

Determination of Arsenic Content in Different Brands of Rice Sold in Port Harcourt, Nigeria.

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ABSTRACT

Arsenic, a naturally occurring element seen in the environment and cycled by water has been seen to be a pollutant in soil, water and air. The inorganic form of arsenic is associated with major health problems and cancer mainly arising due to its anthropogenic activities. The content of arsenic was assayed in six rice brands sold in Port Harcourt, Rivers State, Nigeria. The rice samples were ground to powdered forms and subjected to acid digestion before analysis. The Agilent Micro Plasma Atomic Emission Spectrophotometer (MP-AES) was used to analyze the digested samples. Results showed mean arsenic concentration in Vico Rice, the highest as 1.0073. This was followed by Local Rice 0.9420, Marori Benz 0.9140, Golden Stallion Rice 0.861 and the Cap Rice 0.8077 while the least mean concentration of arsenic was recorded in African Princess Rice 0.6417, all in mg/kg. The mean concentration was significantly different in the six brands of rice ($P < 0.05$). The arsenic content in the different rice brand was within the tolerable concentration of 1.4 mg/kg as in cereals and vegetables. This concentration did not exceed the Maximum Permissible Limit of 1 mg/kg hence considered safe for consumption except Vico rice with a higher concentration above 1 mg/kg. This shows that rice brands sold in Port Harcourt pose no health risk for consumers with respect to arsenic content.

Key Words: Rice Brand, Arsenic Concentration, Port Harcourt

1. INTRODUCTION

Rice (*Oryza sativa*), the second most prevalent cereal in the world is a staple food that is mainly the people's diet. It is the source of about 72% calorie and 66% of the protein in its entire nutritive content [1]. Its global importance cannot be overemphasized especially in the Asian, Caribbean, and Sub-Saharan Africa [2] where there is a higher need for its consumption as a staple food and serves as a major source of their economy.

Despite the fact that Nigeria accounts for about 44% of rice production in West Africa [3], the demand for rice still outweighs the local production, hence, need for importation from countries like India, Thailand, China, etc [4].

Rice is often grown around flooded areas covered with water of irrigation or in paddies that may be contaminated with arsenic thus raising a serious environmental and health concern to humans [5, 6, and 7]. Arsenic is naturally present in the environment. A mineral seen in the earth crust found in soil, water,

plants, and animals. However, humans complicated the issue of pollution by adding more arsenic to the soil through the application of pesticides and fertilizers, discharge of industrial waste into water, mining and smelting activities, coal burning, etc. [8, 9]. Consumption of staple food such as rice is grown in some contaminated soil which might be attributed as a tangible route of human exposure to arsenic. Arsenic (As) can be found in food because of its presence in the soil, air and water environment which might be taken up by crop plants. Arsenic can exist in the inorganic, organic and gaseous forms. The inorganic form of arsenic has been implicated to be the major cause of both cancerous and non-cancerous health related problems due to its toxicity. Examples of such disease include Blackfoot disease [10], hyperkeratosis, conjunctivitis, cardiovascular [11], and cancer of the bladder, skin, lung, liver, and kidney which can result from continuous consumption of elevated levels of arsenic from drinking water however, consumption of even low levels of arsenic over a long period can cause a multitude of diseases [12].

In recent decades, millions of people have suffered from arsenic poisoning as a result of drinking arsenic contaminated water extracted from shallow tube wells in South and South East Asia [13]. Moreover, the presence of arsenic in drinking water has reached calamitous proportion in many parts of the world [14]. The presence of such water on agricultural soils can be a major source of arsenic uptake by crop plants. Moreover, excess uptake of arsenic by crops may present food safety problems. The organic species (monomethylarsonic acid, MMA, and dimethylarsenic acid, DMR) are common metabolites found in the human body which are less harmful and readily eliminated by the body [9]. They are mostly found in kinds of seafood. Moreover, arsenic pollution is of environmental concern because the inorganic form is not easily biodegradable, hence may affect the biological systems in humans, and animals [15] even when they may be present in very low concentration in food and drinking water.

The inorganic forms of arsenic is generally considered more toxic and of public health concern while the organic form though non-toxic is believed to be a promoter for cancer [13] especially in rice. Studies have reviewed alarming levels of arsenic in rice and human exposure to these heavy metals through food needs to be checked and averted to reduce serious health complications and challenges. Ratnaike [16] and Vahidnia et al. [17] highlighted arsenic toxicity and poisoning, coupled with the global issue that rice can be poisonous [18] because rice has been found to absorb more arsenic than other food crops [19]. Therefore, it is of importance in this study to evaluate the content of arsenic in some rice brands sold and consumed within Port Harcourt Metropolis, Rivers State, Nigeria.

2. MATERIALS AND METHODS

Rice Collection: A total of six brands of rice were bought within Port Harcourt metropolis. Vico rice, Marrori Benz rice, Golden Stallion rice, Caprice and African Princess Rice are all produced from Thailand while the local rice is in Nigeria. Three different samples were collected from each of the brands of rice as representative samples. The rice grain samples were ground using an electric blender to fine powdered form which was placed in airtight plastic containers and refrigerated at $\leq 4^{\circ}\text{C}$ until analysis. Each sample was properly labeled accordingly. The Micro Plasma -Atomic Emission Spectroscopy (MP-AES), equipment model 4210 manufactured by Agilent Technology was used for the quantitative determination of arsenic concentration using the API-RP 45 method. All analyses were performed consistently with quality assurance program and analytical procedures performed in the laboratory were validated in accordance with standards provided.

Digestion: The Hot plate aqua regia digestion procedure using HCl: HNO₃ (3:1 v/v) was used. The HCL and HNO₃ are of analytical grade. Accurately weighed 1 gram of well-pulverized rice grain was placed in

a 25 ml beaker followed by the addition of 10mL of concentrated HNO₃ and allowed to stand overnight. The mixture was heated slowly at a low temperature on a hot plate until the production of red NO₂ fumes has stopped. The beaker was then allowed to cool, followed by the addition of 4 ml of 70% HClO₄. It was heated again slowly at a low temperature and allowed to evaporate to a small volume of the mixture. The remaining quantity was then transferred to a 50 ml flask and diluted to volume mark with distilled water. This was then aspirated into the equipment for the analysis.

Statistical Analysis: The results were expressed as Mean ± Standard Deviation (SD). Data were computed to check for statistical significance of arsenic concentrations in the different brands using the Analysis of Variance (ANOVA) and the Turkey Multiple Comparison tests were used to check differences in means between the different brands of rice. Values were considered significant at P<0.05. The SPSS software was used for the computation of data.

3. RESULTS

The result reported in triplicates revealed that variation exists in the arsenic concentrations of the different brands of rice studied as shown by their respective means and standard deviations (Table 1).

Table 1: Statistical Evaluation of Arsenic Concentration in Rice (mg/kg)

Brands of Rice	Mean ± SD
Golden Stallion (GS)	0.8610 ± 0.0029
CAP Rice (CR)	0.8077 ± 0.0068
Africa Princess Rice (APR)	0.6417 ± 0.0021
Vico Rice (VR)	1.0073 ± 0.0064
Marori Benz (MR)	0.9140 ± 0.0122
Local Rice (LR)	0.9420 ± 0.0020

The arsenic content varies between 0.647 ± 0.0021 As mg/kg DW and 1.0073 As mg/kg DW. The result further revealed that Vico rice had the highest arsenic (As) content (1.0073 ± 0.0064 As mg/kg DW), followed by Local rice (0.9420 ± 0.0020 As mg/kg DW), Marrori Benz rice (0.9140 ± 0.0122 As mg/kg DW), Golden Stallion rice (0.8610 ± 0.0027 As mg/kg DW), and Caprice (0.8077 ± 0.0068 As mg/kg DW), while the least concentration was recorded in African Princess rice (0.6417 ± 0.0021 AS mg/kg DW).

The result was subjected to a single factor analysis of variance ANOVA to ascertain if there is any statistically significant difference in arsenic content of the rice studied and this is presented in Table 2.

Table 2: Single Factor ANOVA for Arsenic concentration in Brands of Rice Studied.

Source of variation	SS	df	MS	F	Sig.
Between groups	0.245	5	0.049	1172.154	0.000
Within Groups	0.001	12	0.000		
Total	0.245	17			

The ANOVA result was further subjected to post hoc multiple comparison tests to know where the significance occurred, and presented in Table 3.

Table 3: Multiple Comparison of Arsenic Concentration in Brands of Rice by Post Hoc Test.

Brand of Rice	Arsenic Concentration (mg/kg)
Golden Stallion (GS)	0.8610 ± 0.0027 ^a
Cap Rice (CR)	0.8077 ± 0.0068 ^b
African Princess Rice (APR)	0.6417 ± 0.0021 ^c
Vico Rice (VR)	1.0073 ± 0.0064 ^d
Marori Benz (MR)	0.9140 ± 0.0122 ^e
Local Rice (LR)	0.9420 ± 0.0020 ^f
F Value	1172.154
P-Value	0.000

KEY: Means with different superscripts are significantly different from each other. P<0.05

4. DISCUSSION

From Table 1, the result revealed that the arsenic contents of the brands of rice marketed and consumed in the city of Port Harcourt and its environ varied between 0.6417 (minimum) –

1.0073(maximum). The result is in agreement with results obtained by Gilbert-Diamond et al. [20], Williams et al. [21] and Zavala & John [22] who reported arsenic content of 0.156 – 0.19 mg/kg in rice produced and consumed in most European countries like Italy, Spain, and US respectively. Moreover, the arsenic content in the rice consumed and marketed in Nigeria seems to be having a very low content of arsenic when compared to the foreign rice.

Again, the result obtained from a similar survey in Awka, Nigeria [23], was at variance with the result obtained from this study. The arsenic content (1.373 As mg/kg DW) in the rice from Awka, Nigeria, was found to be very much higher in arsenic content than the one obtained in Port Harcourt [23]. However, this arsenic content in the different brands of rice marketed and consumed in Port Harcourt city and its environs, were smaller or lower than the maximum allowable concentration (MAC) of 1.4mg/kg as recommended by JECFA [24] and [15] who recommended a maximum permissible limit of 1mg/kg.

Furthermore, Vico rice (VR) in this study is the only rice that has arsenic content (1.0073 mg/kg) closer to the recommended limit prescribed by [24] but was at par with the maximum permissible limit prescribed by [15]. This implies that consumption of this brand of rice can be a possible means of exposure to arsenic poisoning, if not properly monitored to know the reasons for the presence of arsenic at that high level. In addition, this may be a major source of dietary arsenic exposure to humans and animals that may consume it [25, 26].

The arsenic (As) content in the studied brands of rice possibly might be a result of the presence of arsenic in the soils from which these brands of rice were grown [25]. Thus, suggesting that the arsenic present in this rice is geogenic. Thus, indicating that arsenic contents found in rice could be traced to the source from which the particular rice was gotten from. This idea was corroborated by Punshon *et al.* [26] who reported documented evidence of arsenic uptake by rice grown in some soils in Asian countries like Bangladesh, Bengal, etc., where geogenic arsenic (As) has been implicated to be a major contributor to the presence of this element in rice however this study did to cover the soil where this rice brand must have been grown. This idea was further corroborated by Carlin *et al.* [27], who unanimously reported the bioaccumulation of arsenic (As) by rice grown in arsenic (As) contaminated soils. It could, therefore, be inferred that Vico rice (VR), local rice (LR), Marori Benz (MB), Golden Stallion (GSR), and Caprice (CR) may have been grown in soils that naturally contained higher levels of geogenic arsenic.

Again, in order to increase agricultural output, farmers sometimes apply arsenic (As) containing pesticides (Sodium, calcium and lead arsenate) and fertilizers exclusively which in their mobile state in the soil, can be absorbed (taken up) by plants [28]. Thus, application of such pesticides and fertilizers on the soil from which these rice brands were grown could be implicated.

Irrigation water containing arsenic (As) bearing effluents used in rice paddy could be another contributor. In most Asian countries this practice is common, and this has led to the uptake of heavy metals into crops irrigated with arsenic (As) bearing water. Moreover, if the source of

water used in planting, is contaminated with arsenic, there is a likely hood that the plant will take up arsenic from the soil [6, 29].

Hence, arsenic contamination from different routes must be monitored in rice production and procession [30, 31, and 32]. This can also be applied to local rice produced in Nigeria which was reported to having arsenic (As) content close to Vico rice, in order to prevent food poisoning from this source. Moreover, this may even reduce arsenic content to a very low level comparable to rice grown and consumed in Thailand [33].

The result when subjected to single factor analysis of variance and a post hoc test revealed and confirmed that the brands of rice statistically differed in their arsenic (As) content at $P < 0.05$. (Table 2 and Table 3).

5. CONCLUSION

Arsenic content in the brands of rice studied varied between 0.6417 ± 0.0021 (minimum) and 1.0073 ± 0.0064 mg As kg^{-1} DW(maximum), which could be attributed to soil geogenicity, application of pesticide and fertilizer containing arsenic, and use of arsenic contaminated irrigation water for rice paddy. This study has showed that trace amount of arsenic is present in some brand of rice sold in Port Harcourt though within permissible limit. Moreover, the method used for the analysis is environmentally friendly. Rice consumption is one of the methods of human and animal exposure to environmental arsenic, which can be reduced by avoiding over usage of the aforementioned contributors.

COMPETING INTERESTS

Authors have declared that no competing interest exists.

AUTHORS CONTRIBUTIONS

This work was carried out in collaboration among authors. Author WHA designed the study, wrote the protocol, literature searches, managed sample collections and supervised the research. Author GDM performed the statistical analysis. Author SSD did literature searches and also supervised the work. All authors read and approved the final manuscript.

REFERENCES

1. Alam MGM. Allinsa G. Stagnath F. Tanaka A. Westbrooke M. Arsenic contamination in Bangladesh ground water, a major environmental and social disaster. International Journal of Environmental Health Research, 2002; 12: 236-253.

2. International Rice Research Institute (IRRI). World Rice Statistics. Los Banos, the Philippines:IRRI.June29,2013.http://irri.org/index.php?option=com_k2&view=item&id=9081&Itemid=100481&Lang=en 2013.
3. West Africa Rice Development Association (WARDA) .The Africa Rice Centre: The Nigerian rice economy in a competitive world: Constraints, opportunities and strategic choices. Strategy for rice sector revitalization in Nigeria, 2003.
4. Food and Agricultural Organization of United Nations. Rice in human Nutrition, Available at:www.fao.org/docrep/to567e/T0567E0d.hmt.2015. Accessed 18th September, 2016.
5. Awasthi S. Chauhan R. Srivastava S. Tripathi R.The journey of arsenic from soil to grains in rice. *Frontiers in Plant Science*, 2017; 8:1007.
6. Rauf MA. Hakim MA. Hanafi MM. Islam GK. Rahman MM. Panaullah GM.Bioaccumulation of arsenic (As) and phosphorus by transplanting Aman rice in arsenic-contaminated clay soils. *Australian Journal of Crop Science*, 2011; 5(12):1678-1684.
7. Islam MR. Salminen R. Laherma PW. Arsenic and other toxic elemental contamination in ground water, surface water and soil of Bangladesh and its possible effects on human health. *Environmental Geochemical Health*, 2000; 22: 33-53.
8. Banerjee M. Banerjee N. Bhattacharjee P. Mondal D. Lythgoe PR. Martínez M. Pan J. Polya DA. Giri AK. High arsenic in rice is associated with elevated genotoxic effects in humans_ *Science Report*, 2013; 3: 2195.
9. Hossain MB. Jahiruddin M. Panaullah GM. Loeppert RH. Islam MR. Duxbury JM.Spatial variability of arsenic concentration in soils and plants, and its relationship with iron, manganese and phosphorus. *Environmental Pollution*, 2008; 156(3):739-744.
10. Shui-wen C. Shou-hung C. Kun-tie H. Arsenic of adsorption characteristics in Taiwan soils. *Journal of Applied Science and Engineering*, 2015; 18(4): 323-330.
11. Khan NI. Owens G. Bruce D. Naidu R. Human arsenic exposure and risk assessment at the landscape level. *A Review of Environmental Geochemistry and Health*, 2009; 31: 143-166.
12. Tyler CR. Allan AM .The effects of arsenic exposure on neurological and cognitive dysfunction in human and rodent studies, A Review. *Current Environmental Health Report*, 2014; 1:132-147.
13. Heitkemper DT. Vela NP. Stewart KR. Determination of total and speciated arsenic in rice by ion chromatography and inductively coupled plasma mass spectrometry. *Journal of Analytical Atomic Spectrophotometry*, 2001; 16: 299–306.
14. Kumar RK. Venkateswarlu S. Reddy KV. Tulasamma P. Govinda V. Jyothi NVV. Venkateswarlu P. Arsenic (III) Determination by Spectrophotometry Coupled with Preconcentration Technique in Water Samples, *Journal of Chemical and Pharmaceutical Research*, 2011; 3(3):626-634
15. Yoon KP. Construction and characterization of multiple heavy metal resistant phenol-degrading pseudomonas strains. *Journal of Microbiology Biotechnology*, 2003; 13(6): 1001-1007.

16. Ratnaike RN. Acute and chronic arsenic toxicity. *Post Graduate Medical Journal*, 2003; 79(933): 391-396.
17. Vahidnia A. Voet GB. Wolff FA. Arsenic neurotoxicity, A review. *Human and Experimental Toxicology*, 2007; 26(10): 823-832.
18. Zhu YG. Williams PN Meharg AA. Exposure to inorganic arsenic from rice: a global health issue?, *Environmental Pollution*, 2008; 154(2): 169-171.
19. Sengupta MK. Hossain MA. Mukherjee A. Ahamed S. Das B. Nayak B. Pal A. Chakraborti D. Arsenic burden of cooked rice: Traditional and modern methods. *Food Chemical Toxicology*. 2006; 44(11):1823-1829.
20. Gilbert-Diamond D. Cottingham K. Gruber J. Punshon T. Sarayath V. Gandolfi A. Baker E. Jackson B. Folt C. Karagas M. Rice consumption contributes to arsenic exposure in US women. *Proceedings of the National Academy of Sciences*, 2011; 108 (51):20656-20660.
21. Williams PN. Raab A. Feldmann J. Meharg AA. Market basket survey shows elevated levels of As in south central U.S. processed rice compared to California: Consequences for human dietary exposure. *Environmental Science Technology*, 2007; 41: 2178–2183.
22. Zavala VL. John MD. Arsenic in Rice: Estimating normal levels of total arsenic in Rice grain. *Environmental Science Technology*, 2008; 42: 3856-3860.
23. Ugochukwu GC. Eneh FU. Igwilo IO. Aloh CH. Comparative study on the heavy metal content of domestic rice (*Oryza sativa* L) brands common in Akwa, Nigeria. *Journal of Environmental Science Toxicology and Food Technology*, 2017; 11(8): 67-70.
24. JECFA (Joint FAO/WHO Expert Committee on Food Additives) (2010). 72th Report of the Joint FAO/WHO Expert Committee on Food Additive, 2010a Available: http://whqlibdoc.who.int/trs/who_trs_959_eng.pdf Accessed 23 September 2016.
25. Norton GJ Islam RM. Duan G. Ming L. Zhu YG. Deacon CM. Moran A. Islam S. Zhao FJ. Stroud JL. *et al.* Variation in grain arsenic assessed in a diverse panel of rice (*Oryza sativa*) grown in multiple sites. *New phytologist*, 2012; 193 (3): 650 -664.
26. Punshon T. Brian P. Jackson A. Mehanrg A. Warczack T. Kirk S. Guerinot ML. Understanding arsenic dynamics in agronomic system to predict and prevent uptake by crop plants. *Science of the Total Environment*, 2017; 561 -582.
27. Carlin DJ. Naujokas MF. Bradham KD. Cowden J. Heacock M. Henry HF. Lee JS. Thomas DJ. Thompson C. Tokar EJ. Waalkes MP. Birnbaum LS. Suk WA. Arsenic and environmental health: state of the science and future research opportunities. *Environmental Health Perspectives*, 2016; 124: 890-899.
28. Yayah B. Melkamu A. Crop production inputs on soil Health. *A Review. Asian Journal of Plant Science*, 2017; 16(3): 109-131.
29. Costa B. Coelho L. Araujo C. Rezende H. Coelho N. Analytical Strategies for the determination of arsenic in rice. *Journal of Chemistry*, 2016; 1-11.

30. Food Drug Administration .Arsenic in rice and rice products. US Food and Drug Administration 2017. .Retrieved May 12, 2018. <http://www.fda.gov/food/foodborneillnesscontaminants/metals/ucm319870>
31. Naujokas MF. Anderson B. Ahsan H. Aposhian H. Graziano JH Thompson C. Suk W.The broad scope of health effects from chronic arsenic exposure. Update on a worldwide public Health Problem. Environmental Health Perspectives, 2013; 121(3): 295-302.
32. Ashiru O.Watch out for arsenic poisoning from rice.2017. Retrieved April 27,2018 [http://www.punchng.com/watch-out-for-arsenic poisoning-from-rice-1](http://www.punchng.com/watch-out-for-arsenic-poisoning-from-rice-1)
33. Potera C. Food Safety US Rice serves up arsenic. Environmental Health Perspective, 2007; 115(6): A296.