DETERMINATION OF THE AMOUNT OF ZINC IN PURE LINE MAIZE AND SEASONAL VARIATIONS IN GRAINS AND SILKS GROWN ACROSS NIGERIA.

E. I. Obolo; S. Ande; C. E. Ejikeme; D. G. Akintunde; M. S. Abdulquadir; R. F. Lawal and M. E. Jaiyesimi.

[1,4,5&7] Department of Chemistry Education, Federal College of Education (Technical) Akoka, Lagos, Nigeria.
[2]Department of Chemistry, Joseph Sarwuan Tarka University Makurdi, Nigeria.
[3]Department of Biology Education, Federal College of Education (Technical) Akoka, Lagos, Nigeria.
[6]Department of Mathematics and Statistics Education, Federal College of Education (Technical) Akoka, Lagos, Nigeria.

Corresponding author: E. I. Obolo (WhatsApp No: +2349139101507; idobolo23@gmail.com)

ABSTRACT

Approximately, 17 percent of the world's population is at risk of zinc (Zn) deficiency. According to literature maize grains and silks are rich in Zn, and the amount varies reflecting different varieties and ecosystems. The amount of Zn in some pure line maize and seasonal variations in grains and silks grown across Nigeria's six geopolitical and seven vegetation zones were determined using acid digestion, and analysis by Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES). The amount of Zn in the pure line (22.40 mg kg^{-1} to 22.46 mg kg^{-1}) and the open-pollinated (22.39 mg kg^{-1} to 22.48 mg kg^{-1}) maize grains are within the same range, likewise, the white and yellow maize silks (27.99 mg kg-1 to 28.10 mg kg-1) but are higher than the amount in their respective grains. The Mann-Whitney U test at 0.05 significant level was used to evaluate the seasonal variation of Zn. There is no significant difference between the amount of Zn in the white maize grains, likewise, the white and yellow maize silks grown in the dry and rainy seasons across Nigeria's geopolitical and vegetation zones. Except in the South-East where the amount of Zn in the yellow maize grains is significantly higher in the dry season compared with the rainy season. Potentially, 0.67 kg, 0.54 kg, 0.45 kg, and 0.22 kg of the maize grains, and 0.54 kg, 0.43 kg, 0.36 kg, and 0.18 kg silks are recommended for Zn daily dietary intake for men, females, adolescents, and formula-fed babies, respectively.

Keywords: Maize grains and silks, varieties, Zinc, Mann-Whitney U test, geopolitical and vegetation zones, daily dietary intake.

INTRODUCTION

Zinc (Zn) is an essential element that is needed for proper human growth, and for the fortification of the immune system to fight common infections [1-3]. About 17 % of the world's population is at risk of zinc deficiency. Children are the most vulnerable because they need a lot of the Zn for proper growth [4-6]. Zinc plays essential roles in many enzymatic reactions participating in the metabolism of carbohydrates, proteins, lipids, nucleic acids, and the processes of genetic expressions [2, 3]. Severe deficiency symptoms of Zn include frequent infections, diarrhoea, compromised immune functions, alopecia, delayed sexual and bone maturation, and mental disturbance. Other dysfunctions that may occur include impaired wound healing, skin lesions, enlarged spleen and liver, impaired taste and smell, and night blindness [2, 4, 7, 8]. The United States National Research Council / World Health Organisation (WHO) recommended Zn dietary allowances for formula-

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fed babies 5 mg day^{-1}, pre-teen 10 mg day^{-1}, females 12 mg day^{-1}, and males 15 mg day^{-1} [9, 10]. The whole body of a 70 kg man is estimated to contain 1.4 – 2.3 g of Zn [5, 10]. Acute toxicity is usually caused by accidental or deliberate ingestion of excess Zn salts for therapeutic purposes [10].

Globally, maize grains contain approximately 25 - 36 mg kg^{-1} Zn [11]. According to literature the amount of Zn in maize grains cultivated in Zimbabwe is sufficient for daily reference human intake for the poor and most vulnerable populace [12]. Also, Malaysian maize silks contain up to 46.37 mg kg^{-1} of Zn [13]. However, the amount of Zn in maize grains varies across the globe reflecting, different ecosystems and varieties [14,15]. About 11.6 million tons of maize was produced in Nigeria in 2021 making, the country the second largest maize producing country in Africa and the 14th largest globally [16]. The pure line and open-pollinated maize grown in Nigeria are mainly the yellow and white varieties. The pure line varieties are single self-fertilized homozygous plants, they are uniform and genetically identical to the parent plants [17].

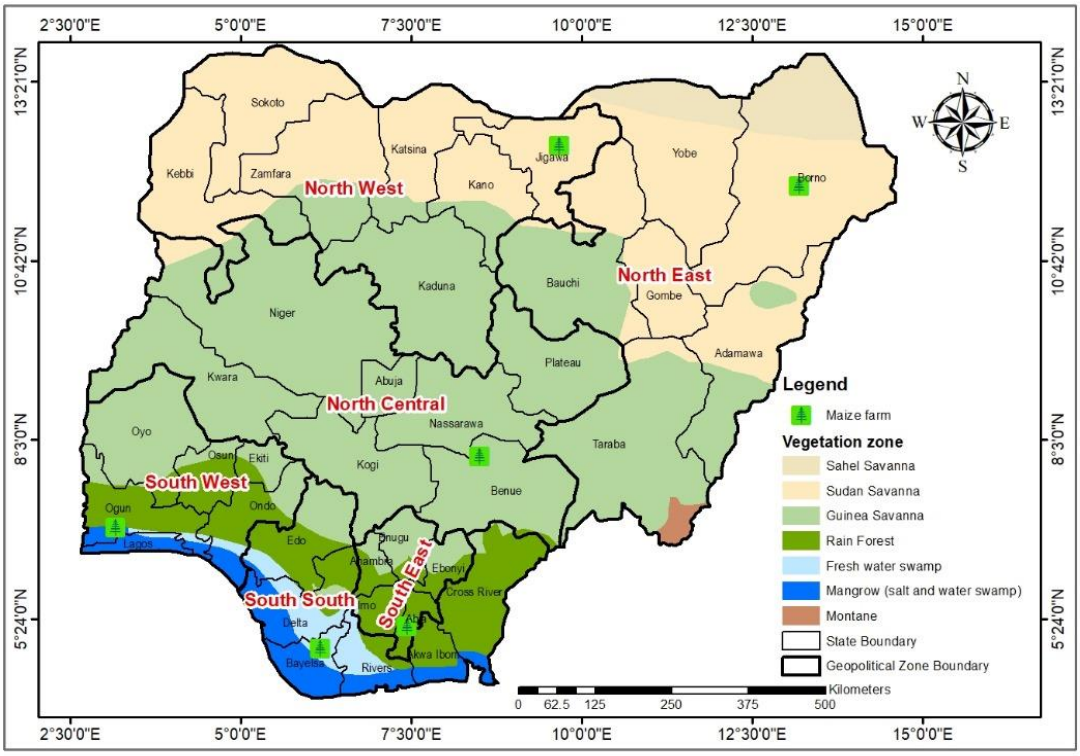

Figure1: Map showing the farm where maize was planted across Nigeria's six geopolitical and seven vegetation zones.

Nigeria has two major seasons: the dry (November to March) and rainy (April to October) seasons. Naturally, maize is a staple cereal cultivated during the rainy season in Nigeria. During the dry season, maize is also grown in some mechanised irrigated farms across Nigeria. Usually, peasant farmers cannot afford mechanised farming. The objectives of this study were to determine the amount of Zn in some pure line maize and seasonal variations in grains and silks grown in traditional farmlands

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across Nigeria's six geopolitical (North-West, North-Central, North-East, South-West, South-South, and South-East) and seven vegetation (Sahel Savana, Sudan Savana, Guinea Savanna, Rain Forest, Fresh Water Swamp, Mangrove and Montane) zones (Figure 1) and recommend a potential daily dietary intake that can mitigate the nutrient deficiency among the populace.

MATERIALS AND METHODS

Study design and sampling

The white and yellow maize were grown in dry (November to March) and rainy (April to October) seasons on purposely selected traditional farmland across Nigeria's six geopolitical and vegetation zones. One farm per geopolitical zone (Figure 1): North-West - Jigawa state (Mudiga: 12.232046°N 9.705337°E); North-Central - Benue state (Makurdi: 7.812359°N 8.501048°E); North-East - Borno state (Maiduguri: 12.232046°N 13.191370°E); South-West - Ogun state (Makogi: 6.737026°N 3.382479°E); South-South - Bayelsa state (Biseni: 5.235983°N 6.541267°E); and South-East - Abia state (Isiala-Oboro: 5.404634°N 7.567838°E). The white and yellow maize were grown at least 100 m apart to minimise cross-pollination. During the dry season, the maize plant was watered early in the morning or evening with a least 2 litres of water per day. Randomly selected 20 maize plants were harvested after 90 days in each farm. Composite samples of the maize grains and silks from each farm were collected. To compare the amount of Zn in the pure line maize grains with the open-pollinated varieties; ten different varieties of pure line maize grains (Table 1) were obtained on the 4th of January 2023, from the Institute of Agricultural Research and Training, Ibadan, Nigeria. All samples were stored in polythene bags and transferred to the laboratory within 5 days.

Sample preparation and analysis

In the laboratory, the samples were oven-dried at 60 °C for 24 hours, ground into fine powder with ceramic mortar and pestle, sieved through 1 mm plastic mesh, and stored in lidded polyethylene containers before analysis. All glassware was soaked in chromic acid for 60 minutes, rinsed with water under a running tap, washed with 1 % soap solution, rinsed with distilled water, allowed to drip, and dried in the oven. All the reagents used were analytical grades.

Approximately 5 g of the sample was placed in a 50 ml volumetric digestion tube, using repipette, 6 ml HNO_3 was added and allowed to digest for 60 minutes. The digestion tube was placed in the digestion block port at 150 °C for 60 minutes after which it was removed and allowed to cool at room temperature. Then 2 ml of $HClO_4$ was slowly added to the digestion tube and returned to the digestion block port at 215 °C for 2 hours. After the HNO_3 fume had evolved the digestion tube was removed from the digestion block and allowed to cool for 20 minutes, and 10 ml distilled water was added on a hot plate at 90 °C. A vortex stirrer was used to mix the digest, after cooling it was diluted to the final volume with distilled water and filtered and quantitatively transferred into a 25 ml volumetric flask. A procedural blank was prepared at the same time [18]. The analytical procedure was monitored using the apple leaf standard reference material 1515 (SRM 1515) obtained from the National Institute of Standards and Technology U.S.

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Department of Commerce [19], and periodic blank analysis. A triplicate run of the digest for Zn concentration analysis was done by ICP-OES (Agilent Technology 5800) at the Nigeria Institute of Medical Research Yaba-Lagos, Nigeria. The SRM 1515 and samples were oven-dried at 110 °C overnight to constant weight.

Data analysis

Microsoft Office Excel Package 2016 was used for the computation of the simple descriptive statistical analysis such as the mean concentration of Zn, standard deviation, and the percentage recovery of the standard reference material. The IBM SPSS 24 statistical software using the robust nonparametric Mann-Whitney U test was used for the computation of the inferential statistical analysis [20]. The difference between the concentration of Zn in maize grains and silks grown in dry and rainy seasons was calculated at 0.05 significant level. The method of simple proportion in mathematics (Equation 1) was used to calculate the samples' recommended daily dietary intake against the WHO recommendations [9, 10] using the minimum Zinc concentration determined in the white and yellow maize grains and silks. The quantity of the sample containing Zn concentration that is equal to the WHO-recommended daily dietary intake (SRDI):

$$SRDI = \frac{RDI}{CS} \qquad \text{Equation 1}$$

where RDI is the WHO Zn recommended daily dietary intake, and CS is the concentration of Zn in the sample.

RESULTS AND DISCUSSION

Total zinc concentration

The total amount of Zn in each of the pure-line maize grains studied is presented in Table 1. The total amount of Zn in each of the white and yellow maize grains and silks grown across Nigeria's geopolitical and vegetation zones during dry and rainy seasons are also presented in Tables 2 and 3. The percentage recoveries of total Zn concentration determined in the SRM 1515 were 99 % to 100 % (Tables 1 - 3). The total amount of Zn in the pure line (22.40 mg kg^{-1} to 22.46 mg kg^{-1}) and the open-pollinated maize (22.39 mg kg^{-1} to 22.48 mg kg^{-1}) grains are within the same range. This shows that the pure line and the open-pollinated maize grains varieties studied have comparable dietary qualities with previously reported genetically influenced varieties cultivated in Nigeria with Zn content of 22.51 mg kg^{-1} to 33.33 mg kg^{-1} [14]. The total amount of Zn found in the white and yellow maize silks (27.99 mg kg-1 to 28.10 mg kg-1) is also within a similar range and higher than the amount found in their respective grains. This is consistent with previous literature which showed that maize silks are richer in Zn than grains [13].

Seasonal variation

Generally, the p-values are less than 0.05 except for the yellow maize grains with p-value of 0.84, and this can be attributed to the wide variation in the amount of Zn determined in Abia state samples (Tables 2 and 3). Consequently, there is no significant difference in the total amount of Zn in the white maize grains, and the white and yellow maize silks grown in the dry season compared with the rainy season in the different Nigeria geopolitical and vegetation zones. Except for Abia

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state where the amount of Zn determined in the yellow maize grains is significantly higher in the dry season compared with the rainy season. Growing the maize crops in dry and rainy seasons of the same year, in the same environment explains why there was no significant difference in the total amount of Zn in most of the maize grains and silks studied. A period of less than one year may not be sufficient to cause a significant change in the ecosystem and the amount of Zn in the farms where the maize was planted. This suggests that the amount of Zn in maize grains and silks can remain unchanged regardless of the season provided there is an adequate water supply and no significant changes in the farm ecosystem and nutrient levels.

Table 1. Total Zinc concentration (mg kg^{-1}, n=3), standard deviation (SD; ± mg kg^{-1}) in pure line maize grains.

Pure line maize grains	Zn concentration
DMR – LSR -Yellow maize	22.46 ± 0.86
BR 9943 – DMR – SR – White maize	22.44 ± 1.03
DMR – ESR – Yellow maize	22.43 ± 2.63
ART 98/SWI Yellow maize	22.45 ± 1.02
ART 98/SW OB. White maize	22.43 ± 0.57
TZPB – SR- White maize	22.41 ± 5.21
ILE- I- White maize	22.46 ± 0.60
SUWAN-1-SR Yellow maize	22.45 ± 0.46
BR 9928 DMR.SR. Yellow maize	22.45 ± 0.40
LNTP Yellow maize	22.40 ± 6.60
Range	22.40 – 22.46
Reference material	
Targeted value	12.45 ± 0.43
Found value	12.45 ± 0.75
Percentage recovery (%)	100

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Table 2. Total Zinc concentration (mg kg^{-1}, n=3), standard deviation (SD; ± mg kg^{-1}) in maize grains.

	Town/state	Zn concentration in Dry season maize grains (November to March) 2022 to 2023	Zn concentration in rainy season maize grains (April to October) 2023	P – value
White maize grains				
	Makogi / Ogun	22.48 ± 0.35	22.41 ± 1.25	0.016
	Isiala-Oboro / Abia	*CF*	22.40 ± 1.44	
	Biseni / Bayelsa	22.42 ± 0.75	22.40 ± 5.53	
	Makurdi / Benue	22.41 ± 3.67	CF	
	Maiduguri / Borno	22.41 ± 1.39	22.41 ± 3.29	
	Mudiga / Jigawa	*CF*	22.40 ± 4.62	
Mean		22.43	22.40	
Range		22.40 – 22.48		
Yellow maize grains				
	Makogi / Ogun	22.48 ± 0.27	22.40 ± 5.13	0.84
	Isiala-Oboro / Abia	22.39 ± 21.62	22.41 ± 1.82	
	Biseni / Bayelsa	22.42 ± 2.18	22.41 ± 4.35	
	Makurdi / Benue	22.41 ± 0.91	*CF*	
	Maiduguri / Borno	22.40 ± 3.47	22.41 ± 1.56	
	Mudiga / Jigawa	*CF*	22.40 ± 7.71	
Mean		22.42	22.41	
Data range		22.39 – 22.48		
Standard reference material 1515				
Target value		12.45 ± 0.43	12.45 ± 0.43	
Found value		12.45 ± 0.75	12.40 ± 2.24	
Percentage recovery		100	99	

**CF = crop failure due to flood or pest attack.*

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Table 3 - Total Zinc concentration (mg kg^{-1}, n=3), standard deviation (SD; ± mg kg^{-1}) in maize silks.

	Town/state	Zn concentration in Dry season maize silk (November to March) 2022 to 2023	Zn concentration in rainy season maize silk (April to October) 2023	P – value
White maize silks				
	Makogi / Ogun	28.01 ± 6.23	27.99 ± 13.96	0.032
	Isiala-Oboro / Abia	*CF*	28.00 ± 4.38	
	Biseni / Bayelsa	28.10 ± 1.32	28.01 ± 2.43	
	Makurdi / Benue	28.08 ± 0.65	CF	
	Maiduguri / Borno	28.04 ± 1.97	27.99 ± 13.97	
	Mudiga / Jigawa	*CF*	27.99 ± 27.9	
Mean		28.06	27.99	
Range		27.99 – 28.10		
Yellow maize silks				
	Makogi / Ogun	28.06 ± 0.75	27.99 ± 15.99	0.016
	Isiala-Oboro / Abia	28.09 ± 1.22	28.01 ± 4.18	
	Biseni / Bayelsa	28. 07 ± 0.69	28.00 ± 8.10	
	Makurdi / Benue	28.04 ± 1.23	*CF*	
	Maiduguri / Borno	28.01 ± 1.57	27.99 ± 14.02	
	Mudiga / Jigawa	*CF*	27.99 ± 9.79	
Mean		28.05	28.00	
Range		27.99 – 28.09		
Standard reference material 1515				
Target value		12.45 ± 0.43	12.45 ± 0.43	
Found value		12.45 ± 0.75	12.40 ± 2.24	
Percentage recovery		100	99	

**CF = crop failure due to flood or pest attack.*

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Recommended daily dietary intake.

The recommended daily dietary intake of the maize grains and silks studied for Zn against the WHO recommendations [9, 10] is listed in Table 4. Potentially, 0.67 kg, 0.54 kg, 0.45 kg, and 0.22 kg of white and yellow maize grains are recommended for Zn daily dietary intake for men, females, adolescents, and formula-fed babies, respectively (Table 4). Similarly, 0.54 kg, 0.43 kg, 0.36 kg, and 0.18 kg white and yellow maize silks are also recommended for Zn daily dietary intake for men, females, adolescents, and formula-fed babies, respectively (Table 4). However, these recommendations are subject to the quantity of maize grains and silks that can be tolerated by an individual per day. Studies have also indicated that not all the Zn present in food such as potato and tea is bioaccessible [21, 22], and suggestively in maize grains and silks. Therefore, further studies are required to assess the bioaccessibility of Zn present in the maize grains and silks.

Table 4. Recommended potential daily dietary intake of Nigeria maize grains and silks for zinc against the World Health Organisation recommendations.

	Male	Female	Adolescence	Formula-fed babies
WHO recommendation (mg day^{-1})	15	12	10	5
White and yellow maize grains (kg)	0.67	0.54	0.45	0.22
White and yellow maize silks (kg)	0.54	0.43	0.36	0.18

CONCLUSION

The pure line and the open-pollinated maize grains grown in this study across Nigeria's different geopolitical and vegetation zones have similar Zn dietary qualities, regardless of the varieties and the seasons they were cultivated, with the assumptions that the soil nutrients were maintained and there was adequate water supply throughout the year. Also, the silks are richer in Zn compared with their respective grains. Therefore, the more maize grains and silks an individual can tolerate the better for Zn daily dietary intake. Potentially, a peasant farmer can grow and consume maize grains and silks to mitigate the consequence of not meeting the WHO Zn recommended dietary allowance throughout the year.

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