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Adequacy of micronutrient fortification in the mandatory fortified food vehicles in Tanzania

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Abstract

Purpose – This study aims to update the information on the current status of micronutrient fortification for iron, zinc, folic acid and vitamin A in mandatory fortified food vehicles such as cooking oil, wheat and maize flours in Tanzania.

Design/methodology/approach – A cross-sectional study was conducted in five regions to analyze the adequacy of micronutrient fortification in mandatory fortified food vehicles. Samples of fortified edible oil (n = 19), wheat flour (n = 12) and maize flour (n = 5) were sampled conveniently from local markets and supermarkets. Samples were analyzed for vitamins (vitamin A and folic acid) and mineral (iron and zinc) content using high-performance liquid chromatography and microwave plasma-atomic emission spectrometer, respectively. Compliance acceptable ranges between the minimum and maximum levels for each nutrient were used as a basis for compliance.

Findings – The results showed that 83.3% and 80% of wheat and maize flour samples, respectively, complied with iron fortification standards (p = 0.05). Only 25% of wheat flour samples and 40% of maize flour samples were within the acceptable ranges for zinc fortification (p = 0.05). Nearly 17% and 20% of wheat and maize flour samples, respectively, were within the acceptable ranges for folic acid fortification (p = 0.05). Moreover, about 10.5% of the analyzed cooking oils were adequately fortified with vitamin A (p = 0.05). Except for iron in wheat and maize flours, the levels of other micronutrients in mandatorily fortified foods were out of acceptable ranges.

Originality/value – Mandatory fortification is still far from the established standards, and this calls for a review of the current fortification strategies regarding standards, training, monitoring and enforcement in Tanzania.

Keywords Compliance, Fortification, Micronutrients, Fortificants, Mandatory fortification

Paper type Research paper

Introduction

Global analyses show that more than two billion people suffer from micronutrients deficiencies worldwide (Bailey, 2015). Most prevalent micronutrient deficiencies are iron,

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iodine, zinc and vitamin A, with women and children in developing countries being the most affected individuals (Bailey, 2015). Micronutrient deficiencies cause a wide range of non-specific physiological impairments, leading to metabolic problems and delayed physical and mental development (Bailey, 2015). According to the Food and Agriculture Organization (FAO) of the United Nations, large-scale food fortification is one of the sustainable approaches and cost-effective strategies for preventing micronutrient malnutrition in populations at risk (Allen *et al.*, 2006). For the proper implementation of this strategy, the World Health Organization (WHO) and FAO have jointly developed standard guidelines for food fortification with micronutrients (Allen *et al.*, 2006).

Voluntarily micronutrient fortification of salt with iodine in Tanzania began in the 1990s – while the mandatory fortification of other fortified food vehicles such as wheat and maize flour with multiple micronutrients and oil with vitamin A has been in place since 2011. The main goal of these fortification programs has been always on addressing the problem of under-nutrition in the country. Despite these efforts, micronutrient deficiency is still a devastating challenge in Tanzania, with anemia reduction being stagnant in under-fives (58%) and worsening (45%) in women of the reproductive age as reported by the Ministry of Health, (2016), Community Development, Gender, Elderly and Children (MoHCDGEC) (MoHCDGEC, 2016). According to the 2010 Tanzania Demographic Health Survey by the National Bureau of Statistics (NBS), 33 and 35% of all children below five years were deficient in vitamin A and about 59% were anemic. Among the women of reproductive age (15–49 years), 37 and 30% were deficient in vitamin A and Fe, respectively, and about 40% were anemic (NBS/Tanzania, 2011).

The first national fortification survey to assess fortification compliance with national and global standards in Tanzania was conducted in 2015. The survey was conducted by the Global Alliance for Improved Nutrition (GAIN) in partnership with other organizations, including the US Centers for Disease Control and Prevention. The study showed that < 20, 18.9 and 5% of oil, wheat flour and maize flour, respectively, complied with the fortification standards (Global Alliance for Improved Nutrition, 2016). On the other side, about 15% of the salt samples looked overfortified based on the WHO standards, but according to the national standards, only $< 1\%$ of salt samples were observed to be overfortified (Global Alliance for Improved Nutrition, 2016). Apart from the first national fortification assessment in 2015, which is approximately four years after food fortification was mandated in 2011, the up-to-date information regarding the compliance of food fortification programs with the national fortification standards is scanty in Tanzania. The challenge of non-compliance to fortification standards probably still exists in the country, as there is no current data on the adequacy of micronutrient fortification in the mandatory fortified food vehicles. Our assumption is based on the fact that deficiencies in micronutrients are still generally high in the country (MoHCDGEC, 2016). This study aimed at updating the information on the current status of micronutrient (iron, zinc, folic acid and vitamin A) fortification in the mandatory fortified food vehicles such as edible cooking oil, wheat and maize flours in Tanzania.

Materials and methods

Site description

The study was conducted in five regions located in northern, central and eastern zones of Tanzania. The regions covered include Arusha, Shinyanga, Singida, Dodoma and Dar es Salaam. These regions were sampled conveniently based on the presence of large-scale food-processing companies in which micronutrient fortification is mandatory. The mandated food products and approved fortificants are iron (sodium iron ethylenediaminetetraacetic acid (EDTA)), zinc (zinc oxide) vitamin B12 and folate (folic acid) for wheat and maize flour, and vitamin A (retinyl palmitate) for vegetable oil.

Study design

A cross-sectional survey was conducted from November–December 2019 in the selected regions. A research protocol of the present study was approved by institutional research ethical clearance committee at the Nelson Mandela African Institution of Science and Technology (NM-AIST), Arusha, Tanzania (KNCHREC00026, 2019). The permits to visit the respective regions were pursued from the local government authorities. Samples were collected from local markets and supermarkets in the selected regions. At the points of sampling, no consent was needed, as all confidential aspects of the sample from data collection, analysis and reporting were maintained.

Food sampling and collection

Food samples were collected by using convenience sampling technique from local markets and supermarkets located in each of the five regions surveyed from November–December 2019, as shown in Table 1. A total of 12 (63.2%) food processing companies were conveniently selected among 19 companies performing mandatory food fortification. Food samples (wheat flour, maize flour and edible cooking oil) were collected from the free markets and supermarkets of the selected regions. From each company, three samples were randomly picked from three batches, packed in dry boxes and transported to the NM-AIST laboratory. The samples were unpacked from their original packages and re-packed in small packages. The flour samples were packed in zip-lock pouches with moisture barrier property. The cooking oil samples were packed in dark bottles to prevent the effects of light, moisture and air that can cause loss of the targeted micronutrients. A simple database with important information such as the type of product, manufacturing and expiring dates, name and address of sample source, brand name, batch numbers and sample codes for identification were recorded on the sample information form. The coded samples were analyzed for iron and zinc content at Tanzania Bureau of Standards laboratory, and for vitamin A and folic acid parameters at Jomo Kenyata Agriculture University of Science and Technology laboratory.

Biochemical measurements

Quantification of vitamin A from cooking oil

The quantification of vitamin A (retinyl palmitate) in cooking oil was carried out using high-performance liquid chromatography (HPLC) with an ultraviolet (UV) detector (Shimadzu LC 10 AVP, Japan) as per the standard procedure described by Jaas *et al.* (2010) with slight modifications. About 2 g of each sample was saponified with 40 mL 95% ethanol (Wagtech Projects Ltd, Thatcham, UK), 50 mg pyrogallic acid (Loba Chemie Pvt. Ltd, India) and 4 mL potassium hydroxide (Loba Chemie Pvt. Ltd, India) heated at 70°C in a water bath for 40 min, vortexed and cooled. The targeted compound in the sample (retinyl palmitate) solution was extracted by liquid–liquid extraction using 5 mL *n*-hexane. The hexane

Region	Cooking oil	Wheat flour	Maize flour
Dar es Salaam	10	9	No large scale
Arusha	3	3	3
Dodoma	3	No large scale	No large scale
Singida	3	No large scale	No large scale
Shinyanga	–	No large scale	2
Total	19	12	5

Table 1. Distribution of food samples by administrative regions

fraction was pooled into one fraction, evaporated until dry, re-diluted in HPLC methanol (Wagtech Projects Ltd, Thatcham, UK), transferred to a volumetric flask and filtered using a 0.45 μm membrane. Both sample and standard solutions (Sigma-Aldrich, USA) (each 20 μL) were separately injected into the HPLC using the RP-18 column. Methanol as a mobile phase was delivered at 0.8 mL/min, and vitamin A was detected at A326 nm by comparing their retention times with those of the standard solutions.

Quantification of folic acid

Folic acid was quantified according to the method described by Ekinci and Kadakal (2005) with slight modifications. Samples were prepared based on solid-phase extraction techniques to eliminate impurities that may interfere with folate. About 2 g of each sample was added in 25 mL of H_2SO_4 (0.1 M) (Loba Chemie Pvt. Ltd, India) solution, and the mixture homogenized and sterilized in an autoclave for 15 min at 121–123°C. The contents were cooled and adjusted to pH 4.5 with 2.5 M sodium acetate. About 50 mg of amylase enzyme (Sigma-Aldrich, USA) was added and the solution was incubated at 40°C for 20 min then cooled with running water. All samples and standard solutions (Sigma-Aldrich, USA) (each 20 μL) were separately injected into the HPLC using the RP-18 column. Methanol was delivered at 0.7 mL/min as a mobile phase, and folic acid was detected at A_{283} nm by comparing their retention times with those of the standard solutions.

Quantification of iron and zinc in wheat and maize flour

The quantities of iron and zinc in wheat and maize flour were determined according to standard procedures as described by Cauduro (2013) with slight modifications. To about 0.5 g of maize and wheat flour samples, 7 mL of concentrated HNO_3 (69 %) and 3 mL of H_2O_2 (Loba Chemie Pvt. Ltd, India) were added and placed in the microwave digestion system. Samples were digested at 190°C for 30 min, cooled for 20 min and transferred to volumetric flasks, followed by dilution to 50 mL with deionized water and analysis using an Agilent 4210 microwave plasma-atomic emission spectrometer (MP AES) instrument (Agilent Technologies Inc. 5301 Santa Clara, CA 95051, USA). The concentrations of iron and zinc were calculated at $A_{371.993}$ nm and $A_{481.053}$ nm, respectively.

Standards used as reference

Fortification levels used in this study to test for the compliance of each fortified food vehicles were set according to the current harmonized East African Standards (EAS) (East African Community, 2011a, 2011b, 2016). Compliance acceptable ranges between the minimum and maximum levels were used as reference to determine the adequacy of fortification levels, as shown in Table 2.

Statistical analysis

Data entry and descriptive analysis (means, standard deviation, frequencies and percentages) was done in a Microsoft Excel 2010. Additionally, a one way analysis of variance (ANOVA) was used to compare the mean differences of micronutrient fortification levels within the batches and between samples of fortified food vehicle samples using R statistical package version 3.6.1. A significance level was set at $p = 0.05$.

Results

Table 1 shows the distribution of food samples collected in all the five regions. Based on the East African fortification standard references (Table 2), 83.3 and 80% of wheat and maize flour, respectively, were adequately fortified with iron (Table 3). Only 16.7 and 20% of the wheat and maize flour samples, respectively, complied with the folic acid standards (Table 3). Similarly, about 25 and 40% of wheat and maize flour samples, respectively, were compliant for zinc fortification standards. Only 10.5% samples of cooking oil complied with the vitamin A fortification standards (Table 3). Also, about 41.7% of the wheat flour samples tested was not fortified with folic acid at all.

A significant difference (at P = 0.05) in fortification quality levels was observed within the batches of the same food processing companies. The results showed that the variations that existed within five batches of cooking oil samples (POE, POF, POG, SOC and SOD) were statistically significant at ($P < 0.001$, $P < 0.001$, $P < 0.001$, $P < 0.001$ and $P < 0.001$, respectively) (Table 4). Significant variations were also observed for folic acid fortification compliance in one batch of wheat flour (WFC) at $P < 0.001$ and two batches of maize flour (MFA and MFB) at ($P < 0.001$ and $P < 0.001$, respectively) (Table 5).

Discussion

The benefits, safety and cost-effectiveness of food fortification in the context of addressing undernutrition have been established worldwide. This assertion is based on the fact that the approach has the advantage of reaching large population groups who are at risk through existing food supply systems and without major changes in food consumption patterns (Serdula, 2010). Because of this, many countries, including Tanzania, have adopted the approach and introduced enforcement law for mandatory fortification (Pachon, 2016). However, based on the present analysis, we noted that unlike iron, which was adequately fortified in wheat and maize flours, fortification compliance is still far from the recommended standards for the majority of micronutrients in the mandatory fortified food vehicles. Very few samples of the mandatory food vehicles were adequately fortified with zinc, folic acid and vitamin A. The observed levels of fortification compliance for zinc, iron and folic acid are still low, negating the impact of the current national fortification projects in Tanzania.

Just as in other previous fortification assessment programs (GAIN, 2016), we had hypothesized that the adequacy of iron as a "marker" could reflect likely fortification of other micronutrients such as zinc, folic acid and B_{12}, but this was not the case in the present analysis. The reasons for the observed difference in fortification adequacy between iron and other micronutrients in the mandatory food vehicles are not much clear. One reason is that some nutrients, especially vitamins that are sensitive to heat, oxidizing and reducing agents,

Table 2. Micronutrient fortification compliance levels adopted from EAS

Food vehicle	Nutrient	Fortificant compound	Regulatory levels Min	Regulatory levels Max
Wheat flour	Folate	Folic acid	1.1[1]	3.21
	Total iron	Total iron	20[1]	60[1]
	Added iron	NaFeEDTA	20[1]	40[1]
	Zinc	Zinc oxide	40[1]	80[1]
Maize flour	Folate	Folic acid	0.6[1]	1.7[1]
	Total iron	Total iron	21[1]	41[1]
	Added iron	NaFeEDTA	10[1]	30[1]
	Zinc	Zinc oxide	33[1]	65[1]
Edible cooking oil	Vitamin A	Vitamin A (retinyl) palmitate)	2.0[2]	4.0[2]

Notes: [1]Regulatory levels are in mg/kg for wheat and maize flour; [2] mg/100 g for edible cooking oil

	Mean ± SD	Level of fortification Inadequately (%)	Adequately (%)	Not-fortified (%)	Overfortified (%)	p-value
Vitamin A fortification in cooking oil samples[1]						
Cooking oil (n = 19)	0.659 ± 0.872	89.5	10.5	0	0	< 0.001***
Micronutrient fortification in wheat flour samples[2]						
Folic acid (n = 12)	0.28 ± 0.3	0	16.7	41.7	41.7	< 0.001***
Iron (n = 12)	36.61 ± 17.52	8.3	83.3	8.3	0	0.004**
Zinc (n = 12)	27.92 ± 15.80	75	25	0	0	0.011*
Micronutrient fortification in maize flour samples[3]						
Folic acid (n = 5)	0.31 ± 0.28	0	20	0	80	< 0.001***
Iron (n = 5)	20.28 ± 7.68	20	80	0	0	0.002**
Zinc (n = 5)	23.60 ± 9.3	60	40	0	0	0.001**

Notes: Values are mean ± SD and %; statistically significant level: ***$p < 0.001$; **$p < 0.01$; *$p < 0.05$ (sample mean differences were compared across batches using one-way ANOVA at confidence level of 5%. [1]Fortification quality for oil was determined by analyzing the total vitamin A levels in samples and comparing the results to EAS 2011 as follows: "Not-fortified" 0 mg/100 g vitamin A, "Inadequately fortified" <2 mg/100 g vitamin A, "Adequately fortified" ≥ 2–4 mg/100 g and "Overfortified" >4 mg/100 g. [2]Fortification quality for iron in wheat flour was determined by analyzing the total iron levels in samples and comparing the results to EAS 2016 as follows: "Not-fortified" 0 mg/kg total iron, "Inadequately fortified" < 20 mg/kg total iron, "Adequately fortified" ≥ 20 mg/kg total iron. Fortification quality for folic acid in wheat flour was determined by analyzing the total folic acid levels in samples and comparing the results to EAS 2016 as follows: "Not-fortified" 0 mg/kg folic acid, "Inadequately fortified" < 1.1 mg/kg folic acid, "Adequately fortified" ≥ 1.1–3.2 mg/kg folic acid and "overfortified" > 3.2 mg/kg folic acid. Fortification quality for zinc in wheat flour was determined by analyzing the total zinc levels in samples and comparing the results to EAS 2016 as follows: "Not-fortified" 0 mg/kg zinc, "Inadequately fortified" < 40 mg/kg zinc "Adequately fortified" ≥ 40–80 mg/kg zinc and "overfortified" > 80 mg/kg. [3]Fortification quality for iron in maize flour was determined by analyzing the total iron levels in samples and comparing the results to EAS 2011 as follows: "Not-fortified" 0 mg/kg total iron, "Inadequately fortified" < 21 mg/kg total iron, "Adequately fortified" ≥ 21– 41 mg/kg total iron and "overfortified" > 41 mg/kg. Fortification quality for folic acid in maize flour was determined by analyzing the total folic acid levels in samples and comparing the results to EAS 2011 as follows: "Not-fortified" 0 mg/kg folic acid, "Inadequately fortified" < 0.6 mg/kg folic acid, "Adequately fortified" ≥ 0.6–1.7 mg/kg folic acid and "overfortified" > 1.7 mg/kg folic acid. Fortification quality for zinc in maize flour was determined by analyzing the total zinc levels in samples and comparing the results to EAS 2011 as follows: "Not-fortified" 0 mg/kg zinc, "Inadequately fortified" < 33 mg/kg zinc, "Adequately fortified" ≥ 33–65 mg/kg zinc and "overfortified" > 65 mg/kg zinc

Table 3. Proportions of fortification levels by food vehicles compared to EAS

might have been lost during food processing or preparation, extrusion moisture and other micronutrients in the premix and the fortified food vehicle (Allen *et al.*, 2006). Also, the nature of packaging material might have influenced the loss of some fortificants like folic acid and other vitamins that are sensitive to light, oxygen and humidity (Hemery *et al.*, 2020). Another reason could be that micronutrients sachets that are termed multiple nutrients that are shipped to Africa contain fewer or no other fortificants other than iron, which in reality is very rare. A major limitation of this study includes its convenience sampling methodology and small sample sizes, which may not accurately represent the current levels of fortification in Tanzanian food vehicles. Further surveys with larger sample sizes and random sampling methods are, therefore, warranted.

Similar results of inadequacy fortification have been reported in a previous national survey where the study revealed inadequacy fortification for vitamins and iron in the

Table 4. Fortification quality levels among sample batches for vitamin A (mg/100 g)

Food vehicle	Sample ID	Mean ± SD	Fortification quality1 levels	*p*-value
Cooking oil	POE[1]	0.40 ± 0.02	Inadequate	< 0.001***
	POE[2]	1.84 ± 0.14	Inadequate	
	POE[3]	0.27 ± 0.14	Inadequate	
Cooking oil	POF[1]	0.24 ± 0.02	Inadequate	0.007**
	POF[2]	0.34 ± 0.03	Inadequate	
Cooking oil	POG[1]	3.14 ± 0.1	Adequate	< 0.001***
	POG[2]	0.27 ± 0.01	Inadequate	
Cooking oil	SOA[1]	2.19 ± 1.90	Adequate	0.12 ns
	SOA[2]	0.38 ± 0.37	Inadequate	
	SOA[3]	0.07 ± 0.00	Inadequate	
Cooking oil	SOC[1]	0.62 ± 0.04	Inadequate	< 0.001***
	SOC[2]	0.25 ± 0.02	Inadequate	
	SOC[3]	0.21 ± 0.02	Inadequate	
Cooking oil	SOB[1]	0.26 ± 0.23	Inadequate	0.72 ns
	SOB[2]	0.24 ± 0.24	Inadequate	
	SOB[3]	0.36 ±0.02	Inadequate	
Cooking oil	SOD[1]	0.66 ±0.03	Inadequate	< 0.001***
	SOD[2]	0.46 ±0.04	Inadequate	
	SOD[3]	0.32 ± 0.02	Inadequate	

Notes: Values are mean ± SD; n = 3; Values are on liquid weight basis, [1], [2],[3] batch number; statistically significant at *p < 0.05, **p < 0.01, ***p< 0.001, ns not significant (p > 0.05); sample mean concentration differences were compared across batches by one-way ANOVA at confidence level of 5% to assess consistency in fortification quality. [1]Fortification quality for oil: "Not-fortified" 0 mg/100 g vitamin A, "Inadequately fortified" <2 mg/100 g vitamin A, "Adequately fortified" ≥ 2– 4 mg/100 g and "Overfortified" > 4 mg/100 g

mandatory fortified food vehicles such as vegetable oil, wheat and maize flours in Tanzania (GAIN, 2016). Other similar results of inadequacy fortification were reported in Nigeria, where an analysis revealed no traces of vitamin A and iron in fortified vegetable oil, sugar and cereal flour samples (Ogunmoyela *et al.*, 2013). Furthermore, inadequate fortification of iodine, iron, zinc, folic acid and vitamin A has also been reported in fewer than half of the samples from 20 national fortification programs in 12 countries, including Ghana, Nigeria, Ethiopia and Philippines (Luthringer *et al.*, 2015).

Unlike the present study, which revealed that the majority of the wheat flour samples (83.3%) and maize flour samples (80%) were adequately fortified with iron, a study in Abidjan, Côte d'Ivoire, revealed a low level of iron fortification compliance. Only 32% of the wheat flour samples were adequately fortified with iron in Abidjan, Côte d'Ivoire (Rohner *et al.*, 2016). Similarly, a national survey conducted in Nigeria revealed significant low levels of compliance for iron (1.0–21.0%) and vitamin A (12.2–33.3%) in wheat and maize flour (Ogunmoyela *et al.*, 2013). Furthermore, similar trends were observed in the subsequent survey, where, only 16.7, 11.6 and 28% of sugar, vegetable oil and cereal flours, respectively, met the minimum fortification levels for vitamin A and iron (Ogunmoyela *et al.*, 2015).

Based on the present analysis, it is evident that since the first survey, there is no much improvement in the adequacy of micronutrient fortification in Tanzania. Anemia is still high, despite the reported improvements in iron fortification compliance in the mandatory large-scale industrial mills in the country (MoHCDGEC, 2016). Large-scale industrial mills alone are not covering a large proportion of the population, making it is difficult to get iron-fortified flour, especially in rural communities, where 80% of the population relies on hammer mills. Most of the people in rural areas consume their own home-grown maize/

Table 5.
Fortification quality for folic acid levels (mg/kg) among flour sample batches

Food vehicle	Sample ID	Mean ± SD	Fortification quality levels[1,2]	*p*-value
Wheat flour	WFA[1]	0	Not fortified	¥
	WFA[2]	0	Not fortified	
	WFA[3]	0	Not fortified	
Wheat flour	WFD[1]	3.82 ± 3.31	Overfortified	0.06^{ns}
	WFD[2]	7.77 ± 0.40	Overfortified	
	WFD[3]	3.35^{c} ± 0.32	Overfortified	
Wheat flour	WFB[1]	3.18 ± 0.32	Adequate	0.81^{ns}
	WFB[2]	3.04 ± 0.18	Adequate	
	WFB[3]	4.08 ±3.56	Overfortified	
Wheat flour	WFC[1]	0	Not fortified	<0.001***
	WFC[2]	0	Not fortified	
	WFC[3]	7.99 ± 0.46	Overfortified	
Maize flour	MFA[1]	2.63 ± 0.23	Overfortified	0.001***
	MFA[2]	0.88 ± 0.21	Adequate	
Maize flour	MFB1	6.03 ± 0.27	Overfortified	<0.001***
	MFB[2]	6.03 ± 0.27	Overfortified	
	MFB[3]	3.95 ± 0.167	Overfortified	

Notes: Values are mean ± SD; n = 3. Values are on solid weight basis, [1, 2,3]batch numbers; statistically significant at $*p < 0.05$, $**p < 0.01$, $***p < 0.001$, ns not significant ($p > 0.05$); Sample mean concentration differences were compared across batches by one-way ANOVA at confidence level of 5% to assess consistency in fortification quality. [1]Fortification quality for folic acid in wheat flour: "Not-fortified" 0 mg/kg folic acid, "Inadequately fortified" < 1.1 mg/kg folic acid, "Adequately fortified" ≥ 1.1– 3.2 mg/kg folic acid and "overfortified" > 3.2 mg/kg folic acid. [2] Fortification quality for folic acid in maize flour: "Not-fortified" 0 mg/kg folic acid, "Inadequately fortified" < 0.6 mg/kg folic acid, "Adequately fortified" ≥ 0.6– 1.7 mg/kg folic acid and "overfortified" > 1.7 mg/kg folic acid. ¥ F-test p-values not estimable because all sample mean concentrations were 0

wheat, milled at small hammer mills that have limited capacity to fortify flour (Pe *et al.*, 2014). Also, the high cost of premix micronutrients and fortified flour has limited majority of companies and consumers from constant access to premix micronutrients and consumption of fortified products. High cost as a reason for the low compliance in fortification has also been reported in Nigeria as the inclusion of vitamin A in the flour fortification premixes increased the cost, and no incentives were provided to lower the burden to processors (Ogunmoyela *et al.*, 2013).

Lack of appropriate technology for maize flour fortification at mills that package flours, poor premix distribution systems, low demand and market for fortified maize flour and products due to low consumer awareness, inadequate resources and weak enforcement mechanisms to available penalties and fines have also been linked to inadequate fortification in Tanzania (Towo *et al.*, 2015; Kavishe and Harris, 2017), in Zambia (Darnton-Hill and Nalubola (2002) and in Vietnam and Morocco (Wirth *et al.*, 2012). This calls for the provision of incentives as a strategy to enable food processing companies to have a similar competitive edge in the market with non-fortifying processors as recommended by Luthringer *et al.* (2015).

On the other side, a fortification assessment coverage conducted by GAIN and the Oxford Policy Management (OPM) in Nigeria in 2018 noticed a significant improvement in the mandatory fortified food vehicles (Global Alliance for Improved Nutrition and Oxford Policy Management, 2018). Their assessment showed that 67, 89, 46, 86 and 80% of the salt, sugar, oil, wheat flour and semolina flour brands, respectively, were fortified. This was a notable improvement from the 2015 survey data (Ogunmoyela *et al.*, 2015), demonstrating higher compliance with fortification standards than in the present study, with the exception of iron fortification in wheat (83 %) and maize flour (80%). Similar improvements have been reported in Uzbekistan, Morocco and Vietnam (Wirth *et al.*, 2012).

Provision of national premix funding to food processors has been noted as a factor for the reported success in Uzbekistan, Morocco and Vietnam when it comes to complying with micronutrient fortification standards (Wirth *et al.*, 2012). Another noted success factor is technical support from international development agencies, which covers funding to purchase appropriate fortification equipment or machinery, training food processors on how to use the equipment and micronutrient premix in small-scale fortification, creating consumer awareness on the health benefits of consuming fortified foods. Researchers have also noted that effective and consistent enforcement of penalties such as fines, suspension of business licenses and closure of processing plants can ensure compliance in food fortification (Luthringer *et al.*, 2015; Wirth *et al.*, 2012). Similar approaches have been adopted in Tanzania, but they need strict and effective enforcement to improve compliance of food fortification in the mandatory food vehicles for improved nutrition and health.

Conclusion

The present study was conducted after eight years of the implementation of the national fortification program in Tanzania. Analysis from this study showed that iron fortification in maize and wheat flours comply with the East Africa fortification standards. On the other hand, the current levels of micronutrient fortification for vitamin A in cooking oil, and for folic acid and zinc in wheat and maize flours are still far from the established standards. This could be due to the underutilization of fortification premixes in the food processing companies due to technical issues or the use of low-quality premixes. Additionally, inadequate and ineffective monitoring and evaluation of fortification compliance by the government regulators due to inadequate resources may also contribute to this. Folic acid and zinc levels in wheat and maize flours should be monitored and analyzed independently instead of relying on iron to represent them. Furthermore, mandatory fortification should be encouraged and monitored in all maize flour milling companies, irrespective of their sizes to bring more impact to the community. The outputs of this study call for a review of the current fortification strategies concerning the standards, training, monitoring and enforcement. This can be achieved by the government in cooperation with the private sectors, food processors and consumers to ensure its proper implementation and sustainability.

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