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Research Article

Level of Fortificants in the "Mandatory Fortified" Wheat Flour Sold in Sokoto Metropolis, Sokoto State, Nigeria

Mode M. Abduljalil[1,2*], Shu'aibu A. Umar[3], Rabi'u A. Umar[3]

[1] *Central Advanced Science Laboratory Complex, Usmanu Danfodiyo University, Sokoto, Nigeria.*
[2] *Department of Biochemistry, Kebbi State University of Science and Technology Aleiro, Kebbi State, Nigeria*
[3] *Department of Biochemistry and Molecular Biology, Usmanu Danfodiyo University, Sokoto, Nigeria.*

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***CORRESPONDENCE**
Abduljalil, M. M.
abduljalil.mode@udusok.edu.ng
+234(0)8032561547

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ABSTRACT

Micronutrient deficiency (MND) is a critical public health problem and contributor to the global disease burden with negative effects on human capital, economic productivity and overall national development. The proven cost-effective and sustainable strategy for the prevention of MND is through food fortification. However, studies evaluating the levels of fortificants in fortified foods in Nigerian markets are scarce. Therefore, this study seeks to evaluate the quantity of fortificants in the "fortified" eight (8) wheat flour brands sampled from different markets in Sokoto metropolis. Vitamin A was determined spectrophotometrically. The levels of Calcium (Ca), Copper (Cu), Iron (Fe), Magnesium (Mg), Manganese (Mn), Phosphorus (P), Selenium (Se) and Zinc (Zn) were estimated according to methods of the American Association of Cereal Chemists (AACC), and Association of Official Analytical Chemists (AOAC) (1995) using Atomic Absorption Spectroscopy (AAS). The results show that the levels of the fortificants (vitamin A, iron and zinc) and other elements (Ca, Cu, Mg, Mn, P, and Se) in the fortified wheat flour brands were significantly ($p < 0.001$) lower than the recommended/mandatory level. The low levels of fortificants could be due to low compliance with the fortification standards by the manufacturers, poor storage or loss during transportation. Improved market surveillance and monitoring for compliance by the regulatory agencies are strongly recommended.

Keywords: *Micronutrient deficiency, Food fortification, Fortificants, Wheat flour, Compliance*

INTRODUCTION

Micronutrient deficiencies (MND) are of great public health and socio-economic significance and one of the main contributors to the Global Burden of Diseases (Tulchinsky *et al.,* 2010). More than two (2) billion people are affected by MND globally (WHO, 2014). Nutrition and food systems (2017) reported that one-third of the global population is affected by a minimum of one kind of micronutrient deficiency. The distribution of people with MNDs across the world is not even. The Global Nutrition Report (2020) show intense disproportions of the problems caused by micronutrient deficiencies (Micha *et al.,* 2020). Similarly, another 2020 global report released by WHO showed that 149 million children (<5 years) were projected to be stunted (low size for their age), while 45 million were wasted (thinner for their height) and another 38.9 million were over nourished or obese (WHO, 2022). The report further revealed that about 45 percent of deaths amongst children (below 5 years) are connected to lack of adequate nourishment, which commonly occurs in developing countries.

Furthermore, MND is very prevalent in Nigeria and poses a great risk to child survival, resulting in an increased risk of death due to diseases like acute gastroenteritis, pneumonia, and measles (Syam *et al.,* 2016). The problem is even more widespread in northern Nigeria, which accounts for 27% of the country's population (NDHS, 2019). Vitamin A, iron, and zinc deficiencies abound as manifested in high levels of diseases, school absenteeism, and anaemia. Pregnant women and women of reproductive age/childbearing age (those of reproductive age including adolescent girls) are not spared as evidenced by high levels of maternal mortality, morbidity and anaemia (MICS, 2011; Harika *et al.,* 2017; Ayogu *et al*., 2018; NDHS 2019; Olonade *et al.,* 2019).

Vitamin A is critical regulator of several body activities amongst which are reproduction, tissue differentiation, growth, vision and immunity (Kundu *et al.,* 2021). Therefore, deficiency of vitamin A lead to health problems among which are vulnerability to numerous infections due to immunity, stunting and vision problems (Rice *et al.,* 2004). Vitamin A deficiency (VAD) is a prevalent public health concern particularly in most of the developing nations, where an estimated 190 million preschool-age children are susceptible to blindness, while the wellbeing and existence of 251 million are extremely affected (WHO, 2011; Kundu *et al.,* 2021). Vitamin A enhances child's survival by 12 to 24% (UNICEF, 2016). Despite the critical biological role of vitamin A, the body cannot synthesize it, and thus must be sourced via food more readily through fortified wheat flour and others (Rice *et al.,* 2004).

Likewise, Fe deficiency is considered as one of the serious nutrient deficiency problem worldwide (Stelle *et al.,* 2019). In pregnancy, Fe deficiency anaemia is one of the contributors to maternal morbidity and mortality mostly due to microcytic anaemia (Horowitz *et al.,* 2013; Hannah, 2017). A survey report by the WHO discovered that from 1993 to 2005, about 42% and 47% of pregnant women and preschool children respectively were anaemic (Turawa *et al.,* 2021). Iron deficiency mostly occurs among children above 4 months of age particularly in children born to mothers with suboptimal iron status at pregnancy period, thereby leading to delay in mental and motor development (Lozoff, 2007). Therefore, infants may experience emotional complications and consequently become unable to meet educational goals in the future which may negatively impact their earning capacity in adulthood (Klemm *et al.,* 2010).

Adequate intake of zinc is indispensable for the ideal heath of children, their physical growth and also for normal pregnancy outcome (Brown *et al.,* 2004). About one-third of the world's population lives in countries with high incidence of Zn deficiency (Maxfield *et al.,* 2022). Deficiency of zinc leads to high incidences of illness and death in children due to common childhood infections, though several studies show that protective zinc supplementation have direct effect on development and improves weight gain in stunted children (Brown *et al.,* 2002; Brown and Hess, 2009). Studies by Iannotti *et al.* (2008) and Stewart *et al.* (2009) also demonstrate that zinc consumption during pregnancy increases postpartum growth and boost resistance to infections.

Food fortification is a proven strategy for combating micronutrient deficiencies (Sun *et al.,* 2008; Huo *et al.,* 2011; Huo *et al.,* 2012). Therefore, national programmes have been initiated to ensure appropriate and effective fortification of widely consumed staple foods (Biebinger and Hurrell, 2008). Consumption of micronutrients-fortified food products have been recommended for increasing the intake of micronutrients and decreasing the adverse effects associated with micronutrients deficiencies (Mannar and Gallego, 2002).

To achieve the same goal, the Nigerian government commenced national food fortification with salt iodization in 1992 (UNICEF, 2005; Busari, 2013) and that of wheat flour, maize flour, semolina flour, sugar, and vegetable oil, with iron (Fe), vitamins (A, B1, B2, B3, B6, B9, B12) and Zinc (Zn) in 2002 (UNICEF, 2006; Sablah *et al.,* 2013). Therefore, by Nigerian law and regulation, five major food vehicles (wheat or maize flour, semolina, sugar; oil and margarine) must be fortified with vitamin A. Despite decades of implementation of the food fortification programme in Nigeria, there are limited independent and reliable data on the evaluation of food fortification programmes or availability of fortified foods in Nigerian markets. Such data are required to determine whether the desired objectives of reaching the vulnerable groups with fortified foods and enhancing their nutritional status are being achieved. Without relevant and independent data obtained through sampling and evaluating the quantity of fortificants in the fortified food products, manufacturers' compliance and the overall objectives of the fortification programme cannot be effectively assessed. Furthermore, it is crucial to ensure that available fortified food vehicles contain the recommended amount of fortificants to guarantee the attainment of the desired impacts of fortification. Therefore, this study was aimed at assessing the quantity of mandatory fortificants such as vitamin A, iron and Zinc as well as other mineral elements (Ca, Cu, Mg, Mn, P and Se) in the fortified wheat flour sold in Sokoto State to ascertain manufacturers' compliance with the mandatory micronutrients supplementation levels for wheat flour as part of the national food fortification regulations [regulation 2(1)(c) and 6(2)] as contained in the Food Fortification Regulation of 2021 (NAFDAC, 2021).

MATERIALS AND METHODS

Study Location

The wheat flour samples used for this study were sampled in Sokoto metropolis, Sokoto State of Nigeria. The state has a projected population of 6,449,161 with a land size of 28,232.37sq kilometres. The state is positioned within longitudes 11° 30' to 13° 50' East and latitude 4° to 6° North (Figure 1).

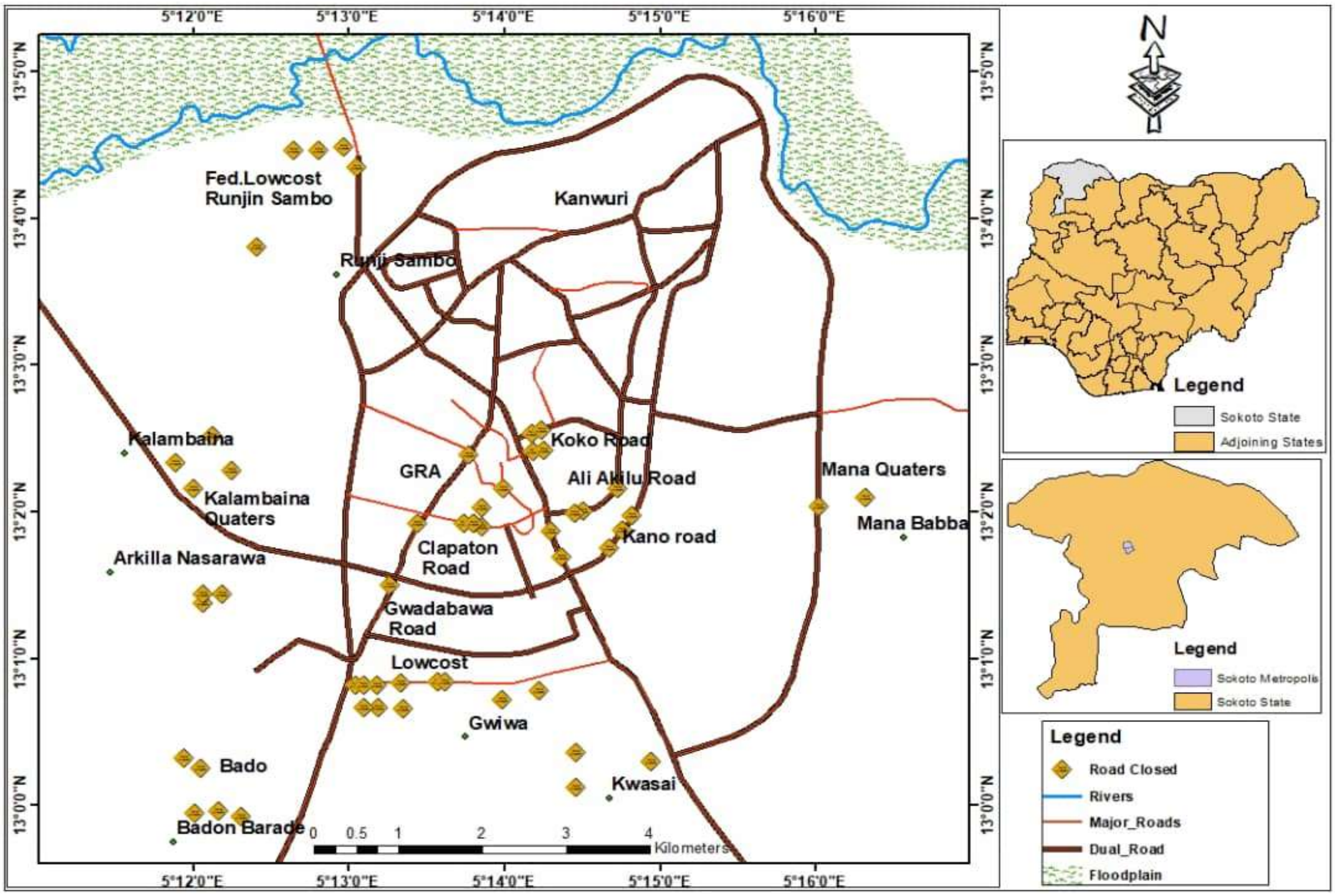

Figure 1: Map created using the ArcGIS 10.5 software showing the location of the study area.

Sample Collection

Eight (8) fortified wheat flour samples were collected from different markets, department stores, and other retail outlets in Sokoto metropolitan areas (comprising Dange-Shuni, Sokoto North, Sokoto South, and Wamakko Local Government Areas). The eight samples were the only available fortified wheat flour brands at the time of the sampling. For the selection of sample representative in each brand, simple random sampling was adopted to ensure that each bag of the product has an independent and equal chance of being selected among the brands. All the products were packaged in a 50 kg polypropylene bag by the manufacturers. About 500 g of each brand were sampled and transferred into clean plastic bottles and well-preserved in a cool dry place as recommended by the manufacturers. Prior to the sampling, the selected sample was thoroughly mixed to ensure full and equal representation. The products were produced by different manufacturers in Nigeria and the details of each product such as brand name, name and address of manufacturer, nutritional information, manufacturing date, best before date and batch numbers of the products were recorded. The sampling and analysis were done in August, 2021.

Chemicals and Reagents

Analytical grade reagents were used throughout the experiments.

Sample Preparation

For the determination of mineral elements such as Calcium (Ca), Copper (Cu), Iron (Fe), Magnesium (Mg), Manganese (Mn), Phosphorus (P), Selenium (Se), and Zinc (Zn), the samples were wet digested as reported by Alves *et al.* (2014). The process was carried out in a fume cupboard. Firstly, 0.5 ml of every sample was taken into a 50 ml conical flask, and then 5 ml Nitric acid (HNO_3) were added which formed a yellow fume mixture which disappeared after gentle heating for 20 min. Subsequently, the mixture was cooled for 30 min; then 2.5 ml Perchloric acid ($HClO_4$) were added and heated until it turned colourless. Lastly, 20 ml of distilled water were added to the heated samples and filtered into plastic bottles and stored for analysis using Atomic Absorption Spectrophotometer (AAS).

Determination of Vitamin A

The level of Vitamin A was determined using spectrophotometric method developed by Makhumula and

Asumani as described by Monica *et al.* (2007). Firstly, 10 g of flour were weighed into a 50 ml centrifuge tube, 20 ml of distilled water were added and vortexed using vortex mixer (G560, Scientific industries, China) for 1 min, another 10 ml of 2-propanol were added and vortexed for 1 minute. Then, 5 ml of the solution were measured into a 50 ml test tube where replicates were prepared. Also, 5 ml of 0.1 N-sodium hydroxide were added to each tube and mixed for 30 sec followed by addition of 2-3 drops of phenolphthalein (1% w/v) into the same tube and mixing for 5 sec. Additionally, 5 ml of n-heptane were added into each tube and vigorously vortexed for 50 sec to ensure complete extraction of retinyl palmitate. The tube was slightly opened to release the pressure. The separations of phases were achieved. The aqueous phase had a fuchsia colour, with the top organic solvent phase becoming colourless and centrifuged for 10 min at 1000 rpm. The absorbance of the organic phase was measured at 362 nm using spectrophotometer (Spec. AE-350, Jefferson Ltd, USA). The procedure was repeated five (5) times for each sample and mean values recorded. The concentration of vitamin A (as retinol palmitate) was obtained by using the relation:

$$\text{Vitamin A (mg/kg)} = \frac{AbsCorrectedb}{a} \times \frac{Vorg.}{Vflour} \times \frac{Vi}{W} \times \frac{CFspec}{R} \times D$$

Where:

Abs corrected = absorbance sample – absorbance blanks. The absorbance of blank is average for three readings which should be less than 0.050. To express the results as un-esterified retinol, the ratio of the molecular weight of retinol/retinyl palmitate (286.46/524.84 = 0.546), must be taken into consideration. Simplified equation to estimate the un-esterified retinol is:

$$\text{Retinyl palmitate (mg/kg)} = \frac{AbsCorrectedb}{a} \times \frac{Vorg.}{Vflour} \times \frac{Vi}{W} \times \frac{CFspec}{R} \times D \times 0.54$$

Where:

A = Retinyl palmitate absorption coefficient in heptane = 0.092mg/cm/L

Vorg. = Volume of the organic phase = 5.0m/L

V four =Volume of aliquot analyzed from the flour solution =5.0 m/L

Vi = Volume of the initial solution of the sample =30m/L

W = Weight of the sample =10 g

R = Recovery =0.906

CF Spec= Correction factor of the spectrophotometer = 1

D = Dilution factor = 1

Determination of mineral elements

Determination of mineral elements (Ca, Cu, Fe, Mg, Mn, P, Se and Zn,) was performed according to the methods of the American Association of Cereal Chemists (AACC), and the Association of Official Analytical Chemists (AOAC) (1995) using an Atomic Absorption Spectrophotometer (model number AA-6300, GBC Scientific Equipment, USA). For all the elements, triplicate determinations were conducted and recorded.

Statistical Analysis

The data were expressed as mean ± standard deviation (SD). Statistical analyses were performed using GraphPad Prism Software (version 6.01; San Diego, USA). Statistical difference were assessed using analysis of variance (ANOVA) followed by Tukey's multiple comparison *post hoc* test to analyse the difference between groups. A $p < 0.001$ was taken as statistically significant.

RESULTS AND DISCUSSION

Figure 2 shows vitamin A concentration in "fortified" wheat flour sold in Sokoto metropolis vis-à-vis the specified mandatory concentrations (2.00 mg/kg). Vitamin A concentration in the samples analysed ranged from 0.347 ± 0.027 mg/kg to 0.586 ± 0.037 mg/kg with sample number 4 (WF-004) having the highest concentration (0.586 ± 0.037 mg/kg) while sample 3 (WF-003) contained the lowest (0.347 ± 0.027 mg/kg). The result of this study shows that the vitamin A concentration in the entire eight (8) samples analyzed were significantly lower ($p < 0.001$) than the mandatory requirement of 2.0 mg/kg specified by the national regulatory agencies.

The concentration of Iron (Fe) is presented in Figure 3. The Fe contents range from 0.235 ± 0.033 mg/kg to 0.520 ± 0.140 mg/kg and are significantly ($p < 0.001$) lower than the mandatory level of 40 mg/kg. But only sample 003 contain the highest concentration (0.520 ± 0.140 mg/kg) while sample 001 has the lowest level (0.235 ± 0.033 mg/kg). The levels of zinc (Zn) in the eight (8) fortified wheat flour samples are presented in Figure 4. Sample WF-002 had the highest level of Zn (0.180 ± 0.033 mg/kg) and sample WF-001 had the lowest (0.024 ± 0.012 mg/kg) which is significantly ($p < 0.001$) lower than the positive control. A significantly lower ($p < 0.001$) level of Zn in the entire samples analysed was observed when compared to the mandatory level of 50 mg/kg recommended by the national regulatory bodies.

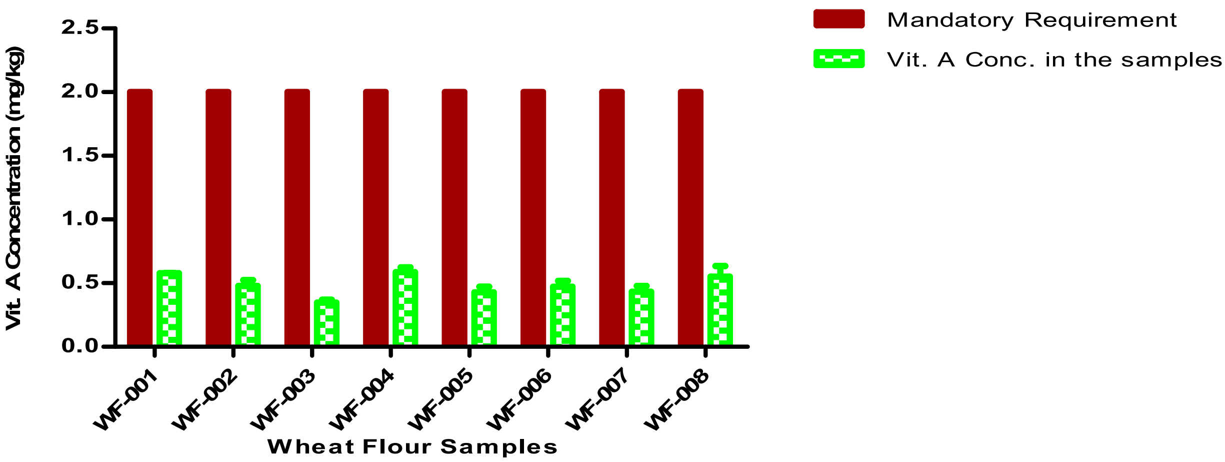

Figure 2: Concentration of Vitamin A in Fortified Wheat Flour Samples Sold in Sokoto Metropolis Compared with the Mandatory Requirement.

Results are means ± SD of triplicate measurements.

Statistical significance: *** $p < 0.001$ vs Mandatory requirement as positive control (One-way ANOVA with Dunnett posttest)

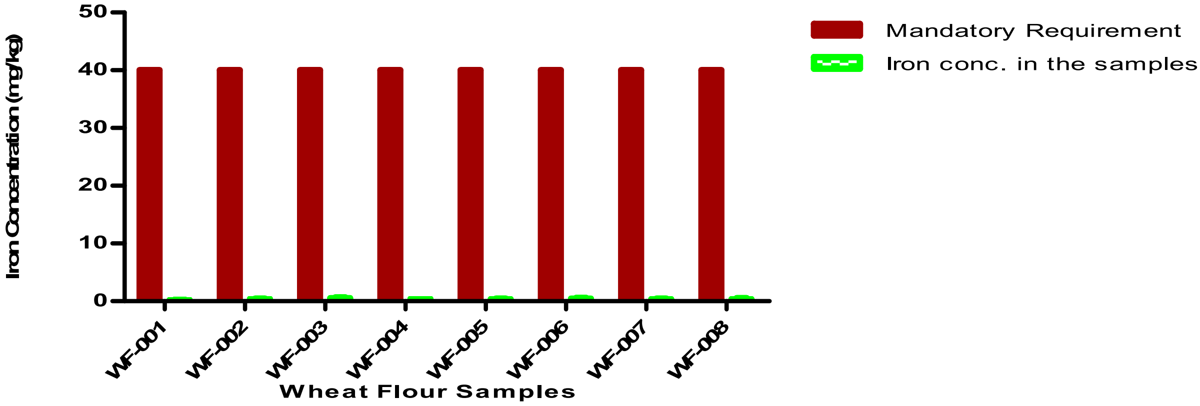

Figure 3: Level of Iron (Fe) in Fortified Wheat Flour Samples Sold in Sokoto Metropolis Compared with the Mandatory concentrations.

Results are means ± SD of triplicate measurements. Statistical significance: *** $p < 0.001$ vs Mandatory requirement as positive control (One-way ANOVA with Dunnett posttest).

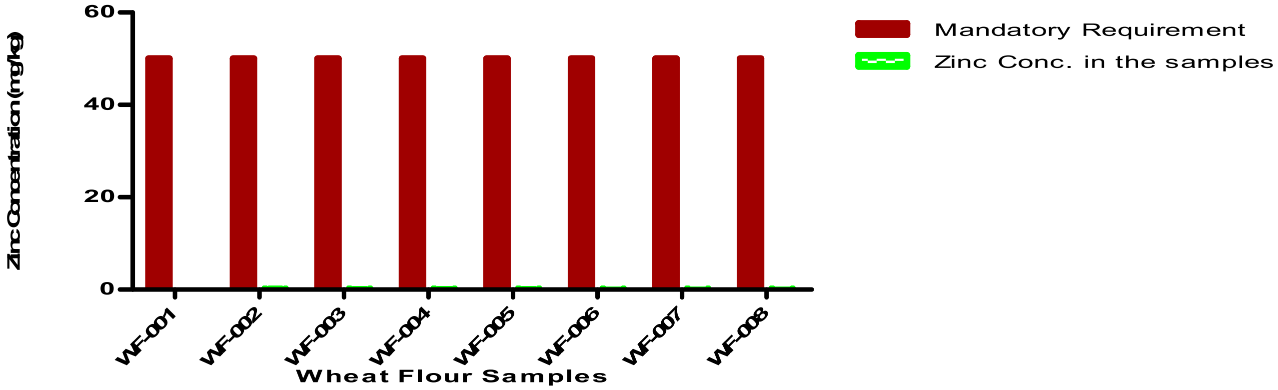

Figure 4: Level of Zinc (Zn) in Fortified Wheat Flour Samples Sold in Sokoto metropolis compared with the mandatory concentrations. Results are means ± SD of five (5) repeated measurements. Statistical significance: *** $p < 0.001$ vs Mandatory requirement as positive control (One-way ANOVA with Dunnett posttest).

Although, mineral elements such as Calcium (Ca), Copper (Cu), Magnesium (Mg), Manganese (Mn), Phosphorus (P) and Selenium (Se) are non-mandatory fortificants for wheat flour, they were also quantified as shown in Table 1. The result reveal that the level of Ca, Cu, Mg, Mn and P was significantly lower ($p < 0.001$) when compared with their Nutritive Reference Values (NRVs) of 1000 mg/kg, 900 mg/kg, 310 mg/kg, 3 mg/kg and 700 mg/kg respectively as specified by the national regulators. The result also show a wider range (7.383 ± 0.489 to 105.631 ± 1.317 mg/kg) in the Selenium (Se) content with the first sample (WF-001) having the highest Se content (105.631±1.317 mg/kg) while sample WF-007 contained the lowest level (7.383 ± 0.489 mg/kg). The levels of Se in the 1st and 2nd samples were significantly higher ($p < 0.001$) than the NRVs of 60 mg/kg while the levels in the other samples were significantly lower ($p < 0.001$) than the NRVs.

Table 1: Concentrations of mineral elements in fortified wheat flour sold in Sokoto metropolis compared with Nutritive Reference Values (NRVs)

	Concentration (mg/kg)					
Sample ID	Ca	Cu	Mg	Mn	P	Se
WF-001	860.895 ± 31.730^{a}	0.200 ± 0.053^{a}	61.467 ± 0.909^{a}	0.167 ± 310^{a}	3.340 ± 0.011^{a}	105.631 ± 1.317^{a}
WF-002	768.360 ± 28.686^{b}	0.049 ± 0.037^{b}	64.748 ± 0.673^{b}	0.145 ± 0.139^{b}	2.275 ± 0.008^{c}	74.766 ± 3.177^{b}
WF-003	872.438 ± 7.619^{c}	0.193 ± 0.026^{c}	62.478 ± 1.342^{c}	0.480 ± 0.146^{c}	2.632 ± 0.009^{c}	52.549 ± 2.599^{c}
WF-004	863.881 ± 26.444^{d}	0.154 ± 0.026^{d}	58.288 ± 3.197^{d}	0.369 ± 0.141^{d}	2.980 ± 0.004^{d}	44.234 ± 1.964^{d}
WF-005	653.731 ± 24.908^{e}	0.103 ± 0.052^{e}	63.969 ± 0.468^{e}	0.220 ± 0.016^{e}	2.189 ± 0.039^{e}	27.966 ± 1.364^{e}
WF-006	565.576 ± 12.569^{f}	0.053 ± 0.029^{f}	61.242 ± 0.280^{f}	0.539 ± 0.301^{f}	2.178 ± 0.039^{g}	25.676 ± 2.212^{f}
WF-007	427.264 ± 13.494^{g}	0.057 ± 0.033^{g}	60.191 ± 1.652^{g}	0.977 ± 0.047^{g}	2.516 ± 0.012^{f}	7.383 ± 0.489^{g}
WF-008	762.836 ± 12.492^{h}	0.060 ± 0.045^{h}	63.483 ± 1.313^{h}	0.311 ± 0.029^{h}	3.629 ± 0.016^{h}	33.791 ± 2.363^{h}
*NRV_s (mg/Kg)	$1000^{a,b,c,d,e,f,g,h}$	$900^{a,b,c,d,e,f,g,h}$	$310^{a,b,c,d,e,f,g,h}$	$3.00^{a,b,c,d,e,f,g,h}$	$700^{a,b,c,d,e,f,g,h}$	$60^{a,b,c,d,e,f,g,h}$

Key: Values are expressed as mean ± standard deviation of triplicate measurements; Statistical significance: $p < 0.001$ vs NRVs as positive control (One-way ANOVA with Dunnett posttest), values with the same superscript in same column are statistically significant ($p < 0.001$).* Nutritive Reference Values (NRVs); Source: Lewis, (2019), NAFDAC (2021).

Discussion

Micronutrient deficiency is considered as a public health threat which has persisted for decades particularly with high prevalence of deficiencies of Vitamin A, folic acid, iron and zinc (Anjorin *et al.,* 2019). Food fortification is recommended as the most scalable, sustainable, cost-effective and reliable strategy for prevention of MND and its consequences (Biebinger and Hurrell, 2008). Although, Nigeria has started implementing food fortification in 1992 which was later expanded in 2002 as a strategy for eradicating MND (Sablah *et al.,* 2013), but there is scarcity of independent and reliable data on the evaluation of fortificants in the fortified food in order to ascertain manufacturers' compliance with the specified regulations. Therefore, this study evaluated the level of mandatory fortificants (vitamin A, Fe and Zn) and non-mandatory (Ca, Cu, Mg, Mn, P and Se) in eight (8) different brands of fortified wheat flour sampled across diverse locations of Sokoto metropolis.

Though, Codex Alimentarius Commission (CAC), a crucial section of the joint FAO/WHO food standard programme as well as Nigerian food regulatory authorities such as NAFDAC and Standard Organization of Nigeria (SON) have recommended Vitamin A, Fe and Zn as a mandatory fortificants for wheat flour fortification and specified minimum requirement for wheat flour fortification with these fortificants, our findings revealed that the levels of vitamin A, Fe and Zn in the eight (8) fortified wheat flour samples analysed were significantly below ($p < 0.001$) the minimum standard of 2 mg/kg, 40mg/kg and 50mg/kg respectively.

This study substantiates the findings of Maigari *et al.* (2012) in Kano metropolis, who reported that the levels of vitamin A in the wheat flour samples were much lower than the required fortification level. Also, a national survey conducted by NAFDAC in 2003 on fortified wheat flour from the distribution chain revealed that only 5% of the products complied with the vitamin A fortification standard (Akinyele, 2009). Another nationwide survey by Ogunmoyela *et al.* (2013), who collected fortified flour samples from factories and markets from all the 36 states of Nigeria, found that compliance of vitamin A and iron (Fe) in wheat flours were 12.2 to 33.3% and 1.0 to 21.0% respectively. Consequently, they recommended that in Nigeria, there was a need for a major and all-inclusive review of the fortification approach in order to achieve its core vision. Additionally, the result of study by the Uchendu and Atinmo (2016) found vitamin A level in wheat flour of 19 to 83% which was lower than the recommended level of 88% (15/17) of the samples analysed and consequently concluded that the quantity of vitamin A in the wheat flour samples analysed was significantly lower than the Nigerian recommended level. A Fortification Assessment Coverage Tool (FACT) Survey conducted in 2 States of Nigeria namely Kano and Lagos by Food Fortification Initiative (FFI) in 2015 concluded that there was low compliance with the fortification standard by the various wheat flour manufacturing industries which hindered the success of the programme despite the high intake of the fortified food vehicles (FFI, 2018).

Sokoto state is situated in tropical region, making the state prone to high temperature and humidity which may affect the fortificants in the wheat flour particularly vitamin A especially if not properly packaged. Poor handling, storage and transportation of wheat flour products may also the reason for the low level of fortificants observed in this study and other studies (Maigari *et al.,* 2012). Another possible reason for the low level of fortificants is the improper packaging of the wheat flours by the manufacturers because polypropylene bags are used as packaging material which might not protect the product from air and moisture particularly when transporting and storing the products (Uchendu and Atinmo, 2016). In support of this, Butt *et al.* (2004) observed that polypropylene bags do not appropriately protect wheat flour from atmospheric oxygen, which degrades it. Another possible reason for the low level of these fortificants in wheat flour samples may be due to the perceived quantities of the fortificants (2 mg/kg, 40 mg/kg and 50 mg/kg for vitamin A, iron and zinc respectively) stipulated by the regulatory bodies by the producers as being too high due to high cost of the premix (Ogunmoyela *et al.*, 2013). Furthermore, Garrett and Luthringer (2015) argued that part of the reasons for the low level of these fortificants in the national regulations and laws regarding to supervision, inspection, surveillance, monitoring and enforcement are scrappy and not adequately established in accordance with legal contexts, thus resulting to feeble implementation. Similarly, another potential reason for low level of fortificants in the fortified flour products may be poor quality control practice. Low resources available to enforcement officers may militate against proper oversight functions and high cost of governance for monitoring of the programmes (Garrett and Luthringer, 2015).

Although the stability of vitamin A is affected by both chemical and physical factors mainly because of its numerous double bonds. It has been reported that once it is added at the recommended level, the flour can hold sixty percent of the added vitamin A within 1 month (Uchendu and Atinmo, 2010). The low fortification compliance by the millers can lead to low availability of micronutrients and low intake by the susceptible groups, thereby preventing the programme's impact of eliminating MND (Yusufali *et al.*, 2012). Another possible reason for the low level of fortificants in the wheat flour samples analysed may be the poor quality of the fortificants added during fortification.

In 2000, the WHO recognized vitamin A, iron and zinc deficiencies as one of the greatest severe health risk elements globally (WHO, 2000). Deficiencies of these micronutrients lead to a vicious cycle of deprived health condition, poor productivity, poverty and destroying economic security of numerous countries across the globe (Bain *et al.,* 2013), thus necessitating of improved intake of these essential micronutrients particularly by the vulnerable groups (children, pregnant and breast feeding women). Furthermore, adequate consumption will protect them from several disabilities and diseases which will subsequently help children to grow, develop the required cognitive abilities as well as improve the health and productivity of adults (Klemm *et al.,* 2010). Therefore, one of the critical means to prevent and eradicate micronutrient deficiencies among vulnerable populations is through micronutrient fortification of flour products (Huo *et al.*, 2011 & 2012). This serves as the basis for several countries through their regulatory bodies mandating fortification of major food vehicles such as wheat flour, wheat semolina, composite flour and maize or whole flour with varieties of fortificants like vitamin A, iron, zinc, B-complex (B1, B2, B3, B6, B9, B12) and folate. Furthermore, in most countries, micronutrient fortification will significantly help in achieving food security as well as attaining the Sustainable Development Goals (SDGs) 1, 2 & 3: no poverty, zero hunger and good health and well-being respectively (UNDP, 2022).

Mineral elements such as Ca, Cu, Mg, Mn, P and Se are non-mandatory fortificants for wheat flour. However, they were also evaluated due to their essentiality for the proper functioning of organisms. An estimated more than 3 million population globally faces deficiency of minerals leading to decreased working efficiency, high cost of healthcare, and high rate of early death (Welch and Graham, 2004). These mineral elements are considered vital mainly due to their antioxidant role, thus are termed antioxidant mineral elements. They are cofactors serving as critical components of antioxidant enzymes responsible for protecting cellular constituents against oxidative damage (Mcdowell *et al.,* 2007). Example: Selenium (Se) for glutathione peroxidase, Iron (Fe) for catalase whereas Cu, Zn, and Mn are cofactors for superoxide dismutase. For effective metabolic functions in the body minerals are required to activate these enzymes; therefore their deficiencies can lead to different chronic diseases (Branca and Ferrari, 2002). These antioxidant enzymes can only be synthesized by the biological system when the mineral elements are sufficient. Thus their deficiency can result in oxidative stress and subsequent impairment of biological molecules including membranes (Mcdowell *et al.,* 2007). Calcium (Ca) is one of the abundant nutrients in the human biological system, where about 99 percent of it can be found in bones and teeth while fewer than one percent is intracellularly stored in serum (Beto, 2015). Calcium (Ca) is a vital element for living organisms being a critical element involved in numerous biological processes ranging from cell signaling to bone growth (Ropo *et al.,* 2016). Phosphorus is a basic and integral unit of nucleic acids and cell membranes that is also involved in energy generation during cellular reactions (Roy and Lall, 2003; NRC, 2011).

Wheat is consumed in different forms of food worldwide, and is recognized as a good nutritional source of mineral elements (Hussain *et al.,* 2010). Hussain *et al.* (2010) revealed that the levels of mineral elements such as Cu, Fe, Se, Mo, Mg, Zn, Mn and P in wheat flour provide more than 70% of their daily intake upon ingestion of about 200g of wheat flour per person per day. The results of this study showed that the levels of Ca, Cu, Mg, Mn and P were significantly lower ($p < 0.001$) than their Nutritive Reference Values (NRVs) of 1000 mg/kg, 900 mg/kg, 310 mg/kg, 3 mg/kg and 700 mg/kg respectively. The levels of Se in the first 2 samples were significantly higher ($p < 0.001$) than the NRVs of 60 mg/kg. The concentration of the mineral elements evaluated in this study follows the sequence Ca > Mg > Se > P > Mn > Cu. The result of this study showed that the level of Ca was higher than any other element which is inconsistent with the reports of Araujo *et al.* (2008), Tejera *et al.* (2013), and Anon *et al.* (2018). Similarly, Anwaar *et al.* (2014) reported that a significantly higher amount of Ca and other minerals were observed in wheat flour, thus wheat flour can significantly add to the dietary intake of essential elements. The concentration of mineral elements in wheat flour varies due to geographical origin, texture, and the features of the technological process used in the milling method (Gonzalez *et al.,* 2001). Other factors that may influence the level of the mineral elements in wheat flour are the type of cultivation, the soil and weather conditions during growth as well as the quantity and nature of fertilizer used (Ekholm *et al.,* 2007). Environmental factors, particularly agricultural soils polluted with heavy metals transferred to the root of the wheat may increase the concentration of the mineral elements in the wheat flour.

Findings of this study suggest the need for improved and sustained monitoring of fortified foods by the relevant regulatory bodies for significant increase in the nutritional status of vulnerable groups through consumption of fortified foods containing adequate and recommended fortificants to address the menace of MND and for improved health status and productivity of the population.

This study is an independent study which employed good experimental design and sensitive equipment for the analysis thereby making the findings reliable and accurate. Furthermore, the study is an important and independent contribution to the literatures on food fortification particularly in Nigeria with a view to improve the effectiveness of the country’s food fortification programme. Nevertheless, the findings of this study were based on eight (8) samples analysed because they were the only available fortified wheat flour products as at the time of sampling. This sample size is considered too small.

Based on the findings of this study, the following recommendations are suggested. Independent studies are recommended nationwide which may encompass large samples of fortified food products such as wheat flour, sugar, oil, margarine, semolina, and maize flours considering that only eight fortified wheat flour samples were investigated by this study. Improved Post Marketing Surveillance (PMS) of fortified food products, using larger sample sizes covering several states, should be conducted by the relevant regulatory bodies in the country. Regular and routine sampling and laboratory evaluation of fortified food products should be conducted by the relevant regulatory agencies to determine the actual content of fortificants in the fortified foods.

CONCLUSION

Although food fortification is acknowledged and recommended as the best cost-effective approach to combating MND, the result of this study has shown that the levels of the fortificants (vitamin A, iron and zinc) in the available wheat flour brands in the markets were significantly ($p < 0.001$) below the recommended level. The population, despite intakes of the food vehicle, has not been getting the required quantities or the beneficial effects of the fortificants. Apparently, the producing firms are far from complying with the mandatory national fortification standards, thereby hindering the achievement of the goals of the fortification programme in Nigeria. This calls for policy review *cum* improved surveillance and enforcement at the factory level.

AUTHORS' CONTRIBUTIONS

MMA participated in laboratory analysis, data analysis, role/writing-original draft writing, review and editing, also provided resources. SAU participated in laboratory analysis, data analysis and provided resources. RAU conceptualize the idea of the research, provided resources, participated in role/writing-original draft writing, review and editing.

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None

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest

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