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Evaluation of Fortificant Levels in Some Selected Fortified Food Products Sold in Sokoto Metropolis

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Abstract

Food fortification is the most scalable, sustainable, cost-effective and reliable strategy for prevention of Micronutrient deficiency (MND). MNDs have persisted for decades in Nigeria with deficiencies of vitamin A, folic acid, iron and zinc being the most prevalent. Only few studies evaluated the levels of fortificants in fortified foods in sale outlets. This study evaluated the level of both the mandatory (vitamin A, iron and zinc) and non-mandatory fortificants such as Calcium (Ca), Copper (Cu), Magnesium (Mg), Manganese (Mn), Phosphorus (P), and Zinc (Zn) in fifteen (15) samples selected from different fortified foods namely: wheat flour, whole wheat flour, maize flour, and wheat semovita. Level of vitamins A was determined spectrophotometrically as described by Adamu (1976) while the levels of Fe, Zn, Ca, Cu, Mg, Mn, Ph, and Se were quantified using Atomic Absorption Spectroscopy (AAS) as approved by the method of AACC and AOAC (1995). Findings of this study show that the levels of both the mandatory and non-mandatory fortificants in the fortified foods analyzed were significantly ($p < 0.001$) lower than the mandatory requirement levels specified by Nigeria's Regulatory Agencies. Thus, the public has not been consuming the required fortificants in their diets and have not been benefiting from these nutrients. The low levels of those fortificants, especially the mandatory ones, can be attributed to the poor compliance with the national fortification guidelines by the manufacturers. Other factors are poor monitoring and enforcement by relevant regulatory bodies, poor storage and transportation. Thus, sustained monitoring, surveillance and enforcement are recommended for total compliance with the specified regulations.

Keywords: Compliance; Food fortification; Fortificants; Maize flour; Micronutrient deficiency; Wheat flour; Whole wheat flour; Wheat semovita

Introduction

Micronutrients are essential vitamins and minerals required from the diet for sustaining life and almost all cellular and molecular functions (West *et al.*, 2012). These micronutrients are required in minute amount by the body system for appropriate growth and development (Best *et al.*, 2011). Micronutrients have a wide range of functions such as enabling the body to produce enzymes, hormones and other critical substances required by the body for regular growth (Celep *et al.*, 2017). Though required in very small amount, their deficiencies can have a wide range of negative health impacts which can ultimately lead to death if untreated. The impacts of micronutrients on a body's health are enormous and their deficiencies can lead to high morbidity, high mortality, and permanent impairment of physical and cognitive development of children in particular (WHO, 2014). The deficiencies of these micronutrients are termed "hidden hunger". These micronutrients whose common deficiencies are prevalent are vitamin A, folate, iron, iodine, and zinc; though, numerous other micronutrient deficiencies exist (Jennifer *et al.*, 2017).

Micronutrient deficiency is also a public health threat in Nigeria which has persisted for decades with high prevalence of deficiencies of Vitamin A, folic acid, iron and zinc (Anjorin *et al.*, 2019). Similarly, MNDs are main contributors to the global burden of disease as it affects about 30% of the world's population (WHO, 2014). It was estimated that about one-third of the world populations suffer from at least one form of micronutrient deficiencies (Nutrition and food system, 2017). Globally, about 149 million and 45 million children (under 5 years) are estimated to be stunted and wasted respectively (WHO, 2022). Same report showed that about 45% of the deaths among these children are due to malnutrition particularly in low and middle income countries.

Micronutrient deficiency has been reported to be one of the main risk causes for child survival in Nigeria, resulting in increased risk of death due to diseases like acute gastroenteritis, pneumonia, and measles (Ekweagwu *et al.*, 2008). There are over 2.6 million severely malnourished children and more than 13 million stunted, thus making the country 3rd globally with highest number of stunted and wasted children (Ministry of Budget and National Planning, 2016). The report further expressed that northern Nigeria, particularly the western geopolitical zone, which accounts for 27% of the country's population bears the greatest burden of the nutritional problem specifically severe acute malnutrition. The percentage of stunted children is highest in the North-West at 57% and lowest in the South-East at 18% (Demographic and Health Survey, 2018).

Report of the Committee on Food Security and Nutrition stated that there are 3 greatest public health concerns namely: vitamin A, iron and iodine deficiencies (Nutrition and Food Systems, 2020). Vitamin A and Iron deficiencies are the furthermost public micronutrient deficiencies, which affects more than one-third of the population globally, hence leading to microcytic anaemia, fatigue, weakness, shortage of breath and dizziness (Allen, 2000; McLean *et al.*, 2009). World Health Organization's report showed that in 2016 alone, more than 40% of children and pregnant women suffered from anaemia, and most of them were due to microcytic anaemia (Horowitz *et al.*, 2013; Hannah, 2017). Furthermore, Semba *et al.* (1993) and Thurnham *et al.* (2003) reported that vitamin A deficiency is the principal cause of preventable blindness in children and increases the risk of severe infections, such as diarrheal diseases and measles. The WHO projected that vitamin A deficiency is the leading cause of blindness to more than 250 million children, where half of them die within a year of blindness (WHO, 2009). Iron deficiency is the world's most prevalent, but easily preventable (WHO, 2007) and the main cause of preventable brain damage in childhood (Andersson *et al.*, 2012). Andersson *et al.* (2012) stated that about 2 billion people worldwide suffered from inadequate iron status, which negatively affects countries' overall health and productivity, thereby hindering their socioeconomic growth.

Strategies have been identified and implemented to combat micronutrient deficiency (MND), which include supplementation (orally or intravenously via administration of pharmaceutical micronutrients preparations) and fortification of major food vehicles such as cereal flour, salt, sugar, vegetable oil, margarine (butter) and soy sauce with relevant micronutrients (vitamin A, iron, iodine and zinc). Due to prevalent and consistent consumption of these major food vehicles across socioeconomic sections of many geographies of the world, there are considered major food routes for micronutrients fortification (WHO/FAO, 2006). Food fortification is considered as the most cost-effective as well as long term approach for prevention of micronutrient deficiencies, therefore, national programmes have been initiated to ensure appropriate and effective fortification of widely consumed staple foods (Biebinger and Hurrell, 2008). Researchers namely Sun *et al.* (2008); Huo *et al.* (2011; 2012) are of the opinion that micronutrient fortification shows a substantial impact in the prevention of micronutrient deficiencies among vulnerable populations.

Micronutrients fortified food products have been recommended to be effective and efficient in increasing the intake of micronutrients and decreasing the menace of micronutrients deficiencies (MND) in numerous countries across the globe (Mannar and Gallego, 2002). In a report released by UNICEF (2013) governments of more than 140 countries through collaboration with industries and civil societies have implemented salt iodization (UNICEF, 2013) while 83 countries have implemented fortification of at least one type of cereal grain with vitamin A (Food Fortification Initiative, 2013). Twenty-three (23) other countries had authorized fortification of edible oils (Sablah *et al.*, 2013). Globally, the Codex Alimentarius of the Food and Agriculture Organization (FAO) and the World Health Organization (WHO) have approved common principles and guidelines for the addition of fortificants (vitamins and minerals) to foods (Maria *et al.*, 2012).

To eradicate MND, the Nigerian government has mandated the fortification of five (5) major foods vehicle namely wheat flour, semolina flour, maize flour, sugar, and oil with iron and vitamins (A, B1, B2, B3, B6, B9, B12) and Zinc (UNICEF, 2005; Busari, 2013). Therefore, food fortification in Nigeria is mandatory and a critical pillar of national food and nutrition security plan. For decades the food fortification programme has been in existence in Nigeria, but there are scarcities of independent and reliable data which evaluated the levels of fortificants in the mandatory fortified food products with a view to ascertain the effectiveness of the programme and the manufacturers' compliance with the national fortification regulation. Moreover, evaluation of fortificants levels in the fortified foods is one of the critical tools of guaranteeing that the available fortified food vehicles contain the specified quantity of fortificants for the overall achievement of the core objectives of the food fortification approach in the country. Consequently, this study was intended to evaluate the level of mandatory fortificants (vitamin A, iron and Zinc) and mineral nutrients such as Ca, Cu, Se, Mg, Mn and P in some selected fortified foods sold in

Sokoto State. This is to establish the degree of manufacturers' compliance with the Nigerian food fortification regulations which mandate fortification of fortified foods with mandatory micronutrient requirements levels or nutrient reference values (NRVs) as contained in the 2021 official gazettes of Food Fortification Regulation.

Materials and methods

Sample sources and collection

A total of Fifteen (15) different fortified foods were sampled from different open markets, stores and retail outfits in diverse locations of Sokoto metropolis. These fortified foods include 8 fortified wheat flour, 3 wheat semovita products, 3 brands of whole wheat flour, and 1 product of maize flour. These fortified foods are the only available fortified foods of that category as at the period of sampling. Sample representative from each brands were selected randomly, this is to ensure that each bag or pack size of the product was given an independent and equal chance of selection. The selected sample was mixed thoroughly to ensure uniformity of the parts of the sample. The sample representative was collected into clean plastic and stored in a cool dry place as recommended by the manufacturers.

Criteria for sampling

The criteria adopted for sampling in this study were as follows:

- Only foods claimed to be fortified by the manufacturer were sampled.
- Products that were not expired (valid products).
- Products with details such as brand name, name and address of the manufacturer, sign and symbol of fortification, nutritional claim, batch number, manufacture date and best before date were sampled for this study.
- Products that was well packaged and sealed by the manufacturer to avoid being tempered.
- Products that were not exposed to harsh conditions which can affect the fortificants.

Chemical and reagents

All the reagents used for this study were of analytical grade.

Sample Digestion

Atomic Absorption Spectrophotometer (AAS) was used to quantify the levels of mineral elements such as Iron (Fe), Zinc (Zn), Phosphorus (P), Magnesium (Mg), Manganese (Mn), Calcium (Ca), Copper (Cu) and Selenium (Se). Therefore, all the samples were subjected to wet digestion according to the method of Alves *et al.* (2014). About 0.5 g of each sample was measured and transferred into a 50 ml conical flask, followed by addition of 5 ml of Nitric acid (HNO_3) which resulted in the formation of a yellow colour. After a 20 min gentle heating, the colour disappeared and the mixture was allowed to cool for 30 minutes. Thereafter, 2.5 ml of perchloric acid ($HClO_4$) was added and heated until it turned colourless. Finally, 20 ml of distilled water were added to the heated samples and filtered into plastic bottles and stored for mineral elements analysis.

Spectrophotometric determination of vitamin A

Determination of vitamins A in flour was carried out using spectrophotometric method as described by Adamu (1976). Firstly, 1 g of the sample was weighed and transferred into clean glass test tube followed by addition of 1 ml of 95% ethanol. Thereafter, 2 ml of petroleum ether was added where vitamin A in the sample was extracted by shaking the mixture with the aid of a vortex mixer for 5 minutes, after which the mixture was centrifuged for 10 minutes at 2000 rpm. About 2 ml of the hexane layer was transferred to a 10 ml silica cuvette and the absorbance (A1) was spectrophotometrically (Spec. AE-350, Jefferson Ltd, USA) measured at 450 nm. Similarly, a standard calibration curve was prepared by diluting 0.5 g of vitamin A standard with 50 ml of hexane from which the working standard was formed. The concentrations of vitamin A in the samples were evaluated from the standard calibration curve.

Determination of mineral elements

A method approved by the American Association of Cereal Chemists (AACC), and the Association of Official Analytical Chemists (AOAC) methods of (1995) using a Microwave Plasma Atomic Emission Spectroscopy (MP-AES) (G8007A, Agilent technologies, Australia). The result was read and recorded in triplicate.

Statistical Analysis

The data expressed as mean ± standard deviation (SD) were analyzed using Graph pad Instat version 3.02 (Graph pad Corp., San Diego, USA). Statistical difference analysis was made using analysis of variance (ANOVA) with post hoc Turkey's multiple comparison tests. A $p < 0.001$ was taken as statistically significant.

Results and Discussion

Results

The results of the concentration of mandatory fortificants (vitamin A, Fe and Zn) in fifteen (15) differently selected fortified foods vehicles (wheat flour, wheat semolina, whole wheat flour, and maize flour) are presented in Table 1. The results show that the concentration of these fortificants in the entire 15 samples (in 4 categories of foods) analyzed were significantly lower ($p<0.001$) than the mandatory requirements mandated by the national food regulatory Agencies. The concentration of vitamin A in the wheat flour, wheat semovita, and whole wheat flour samples analyzed range from 0.347±0.027 mg/kg - 0.586±0.037 mg/kg, 48.181±2.083 - 54.100±0.788 mg/kg, and 45.821±1.971 - 49.618±1.274 respectively. The single maize flour sample analyzed contained 47.234±1.697 mg/kg concentration of vitamin A. The concentration of Fe and Zn in the fortified wheat flour samples range from 0.235±0.033 mg/kg - 0.520±0.140 mg/kg, and 0.024±0.012 - 0.180±0.033mg/kg respectively. Wheat semovita contained 0.497±0.050 - 9.057±0.080 mg/kg, and 0.078±0.015 - 0.187±0.006 mg/kg of iron and zinc respectively. The concentration of Fe and Zn in the 3 whole wheat flour samples ranged from 0.313±0.006 - 5.007±0.021 and 0.107±0.0210.340±0.010 mg/kg respectively. The concentration of Fe and Zn in the maize flour sample is 0.483±0.006 mg/kg and 0.123±0.015 mg/kg respectively.

FOOD VEHICLE	SAMPLE ID	VITAMIN A (iu/kg)	IRON (mg/kg)	ZINC (mg/kg)
	WF-001	1.932±0.010^{a}	0.235±0.033^{a}	0.024±0.012^{a}
	WF-002	1.622±0.151^{b}	0.410±0.030^{b}	0.180±0.033^{b}
	WF-003	1.183±0.078^{c}	0.520±0.140^{c}	0.141±0.032^{c}
	WF-004	1.977±0.129^{d}	0.376±0.037^{d}	0.138±0.041^{d}
	WF-005	1.422±0.145^{e}	0.371±0.046^{e}	0.143±0.014^{e}
	WF-006	1.602±0.157^{f}	0.431±0.137^{f}	0.079±0.015^{f}
	WF-007	1.473±0.156^{g}	0.363±0.059^{g}	0.071±0.017^{g}
Wheat Flour	WF-008	1.811±0.283^{h}	0.379±0.156^{h}	0.070±0.019^{h}
	SVT-001	168.726±2.264^{i}	0.497±0.050^{i}	0.187±0.006^{i}
	SVT-002	165.271±2.622^{j}	9.057±0.080^{j}	0.078±0.015^{j}
Wheat Semovita	SVT-003	183.666±2.389^{k}	6.457±0.015^{k}	0.097±0.006^{k}
	WWF-001	165.303±2.504^{l}	5.007±0.021^{l}	0.147±0.006^{l}
Whole Wheat Flour	WWF-002	163.726±1.469^{m}	0.393±0.006^{m}	0.340±0.010^{m}
	WWF-003	156.071±1.910^{n}	0.313±0.006^{n}	0.107±0.021^{n}
Maize Flour	MZF-001	154.115±1.863^{o}	0.483±0.006^{o}	0.123±0.015^{o}
***Mandatory Req.**		6000 iu/kg$^{a,b,c,d,e,f,g,h,i,j,k,l,m.n,o}$	40.0 mg/kg$^{a,b,c,d,e,f,g,h,i,j,k,l,m.n,o}$	50.0 mg/kg$^{a,b,c,d,e,f,g,h,i,j,k,l,m.n,o}$

Table 1: Concentration of Mandatory Fortificants in some Selected Fortified Foods sold in Sokoto.
Values are expressed as mean ± standard deviation. Values with the same superscript in same column are statistically significant ($p < 0.001$). Statistical significance: $p < 0.001$ vs mandatory requirement as positive control (One-way ANOVA). *Mandatory requirement are specified by NAFDAC as contained in the national fortification regulations act of 2021 (NAFDAC, 2021). Abbreviation: WF: Wheat Flour; SVT: Semovita; WWF: Whole Wheat Flour; MZF: Maize Flour.

The level of the six (6) non-mandatory fortificants such as mineral elements such as Calcium (Ca), Cupper (Cu), Magnesium (Mg), Manganese (Mn), Phosphorus (P), and Selenium (Se) in the fifteen (15) differently selected fortified foods analyzed are presented in Table 2. The level of these mineral element in the entire 15 samples were significantly below ($p <0.001$) the Nutritive Reference Values (NRVs) of the 6 mineral elements (1000 mg/kg, 900 mg/kg, 310 mg/kg, 3 mg/kg, 700 mg/kg, and 60 mg/kg for Ca, Cu, Mg, Mn, P, and Se respectively). The result revealed that wheat flour (the first 8 sample) contained highest concentration of Ca, Mg, P, and Se which ranged from 427.264±13.494 to 872.438±7.619 mg/kg, 58.288±3.197- 64.748±0.673 mg/kg, 2.178±0.039 - 3.629±0.016 mg/kg, and 7.383±0.489-105.631±1.317mg/kg respectively compared to other fortified food samples. The result of this study shows that the 15 samples analyzed contained higher concentration of Ca compared to other mineral elements quantified.

	SAMPLE ID	Concentration (mg/kg)					
		Ca	Cu	Mg	Mn	P	Se
	WF-001	860.895±31.730	0.200±0.053	61.467±0.909	0.167±0.013	3.340±0.011	105.631±1.317
	WF-002	768.360±28.686	0.049±0.037	64.748±0.673	0.145±0.139	2.275±0.008	74.766±3.177
	WF-003	872.438±7.619	0.193±0.026	62.478±1.342	0.480±0.146	2.632±0.009	52.549±2.599
	WF-004	863.881±26.444	0.154±0.026	58.288±3.197	0.369±0.141	2.980±0.004	44.234±1.964
	WF-005	653.731±24.908	0.103±0.052	63.969±0.468	0.220±0.016	2.189±0.039	27.966±1.364
	WF-006	565.576±12.569	0.053±0.029	61.242±0.280	0.539±0.301	2.178±0.039	25.676±2.212
	WF-007	427.264±13.494	0.057±0.033	60.191±1.652	0.977±0.047	2.516±0.012	7.383±0.489
Wheat flour	WF-008	762.836±12.492	0.060±0.045	63.483±1.313	0.311±0.029	3.629±0.016	33.791±2.363
	SVT-001	68.170±0.500	0.173±0.015	8.627±0.012	0.170±0.010	0.767±0.102	14.300±0.102
Wheat semovita	SVT-002	56.283±0.174	0.060±0.010	19.267±0.085	0.513±0.015	1.040±0.046	12.933±1.992
	SVT-003	77.553±0.750	0.063±0.015	22.320±0.052	1.150±0.010	1.420±0.072	14.787±1.859
	WWF-001	55.527±1.102	0.277±0.367	15.527±0.056	1.777±0.015	1.927±0.136	16.483±1.114
Whole wheat flour	WWF-002	35.963±0.525	0.220±0.010	11.033±0.081	0.213±0.006	0.583±0.031	12.240±0.884
	WWF-003	55.930±0.178	0.070±0.010	9.207±0.021	0.083±0.015	0.607±0.103	14.827±0.475
	MZF-001	52.127±0.363	0.120±0.010	4.663±0.051	0.070±0.010	0.827±0.021	24.939±0.610
Maize flour	*NRVs	1000 mg/kg	900 mg/kg	310 mg/kg	3.00 mg/kg	700 mg/kg	60 mg/kg

Table 2: Concentrations of Mineral Elements in some Selected Fortified Foods sold in Sokoto.

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 post -test). Values of each element in the same column are statistically significant ($p < 0.001$) with NRVs. *Nutritive Reference Values (NRVs) are stipulated by NAFDAC as contained in the national fortification regulations act of 2021 (NAFDAC, 2021). Abbreviation: WF: Wheat Flour; SVT: Semovita; WWF: Whole Wheat Flour; MZF: Maize Flour.

Discussion

The food fortification initiative is the practice of intentionally increasing the content of a micronutrient in a food to improve the nutritional quality of the food and provide a public health benefit without any adverse effects (Gavvett, 2014). Moreover, it has been reported that large scale food fortification is connected to numerous economic benefits such as improved productivity, increased earning potentials, and GDP growth (Boy *et al.*, 2009; Christian *et al.*, 2010; Semba, 2010). For this, the Nigerian apex drug and food regulatory Agency, National Agency for Food and Drug Administration and Control (NAFDAC) and other relevant bodies have recommended vitamin A, iron (Fe), and zinc (Zn) to be the mandatory fortificants (micronutrients) for wheat flour fortification as an initiative under the national food fortification programme. This initiative was aimed at preventing micronutrient deficiency (MND) which is a public health threat that has persisted for decades with high prevalence of deficiencies of Vitamin A, folic acid, iron and zinc (Anjorin *et al.*, 2019). Despite the benefits of the initiative, there have been limited independent and reliable studies either nationally or sub-nationally which evaluated the level of fortificants in fortified food vehicle in order to ascertain the manufacturers' compliance with the fortification standard. The evaluation will no doubt evaluate the effectiveness of the fortification programme in the Nigeria particularly due to persistent increase in the numbers of MND despite huge investment in the programme by government and other relevant international supporter. This study evaluated the level of mandatory fortificants (vitamin A, iron and Zinc) including non-mandatory ones (Ca, Cu, Se, Mg, Mn and Ph) in some fifteen (15) selected fortified foods sampled across diverse locations of Sokoto metropolis. In spite of the national fortification mandates as specified in the national food fortification regulations [regulation 2(1)(c) and 6(2)] of 2021 Food Fortification Regulation (NAFDAC, 2021), the findings of this study showed that the levels of the mandatory fortificants were below the standard requirement specified by the regulatory Agencies.

To effectively and efficiently achieve the core objective of food fortification programme of eradicating MND in Nigeria, the WHO and other relevant stakeholders particularly the 2 major food regulatory bodies in Nigeria (NAFDAC and SON) authorized the level of mandatory fortificants in wheat and maize flour products to be 6000 iu/kg, 40 mg/kg, and 50 mg/kg for vitamin A, Fe, and Zn respectively. Nevertheless, our findings revealed that the levels of these mandatory fortificants in the entire fifteen (15) fortified foods samples analysed were significantly below ($p < 0.001$) their stipulated minimum requirement. The outcome of this study corroborate with the findings of similar study by Maigari *et al.* (2012) conducted in Kano metropolis where low level of vitamin A was reported in the entire wheat flour samples analyzed. Similarly, Uchendu and Atinmo (2016) reported similar finding of significantly lower concentration of vitamin A in the wheat flour samples from different locations of Lagos State. To also substantiate our finding, a 2003 national survey by NAFDAC on the level of fortificants in fortified wheat flour revealed that only 5 of the samples analyzed complied with standard fortification level of vitamin A (Akinyele, 2009). Ogunmoyela *et al.* (2013) obtained about 12.2-33.3% and 1.0 - 21.0 % compliance in the level of vitamin A and Fe respectively in the fortified wheat flour sampled from factories and markets outlets in all the 36 states of the Federation, and consequently, recommended total review of the fortification approach in Nigeria. Additionally, a non-governmental organization called Food Fortification Initiative (FFI) which focuses exclusively on large scale fortification of wheat flour conducted a Fortification Assessment Coverage Tool (FACT) survey in Kano and Lagos States. Their survey's finding revealed low level of fortificants in the fortified wheat flour sample, which indicate low compliance with the stipulated fortification standard, which will eventually thwart the effectiveness of the fortification initiative, despite high consumption of the fortified foods (Food Fortification Initiative, 2018). Likewise, a study conducted in South Africa by Yusufali *et al.* (2012) observed low level of fortificants in wheat flour and maize meal, thus they concluded that the low compliance was due to inadequate addition of premix by the millers, contributing to low levels of added micronutrients within the fortification program. Results from Coverage Surveys in 8 Countries (Bangladesh, Cote d'Ivoire, India, Nigeria, Senegal, South Africa, Tanzania, and Uganda) carried out by Aaron *et al.* (2017) aimed at presenting the Large Scale Food Fortification (LSFF) coverage survey findings from 18 food fortification programs conducted in between 2013 and 2015 concluded that there is need for routine monitoring of the fortification process to ensure that fortification occurs at the desired level. In 2019, the Government of Rwanda, developed mandatory fortification standard regulations and collaborated with both public and private sectors where all stakeholders meet to discuss matters related to the implementation of the food fortification regulation, this initiatives have significantly improved compliance and monitoring (Olson *et al.,* 2021). Therefore, if proper partnership and collaboration can be formed not only amongst the public and private sectors but also between relevant domestic and foreign organisations that will no doubt contribute to the effective implementation of Nigerian food fortification programme particularly in areas of regulatory monitoring, implementation, advocacy, capacity building, and overall management as postulated by Olson *et al.* (2021).

For several years, the Global Alliance for Improved Nutrition (GAIN) has been providing funding and technical support to the National Food Fortification Programme through collaboration with the National Fortification Alliance, the National Agency for Food and Drug Administration and Control (NAFDAC) and Standards Organization of Nigeria (SON) in the mandatory fortification of wheat and maize flours with stated mandatory fortificants (Anjorin *et al.,* 2019). GAIN also provides funding to create the necessary awareness to increase production and consumption of fortified foods. But available evidence shows that Nigeria still has one of the highest rates of under-5 children and maternal mortality in the world with vitamin A deficiency (VAD) being a major contributory factor (MICS, 2011). Additionally, several non-national representative studies have highlighted the high prevalence of anaemia and vitamin A deficiencies in Nigeria (NDHS, 2008; ORIE, 2013). Deficiencies of vitamin A, Fe, and Zn are considered to be one of the global severe health risk factors (WHO, 2000), which can also lead to vicious cycle of poor health and miserable productivity and poverty (Klemm *et al.*, 2010). Vitamin A can boost the child's survival chance by 12-24% (UNICEF, 2016) and it cannot by synthesized biologically, thus it must be obtained exogenously mostly through diet like fortified foods or other sources (Rice *et al.,* 2004). Iron deficiency anaemia is more aggravated in rural areas than in urban settings and is a risk factor for maternal morbidity and mortality (Horowitz *et al.*, 2013; Hannah, 2017). Zinc deficiency is also a leading cause of morbidity and mortality among children particularly due to childhood infection and one-third of the global population survive in nations with high risk of Zn deficiency (Brown and Hess, 2009; Hess *et al.*, 2009).

Therefore, one of the primary objectives of food fortification policy is to prevent micronutrient deficiency particularly within the vulnerable group (National Policy on Food and Nutrition, 2001). Food fortification is considered to be the most scalable, sustainable, cost-effective and reliable strategy for eradication of MND and its dare consequences (Biebinger and Hurrell, 2008). This is the reason why numerous countries across the globe adopted this strategy and authorized fortification of some foremost flour food products like wheat flour, maize flour, composite flour, and wheat semovita with some critical fortificants such as vitamin A, iron, zinc, B-complex (B1, B2, B3, B6, B9, B12) and folate. In order to enhance the bioavailability of the micronutrients (especially vitamin A, iron and zinc) particularly among vulnerable groups, a mass fortification of wheat flour was considered to eliminate MND among them (Klemm *et al.*, 2010). This is because in 2021 alone about 778 million metric tonnes of wheat flour were produced globally for human consumption (Shahbandeh, 2022) and in Nigeria alone, a total of over 36 million metric tonnes of wheat are produced in the same year where majority of these wheat are milled and fortified (Oluwaseun, 2022). Therefore, fortification of wheat flour, when properly implemented is an effective, harmless, simple, inexpensive, and sustainable means of reducing MND and its public health related problems (WHO, 2009; Brown *et al.*, 2010). In spite of the influence of some physical and chemical factors on vitamin A stability, studies showed that wheat flour, if properly fortified with vitamin A, can retain 60% for 1 month (Uchendu and Atinmo, 2010).

Despite huge investment on food fortification programme, low level of fortificants in the fortified food was consistently reported as highlighted above which was attributed to the non-compliance to the fortification regulations by the wheat flour millers (Yusufali *et al.*, 2012). This was attributed to many factors such as high cost of production due to high cost of premix because it was reported that about $1.2/MT (cost of vitamin A exclusive) is required (Aaron *et al.*, 2012). Therefore, fortification of wheat flour with vitamin A can considerably increase the cost to above $5/MT (Nutrition GAfI, 2012) which is a great liability to the manufacturing industries without any incentives and this may be the reason for their non-compliance to the fortification standard requirement. Similarly, the quantity of these fortificant (6000 iu/kg, 40 mg/kg, and 50 mg/kg for vitamin A, Fe, and Zn respectively) mandated by regulatory bodies to be the minimum requirements for wheat or maize flour fortification may be too high for the manufacturers as asserted by Ogunmoyela (2013). Additionally, poor regulations by relevant regulatory bodies particularly related to monitoring, inspections, and enforcement of the specified food fortification regulations. To support this, it has been reported that food fortification regulations related to monitoring, inspection, and enforcement are too often fragmented and not appropriately set within legal frameworks, leading to a lack of or weak enforcement. Introduction of sugar fortification with vitamin A by Latin America in 1975 reduced the rate of vitamin A deficiency drastically from 22 to 5% in only a year, a development attributed to their excellent regulatory framework which enforced stringent regulatory monitoring and enforcement (Olson *et al.*, 2021). Similarly, Luthringer *et al.* (2015) also reported that good regulatory monitoring and quality assurance/quality control practices can ensure that fortified food items are adequately fortified with relevant fortificants. Also other factors or challenges that prevent consistent compliance include challenges at the industry, government, retail levels and humanitarian level (Luthringer *et al.*, 2015). Studies from other developed countries like India, and Sri Lankan showed a high compliance to the fortification regulations which has been revealed through improved haematological and growth parameters of the citizens, which was attributed to the effective monitoring, strong enforcements, good regulatory framework, and technical advancements (Mora, 2002; Hettiarachchi *et al.,* 2004).

Therefore, holistic review of the Nigeria food fortification regulation is required to achieve the core objective of the fortification strategy. Environmental factors such as temperature, humidity, moisture, and air may also affect the level of fortificants (especially vitamin A) particularly with the type of packaging material (polypropylene) used for packaging. Study by Uchendu and Atinmo (2016) proved that polypropylene bags do not protect food products from moisture and air particularly during transportation and storage. Likewise, Butt *et al.* (2004) reported that polypropylene bags hardly protect wheat flour from atmospheric oxygen, humidity, environmental moisture, sand, dust, insects, pest and microbes. The impact of packaging materials on the fortificants as postulated may be the reason for the higher level of vitamin A in the seven (7) samples of wheat semovita, whole wheat flour, and maize flour compared to the 8 samples of wheat flour as observed by this study. The seven (7) samples of wheat semovita, whole wheat flour, and maize flour are packaged in polyethylene packaging materials (2 kg of weight) which are considered more protective than polypropylene used for packaging wheat flour in 50 kg capacity. Therefore, low level of fortificants observed in our study may also be attributed to poor handling, storage, and transportation particularly due to the high temperature and humidity of Sokoto State (having annual average temperature of 28.3ºC or 82.9ºF).

Wheat is one of the most widely consumed foods globally, due to varieties of food products commonly derived from it and its convenience in consumption (Araujo *et al. et al.,* 2008). Wheat also serves as a good source of mineral elements and capable of providing above 70% of the recommended daily intake of minerals such as Cu, Se, Fe, Mg, Zn, Mn, Mo and Ph if about 200kg of wheat flour is consumed in a day by person (Hussain *et al.,* 2010). Consequently, in addition to the mandatory fortificant assessed by this study, level of some selected mineral element (Ca, Cu, Mg, Mn, P, and Se) in 15 differently selected food fortified samples were evaluated. There is a need for this mineral element due to their antioxidant properties; hence their availability will enhance working efficiency, decrease in healthcare cost, and also reduction in premature death (Welch and Graham, 2004). These mineral elements are called “antioxidant mineral elements” because of their ability to serve as cofactors to numerous important antioxidant enzymes such as glutathione peroxidase (Se), catalase (Fe), and superoxide dismutase (Cu, Zn, and Mn), thus becoming critical in protecting cellular components from oxidative damage (Branca and Ferrari, 2002; Mcdowell *et al.,* 2007). For synthesis of these enzymes by the biological system as well as their optimum activity, those mineral elements are required and their deficiencies can lead to deleterious health consequences (Mcdowell *et al.,* 2007). In addition to antioxidant role, these mineral elements also help in muscle contraction, and blood clotting (Abdulkadir, 2014).

Although, these mineral elements are considered non-mandatory for fortification, but NAFDAC has specified their Nutritive Reference Values (NRVs) in wheat and maize flour probably due to their biological importance. Findings of this study imply that the level of mineral elements (Ca, Cu, Mg, Mn, P, and Se) analyzed in the entire sample were significantly lower ($p < 0.001$) than the NRVs specified by NAFDAC as contained in the 2021 food fortification regulation (NAFDAC, 2021). In all the elements analyzed, the result of this study showed that Ca was higher than others and the first 8 samples of wheat contained higher amount of this element when compared with the other samples. Therefore, based on our finding, the wheat flour can be a good source of Calcium, which is an important element required by humans due to its critical role in a multitude of functions from cell signaling to bone growth (Ropo *et al.,* 2016). The finding of this study is in conformity with the findings of other scholars such as Araujo *et al.* (2008); Tejera *et al.* (2013); Anwaar *et al.* (2014) and Anon *et al.* (2018). Specifically, Anwaar *et al.* (2014) revealed that wheat flour and its products can contribute immensely to the dietary consumption of mineral element particularly Ca, because his finding showed that wheat flour contained significant amounts of Ca compared to other minerals. But our finding is contrary to the study by Abdulkadir (2014) who reported that Mg was higher in the entire wheat flour sample he analyzed. Numerous studies attributed the difference in the level of these elements as observed in this study to a number of factors such as geographical origin of the wheat and its texture, type of cultivation, nature of the soil and the weather conditions during its germination, the quantity and nature of fertilizer of manure used, soil pollution particularly with heavy metals, and finally the type of equipment used in the milling process (Gonzalez *et al.*, 2001; Ekholm *et al.*, 2007).

This study has some limitations. Only fifteen (15) different brands fortified wheat flour, semovita, whole wheat flour and maize flour samples were collected and analyzed, as they were the only ones available. Therefore, due to the small size of the samples the result should be used with caution but it is still an important and independent contribution to the literature on food fortification. Furthermore, good experimental design and sensitive equipment used for the analysis are considered as the strength for this study, thus making the findings reliable and accurate. Further studies should focus on the levels of fortificants in the fortified foods at the household levels and explore the role small food producers and millers can play in making fortified foods available.

Based on our findings, the following recommendations are made:

i. National or subnational surveys for evaluations of the entire fortified foods (wheat and maize flour, sugar, oil, margarine, semolina, whole wheat flours, and iodine) are recommended. This will allow inclusion of large sample size.
ii. The use of globally advanced and recognised equipment such as iCheck equipment and reagents (products of BioAnalyt) for analysis of vitamin A, iron and zinc due to their precision and reliability.
iii. The need for monitoring and surveillance of fortified food products by national food regulators to enforce total compliance to the national food fortification regulations.
iv. *Impromptu* sampling of fortified food products particularly at markets or households for laboratory evaluation to determine the actual content of fortificants.

Conclusion

Despite enormous investment of resources by relevant stakeholders (both at national and international levels) for proper implementation and coordination of food fortification programme in Nigeria, the results of this study showed that the level of vitamin A, iron (Fe), and zinc (Zn) in the entire fifteen (15) fortified foods samples (wheat flour, semovita, whole wheat flour and maize flour) analysed were significantly lower ($p < 0.001$) than the minimum levels recommended by NAFDAC. The levels of the fortificants are far from complying with the recommended national and international standard, thereby hindering the effective implementation of national fortification programme in Nigeria. This will hinder the vulnerable group from getting the desired quantity of these micronutrients despite consumption of fortified foods. Therefore, to effectively achieve the objectives of the food fortification programme in Nigeria, there is need for active and well-organized monitoring and enforcement of food fortification regulations particularly for total manufacturers' compliance with specified regulations.

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Conflict of Interest

The authors declared no conflict of interest and no other relationship or activities that could appear to have influenced this study.

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