  $K > Ca > Mg > Cl > Na > Mn > Cu > I > V$ .

The contribution of all the other micronutrients can also be inferred. The micronutrient positioned at the origin of the PC Biplot (Cl) have a neutral effect, whereas the micronutrients in the negative (Ca, Mg, Na, Mn, Cu, I and V) show an inverse relationship with the only micronutrient at the positive (K). None of the micronutrients positioned at the origin of the PC Biplot which means all the micronutrients were significant or does not have any neutral effect. Two other very useful deductions can be made from Figure 5. The first is that it is possible to trace the particular farm whose rice is based on the measured levels of micronutrients. For instance, a bowl of unknown rice which has high levels of I but relatively lower levels in Mg and Ca is most likely to come from Afienya farms or Dawhenya farms. The second deduction is that the type of micronutrients observed can be related to the activity that goes on around the farming area. For instance, apart from Aveyime farms and Afife farms which are high in K but low in the other micronutrients, Ashaiman farms, Afienya farms, and Dawhenya farms are high in all the micronutrients except K. It can also be inferred that since all the farms are to the right on the PC1 axis, then the major micronutrients running through the five farms are K, Mg and Ca. But the PC biplot has K as the most dominating micronutrient and is highly correlated with Na, Cl and V. These correlations are as shown in Table 3

and explained after the table.

### 3.1.5 Assessment according to Correlation between Elements

Pearson's correlation coefficient was used to draw parallels between any two of the micronutrients. The matrix between the elements, shown in Table 3, gives information about their possible sources (Currie, 1991; Alfassi, 1994). The correlation coefficient which is significant at 95% confidence level, and could indicate the same or similar source input is highlighted in red and discussed. Though 95% confidence level was used to ascertain the strength of their relationship, there are other strongly correlated elements with high coefficients of determination, hence they cannot be ruled out and are also highlighted in blue, green and black. The focus would be on the strength of the relationship and while reporting statistical significance (Pallant, 2007). The interpretation of the strength of the correlation coefficients usually depends on the researcher, however, there are suggested guidelines. A correlation coefficient exactly  $\pm 1.0$  depicts a perfect downhill/uphill (negative/positive) linear relationship;  $\pm 0.7$  indicates a strong downhill/uphill (negative/positive) linear relationship;  $\pm 0.5$  signifies a moderate downhill/uphill (negative/positive) relationship;  $\pm 0.3$  signifies a weak downhill/uphill (negative/positive) linear relationship and 0 indicates the absence of a linear relationship (Rumsey, 2010).

The seasonal variation in the chemical make-up of plants has been previously studied (Cannon, Papp, and Anderson, 1972; Sauchelli, 1969). The absorption of the elements from the soil is regulated by many factors like the amount in the lithosphere, the form of an element, the pH of the soil, the physical condition of the soil, temperature, moisture content, the genetic constitution of the plant type (Teherani, 1987). Plants at times undergo a phenomenon known as the Steenbjerg effect, where under acute deficiency conditions, it is likely that the decrease of the concentration of an element results in a small increase in growth (Bista, Heckathorn, Jayawardena, Mishra and Boldt, 2018). The intake of elements by plant roots consists of two phases: absorption and accumulation (Teherani, 1987). The interaction between ions can result in competition or competitive inhibition or in the stimulation of uptake (Hemphill, 1972). Discharges from groundwater are important sources of nutrients, trace elements and contaminants to many types of ecosystems (Kelly and Moran, 2002). It is therefore important to characterize each individual source of micronutrients and determine their input.

Table 3: Correlation matrix between the micronutrients in the rice samples

	Na	Mg	Cl	K	Ca	V	Mn	Cu	I
Na	1								
Mg	-0.195	1							
Cl	<b>0.549</b>	<b>-0.799</b>	1						
K	<b>0.951</b>	-0.380	<b>0.767</b>	1					
Ca	-0.078	<b>0.631</b>	-0.321	-0.131	1				
V	<b>0.842</b>	0.186	0.353	<b>0.812</b>	0.104	1			
Mn	0.189	-0.192	0.297	0.280	<b>-0.697</b>	0.399	1		
Cu	-0.361	<b>-0.589</b>	<b>0.534</b>	-0.066	-0.388	-0.286	0.427	1	
I	0.014	0.405	0.100	0.125	<b>0.780</b>	0.357	-0.195	0.118	1

Some of the significant correlations on Table 3 can be drawn between the micronutrients Na and K ( $r = 0.951$ ), Na and V ( $r = 0.842$ ) and K and V ( $r = 0.812$ ). These pairs could each indicate the same or similar source inputs.

The high levels of Mg in the rice may be as a result of the activities of car mechanics along the banks of the rice farms. Magnesium is again used as an anode material in primary batteries due to its high standard potential. Magnesium/manganese dioxide (Mg/MnO<sub>2</sub>) battery has twice the service life capability compared to zinc/manganese dioxide (Zn/MnO<sub>2</sub>) battery of the same size, and has a better ability to retain its capacity during storage, even at high temperature. Mg/MnO<sub>2</sub> battery is consequently more durable and better storable as it has a protective cover which is formed on the surface of the magnesium anode (Electrical4u, 2015). A critical screening of the debris along the farms revealed the presence of used, spoilt and discarded car batteries. This practice can explain the high levels of magnesium and manganese in the rice.

About 80% of vanadium turned out is exploited as a steel additive. Vanadium-steel alloys are tough and utilized for the construction of tools, armour plates, axles, piston-rods and crankshafts used in cars (Royal Society of

Chemistry [RSC], 2015). Manganese in its pure state is too brittle to be of much use and as a result used in alloys such as steel. Steel, which has improved workability and resistance to wear, contains about 1% manganese. Manganese-steel contains about 13% manganese (Royal Society of Chemistry [RSC], 2015). One can, therefore, infer that the high levels of Mn and V in the salt could be assigned to the same activities of car mechanics operating around the farms.

### 3.1.6 Assessment According to Dietary Reference Intake

Dietary Reference Intakes are a set of guiding principle for every day intake of nutrients (as vitamins, protein, and fats) and other food supplements (as fibre). It comprises suggested dietary allowances (RDA), adequate daily intake (AI), values for nutrients having undetermined recommended daily allowances and tolerable upper level (UL) values of dietary reference intake (DRI) (*Merriam-Webster Medical Dictionary, 2015*).

Recommended Dietary Allowable (RDA) is an intake level that meets specified criteria for adequacy, thereby minimizing the risk of nutrient deficiency or excesses. A Maximum Upper Intake Level (UL) is the maximum level of every day nutrient intake that is not likely to pose any adverse effect on health to an individual, and denotes complete intake from food, water, and other additions (Food and Nutrition Board, 2001; Institute of Medicine, 2001).

Adequate Intake (AI) is the suggested average daily nutrient ingestion level based on experimental approximations of nutrient intake by groups of apparently fit people who are thought to be maintaining a sufficient nutritional state. It is expected to meet the needs of most individuals in a specific life-stage and gender group (Institute of Medicine, 2001). The maximum Upper Limit (UL) of Recommended Dietary Allowable (RDA) and Adequate Intake (AI) for the Life Stage Groups of the elements investigated are presented in Table 1 in the Appendix.

Sodium is an electrolyte/mineral and a major ion of the extracellular fluid that aids nerve-impulse transmission (The National Academies, 2004; Nutritional Health Resource, 2010). For the most part, over 70% of dietary sodium is obtained from eating packaged and prepared foods and not from salt added to food during cooking or when eating. The Daily Value for sodium is less than 2,300 milligrams (mg) per day (US FDA, 2019).

Chlorine is an electrolyte that works with potassium and sodium to regulate the amount of fluids in the body and its pH (Minerals Education Coalition, 2013). Table salt and many vegetables such as celery, tomatoes, lettuce, and seaweeds are high-quality sources of chloride. The recommended daily dose of elemental Chlorine is 3400 mg per day (Lenntech B.V., 2019).

Practitioners are cautious to recommend oral Magnesium preparations as a result of its known side effect of causing diarrhoea. The suggested daily dose of elemental Magnesium is 400 mg per day, with a single dose of 800-1600 mg being essential to produce a laxative result (Fine, 1991; Gums, 2004; Nishizawa, Morii and Durlach, 2007). Food intake is the main source of Vanadium with its dietary intake estimated as 0.34 µg/kg (US EPA, 2015) and an Upper Tolerable Limit of 1.8 mg/day (ATSDR, 2012; US Institute of Medicine, 2001). Potassium is the third most abundant mineral in your body and plays a relevant part in several body functions. A variety of whole foods are rich sources of potassium, including beet greens, yams, banana, avocado, potatoes and spinach (Healthline, 2019). Its daily intake is 3500 mg (Lenntech B.V., 2019).

Studies have shown that both Calcium and Vitamin D are essential in building bone. Calcium can be found in many foods like Seafood and dairy (Harvard University, 2019). The recommended daily dose of elemental Calcium is 1000 mg per day (Lenntech B.V., 2019). Manganese is an essential nutrient/mineral that is found in several foods including nuts, legumes, seeds, tea, whole grains, and leafy green vegetables (U.S. National Library of Medicine, 2019). Its daily intake is 5 mg (Lenntech B.V., 2019).

Iodine is a vital trace element that plays a very important role in human physiological actions of thyroid hormones. Every cell in the body depends upon thyroid hormones for regulation of their metabolism and promotes growth and development in the body including the brain. (Endocrineweb, 2017). The leading preventable causes of brain damage, that is Iodine deficiency can significantly lower the intelligence Quotients (IQ) of a whole population. The most severe impact occurs during fetal development and in the first few years of life. Its consequence is derangement in the development of the brain and the central nervous system which is irreversible with the most serious for being that of cretinism (Chung, 2014). Iodine daily intake is 150 µg (Lenntech B.V., 2019).

Copper is present in organ-meat foods, seafood's, nuts, wheat bran cereals, whole grain and seeds. It is absorbed largely in the small intestine although some absorption may take place in the stomach. Absorption varies with copper intake ranging from more than 50% for intakes below 1 mg/day to less than 20% for intakes above 2 mg/day (Lenntech B.V., 2019). The very high levels of zinc or iron taken as supplements generally affects Cu absorption

in the body (Botash, Nasca, Dubowy, Weinberger and Oliphant, 1992; Morais, Fisberg, Suzuki, Amancio and Machado, 1994; Turnlund, 1999).

### 3.1.7 Calculating the Daily Average Intake based on Dietary Reference

Considering the per capita rice consumption in 2016/17 estimated at about 35 kg/year, with Ghana's population at 28.2 million (Global Agricultural Information Network, 2018), then an average daily rice intake is 95.8904 g/d. Using Pourgheysari formula presented in equation 2 (Pourgheysari, Moazeni, and Ebrahimi, 2012; Mahan and Escott-Stump, 2008; Ireland, Clifton and Keogh, 2010), the daily average intake of the micronutrients when one consumes rice from the five farms is calculated as Table 4.

$$\text{Daily Intake of Micronutrients} = \text{COMITR} \times \text{MRIGPD} \quad (2)$$

where COMITR is the concentration of micronutrients in the rice and MRIGPD is the mean rice intake (g/person/day)

Table 4. Calculated mean daily intake of the elements

	Mean Concentration of Elements (mg/kg)	Calculated Mean Daily Intake (mg/day)
Na	160.34	15.375
Mg	730.8	70.077
Cl	586.1	0.096
K	1611.702	652,593.484
Ca	2494.6	239.208
V	0.113	0.011
Mn	12.6732	1.215
Cu	1.2830	0.123
I	0.1293	0.012

The calculated mean daily intake of the nine micronutrients values in Table 4 were compared to the Mean and the Maximum Upper Limit (UL) of Recommended Dietary Allowable (RDA) and Adequate Intake (AI) for the all the Life Stage Groups (Tables 1A and 2A respectively in Appendix) and the difference in values presented in Tables 4A and 5A (also in the Appendix). It will be realised that all the calculated values did not exceed the mean and Upper Tolerable Limit of its RDA except K, for all Life Stage Groups. The calculate Mg and Ca also show a high value for infants between 0 to 6 months for normal RDAs but could not go beyond the UL for RDA. Mg for Children between 1 to 3 years and V for females between 9 to 18 years did also exceed the UL for RDAs. Finally, Mn for infants between 0 to 3 years was above the normal RDA values. To determine its effect on the health of the consumer the Health Risk was estimated by calculating the Hazard Index (HI).

### 3.1.8 Assessment According to Health Risk Estimation

The Hazard Index is calculated by comparing the estimated dose (ED) to the Reference Dose RfD (an estimate of a daily consumption level that is likely to be without deleterious effects in a lifetime). It is defined by equation 3 (Laar et al, 2011) as:

$$\text{The hazard index (HI)} = \frac{\text{ED}}{\text{RfD}}, \quad (3)$$

HI < 1 suggests an improbable unfavourable health effects whereas HI > 1 suggests the probability of adverse health effect (Laar et al, 2011). The calculated HI which estimates the health risk associated with the consumption of the rice is presented in Table 6A (in Appendix). It will be seen that apart from the sections that could not be determined due to lack of data (ND) all the calculated values for all the micronutrients were less than 1, suggesting there is no probability of adverse health effects for all life stage groups. The only HI > 1 was for Mg (children between the ages of 1 and 3). As said earlier all these elements investigated are essential to human health but can be toxic at concentrations higher than that necessary for the biological functions of the growth processes. Table 1 lists the functions of the elements in the human body and their effects when consumed in deficient or in excessive amounts.

#### 4. Conclusion

This work has imparted knowledge on the levels of Na, Mg, Cl, K, Ca, V, Mn, Cu and I present in Jasmine 85 rice grown in five farms in the South-Eastern part of Ghana. This rice type was studied because it is one of the most widely patronized rice by the local residents. The NAA method applied in the analysis of the reference materials IAEA-530 Tuna fish homogenate and NIST USA 1566b Oyster Tissue in order to check the accuracy and reproducibility. This method can accurately determine the content of these nine micronutrients in rice and can be used as traceability of producing area.

The dietary assessment done we hope has thrown more light on the nine micronutrients in the rice farms in the south-eastern part of Ghana. It is recommended that nutritionists; toxicologists and scientists of different background get together and look at the low levels of Iodine in the rice, since its deficiency disorder, IDD, among children may slow down the intentions of the educational restructuring programme and the nation's developmental efforts (Caulfield, Richard, Rivera, Musgrove, and Black, 2006). This will go a long way in helping the country to solve its nutritional and health-related problems.

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## Appendix

Table 1A. Measured concentrations of the 9 elements at the 5 Rice farms in mg/kg

Elements	Afienva Farms	Afife Farms	Dawhenya Farms	Ashaiman Farms	Aveyime Farms	Mean Value	SD Value
Na	153.4000	167.6000	142.3000	150.3000	188.1000	160.34	18.0120
Mg	759.3000	483.2000	875.7000	719.5000	816.6000	730.8	150.5019
Cl	492.0000	718.0000	465.6000	636.8000	618.1000	586.1	105.3176
K	875.2000	2281.0000	514.6000	1438.7057	2949.0000	1611.702	1001.539
Ca	2541.0000	2303.0000	2455.0000	2622.0000	2552.0000	2494.6	122.4308
V	0.0698	0.1091	0.1023	0.1020	0.1925	0.113	0.0482
Mn	9.9560	14.4600	14.3500	11.4700	13.1300	12.6732	1.9393
Cu	0.8728	1.6790	1.3440	1.6420	0.8771	1.2830	0.3945
I	0.1211	0.1181	0.1277	0.1447	0.1351	0.1293	0.0108



Table 2A. Recommended Dietary Allowable (RDA) and Adequate Intake (AI) for the Life Stage Groups (Food and Nutrition Board, 2001; Institute of Medicine, 2001)

Life Stage Group		Na	Mg	Cl	K	Ca	V	Mn	Cu	I
		<i>RDA/AI</i>	<i>RDA/AI</i>	<i>RDA/AI</i>	<i>AI</i>	<i>RDA/AI</i>	<i>AI</i>	<i>AI</i>	<i>RDA/AI</i>	<i>RDA/AI</i>
		(mg/d)	(mg/d)	(mg/d)	(mg/d)	(mg/d)	(mg/d)	(mg/d)	(mg/d)	(mg/d)
Infants	0-6months	120	30	180	400	200	ND	0.003	0.2	0.11
	7-12months	370	75	570	860	260	ND	0.6	0.22	0.13
Children	1-3y	1000	80	1500	2000	700	ND	1.2	0.34	0.09
	4-8y	1200	130	1900	2300	1000	ND	1.5	0.44	0.09
Males	9-13y	1500	240	2300	2500	1300	ND	1.9	0.7	0.12
	14-18y	1500	410	2300	3000	1300	ND	2.2	0.89	0.15
	19-30y	1500	400	2300	3400	1000	ND	2.3	0.9	0.15
	31-50y	1500	420	2300	3400	1000	NDN	2.3	0.9	0.15
	50-70y	1300	420	2000	3400	1000	D	2.3	0.9	0.15
	>70y	1200	420	1800	3400	1200	ND	2.3	0.9	0.15
Females	9-13y	1500	240	2300	2300	1300	ND	1.6	0.7	0.12
	14-18y	1500	410	2300	2300	1300	ND	1.6	0.89	0.15
	19-30y	1500	400	2300	2600	1000	ND	1.8	0.9	0.15
	31-50y	1500	420	2300	2600	1000	NDN	1.8	0.9	0.15
	50-70y	1300	420	2000	2600	1200	D	1.8	0.9	0.15
	>70y	1200	420	1800	2600	1200	ND	1.8	0.9	0.15
Pregnant	≤ 18y	1500	400	2300	2600	1300	ND	2.0	1	0.22
Women	19-30y	1500	350	2300	2900	1000	ND	2.0	1	0.22
	31-50y	1500	360	2300	2900	1000	ND	2.0	1	0.22
Lactation	≤ 18y	1500	360	2300	2500	1300	ND	2.6	1.3	0.29
Women	19-30y	1500	310	2300	2800	1000	ND	2.6	1.3	0.29
	31-50y	1500	320	2300	2800	1000	ND	2.6	1.3	0.29

Table 3A. Maximum Upper Limit (UL) of Recommended Dietary Allowable (RDA) and Adequate Intake(AI) for the Life Stage Groups (Food and Nutrition Board, 2001; Institute of Medicine, 2001)

Life Stage Group		Na	<sup>b</sup> Mg	Cl	<sup>d</sup> K	Ca	<sup>d</sup> V	Mn	Cu	I
		<i>RDA/AI</i>	<i>RDA/AI</i>	<i>RDA/AI</i>	<i>AI</i>	<i>RDA/AI</i>	<i>AI</i>	<i>AI</i>	<i>RDA/AI</i>	<i>RDA/AI</i>
		(mg/d)	(mg/d)	(mg/d)	(mg/d)	(mg/d)	(mg/d)	(mg/d)	(mg/d)	(mg/d)
Infants	0-6months	ND	ND	ND	ND	1000	ND	ND	ND	ND
	7-12months	ND	ND	ND	ND	1500	ND	ND	ND	ND
Children	1-3y	1500	65	2300	ND	2500	ND	2	1	0.2
	4-8y	1900	110	2900	ND	2500	ND	3	3	0.3
Males	9-13y	2200	350	3400	ND	3000	ND	6	5	0.6
	14-18y	2300	350	3600	ND	3000	ND	9	8	0.9
	19-30y	2300	350	3600	ND	2500	1.8	11	10	1.1
	31-50y	2300	350	3600	ND	2500	1.8	11	10	1.1
	50-70y	2300	350	3600	ND	2000	1.8	11	10	1.1
	>70y	2300	350	3600	ND	2000	1.8	11	10	1.1
Females	9-13y	2200	350	3400	ND	3000	ND	6	5	0.6
	14-18y	2300	350	3600	ND	3000	ND	9	8	0.9
	19-30y	2300	350	3600	ND	2500	1.8	11	10	1.1
	31-50y	2300	350	3600	ND	2500	1.8	11	10	1.1
	50-70y	2300	350	3600	ND	2000	1.8	11	10	1.1
	>70y	2300	350	3600	ND	2000	1.8	11	10	1.1
Pregnant	≤ 18y	2300	350	3600	ND	3000	ND	9	8	0.9
Women	19-30y	2300	350	3600	ND	2500	ND	11	10	1.1
	31-50y	2300	350	3600	ND	2500	ND	11	10	1.1
Lactation	≤ 18y	2300	350	3600	ND	3000	ND	9	8	0.9
Women	19-30y	2300	350	3600	ND	2500	ND	11	10	1.1
	31-50y	2300	350	3600	ND	2500	ND	11	10	1.1

**Note:**

<sup>b</sup>The UL for magnesium represents intake from a pharmacological agent only and does not include intake from food and water.

<sup>d</sup>Although vanadium in food has not been shown to cause adverse effects in humans, there is no justification for adding it to food.

Its supplements should be used with caution. The UL is based on adverse effects in laboratory animals and this data could be used to set an UL for adults but not children or adolescents.

ND = Not determinable due to lack of data of adverse effects in this age group and concern with regard to lack of ability to handle excess amounts. Source of intake should be from food only to prevent high levels of intake (Food and Nutrition, 2005).

Table 4A. Differences between the RDA / AI and the Calculated Means for the Life Stage Groups

Life Stage Group		Na	Mg	Cl	K	Ca	V	Mn	Cu	I
		<i>RDA/AI</i>	<i>RDA/AI</i>	<i>RDA/AI</i>	<i>AI</i>	<i>RDA/AI</i>	<i>AI</i>	<i>AI</i>	<i>RDA/AI</i>	<i>RDA/AI</i>
		(mg/d)	(mg/d)	(mg/d)	(mg/d)	(mg/d)	(mg/d)	(mg/d)	(mg/d)	(mg/d)
Infants	0-6months	-104.625	<b>+40.077</b>	-179.904	<b>+652193.484</b>	<b>+39.208</b>	ND	<b>+1.212</b>	-0.077	-0.098
	7-12months	-354.625	-4.923	-569.904	<b>+651733.484</b>	-20.792	ND	<b>+0.615</b>	-0.097	-0.118
Children	1-3y	-984.625	-9.923	-1499.9	<b>+650593.484</b>	-460.792	ND	<b>+0.015</b>	-0.217	-0.078
	4-8y	-1184.63	-59.923	-1899.9	<b>+650293.484</b>	-760.792	ND	-0.285	-0.317	-0.078
Males	9-13y	-1484.63	-169.923	-2299.9	<b>+650093.484</b>	-1060.79	ND	-0.685	-0.577	-0.108
	14-18y	-1484.63	-339.923	-2299.9	<b>+649593.484</b>	-1060.79	ND	-0.985	-0.767	-0.138
	19-30y	-1484.63	-329.923	-2299.9	<b>+649193.484</b>	-760.792	ND	-1.085	-0.777	-0.138
	31-50y	-1484.63	-349.923	-2299.9	<b>+649193.484</b>	-760.792	ND	-1.085	-0.777	-0.138
	50-70y	-1284.63	-349.923	-1999.9	<b>+649193.484</b>	-760.792	ND	-1.085	-0.777	-0.138
	>70y	-1184.63	-349.923	-1799.9	<b>+649193.484</b>	-960.792	ND	-1.085	-0.777	-0.138
Females	9-13y	-1484.63	-169.923	-2299.9	<b>+650293.484</b>	-1060.79	ND	-0.385	-0.577	-0.108
	14-18y	-1484.63	-339.923	-2299.9	<b>+650293.484</b>	-1060.79	ND	-0.385	-0.767	-0.138
	19-30y	-1484.63	-329.923	-2299.9	<b>+649993.484</b>	-760.792	ND	-0.585	-0.777	-0.138
	31-50y	-1484.63	-349.923	-2299.9	<b>+649993.484</b>	-760.792	ND	-0.585	-0.777	-0.138
	50-70y	-1284.63	-349.923	-1999.9	<b>+649993.484</b>	-960.792	ND	-0.585	-0.777	-0.138
	>70y	-1184.63	-349.923	-1799.9	<b>+649993.484</b>	-960.792	ND	-0.585	-0.777	-0.138
Pregnant	≤ 18y	-1484.63	-329.923	-2299.9	<b>+649993.484</b>	-1060.79	ND	-0.785	-0.877	-0.208
Women	19-30y	-1484.63	-279.923	-2299.9	<b>+649693.484</b>	-760.792	ND	-0.785	-0.877	-0.208
	31-50y	-1484.63	-289.923	-2299.9	<b>+649693.484</b>	-760.792	ND	-0.785	-0.877	-0.208
Lactation	≤ 18y	-1484.63	-289.923	-2299.9	<b>+650093.484</b>	-1060.79	ND	-1.385	-1.177	-0.278
Women	19-30y	-1484.63	-239.923	-2299.9	<b>+649793.484</b>	-760.792	ND	-1.385	-1.177	-0.278
	31-50y	-1484.63	-249.923	-2299.9	<b>+649793.484</b>	-760.792	ND	-1.385	-1.177	-0.278

Table 5A. Differences between the UL of the RDA / AI and the Calculated Means for the Life Stage Groups

		Na	<sup>b</sup> Mg	Cl	<sup>d</sup> K	Ca	<sup>d</sup> V	Mn	Cu	I
Life Stage Group		<i>RDA/AI</i> (mg/d)	<i>RDA/AI</i> (mg/d)	<i>RDA/AI</i> (mg/d)	<i>AI</i> (mg/d)	<i>RDA/AI</i> (mg/d)	<i>AI</i> (mg/d)	<i>AI</i> (mg/d)	<i>RDA/AI</i> (mg/d)	<i>RDA/AI</i> (mg/d)
Infants	0-6months	ND	ND	ND	ND	-760.79	ND	ND	ND	ND
	7-12months	ND	ND	ND	ND	-1260.79	ND	ND	ND	ND
Children	1-3y	-1484.63	<b>5.077</b>	-2299.9	ND	-2260.79	ND	-0.785	-0.877	-0.188
	4-8y	-1884.63	-39.923	-2899.9	ND	-2260.79	ND	-1.785	-2.877	-0.288
Males	9-13y	-2184.63	-279.923	-3399.9	ND	-2760.79	ND	-4.785	-4.877	-0.588
	14-18y	-2284.63	-279.923	-3599.9	ND	-2760.79	ND	-7.785	-7.877	-0.888
	19-30y	-2284.63	-279.923	-3599.9	ND	-2260.79	-1.79	-9.785	-9.877	-1.088
	31-50y	-2284.63	-279.923	-3599.9	ND	-2260.79	-1.79	-9.785	-9.877	-1.088
	50-70y	-2284.63	-279.923	-3599.9	ND	-1760.79	-1.79	-9.785	-9.877	-1.088
	>70y	-2284.63	-279.923	-3599.9	ND	-1760.79	-1.79	-9.785	-9.877	-1.088
Females	9-13y	-2184.63	-279.923	-3399.9	ND	-2760.79	<b>+0.011</b>	-4.785	-4.877	-0.588
	14-18y	-2284.63	-279.923	-3599.9	ND	-2760.79	<b>+0.011</b>	-7.785	-7.877	-0.888
	19-30y	-2284.63	-279.923	-3599.9	ND	-2260.79	-1.789	-9.785	-9.877	-1.088
	31-50y	-2284.63	-279.923	-3599.9	ND	-2260.79	-1.789	-9.785	-9.877	-1.088
	50-70y	-2284.63	-279.923	-3599.9	ND	-1760.79	-1.789	-9.785	-9.877	-1.088
	>70y	-2284.63	-279.923	-3599.9	ND	-1760.79	-1.789	-9.785	-9.877	-1.088
Pregnant	≤ 18y	-2284.63	-279.923	-3599.9	ND	-2760.79	ND	-7.785	-7.877	-0.888
Women	19-30y	-2284.63	-279.923	-3599.9	ND	-2260.79	ND	-9.785	-9.877	-1.088
	31-50y	-2284.63	-279.923	-3599.9	ND	-2260.79	ND	-9.785	-9.877	-1.088
Lactation	≤ 18y	-2284.63	-279.923	-3599.9	ND	-2760.79	ND	-7.785	-7.877	-0.888
Women	19-30y	-2284.63	-279.923	-3599.9	ND	-2260.79	ND	-9.785	-9.877	-1.088
	31-50y	-2284.63	-279.923	-3599.9	ND	-2260.79	ND	-9.785	-9.877	-1.088

Note: The negative sign (–) denotes that the values are below the RDA/AI or ULs, while the positive sign (+) denotes that the values are above the RDA/AI or ULs.

Table 6A. Health Risk Estimates Associated with the Rice collected from the 5 Farms for the Life Stage Groups

Life Stage Group		Hazard Index								
		Na	Mg	Cl	K	Ca	<sup>d</sup> V	Mn	Cu	I
Infants	0-6months	ND	ND	ND	ND	0.24	ND	ND	ND	ND
	7-12months	ND	ND	ND	ND	0.16	ND	ND	ND	ND
Children	1-3y	0.013	<b>1.078</b>	4.17E-05	ND	0.10	ND	0.608	0.123	0.06
	4-8y	0.008	0.637	3.31E-05	ND	0.10	ND	0.405	0.041	0.04
Males	9-13y	0.007	0.200	2.82E-05	ND	0.08	ND	0.203	0.025	0.02
	14-18y	0.007	0.200	2.67E-05	ND	0.08	ND	0.135	0.015	0.01
	19-30y	0.007	0.200	2.67E-05	ND	0.10	0.006	0.110	0.012	0.01
	31-50y	0.007	0.200	2.67E-05	ND	0.10	0.006	0.110	0.012	0.01
	50-70y	0.007	0.200	2.67E-05	ND	0.12	0.006	0.110	0.012	0.01
	>70y	0.007	0.200	2.67E-05	ND	0.12	0.006	0.110	0.012	0.01
Females	9-13y	0.007	0.200	2.82E-05	ND	0.08	ND	0.203	0.025	0.02
	14-18y	0.007	0.200	2.67E-05	ND	0.08	ND	0.135	0.015	0.01
	19-30y	0.007	0.200	2.67E-05	ND	0.10	0.006	0.110	0.012	0.01
	31-50y	0.007	0.200	2.67E-05	ND	0.10	0.006	0.110	0.012	0.01
	50-70y	0.007	0.200	2.67E-05	ND	0.12	0.006	0.110	0.012	0.01
	>70y	0.007	0.200	2.67E-05	ND	0.12	0.006	0.110	0.012	0.01
Pregnant	≤ 18y	0.007	0.200	2.67E-05	ND	0.08	ND	0.135	0.015	0.01
Women	19-30y	0.007	0.200	2.67E-05	ND	0.10	ND	0.110	0.012	0.01
	31-50y	0.007	0.200	2.67E-05	ND	0.10	ND	0.110	0.012	0.01
Lactation	≤ 18y	0.007	0.200	2.67E-05	ND	0.08	ND	0.135	0.015	0.01
Women	19-30y	0.007	0.200	2.67E-05	ND	0.10	ND	0.110	0.012	0.01
	31-50y	0.007	0.200	2.67E-05	ND	0.10	ND	0.110	0.012	0.01

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