

Research Article

Assessment of Metal Pollution Index (MPI) in Selected Rice Brands

Jamila M Machano; Abdul AJ Mohamed*

Department of Natural Science, School of Natural and Social Sciences, the State University of Zanzibar. P. O. Box 146, Zanzibar – Tanzania

*Corresponding author: Abdul AJ Mohamed, Department of Natural Science, School of Natural and Social Sciences, the State University of Zanzibar. P. O. Box 146, Zanzibar – Tanzania. Email: jumabdull@yahoo.com

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Abstract

Background: This study aims at assessing the level of metal pollution index in different rice brands. While the metals involved in this assessment are K, Mg, Cu, Fe, Mn and Zn, the rice brands are Basmati, Jasmine, Shinyanga, Mbeya, Morogoro, Mapembe and Cheju.

Method: Samples were prepared in accordance with applicable Standard Operating Procedures (SOPs) and laboratory SOPs using information provided by field sample preparation. The samples were grinded to fineness and an aliquot of about 10.0 g was measured on the beam balance and mounted on the sample holders for laboratory analysis. An Energy Dispersive X-Ray Fluorescence (EDXRF) technique with a Rigaku NEX CG EDXRF model spectrometer was used to quantify the level of analyzed metals.

Results: The data analysis reveals the remarkable highest concentrations for potassium and magnesium in all analyzed rice brands, their values were 1700 mg/Kg and 1000 mg/Kg respectively. On the other hand, all rice brands contained low concentrations of copper. Additionally, the Metal Pollution Index (abbreviated as P) intended to show the degree of contamination for the analyzed metals in all rice brands was also assessed. Importantly, there is an existence of strong correlation in P levels ($R^2 = 0.98$) for analyzed metals in the local rice brands cultivated from Shinyanga and Mbeya regions in Tanzania. Similar observation on correlation of P levels for the same metals was observed between Jasmine rice brand and Mapembe rice brand ($R^2 = 0.99$). The sound reasons for this remarkable trend could be but not limited to a common agricultural practices involving similar fertilizer applications, spray of pesticides and herbicides, the background concentration of the metals in irrigation water could have a significant impact as well. Moreover, the P level for K and Cu metal in all rice brands was less than 1, indicating low degree of contamination. Nevertheless, for the case of Fe, the degree of contamination was also low in all rice brands except for the Jasmine rice ($P = 2.62$). P level for Mg in five rice brands shows a moderate degree of contamination ($1 \leq P < 3$) with exception of Mbeya and Cheju rice. For the case of Mn and Zn, all rice brands show highest contamination level ($P > 3$).

Conclusion: With respect to the analyzed metals and their respective P values, it is very clear that, the trend for the metal contamination in all rice brands depicts the following trend: Jasmine > Mbeya > Mapembe > Shinyanga > Cheju > Morogoro > Basmati. However, it is very apparent that, it is not easy to draw a general irrefutable statement with regard to the safety of the analyzed rice brands. Hence, the study recommends intensive analysis of the imported rice and proper cultivation methods specifically in soil and agrochemicals analysis before utilization.

Keywords: Jasmine; Cheju; Manganese; Zinc; Irrefutable statement; MPI

Introduction

Rice is one among the nutritious food that contains nutritive vitamins, 20% proteins, 3 % fat and provides 27% nutritive energy as well [2,3], although it is more susceptible for heavy metal contamination than other crops [8].

Heavy metal contamination in rice might be caused by various factors including agrochemicals used such as chemical fertilizer, pesticides and herbicides, inappropriate burning of waste materials, water for irrigation, and exhaust of vehicles [11].

Some metals including Cu, Fe, Mn and Zn are considered as micronutrients and they are useful in human body although they should be taken in small concentration, if they exceed the permissible limit, they become toxic and hence lead several acute and chronic effects [12]. These metals have the tendency of changing their form and remain in human body for extended period of time [10]. Heavy metals are carcinogenic in nature and are suspected for several diseases including bone, blood, kidney and heart damage [7].

Table 1: Min. and Max. Concentrations of analyzed Elements in Rice Samples.

Element (mg/Kg)	BASMATI		JASMINE		SHINYANGA		MBEYA		MOROGORO		MAPEMBE		CHEJU	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
K	900	1400	800	1100	1000	1300	1200	1700	1000	1100	1100	1400	600	1700
Ca	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Mg	300	800	300	400	800	800	700	1000	700	800	400	400	500	1100
Cu	3.75	5.27	6.32	9.86	5.11	6.77	6.06	6.44	4.8	5.34	6.51	6.83	4.71	8.8
Fe	9.68	15.3	12.8	51.4	15.5	18	18.6	18.8	13.1	14.1	12.3	16.4	12.4	19.7
Mn	BDL	7.22	13.3	21.9	16.1	17.6	16.3	21.6	10.9	16.3	13.1	18.8	9.79	16.4
Zn	5.31	8.42	20.4	30.8	17.4	22.2	17.1	21	16.1	18.8	17.9	21.7	18.4	23.3

Table 2: Elemental Comparison of Present Study with Previous Studies.

Elements	This study			Other Studies			WHO/ FAO Std.
	Zanzibar (Cheju)	Tanzania mainland	Imported	Ethiopia (Tegegne <i>et al.</i> , 2017)	United States (TatahMentan <i>et al.</i> , 2020)	Tanzania (Mohammed., 2008)	
K	1700	1700	1400	1100	2252	1068	3500
Mg	1100	1000	800	99.5	1110	509	310
Cu	8.8	6.77	9.86	15.0	5.2	3.0	0.50
Fe	19.7	18.8	51.4	108	11	25.0	19.60
Mn	16.4	21.6	21.9	3.7	27.0	13.0	0.50
Zn	23.3	22.2	30.8	51.6	19.0	29.0	1.0

Assessment of the level of metal contamination is given as Metal Pollution Index (abbreviated as P) in all samples has been used in this study to distinguish the dominated metal while estimating the pollution status in analyzed rice brands. This was done through calculation expressed by the formula;

$$P = C/MAC$$

C is the concentration of specific metal in sample,

MAC is the maximum permissible level of metal

Values of Metal Pollution Index obtained after formula manipulation can be categorized in three main stages (Alberto Then *et al.*, 2023), these stages are as follows:

- i. $P < 1$: Indicates Low Pollution Level
- ii. $1 \leq P < 3$: Indicates Moderate Pollution Level
- iii. $P > 3$: Indicates Highest Pollution Level

Materials and Methods

Sample Collection and Analysis

About 18 varieties of rice samples were collected from seven common rice brands namely; Basmati, Jasmine, Mbeya, Morogoro, Shinyanga, Mapembe and Cheju). 1.0 kilogram each, were randomly collected from Darajani and Mwanakwerekwe markets. Basmati, Jasmine, and Mapembe were obtained from Darajani market and Shinyanga, Mbeya, and Morogoro were collected from Mwanakwerekwe market. Cheju rice was collected from Cheju district. Samples were separately stored in polyethylene bags before being sent to SEAMIC, Kunduchi - Dar - es - salaam for metal analysis.

An Energy Dispersive X-Ray Fluorescence (EDXRF) Spectrometer was used for sample analysis. This instrument is able to undergo elemental analysis in solid, liquid and powder samples. X-rays strike the sample and cause the atoms in the sample to fluoresce their own characteristic low energy "soft" X-rays. These fluorescent X-rays are then brought in a detector and counted by a multi-channel analyzer. Finally, the NEX CG software calculates the elemental concentration from Sodium to Uranium for all the detected elements in a given sample.

Results and Discussion

Table 1 shows the minimum and maximum concentrations of analyzed metals in seven brands of rice. In all rice brands, K was detected at highest concentration, it ranged between 1100 to 1700 mg/Kg. Meanwhile, Cheju rice was found to contain the highest level of Mg (1100 mg/Kg). Besides, Jasmine rice had highest concentration of Cu, Fe, Mn and Zn, their levels were 9.86, 51.4, 21.9 and 30.8 mg/Kg respectively.

Data from Table 2 gives the description that, the concentration of K in this study and previous studies is within WHO/FAO Maximum Permissible Levels. Other metals including Cu, Fe, Mn and Zn were above the Maximum Permissible Level set by WHO/FAO standards.

Mbeya and Cheju showed highest levels of K (1700 mg/Kg), which is still safe with respect to Maximum Permissible Limit set by FAO/WHO. Meanwhile, in all rice brands, Mg concentration was found to exceed the WHO/FAO Maximum Permissible Limit, Cheju rice being the leading brand (Figure 1).

Zinc metal was highly concentrated in all rice brands and its concentration was beyond WHO/FAO maximum permissible limit, but Jasmine rice specifically was the most leading brand. In terms of iron metal, only Jasmine rice was beyond the maximum permissible limit set by WHO/FAO, other brands were within the Maximum Permissible Limit (Figure 2).

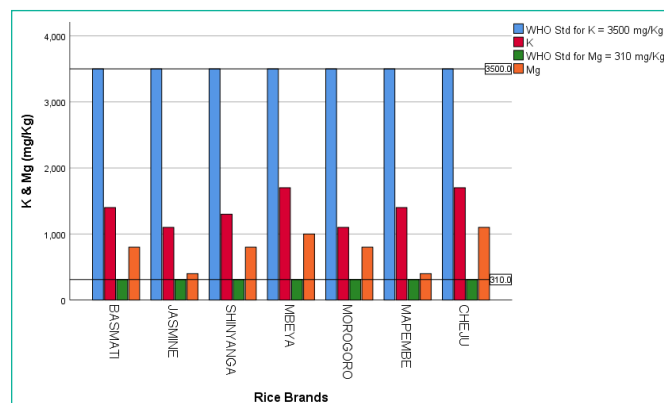


Figure 1: K and Mg Concentration in Rice Brands.

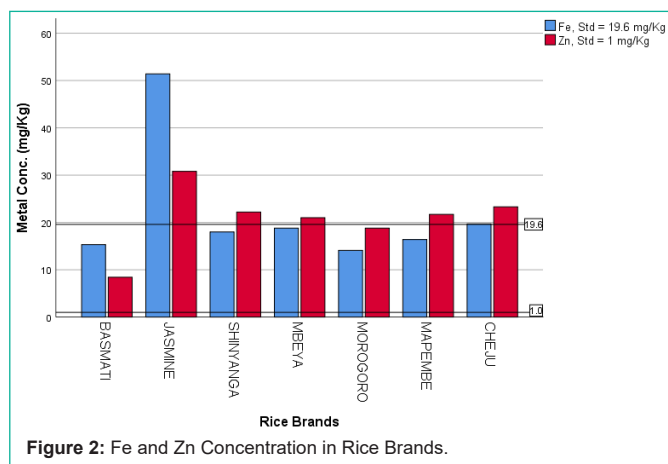


Figure 2: Fe and Zn Concentration in Rice Brands.

Table 3: MPI in Rice Brands.

MPI	K	Mg	Cu	Fe	Mn	Zn
BASMATI	0.40	2.58	0.53	0.78	14.44	8.42
JASMINE	0.31	1.29	0.99	2.62	43.80	30.80
SHINYANGA	0.37	2.58	0.68	0.92	35.20	22.20
MBEYA	0.49	3.23	0.64	0.96	43.20	21.00
MOROGORO	0.31	2.58	0.53	0.72	32.60	18.80
MAPEMBE	0.40	1.29	0.68	0.84	37.60	21.70
CHEJU	0.49	3.55	0.88	1.01	32.80	23.30

Pollution Index Assessment (P)

This parameter P, determines the degree of metal contamination in rice samples as depicted in Table 3.

Both Table 3 and Figure 3 a & b show the P level for potassium and copper in all analyzed samples to be less than 1. The same results was noted for Fe (except in Jasmine rice, P = 2.62) indicating that these rice brands with respect to these analyzed metals are safer for human consumption. Furthermore, the P level for Mg in five rice brands with exception of Mbeya and Cheju rice displays a moderate degree of contamination ($1 \leq P < 3$). Extraordinarily, there was highest contamination for Mn and Zn ($P > 3$) in all analyzed rice brands, indicating that there is great possibility for acute and chronic effects to the rice consumers. Hence, there is difficulty in making general statement with regard to the safety of the analyzed rice brands.

Correlationship of MPI on Rice Brands with respect to Regions

Figure 4a indicates a strong correlation ($R^2 = 0.98$) in P values of analyzed metals between rice brand cultivated in Shinyanga and that of Mbeya. As noted earlier for the MPI correlation between Shinyanga and Mbeya rice, similar observation (Figure 4b) for Jasmine rice brand

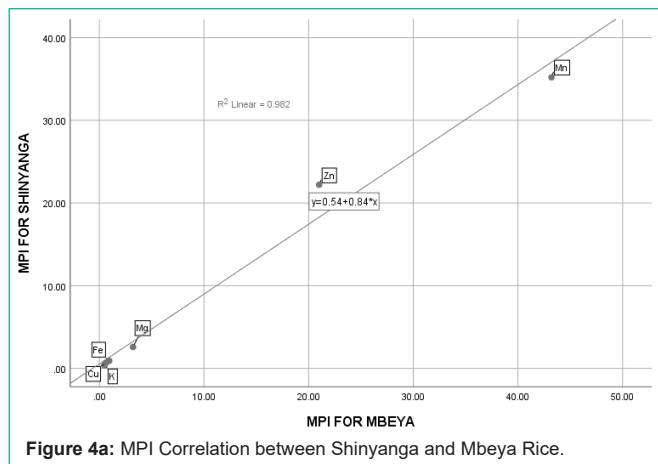


Figure 4a: MPI Correlation between Shinyanga and Mbeya Rice.

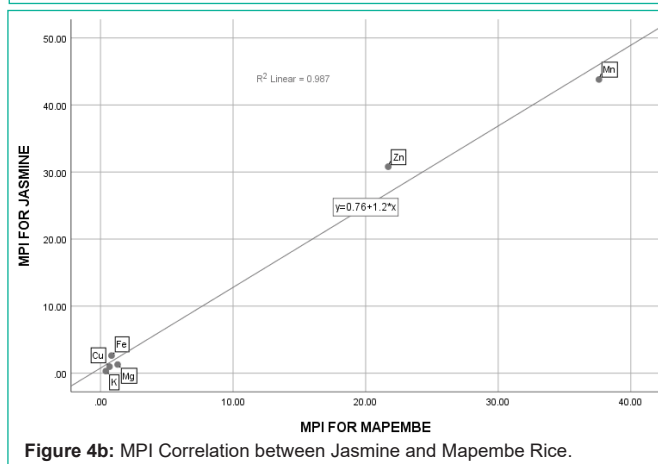


Figure 4b: MPI Correlation between Jasmine and Mapembe Rice.

and Mapembe rice brand, the strong correlation in P values for these metals in imported rice was also noted ($R^2 = 0.99$). The sound reasons for these remarkable trends could be but not limited to a common agricultural practices involving similar fertilizer applications, spray of pesticides and herbicides, the background concentration of the metals in irrigation water also could have a significant impact on quality of harvested rice.

Conclusion

The results of this study revealed the presence of highest concentration of Cu, Fe, Mn and Zn in Jasmine rice. This can be generalized by the statement that, Jasmine rice has highest levels of analyzed metals compared to other rice brands. Nevertheless, the consumption of foodstuff containing metal could be considered as a silence killer. This concern has to be precaustiously considered by agricultural experts in order to ensure that the concentrations of chemicals in rice and other foodstuff are in safe limit for the consumer's health and the environment in general. Comprehensive analysis of foodstuff as well as agricultural soil in which the food are grown should also be routinely done, so as to ensure that people consume safe and healthy foods.

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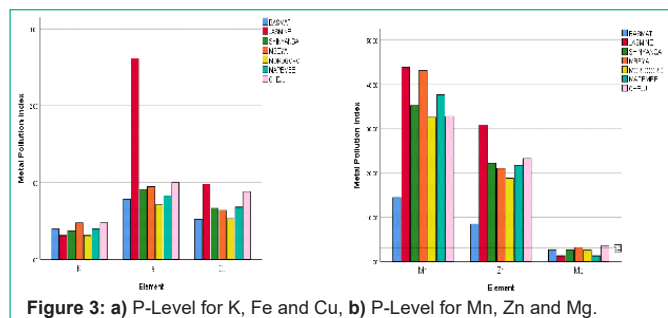


Figure 3: a) P-Level for K, Fe and Cu, b) P-Level for Mn, Zn and Mg.

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