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Arsenic concentration in rice grown from three local government areas of Kano, Nigeria

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Arsenic (As) in food and water has been linked to cancers and other diseases. Rice is of interest because many types may contain higher contents of As than other foods of terrestrial origin. As concentrations in rice produced from three Local Government Areas of Kano State were determined using Atomic Absorption Spectrophotometer. The mean As concentrations were 0.369 ± 0.092, 0.293 ± 0.126, and 0.255 ± 0.125 mg/kg in Kura, Tudun Wada, and Bagwai Local Government Areas of Kano State, respectively. The mean concentrations were all above the maximum limit of 0.2 mg/kg set by Alimentratious Commission (2014) and Commission Regulation (EU, 2015). Analysis of variance (ANOVA) revealed that there is no significant difference in mean concentration of As (mg/kg) among the three local government areas.

Key words: Rice, arsenic, Kura, Tudun Wada, Bagwai.

INTRODUCTION

Arsenic (As) is a chemical element widely distributed in the earth crust. It is released from volcanoes and from the erosion of mineral deposits and is found throughout the environment. Human activities also add arsenic to the environment, through the burning of coal, oil, gasoline and wood, mining and the use of As compounds such as pesticides, herbicides, and wood preservatives (Singsby et al., 2007).

As is a contaminant which exists in both toxic and non-toxic forms. Inorganic As species (asernite (As^{III}) and asernate (As^{V})) are more toxic than organic As (monomethyl As acid (MMA) and dimethyl As acid (DMA) (Ji-Young et al., 2013).

Rice is the main food for over half of the world's population owing to its nutritive properties and relatively low cost (Williams et al., 2008). Rice is the predominant food in at least thirty three developing countries (including Nigeria). It is a good source of carbohydrate providing 27% of dietary energy supply (Kennedy et al., 2015). The protein component in rice is relatively low (7 to 9% by weight), but it forms a major source of protein (50%) in these countries (Chammannejadian et al., 2013). Rice can contribute significant amount of thiamine, riboflavin, niacin, and zinc to the diet and smaller amounts of other micronutrients (Kennedy et al., 2015).

As is taken up by plants from the water and soil when they are growing (Tritscher, 2014). While most crops do not readily take up As from the ground, rice easily absorbs the toxins from soil or water. This is primarily because it is grown in water flooded conditions,

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Table 1. Commission Regulation EU 2015/1006 as regards maximum level of inorganic arsenic in food stuffs amended Annex to Regulation (EU) No. 1881/2006.

Parameter	Inorganic Arsenic
Non parboiled milled rice (polished or white rice)	0.2
Parboiled rice and husked rice	0.25
Rice waffles, rice wafers, rice crackers and rice cakes	0.30
Rice destined for the production of food for infants and young children	0.10

which allows arsenic to be more easily taken up by roots and stored in grains. Therefore, a key problem is paddy fields irrigated with water pumped from shallow wells containing As-rich sediments (Codex Alimentarius Commission, 2014). Thus, rice could be considered an important contributor to total As intake in many parts of the world, where the diet is rice based (Liorente et al., 2012). Furthermore, it is estimated that the As content of rice is over 10 times greater than that found in cereal (Liorente et al., 2012).

As in food and water has been linked to cancers and other diseases like heart disease, stroke, chronic lower respiratory diseases, diabetics and damage to the nervous system and brain. The final result of arsenic poisoning is coma and death (Agrawal, 2012; Green Facts, 2016).

The determination of inorganic As species in food has become very important during the last few years, when As(III) and As(V) were reported to be class one human carcinogenic and found at high concentration in rice and rice-products. Therefore, from the health point of view, rice is of interest because many types may contain higher contents of As than other foods of terrestrial origin (Liorente et al., 2012).

Since rice is a very important staple food for many countries and many regions of the world, a significant part of the global population is affected (Tritscher, 2014). United Nations have agreed to set the first international tolerable standard in order to limit cancer causing As pollution in rice, a key move to protect billions consumers (UN, 2014).

There have been a number of reports concerning the level of As found in rice and rice products. Yonkers (2012) has recommended that people should limit their rice consumption, after finding As in more than 60 rice products tested in U.S.A. Consumer report group is urging the US government to set limit on As in rice.

Since the analysis of inorganic As is reliable for rice and rice based products, maximum levels for inorganic As should be set (EU, 2015). Codex Alimentarius Commission (CAC), at their annual meeting held in July, 2014 set a maximum of 0.2 mg of As per kg of polished rice. Commission Regulation EU 2015/1006 as regards maximum level of inorganic arsenic in food stuffs amended Annex to Regulation (EU) No. 1881/2006 as shown in Table 1. The commission suggested that the amendment should be effective from January, 2016.

This paper aims to report the concentration of As in rice produced from Tudun Wada, Kura and Bagwai Local Government Areas of Kano State, during the wet season. The objectives of the study includes, comparison of the contents of As in rice between the three local government areas; findings would also be compared with the maximum permissible limit and other published results to ascertain if the study reveals normal and/or threat to health relative to the content of As in the rice samples. Statistical computation (ANOVA) would also be carried out to fix significant difference.

MATERIALS AND METHODS

Sampling

Thirty rice samples were collected from ten different farms at various villages of Tudun Wada, Bagwai and Kura Local Government Areas during the raining season.

Sample preparation

Each sample was dried at 105°C in an oven and ground to fine powder using porcelain motor and pestle.

Sample digestion

Each sample powder (1 g) was weighed and transferred into 500 cm^3 beaker. Aqua regia (30 cm^3; HCl, HNO_3 and H_2O in the ratio of 1:1:5) was added to each of the samples. The mixture was heated at 120°C for about 5 h using hot plate. It was then filtered and transferred into 50 cm^3 volumetric flask and made up to the mark with deionized water.

Preparation of calibration standard

As stock solution (100 mg/L) was prepared by drying 0.132 g of AS_20_3 powder at 105°C for 5 h. The dried powder was then dissolved in 5 cm^3 of NaOH solution. The solution was neutralized with 10 cm^3 diluted H_2SO_4 (1:20). The solution was transferred into 1000 cm^3 volumetric flask and made up to the mark with freshly boiled and cooled deionized water 0.00, 0.10, 0.20, 0.30, 0.40, 0.50, and 0.60 mg/L As solutions were prepared from 50 mg/L (50 cm^3 of 1000 mg/L stock solution diluted to 1000 cm^3) by serial dilution (Nall, 1971; Jill, 2016).

Arsenic determination

As level of all digested samples and working standards were

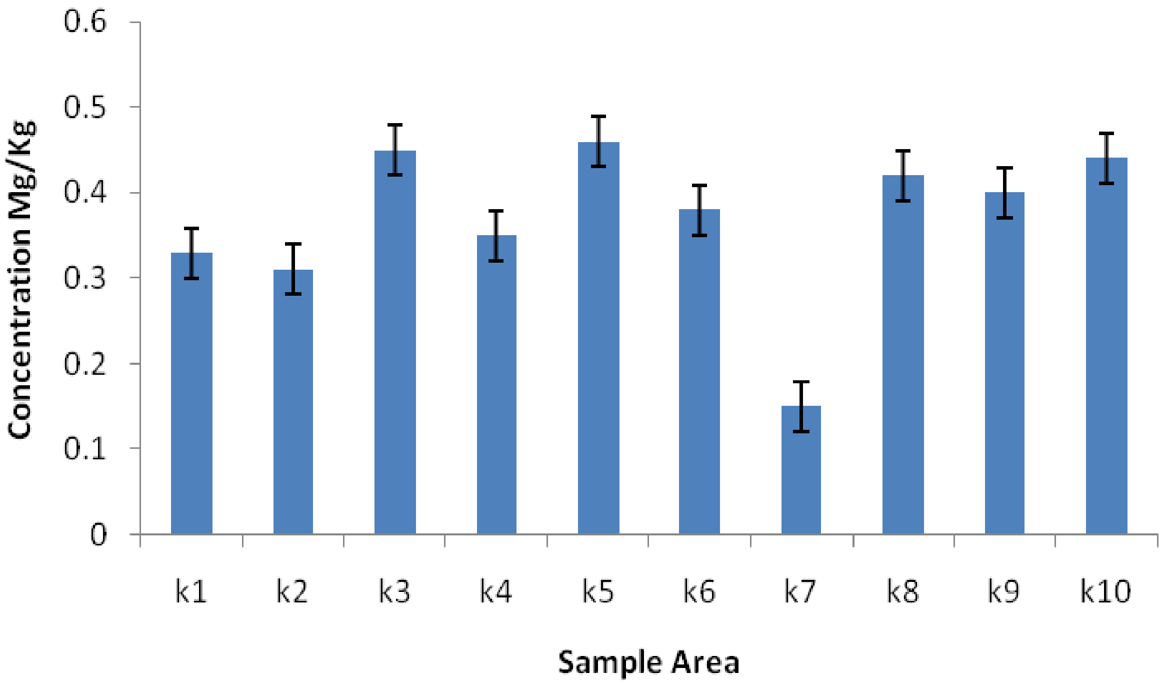

Figure 1. Bar chart showing Arsenic (As) concentrations in rice produced in Kura LGA sampling area.

measured using Buck Scientific Model 210/211 VGP Graphite Furnace Atomic Absorption Spectrophotometer. The concentration of As in each sample was obtained from the calibration plot by interpolation.

Statistical computation

Statistical computations were carried out using integrated statistical package for windows. Analysis of variance (ANOVA) was carried out on the results.

RESULTS AND DISCUSSION

As content in different samples of rice produced from Tudun Wada, Kura and Bagwai Local Government Areas were determined using Atomic Absorption Spectrophotometry.

The bar chart (Figure 1) represents the concentration of As in rice from ten different sampling areas in Kura Local Government Area. It is evident from the chart that the concentrations were of the order $K_5 > K_3 > K_{10} > K_8 > K_9 > K_6 > K_4 > K_1 > K_2 > K_7$. Rice obtained from sampling area K_7, has a much lower As content that falls below the maximum limit.

The concentration in the sampling area in Tudun Wada Local Government (Figure 2) were of the order $T_3 > T_2 > T_8 > T_4 > T_5 > T_1 > T_6 > T_9 > T_{10} > T_7$ with T_3 having the highest content and K7 much lower content, samples T7, T9 and T10 falls within the safe level. While the level in the sampling areas from Bagwai is as shown in Figure 3. The order is $B_6 > B_7 > B_8 > B_3 > B_5 > B > B_9 > B_2 > B_1 > B_{10}$. Samples B_1, B_2, B_9 and B_{10} were within the safe level (that is, below 0.2 mg/kg).

The mean and standard deviation of As concentration in Kura, Tudun Wada and Bakwai Local Government Areas were 0.369 ± 0.092, 0.293 ± 0.126 and 0.055 ± 0.125 mg/kg, respectively. The mean concentration was all a little above the maximum limit of 0.2 mg/kg set by Alimentarious Commission, United Nations (UN, 2014) and Commission Regulation (EU, 2015).

Kura Local Government has the highest As content followed by Tudun Wada Local Government, while samples obtained from Bagwai has the least content. However, analysis of variance (ANOVA) revealed that there is no significant difference in mean concentration of Arsenic (mg/kg) among the three local government areas (Table 2).

These results are similar to those reported by Williams et al. (2005), Nishimura et al. (2010), Yamil and John (2008) but in contrast to other authors (Liorente et al., 2012; Nookabkaew et al., 2013) who reported higher values in their regions (Table 3).

Conclusion

Human exposure to toxic elements has been the topic of increasing attention among researchers, formulators and managers of health and nutritive policies due to its damages to health (Ayodele and Bayero, 2010).

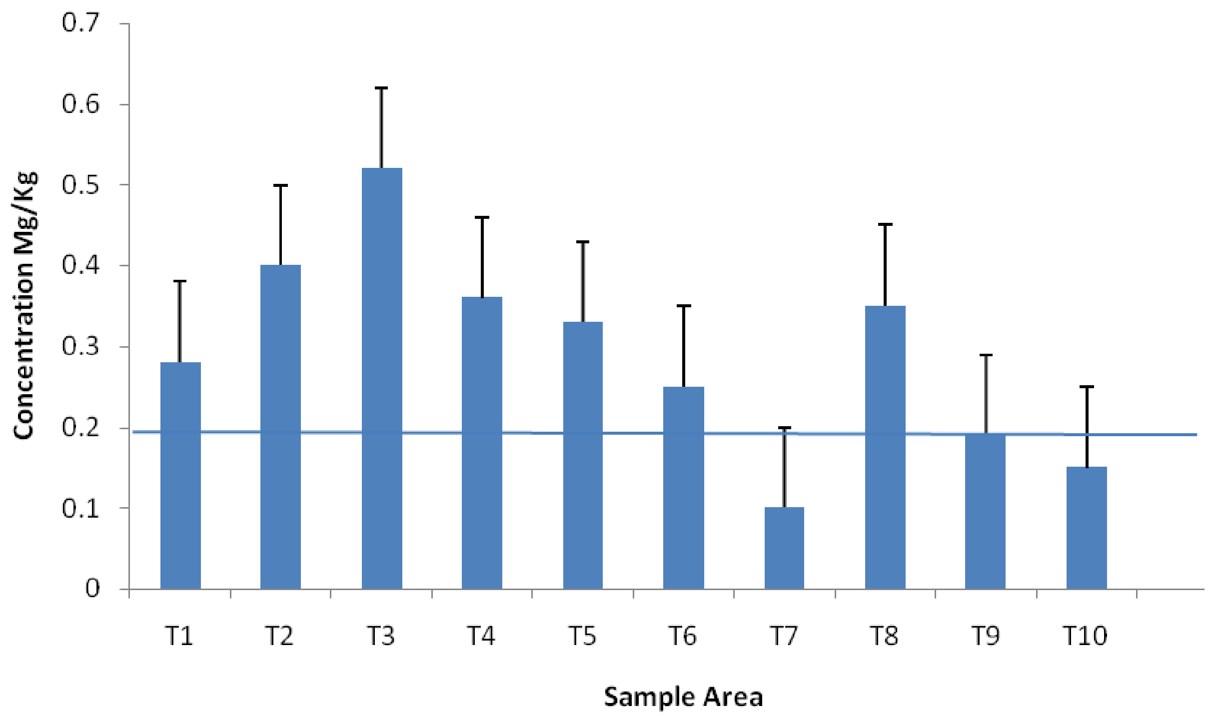

Figure 2. Bar chart showing As concentrations in rice produced in Tudun Wada Local Government Area sampling areas.

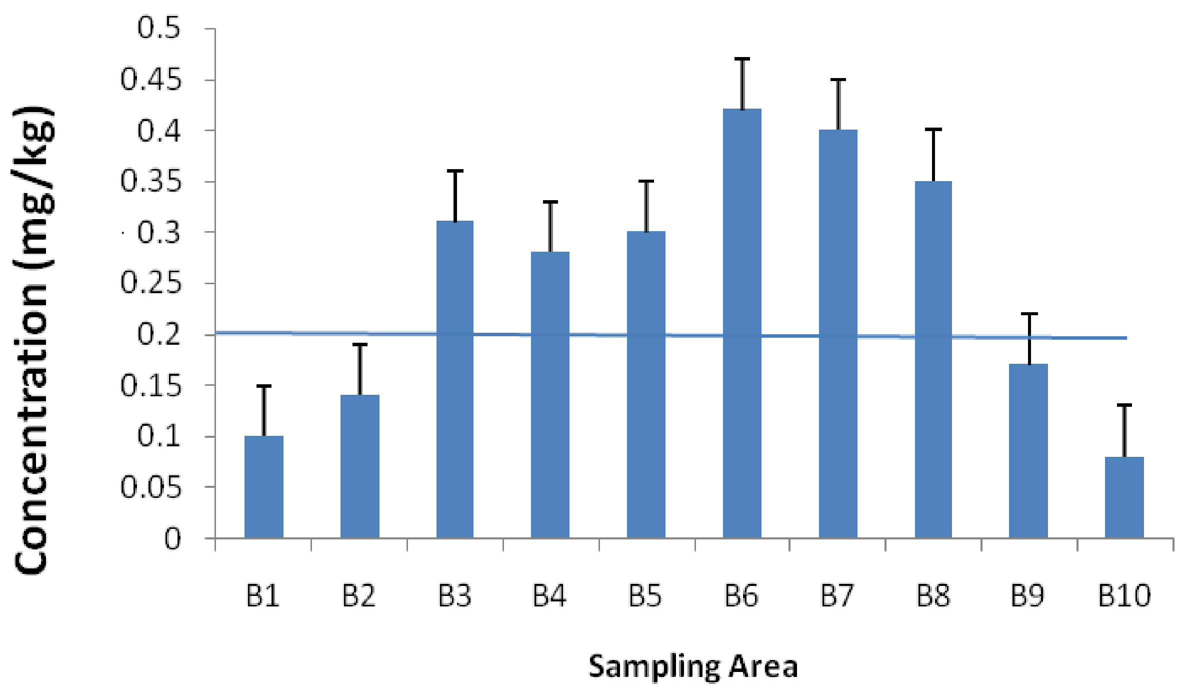

Figure 3. Bar chart showing Arsenic (As) concentration in rice produced from Bagwai LGA sampling area.

The results obtained in this study revealed that the mean concentrations of As in rice from the three local government areas were all above the maximum limit set by the Alimentarious Commission, United Nations (UN, 2014) and Commission Regulation (EU, 2015).

However, the levels in some sampling areas were

Table 2. Analysis of variance for As between the three Local Government Areas.

Area	Descriptive Arsenic sample							
	N	Mean	Std. deviation	Std. Error	95% Confidence interval for mean		Minimum	Maximum
					Lower bound	Upper bound		
T/Wada	10	0.2930	0.12579	0.03978	0.2030	0.3830	0.10	0.52
Bagwai	10	0.2550	0.12385	0.03916	0.1664	0.3436	0.08	0.42
Kura	10	0.3690	0.09243	0.02923	0.3029	0.4351	0.15	0.46
Total	30	0.3057	0.12102	0.02210	0.2605	0.3509	0.08	0.52

	ANOVA Arsenic sample				
	Sum of squares	Df	Mean square	F	Sig.
Between groups	0.067	2	0.034	2.546	0.097
Within groups	0.357	27	0.013	-	-
Total	0.425	29	-	-	-

Table 3. Typical results of As in rice reported by several authors.

S/N	Country	Concentration (Mean/Range)	Unit	References
1	-	40.1 - 323.7	µg/kg	Liorente at al. (2012)
2	USA	0.26	µg/g	Williams et al. (2005)
3	Japan	0.04 - 0.54 (Total As) 0.02 - 0.41 (Inorganic As)	mg/kg	Nishimura et al. (2010)
4	Thailand	22.51 - 375.39 (Total As) 13.89 - 233.62 (Inorganic As)	µg/kg	Nookabkaew et al. (2013)
5	Bangladesh	0.31 - 0.70	mg/kg	Yamil and John (2008)
6	China	0.03 - 0.04	mg/kg	Yamil and John (2008)
7	India	0.10 - 0.76	mg/kg	Yamil and John (2008)
8	Taiwan	0.11 - 0.66	mg/kg	-
9	US	0.03 - 0.47	mg/kg	-
10	Vietnam	0.08 - 0.47	mg/kg	-
11	Kano, Nigeria	Kura Local Govt - 0.369 ± 0.092mg/kg T/Wada Local Govt - 0.293 ± 0.126mg/kg Bagwai Local Govt - 0.255 ± 0.125mg/kg	mg/kg	Present study

below the limit (that is, within the safe level). Comparing the levels of As between the three local government areas, ANOVA revealed that there is no significant difference.

RECOMMENDATIONS

(1) Measures should be taken to avoid irrigation of rice in an environment contaminated with As by constantly monitoring its level in water and soil, as rice is grown in water flooded condition.
(2) People should limit rice consumption to avoid accumulation of the toxic element.
(3) Government should set a monitoring committee to encourage collaboration between the farmers and researchers.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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