

**AN INVESTIGATION OF ADEQUACY OF THE CURRENT
MICRONUTRIENT FORTIFICATION IN THE MANDATORY
FORTIFIED FOOD VEHICLES IN TANZANIA**

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ABSTRACT

Micronutrient fortification of cooking oil, wheat and maize flours is mandatory in Tanzania since 2011. Up-to-date information regarding the compliance of micronutrient fortification is limited in the country. This study aimed at updating the information on the current status of micronutrient fortification in mandatory food vehicles in Tanzania. A cross-sectional study was conducted in 5 regions to analyze the adequacy of micronutrient fortification and identify challenges facing fortification programs. Samples (from selected companies) of fortified edible oil (n = 19), wheat flour (n = 12) and maize flour (n = 5) were collected from supermarkets and analyzed for vitamin A, folic acid, iron and zinc using standard methods and procedures. Questionnaires were used to identify challenges regarding fortification compliance. About 80% and 83% of the maize and wheat flour samples respectively complied with the iron fortification standards. Only 25% and 40% of the wheat and maize flour samples respectively complied with zinc fortification. Nearly 17% and 20% of the wheat and maize flour samples and 10.5% of the cooking oils respectively complied with folic acid and vitamin A standard. Significant variations ($p < 0.001$) were observed in 5 batches of cooking oil, 1 batch of wheat flour and 2 batches of maize flour. Moreover, high cost of premixes (83%), low consumer awareness (75%) and poor laboratory facilities (67%) were highlighted as barriers to food fortification compliance. This shows that food fortification is still facing challenges in Tanzania and hence calls for a review of the current fortification programs in Tanzania.

DECLARATION

I, Flavia A. Kiwango do hereby declare to the Senate of Nelson Mandela African Institution of Science and Technology that this dissertation is my original work and that it has neither been submitted nor has it been concomitantly submitted for degree award in any other institution.


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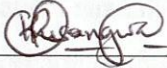
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CERTIFICATION

The undersigned certify that they have read the dissertation titled, “*An Investigation of Adequacy of the Current Micronutrient Fortification in the Mandatory Fortified Food Vehicles in Tanzania*” and recommend for examination in fulfillment of the requirements for the degree of Master’s in Life Sciences of the Nelson Mandela African Institution of Science and Technology.

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DEDICATION

This work is dedicated to my late parents.

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LIST OF ABBREVIATIONS AND SYMBOLS

ANOVA	Analysis of Variance
B ₉	Folic Acid
CDC	United States Centre for Disease Control and prevention
CEDHA	Centre for Educational Development in Health
FAO	Food and Agriculture Organization
Fe	Iron
GAIN	Global Alliance for Improved Nutrition
GDP	Gross Domestic Product
HPLC	High-Performance Liquid Chromatography
KIDH	Kibong'oto Infectious Diseases Hospital
KNCHREC	Kibong'oto Infectious Diseases Hospital-Nelson Mandela African Institution of Science and Technology-Centre for Educational Development in Health
MFA	Maize Flower from Company A
MFB	Maize Flower from Company B
MoHCDEC	Ministry of Health Community Development Elderly and Children
MP AES	Microwave Plasma Atomic Emission Spectrometer
NaFeEDTA	Sodium Iron Ethylene Diamine Tetraacetic Acid
NBS	National Bureau of Statistics
NM-AIST	Nelson Mandela African Institution of Science and Technology
OPM	Oxford Policy Management
POE	Palm Oil from Company E
POF	Palm Oil from Company F
POG	Palm Oil from Company G
SD	Standard Deviation
SOC	Sunflower Oil from Company C
SOD	Sunflower Oil from Company D
TBS	Tanzania Bureau of Standards
TDHS	Tanzania Demographic Health Survey

WHO

World Health Organization

Zn

Zinc

CHAPTER ONE

INTRODUCTION

1.1 Background of the problem

Global analyses show that more than two billion people suffer from micronutrient deficiencies worldwide (Bailey, 2015). The most prevalent micronutrient deficiencies are iron (Fe), iodine (I), zinc (Zn) and vitamin A, with women and children in developing countries being the most affected individuals. Micronutrient deficiencies cause a wide range of nonspecific physiological impairments, leading to metabolic problems and delayed physical and mental development (Bailey, 2015). Micronutrient deficiencies also account for 7.3% of all diseases globally with Fe and vitamin A deficiency being among the top 15 leading causes of the diseases worldwide (Allen *et al.*, 2006).

Food fortification is the process of deliberately increasing the content of an essential micronutrient in food to improve its nutritional quality and provide a public health impact with minimal risk to health (Allen *et al.*, 2006). According to the Food and Agriculture Organization (FAO), the fortification of food is one of the workable approaches for averting micronutrient malnutrition of populations at risk (Allen *et al.*, 2006). This assertion is based on the fact that this approach can reach large populations of people at risk using the existing food supply channels and without major changes in their food consumption patterns (Serdula, 2010). Furthermore, the program is pursued to focus on principal foods in developing countries like wheat and maize flour and condiments. For the proper execution of this strategy, FAO and the World Health Organization (WHO) have jointly established standard guidelines for the fortification of food with micronutrients (Allen *et al.*, 2006).

The fortification of foods with micronutrients has been established to significantly improve nutrition in mothers and children in different interventional studies. For instance, a study by Das *et al.* (2013) revealed a significant improvement in the levels of hematologic markers in children when foods were enriched with vitamin A, Fe and various micronutrients. The analysis further showed an increase in the hemoglobin amount in women of reproductive ages as well as those who were pregnant after Fe fortification intervention (Das *et al.*, 2013), and that folate fortification significantly decreased the prevalence of neural-tube disorders without increasing twinning incidences (Das *et al.*, 2013). Another study by Solon *et al.* (2000) on vitamin A fortification improved the condition of the micronutrient in school children in the Philippines

by 50%. In Australia, the compulsory fortification of wheat flour with folic acid significantly reduced the incidence of folate problems in women of the child-bearing age (Brown *et al.*, 2011). These studies all indicate that the fortification of food is a suitable method for improving nutrition in developing and low-income countries such as Tanzania where micronutrient-malnutrition is still persistent according to the Tanzania Demographic Health Survey (TDHS) of 2015-16 published by the Ministry of Health, Community Development, Elderly and Children (MoHCDEC, 2016).

According to the report of the Tanzania Demographic Health Survey (TDHS, 2010), 33% and 35% of children under 5-years old were deficient in vitamin A and Fe respectively, while close to 60% were anemic. Among the women between 15 and 49 years, 37% and 30% were also deficient in vitamin A and Fe respectively, and 40% anemic (National Bureau of Statistics [NBS], 2011). Voluntarily micronutrient fortification of salt with iodine in Tanzania began in the 1990s but in 2011, the Government of Tanzania put in place the legislation for the compulsory fortification of food like wheat and maize flour and vegetable oils. The permitted fortificants were Fe in the form of sodium iron ethylene diamine tetra acetic acid (NaFeEDTA), Zn in the form of zinc oxide (ZnO), vitamin B₁₂, and folic acid (B9) for wheat and maize flour, vitamin A in the form of retinyl palmitate for vegetable oils, and iodine for salt (Kavishe & Harris, 2017). The key objective was to address under-nutrition in the nation. Despite these efforts, the MoHCDEC report that the deficiency of micronutrients remains a major challenge in Tanzania with anemia reduction stagnating in under-fives at 58% and worsening in women of the reproductive age at 45% (MoHCDEC, 2016). This malnutrition is most likely due to the inadequate fortification of food in the country.

The first national fortification survey to assess fortification compliance with national and global standards in Tanzania was conducted by the Global Alliance for Improved Nutrition (GAIN, 2015) in partnership with other organizations including the United States Centers for Disease Control and Prevention. The survey showed that less than 20%, 19% and 5% of oil, wheat flour and maize flour respectively, complied with the fortification standards (GAIN, 2015). On the contrary, the survey established that 15% of the salt samples were over-fortified according to WHO standards while less than 1% of salt samples were over-fortified based on national standards (GAIN, 2015). Apart from this survey which was done approximately close to 5 years after the fortification of food was mandated in 2011, there is no up-to-date evidence regarding the compliance of food-fortification programs with the national standards in

Tanzania. Moreover, fortificants such as Vitamin B₁₂, folic acid and Zn were not evaluated in the survey. Similarly, there is no current data on the adequacy of micronutrient fortification in the mandatory fortified food vehicles, and the challenge of non-compliance to fortification standards perhaps still exists in Tanzania. This assumption is founded on the fact that micronutrient deficiencies are still generally high in the country (MoHCDGEC, 2016), calling for another survey to assess the adequacy of the existing mandatory food-fortification practices in the country. The present study aimed at updating the information on the current status of micronutrient fortification in the mandatory fortified food vehicles such as edible cooking oil, wheat and maize flours in Tanzania. The information from this survey can help regulatory authorities develop adequate enforcement systems to ensure compliance with food fortification programs.

1.2 Statement of the problem

Apart from the first national food fortification assessment in Tanzania in 2015, close to 5 years after the introduction of mandatory food fortification in 2011, information regarding the state of food fortification programs with regard to the national fortification standards is scanty. The initial national assessment of food fortification in the country revealed that maize and wheat flours and vegetable oils, were inadequately fortified (GAIN, 2015). Less than 20% of maize flour and vegetable oils, and less than 5% of wheat flour samples were adequately-fortified (GAIN, 2015). Moreover, fortificants such as Vitamin B₁₂, folic acid and Zn were not evaluated in the survey instead Fe was used as an indicator to reflect the likely fortification of those nutrients. Despite the efforts to mandatory fortification performed by the government of Tanzania, micronutrient deficiency remains persistent in the country, with anemia being constant in under-fives at 59% (NBS, 2011), and 58% (MoHCDEC, 2016) and worsening from 40% (NBS, 2011) to 45% (MoHCDEC, 2016) in women of the reproductive ages (MoHCDEC, 2016; NBS, 2011). The inadequate fortification of foods with micronutrients exists in other countries as well. For instance, the study by Luthringer *et al.* (2015) revealed that close to half of the food samples taken from 20 national food fortification programs in 12 countries were not adequately-fortified according to national standards. Apart from this evidence of poor fortification practices which confirm the slow progress of the fortification programs, there exist challenges at the industry, government, and community levels like poor quality of inputs, unawareness of standards, insufficient capacity for law enforcement, limited funds and human resources as well as insufficient or lack of well-equipped laboratories (Kavishe & Harris, 2017;

Luthringer *et al.*, 2015; Towo *et al.*, 2015). Similarly, there is no current data on the adequacy of micronutrient fortification in the mandatory fortified food vehicles, and the challenge of non-compliance to fortification standards probably still exists in the country, necessitating another study to substantiate the adequacy of mandatory fortification of foods with micronutrients in Tanzania.

1.3 Rationale of the study

Micronutrient fortification of cooking oil, wheat and maize flours is mandatory in Tanzania since 2011. Apart from the first national food fortification assessment in Tanzania in 2015 which revealed inadequately micronutrient fortification, up-to-date information regarding the compliance of micronutrient fortification is limited in the country. The rationale for conducting the survey in Singida, Dodoma, Shinyanga, Arusha and Dar es Salaam is that these areas have large scale food processing companies in which micronutrient fortification is mandatory. The findings of this study provide updated data on micronutrient fortification compliance. The study additionally provides information on the challenges that private food-processing companies face in implementing the food fortification programs in the country.

1.4 Objectives of the study

1.4.1 General objective

The general objective of the present study was to authenticate compliance with the current mandatory food fortification practices with regard to the national standards and regulations in Tanzania.

1.4.2 Specific objectives

- (i) To evaluate the adequacy of current fortification of wheat and maize flour (Fe, Zn and folic acid) and vegetable oils (vitamin A) from large food-processing companies in Tanzania.
- (ii) To investigate the constraints facing large-scale food-processing companies in implementing the food-fortification programs in Tanzania.

1.5 Research questions

- (i) Does the current fortification of foods with micronutrients in Tanzania conform to the national standards?
- (ii) What are the challenges that large-scale food-processing companies in Tanzania face in implementing food-fortification programs?

1.6 Significance of the study

The present study provides updated information on the levels of vitamin A, folic acid, Fe and Zn in wheat and maize flour, and vegetable oils in Tanzania. The study additionally provides information on the challenges that private food-processing companies face in implementing the food fortification programs in the country. Such information can help the relevant authorities to develop proper mechanisms of enforcing compliance to food fortification standards and support the ongoing efforts to strengthen the national food-fortification program in the country.

1.7 Delineation of the study

This study was investigating the adequacy of micronutrient fortification in the mandatory fortified vehicles and challenges facing the food processing companies regarding fortification compliance. The survey was conducted in Singida, Arusha, Shinyanga, Dodoma and Dar es Salaam regions using standard method procedures and questionnaires. Except for Fe in wheat and maize flours, the levels of other micronutrients were inadequately fortified. Moreover, high cost of premixes, low consumer awareness, poor laboratory facilities and insufficient government incentives were highlighted as barriers to food fortification compliance.

CHAPTER TWO

LITERATURE REVIEW

2.1 Prevalence of micronutrient deficiency

According to WHO, over 2 billion people are faced with a deficiency of micronutrients such as iodine, vitamin A, Fe and Zn, the most affected being the women and children in developing countries (Musgrove *et al.*, 2000). Iron (Fe) is the leading micronutrient deficiency, affecting more than 30% of people, globally (McLean *et al.*, 2009). About 17.3% of the world population is Zn deficient, with the highest prevalence in Africa and Asia at 23.9% and 19.4% respectively, and an additional estimated population of between 250 and 500 million children is blind from the deficiency of vitamin A (Bailey, 2015). According to the Tanzania Demographic Health Survey (TDHS, 2010), about 59% of under-five children were anemic and 33% and 35% deficient in vitamin A and Fe respectively. Additionally, among the women of the reproductive age, about 40% were anemic, and 37% and 30% deficient in vitamin A and Fe respectively (NBS, 2011).

2.2 Impacts of the micronutrient deficiency

Micronutrient deficiency causes unspecific physiological impairments that generally lead to reduced resistance to infections, metabolic problems, perinatal complications, delayed physical and mental development, and increased risk of morbidity and mortality (Bailey, 2015). Each year, between 40% and 60% of 2-year-olds in developing countries face the risk of delayed cognitive development as a result of insufficient Fe intake and anemia during pregnancy accounts for 20% of all maternal deaths (Black *et al.*, 2013). According to De-Benoist (2008), inadequate folate intake during pregnancy also contributes to low birth weight, fetal mental and physical growth retardation, and preterm delivery. In the year 2013, approximately 2.3% and 1.7% of all child mortality rates worldwide were associated with the inadequate intake of vitamin A and Zn respectively (Black *et al.*, 2013), and close to 300 000 children are born with severe birth disorders annually due to deficiency of folate during pregnancy (Dwyer *et al.*, 2015a).

The deficiency of micronutrients also has economic effects as a result of impacts on work efficiency due to morbidity and mortality, as well as the indirect costs on health systems (Horton, 2004). Micronutrient malnutrition has also been shown to contribute to between 2%

and 5% loss in Gross Domestic Product (GDP) in developing countries annually, with direct costs of US Dollar 20 to 30 billion every year (Dary, 2008).

2.3 Food fortification

Micronutrient malnutrition can be prevented through the intake of balanced and adequate diets. However, this is usually not commonly achievable as it requires suitable dietary habits and access to enough food (Allen *et al.*, 2006). According to WHO and FAO, food fortification is among the sustainable approaches to curbing micronutrient deficiencies in populations at risk, favorably because it can reach many people at risk through the existing food supply systems with zero changes to the already prevailing consumption patterns (Serdula, 2010). Moreover, the program focuses on principal foods in developing countries like wheat and maize flours and condiments. To properly implement this strategy, standard guidelines on food fortification with micronutrients were put in place by WHO and FAO to outline how food fortification should be implemented, monitored, and evaluated to prevent micronutrient deficiencies. For instance, they have established procedures for the identification of suitable food vehicles and fortificants and how to analyze fortification levels (Allen *et al.*, 2006).

2.4 Impacts of micronutrient fortification

Several interventional studies on micronutrient fortification have reported a significant improvement in maternal and child nutrition. For instance, a significant improvement in the levels of hematologic markers in children was observed when foods were fortified with multiple micronutrients (Das *et al.*, 2013). This study also revealed enhanced haemoglobin levels in women of the reproductive age and pregnant women after Fe fortification intervention. In a different investigation, it was shown that fortification with folate significantly subsidized incidences of inherited abnormalities like neural-tube disorders without increasing twinning incidences (Das *et al.*, 2013). The mandatory fortification of milk and wheat flour in Costa Rica also significantly contributed to the reduced cases of anemia in children and women from 19.3 to 4.0% and 18.4 to 10.2% respectively at the national level (Martorell *et al.*, 2016). According to systematic reviews (Brown *et al.*, 2011; Gera *et al.*, 2012; Hilder's, 2016; Solon *et al.*, 2000), the fortification of foods with micronutrient has the potential of significantly enhancing micronutrient concentrations in the serum. For example, controlled trials including 60 acceptable trials on Fe fortification reported enhanced in hemoglobin (0.42 g/dL) and serum

ferritin (1.36 ug/L) coupled with subsidized risks to anemia and Fe deficiency (Gera *et al.*, 2012).

The mandatory fortification of wheat flour with folic acid in Australia also effected the reduced incidences of folate problems in women of the reproductive age (Brown *et al.*, 2011). This was also maintained by Hilder's (2016) observation of reduced neural-tube defect rates for babies conceived following the introduction of mandatory folic acid fortification. In another study by Solon *et al.* (2000) on vitamin A fortification showed an improved vitamin A status of school-going children by 50% after intervention in the Philippines. Similar outcomes were observed in another study on school-going children in Mpwapwa-Tanzania where a significant increase of hematologic and anthropometric measurements, as well as a reduction in the prevalence of vitamin A deficiency and anemia were observed when the fortified beverages were consumed (Ash *et al.*, 2003).

A study in South Africa, micronutrient fortification was shown to significantly reduce morbidity and mortality rates in addition to reducing neural tube defects like spinal-bifida and anencephaly by 41% and 10% respectively. Similar observations were made in yet another study where perinatal mortalities related to neural-tube defects related to infant mortality rates were reduced to 66% and 39% respectively (Sayed *et al.*, 2008). These results are evidence that the fortification of food is a suitable approach towards improving micronutrient nutrition in developing/low-income countries like Tanzania where micronutrient malnutrition remains a huge challenge.

2.5 Mandatory food fortification in Tanzania

In 2011, the Government of Tanzania approved the legislation for mandatory fortification of staple foods and condiments like wheat and maize flours and vegetable oils. The approved fortificants were Fe as sodium iron ethylene diamine tetra acetic acid (NaFeEDTA), Zn as zinc oxide (ZnO), vitamin B₁₂ and folic acid (B₉) for wheat and maize flours, vitamin A as retinyl palmitate for vegetable oils, and iodine for salt (Kavishe & Harris, 2017). The major objective was to tackle micronutrient deficiency in the country. This was after the report by NBS (2011) that, 33% of under-five-year-olds 59% were anemic while 33% and 35% were deficient in Vitamin A and Fe respectively, and that for women of the reproductive age (15 - 49 years old), 40% were anemic while 37% and 30% were deficient in vitamin A and Fe respectively (NBS, 2011). Despite the mandatory food fortification and other approaches such as increasing

agricultural production, micronutrient supplementation (vitamin A, folic acid, combined folic acid and Fe), and nutrition education, micronutrient deficiency remains a problem in Tanzania with anemia is still stagnant in under five-year-olds at 59% (NBS, 2011), 58% (MoHCDEC, 2016) and even worsening at 40% (NBS, 2011) and 45% (MoHCDEC, 2016) in women of the reproductive age (MoHCDEC, 2016; NBS, 2011). This is probably due to the inadequate fortification of food in the country.

2.6 Inadequate food fortification

Although the fortification of main foods and condiments has attracted a lot of attention worldwide, poor performance remains in many aspects of implementation, especially in regulatory inspection and monitoring which are very important in ensuring foods are fortified according to national standards (Kavishe & Harris, 2017; Luthringer *et al.*, 2015; Towo *et al.*, 2015). For instance, the observations of Luthringer *et al.* (2015) showed that less than half of food samples from 20 national food-fortification programs in 12 countries (Tanzania excluded) were inadequately-fortified based on national standards. Similar observations have been seen from Abidjan, Côte d'Ivoire where a cross-sectional survey established that only 32% of wheat flour samples were adequately-fortified (Rohner *et al.*, 2016). Similarly, a national survey in Nigeria to determine the levels of Fe and vitamin A in common foods like maize and wheat flours, and condiments such as sugar and vegetable oils showed that the compliance for Fe and vitamin A fortification in flours were only 1% to 21% and 12% to 33%, respectively (Ogunmoyela *et al.*, 2013). Similar trends were reported in a follow-up survey in the country where only approximately 17%, 12% and 28% of sugar, vegetable oil and cereal flours respectively met the minimum fortification standards for vitamin A and Fe (Ogunmoyela *et al.*, 2015).

Inadequate fortification of foods has also been established in Tanzania. For instance, an analysis of the adequacy of food fortification in the country the quality of food fortification based on national standards varied significantly by the type of food vehicle. This analysis established that only 16.3%, 18.9%, 3.3% and 62.7% of oil, wheat flour, maize flour and salt samples, respectively were adequately fortified. Surprisingly, among the salt samples, 15 and less than 1% were over-fortified based on WHO and national standards respectively (GAIN, 2015). However, other fortificants like folic acid, vitamin B₁₂ and Zn were not analyzed, creating room for the evaluation of the adequacy of current mandatory food fortification practices in Tanzania.

2.7 Challenges in implementing food fortification

Apart from the evidence of poor fortification practices that confirm the slow progress in fortification programs in the aspects of compliance, there exist challenges at the industry, government and community levels (Darnton-Hill & Nalubola, 2002; Luthringer *et al.*, 2015). For instance, the survey done by Luthringer and his colleagues with 39 experts from regulatory bodies and the food fortification companies in 17 countries outlined top challenges such as high cost of premixes, low consumer awareness, poor laboratory facilities and low government incentives (Luthringer *et al.*, 2015). A similar study in Zambia also reported the same findings such as poor quality of inputs, unawareness of standards, insufficient capacity for law enforcement being limited in funds and human resources as well as insufficient well-equipped laboratories (Darnton-Hill & Nalubola, 2002). This highlights that, there are still challenges which are facing food fortification programs and hence the need to address them.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study site description

The study was conducted in 5 regions in Tanzania (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. Large companies are ones that have high investment, sophisticated technologies (automated processing) and high production capacity, hence the need for fortification as their products reach many consumers. The mandated food products and approved fortificants are Fe, Zn, folic acid and vitamin B₁₂ for maize and wheat flour and vitamin A for vegetable oil.

3.2 Study design

A cross-sectional survey was conducted from June to August 2019 in the selected regions. A research protocol of the present study was approved by Kibong'oto Infectious Diseases Hospital (KIDH)-Nelson Mandela African Institution of Science and Technology (NM-AIST)-Centre for Educational Development in Health (CEDHA), Arusha (KNCHREC). The permits to visit the food processing companies in the respective regions were pursued from the Local Government Authorities. Company managers were contacted and briefed about the objectives and benefits of the study and agreed to participate in the study. The purpose of the study was explained to every respondent before the initiation of interviews. Confidentiality assurance through data collection and analysis was explained, consent forms were given and signed by the two parties and none of the participants refused to participate. 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.

3.3 Sampling and data collection

A cross-sectional survey that involved questionnaire data and food sample collection was conducted from June to August 2019. Structured questionnaires were designed to obtain feedback for every part of the 5 major elements for quality assurance in fortification namely; food regulations, food handling, food inspection, laboratory capacity and education,

information, and training as recommended by FAO and WHO (Allen *et al.*, 2006). The questionnaires were administered to key personnel who were directly involved in the production process like operation managers and quality assurance officers.

Food samples were collected by convenience sampling from local markets and supermarkets located in each of the 5 regions surveyed (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 in the selected regions. From each company, 3 samples were randomly-picked from 3 batches, packed in dry boxes and transported to the Nelson Mandela African Institution of Science and Technology (NM-AIST) laboratory.

Table 1: Distribution of samples by administrative regions

Region	Cooking oil (1L)	Wheat flour (1kg)	Maize flour (1kg)
Dar es Salaam	10 (3 companies)	9 (3 companies)	No large scale processors
Arusha	3 (1 company)	3 (1 company)	3 (1 company)
Dodoma	3 (1 company)	No large scale processors	No large scale processors
Singida	3 (1 company)	No large scale processors	No large scale processors
Shinyanga	-	No large scale processors	2 (1 company)
Total	19	12	5

3.4 Samples preparation

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 while the cooking oil samples were packed in dark bottles to prevent the effects of light, moisture and air that could cause loss of the targeted micronutrients. A simple database with important information such as the type of product, dates of manufacturing and expiry, name and address of the source of the sample, brand name, batch numbers and sample codes for the identification were recorded on the sample information form. The coded samples were analyzed for Fe and Zn content at the Tanzania Bureau of Standards (TBS) laboratory and vitamin A and folic acid parameters at the Jomo Kenyata Agriculture University of Science and Technology laboratory.

3.5 Laboratory analyses

3.5.1 Determination of vitamin A (Retinyl palmitate) in cooking oil

The quantification of vitamin A in cooking oil was carried out using high-performance liquid chromatography (HPLC) with a UV detector (Shimadzu LC 10 AVP, Japan) as 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 pyrogalllic 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. Vitamin A was analyzed using liquid-liquid extraction using 5 mL n-hexane. The hexane-fraction was pooled into 1 unit, evaporated till 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 introduced into the HPLC using the RP-18 column. Methanol was delivered at 0.8 mL/min as a mobile phase and vitamin A was detected at A₃₂₆ by comparing their retention times with those of the standard solutions (Appendix 2). The final concentration results were expressed in mg/100g and were obtained by a comparison of the peak area of the samples and those of the standards solutions (Equation 1).

$$\text{Concentration (mg/100g)} = \frac{C}{m} \times D \quad \text{Equation 1}$$

Where:

C is the HPLC concentration of the sample, m is the weight of the sample portion, D is dilution volume.

Also, HPLC concentration was calculated using Equation 2.

$$\text{HPLC concentration (C)} = \frac{\text{Peak area of sample (PA)}}{\text{Response factor (RA)}} \quad \text{Equation 2}$$

Where the RF was determined using Equation 3.

$$\text{RF} = \frac{\text{Peak area of known concentration of standard solution}}{\text{A known concentration of the standard solution}} \quad \text{Equation 3}$$

3.5.2 Determination of folic acid in maize and wheat flour

Folic acid was determined according to the method by Ekinici and Kadakal (2005) with slight modifications. The samples were prepared using solid-phase extraction (SPE) to get rid of impurities that may interfere with folate. In 25 mL of H₂SO₄ (0.1 M) solution, 2 g of each sample was added, 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 was added and the solution was incubated at 40 °C for 20 min and cooled. All samples and standard solutions (each 20 µL) were separately introduced into HPLC using an RP-18 column. Methanol was delivered at 0.7 mL/min as a mobile phase and folic acid (ug/mL) was detected at UV 283 nm by comparing their retention times with those of the standard solutions (Appendix 2). The final concentration results were expressed in mg/kg (Equation 4).

$$\text{Concentration of sample (mg/kg)} = \frac{\text{HPLC concentration (mg/kg)} \times \text{Dilution factor}}{\text{Sample weight}} \quad \text{Equation 4}$$

3.5.3 Determination of Zinc and Iron in maize and wheat flour

The quantities of Zn and Fe in wheat and maize flour were determined according to standard procedures described by Cauduro (2013) with slight modifications. The maize and wheat flour samples were approximately weighed to 0.5 g, followed by the addition of 7 mL of concentrated HNO₃ (69%) and 3 mL of H₂O₂ and then placed in the microwave digestion system. The samples were digested at 190 °C for 30 min cooled for 20 min, transferred to a volumetric flask, and diluted to 50 mL with deionized water and labeled clearly for analysis using an Agilent 4210 Microwave Plasma Atomic Emission Spectrometer (MP AES). The quantification of the Fe and Zn (ppm) was evaluated at 371.993 nm and 481.053 nm wavelengths respectively (Equation 5).

$$\text{Concentration of Fe and Zn (mg/kg)} = \frac{\text{Final volume} \times \text{Dilution factor}}{\text{Sample weight}} \quad \text{Equation 5}$$

3.5.4 Standards used as reference

The fortification levels used in this study for each of the food vehicles to test for compliance with the national fortification standards were set according to the current harmonized East African Standards specifications based on those which are mandatory in Tanzania (East

African Standards [EAS], 2011a, 2011b, 2016). Compliance acceptable ranges between the minimum and maximum levels were used as a reference to determine the adequacy of fortification levels as shown in Table 2.

Table 2: Micronutrient fortification compliance levels adopted from East Africa Standards

Food vehicle	Nutrient	Fortificant compound	Regulatory levels	
			Min	Max
Wheat flour	Folate	Folic acid	1.1 ¹	3.2 ¹
	Total Iron	Total Iron	20 ¹	NA ³
	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
	Zinc	Zinc oxide	33 ¹	65 ¹
Edible cooking oil	Vitamin A	Vitamin A (Retinyl) palmitate)	2.0 ²	4.0 ²

¹Regulatory levels are in mg/kg for wheat and maize flour and ²mg/100 g for edible cooking oil

³NA = Not applicable. The maximum limits for these nutrients are not necessary because the upper tolerance limits of these nutrients are very high (60 mg/kg)

3.6 Data analysis

A descriptive analysis of the responses and simple interpretation of the data from the questionnaires was performed using the Statistical Package for the Social Sciences (SPSS) version 20.0. As for the determination of micronutrient levels, data entry and descriptive analysis (means, standard deviation, frequencies and percentages) were done in Microsoft Excel 2010. Additionally, 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 (2019-07-05). A significance level was set at $p = 0.05$.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Characteristics of participants

A total of 12 (63.2%) among 19 food processing companies were surveyed with 12 participants who responded to the questionnaires. The respondents should be working at the production cycle as part of their job and know about food fortification. Among the respondents, six (50%) were Quality Assurance officers with University degrees, four (33.3%) were production managers with University degrees, one (8.3%) was a miller with college education and another one (8.3%) was a laboratory technician with secondary education (Table 3).

Table 3: Characteristics of the respondents (n=12)

Variable	Frequency (n)	Percentage (%)	χ^2
Education level			13.500**
Secondary	1	8.33	
College	1	8.33	
University degree	10	83.37	
Job title			6.000 ^{ns}
Quality assurance officer	6	50.00	
Laboratory technician	1	8.33	
Miller	1	8.33	
Production manager	4	33.34	

4.2 Mandatory fortification and awareness on food fortification

The benefits, safety and cost-effectiveness of food fortification in the context of addressing under nutrition have been established worldwide. This assertion is based on the fact that the strategy can advantageously reach large populations of people at risk through the prevailing food supply systems and without major changes in the 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). As shown by the survey from the 12 food processing companies across the country, every company is mandated to fortify all staple foods like wheat, maize flour, or vegetable oil according to the Tanzania Food Fortification Legislation Act of 2011. All the respondents reported awareness of food

fortification and knew of at least one reason for food fortification, which is to fight micronutrient deficiencies. The mandated staples as well as fortification awareness as reported by the respondents are shown in Table 4.

Table 4: Mandatory food fortification awareness (n=12)

Variable	Frequency (n)	Percentage (%)
Are you aware of food fortification		
Yes	12	100.00
No	-	-
Fortified food products		
Wheat flour	4	33.30
Maize flour	3	25.00
Cooking oil	5	41.70
Food fortificants added		
Iron (Fe), Folic, B ₁₂ and zinc	7	58.30
Vitamin A	5	41.70
Reasons for food fortification		
To reduce micronutrient deficiency	12	58.30
To compensate for the effect of processing	5	41.70

4.3 Challenges facing food companies in ensuring adequate fortification

The respondents from the food processing companies were asked about the challenges they face in ensuring adequate fortification (Fig. 1). The four challenges which dominated are; a) Cost and unavailability of premix (the powdery blend of vitamins and minerals for fortification), b) Less demand for fortified products due to lack of awareness, c) Poor laboratory facilities, and d) Low government incentives. These are further elaborated in subsections 4.3.1– 4.3.4.

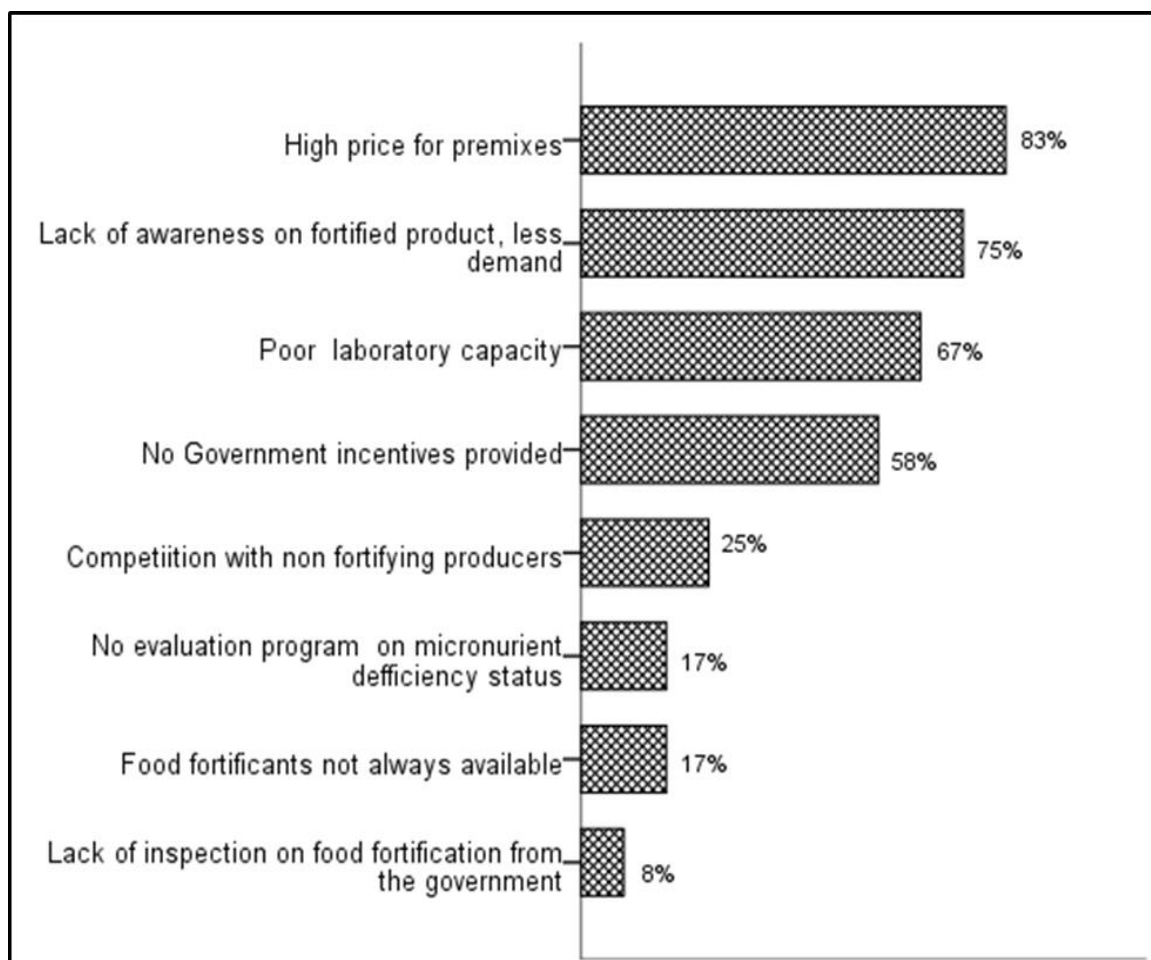


Figure 1: Challenges faced by food processors in ensuring fortification compliance (n=12)

4.3.1 Cost of premix

The analysis indicated that high price for premix is a common challenge (83%; 10 out of 12) which is aggravated by a lack of government incentives which accounted for 58% (7 out of 12) (Fig. 1). This raises the cost of processing and the need to raise the selling price which is not compensated by most food companies. Contrary to this, the premixes are not always available 17% (2 out of 12) (Fig. 1). About 75% (9 out of 12) of the respondents recommended government support, as well as stakeholders on the premixes (Fig. 2), and about 33% (4 out of 12) noted the need to make them fully available by having local suppliers in zonal areas (Fig. 2). These findings are similar to those reported by Darnton-Hill and Nalubola (2002) and Luthringer *et al.* (2015).

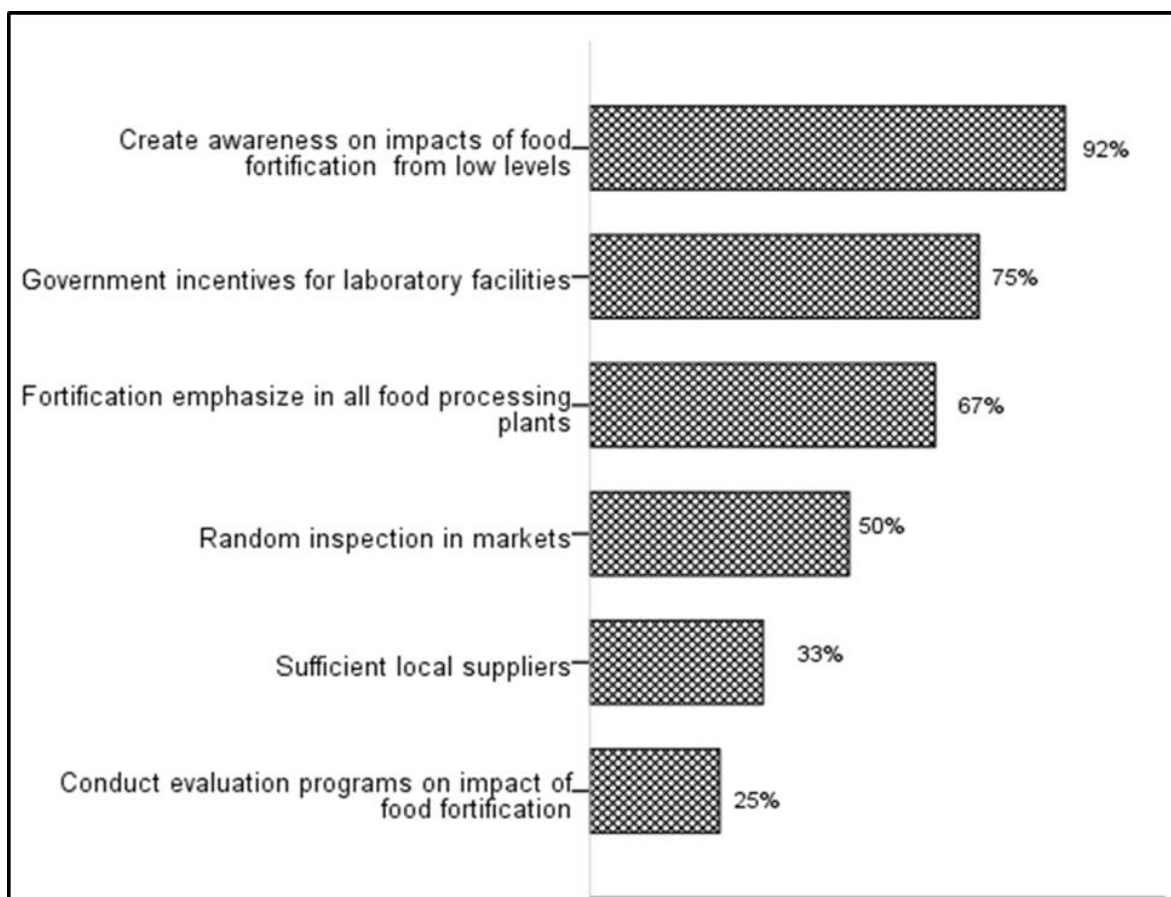


Figure 2: Recommendations from food processors on how to improve fortification practices (n=12)

4.3.2 Lack of awareness

Darnton-Hill and Nalubola (2002) reported the lack of awareness on fortified products as one of the challenges to successful fortification in Zambia. This agrees with the findings of the present study where 75% (9 out of 12) of the respondents also noted the same (Fig. 1). Communities are not aware of food fortification, resulting in low demand. This might also be due to inadequate experts and other resources to provide the right information to the consumers. Currently, Tanzanian people buy fortified products unknowingly but if informed about the importance of consuming fortified foods, they most likely will make the right choice. In as much as this approach requires little changes in consumer eating habits, awareness and social marketing should not be ignored.

Similarly, it is suggested that policy-makers and consumers be informed of the benefits of fortification to sustain the program. About 92% (11 out of 12) of the respondents suggested the introduction of fortification issues in nutrition subjects from low levels of education to create more awareness and increase the demand for fortified foods (Fig. 2). Additionally, awareness

needs to be created through all social media such as radio, televisions and public meetings but the costs involved in such social marketing strategies should be considered. For instance, in Indonesia, the buying and consumption of fortified foods were associated with social-economic status, leaving the poor consuming less (Pee *et al.*, 2000). Therefore, fortified products should not only be available but also affordable to have more impact.

4.3.3 Laboratory capacity

In the present study, we also observed that laboratory capacity is another major barrier to fortification compliance as mentioned by 67% (8 out of 12) of the respondents (Fig. 1). These findings are similar to those reported by Luthringer *et al.* (2015). Lack of equipment, trained personnel, and other inputs makes it difficult for both qualitative and quantitative testing procedures. According to Allen *et al.* (2006), quantitative analysis is used to verify the micronutrient content of fortified foods and is believed to be a very important and strong factor for compliance though not always practiced (Luthringer *et al.*, 2015). In the present study, only 17% of the surveyed companies reported conducting both tests while the remaining 83% (10 out of 12) perform only the qualitative tests whereas the quantitative analyses are not well implemented since the laboratory equipment such as the HPLC and its accessories such as standards and columns are very expensive. Presently, these quantitative tests are mainly performed by regulatory authorities but where resources are available, internal monitoring of the fortification process by food processors is important.

4.3.4 Government and stakeholders support

From the analysis, 58% of the respondents reported inadequate government incentives for micronutrient fortification premixes. About 75% (9 out of 12) of the respondents believed that the government and stakeholders should provide incentives not only for premixes but also for laboratory equipment and other inputs such as chemicals and reagents (Fig. 2). Nevertheless, government support in training and monitoring seemed to perform well as 67% (8 out of 12) of the respondents claimed to have received training from both the government and private sectors and 92% (11 out of 12) received inspection, these are notable support from the government. Furthermore, about 67% (8 out of 12) of the respondents recommended frequent and random inspections of both companies and markets to increase compliance (Fig. 2). This should also go hand in hand with law enforcement such as penalties for non-compliant companies. On the contrary, lack of inspection from the government authorities was found to

be a big challenge in Zambia and other countries (Darnton-Hill & Nalubola, 2002). Support from government and other partners including funding to purchase appropriate fortification equipment or machinery, training, and consumer awareness is very crucial for the sustainability of micronutrient fortification programs (Wirth *et al.*, 2012).

4.3.5 Competition with non-fortifying companies

In the present study, only 25% (3 out of 12) of the respondents mentioned competition with non-fortifying companies as a challenge and these were only from the maize processing companies (Fig. 1). On the contrary, competition with non-fortifying food processing companies was rarely mentioned as a challenge as opposed to previous studies reported by Luthringer and her colleagues where this was identified as a top barrier (Luthringer *et al.*, 2015). This difference can be explained by the fact that most maize flour is processed by local millers in the rural areas and other small scale plants in which fortification for them is not mandatory. This makes the large scale fortification companies raise their selling prices or they are forced to sell the same price as their competitors for low profits. To equalize this, about 67% (8 out of 12) of the respondents suggested that fortification should be done in all food processing companies especially the maize companies (Fig. 2).

Sometimes the fortification of micronutrients does not meet the nutritional needs of the population, hence, the need for other supplementation strategies. For instance in Guatemala, the fortification of sugar with vitamin A has been implemented since 1974 but the government supplies vitamin A supplementation to children twice yearly (Dwyer *et al.*, 2015). This strategy is also applied in Tanzania where children aged 6 - 59 months are supplemented with vitamin A twice a year and pregnant women are also supplemented with Fe/folic tablets. This bi-annual distribution of Vitamin A supplementation was introduced in 2001 as part of two common annual events; the African Child day (June 16) and the World AIDS Day (1st December). De-worming tablets were also introduced as part of these occasions in December 2004 (Masanja *et al.*, 2006).

4.3.6 Lack of impact evaluation of micronutrient interventions

Lack of impact evaluation though mentioned by only 17% (2 out of 12) (Fig. 1) may have an impact on the adequacy of fortification practices but the biochemical indicators, human capacity, and equipment for assessment can be a challenge. This is because identifying a problem and setting strategies to solve the problem will not suffice if the program is not well

monitored and evaluated and the outputs presented to all stakeholders. For instance, from a study done to evaluate the impact of Fe fortification in India, it was concluded that anemia decreased in countries that fortified flour with micronutrients compared to those that did not (Barkley *et al.*, 2015). In Tanzania, the TDHS indicated that micronutrient deficiency is still a problem and anemia reduction is still stagnant in under-fives (58% - 59%), and even worsening (increased from 40% to 45%) in women of the reproductive age (MoHCDEC, 2016; NBS, 2011). If the implementation partners would have been involved in the data dissemination, changes would have been evident but there is no other current impact assessment data to prove otherwise. Food processing companies are part and parcel of food fortification programs and this type of data is likely to motivate them to put more effort into the implementation.

4.4 Micronutrient adequacy in fortified food vehicles

Table 1 in section 3.3 shows the distribution of food samples collected in all the 5 regions. Based on the East African fortification standard references presented in Table 2 in section 3.5.4, 83.3% and 80% of wheat and maize flour respectively were adequately fortified with Fe (Table 5). Only 16.7% and 20% of the wheat and maize flour samples respectively complied with the folic acid standards (Table 5). Similarly, about 25% and 40% of wheat and maize flour samples respectively were compliant for Zn fortification standards. Only 10.5% of samples of cooking oil complied with the vitamin A fortification standards. Also, about 41.7% of wheat flour samples tested were not fortified with folic acid at all (Table 5).

A significant difference ($p < 0.05$) in fortification quality levels was observed within the batches of the same food processing companies. The results showed that the variations that existed within 5 batches of cooking oil samples (POE, POF, POG SOC and SOD) were statistically significant at $p < 0.001$ (Table 6). Significant variations were also observed for folic acid fortification compliance in 1 batch of wheat flour (WFC) at $p < 0.001$ and 2 batches of maize flour (MFA and MFB) at ($p < 0.001$ (Table 7).

Table 5: Proportion of fortification levels by food vehicles compared to East African standards

	Level of fortification					p-value
	Mean \pm SD	Inadequately (%)	Adequately (%)	Not-fortified (%)	Overfortified (%)	
Vitamin A fortification in cooking oil samples¹						
Cooking oil (n = 19)	0.659 \pm 0.872	89.5	10.5	0	0	<0.001***
Micronutrient fortification in wheat flour samples²						
Folic acid (n = 12)	0.28 \pm 0.3	0	16.7	41.7	41.7	<0.001***
Iron (n = 12)	36.61 \pm 17.52	8.3	83.3	8.3	0	0.004**
Zinc (n = 12)	27.92 \pm 15.80	75	25	0	0	0.011*
Micronutrient fortification in maize flour samples³						
Folic acid (n = 5)	0.31 \pm 0.28	0	20	0	80	<0.001***
Iron (n = 5)	20.28 \pm 7.68	20	80	0	0	0.002**
Zinc (n = 5)	23.60 \pm 9.3	60	40	0	0	0.001**

Values are mean \pm 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 East African Standard 2011 as follows: “Not-fortified” 0 mg/100g vitamin A, “Inadequately fortified” <2 mg/100g vitamin A, “Adequately fortified” \geq 2-4 mg/100g and “Overfortified” >4 mg/100g. ² Fortification quality for iron in wheat flour was determined by analyzing the total iron levels in samples and comparing the results to East African Standard 2016 as follows: “Not-fortified” 0 mg/kg total iron, “Inadequately fortified” <20 mg/kg total iron, “Adequately fortified” \geq 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 East African Standard 2016 as follows: “Not-fortified” 0 mg/kg folic acid, “Inadequately fortified” <1.1 mg/kg folic acid, “Adequately fortified” \geq 1.1-3.2 mg/kg folic acid and “over fortified” >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 East African Standard 2016 as follows: “Not-fortified” 0 mg/kg zinc, “Inadequately fortified” <40 mg/kg zinc “Adequately fortified” \geq 40-80 mg/kg zinc and “over fortified” >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 East African Standard 2011 as follows: “Not-fortified” 0 mg/kg total iron, “Inadequately fortified” <21 mg/kg total iron, “Adequately fortified” \geq 21- 41 mg/kg total iron and “over fortified” >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 East African Standard 2011 as follows: “Not-fortified” 0 mg/kg folic acid, “Inadequately fortified” <0.6 mg/kg folic acid, “Adequately fortified” \geq 0.6-1.7 mg/kg folic acid and “over fortified” >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 East African Standard 2011 as follows: “Not-fortified” 0 mg/kg zinc, “Inadequately fortified” <33 mg/kg zinc, “Adequately fortified” \geq 33-65 mg/kg zinc and “over fortified” >65 mg/kg zinc.

Table 6: Fortification quality levels among sample (cooking oil) batches for vitamin A (mg/100g)

Sample ID	Mean \pm SD	Fortification quality ¹ levels	P-value
POE ¹	0.40 ^{a, c} \pm 0.02	Inadequate	<0.001 ^{***}
POE ²	1.84 ^b \pm 0.14	Inadequate	
POE ³	0.27 ^c \pm 0.14	Inadequate	
POF ¹	0.24 ^a \pm 0.02	Inadequate	<0.001 ^{***}
POF ²	0.34 ^b \pm 0.03	Inadequate	
POG ¹	3.14 ^a \pm 0.1	Adequate	
POG ²	0.27 ^b \pm 0.01	Inadequate	0.12 ^{ns}
SOA ¹	2.19 ^a \pm 1.90	Adequate	
SOA ²	0.38 ^a \pm 0.37	Inadequate	
SOA ³	0.07 ^a \pm 0.00	Inadequate	<0.001 ^{***}
SOC ¹	0.62 ^a \pm 0.04	Inadequate	
SOC ²	0.25 ^b \pm 0.02	Inadequate	
SOC ³	0.21 ^{c, b} \pm 0.02	Inadequate	0.72 ^{ns}
SOB ¹	0.26 ^a \pm 0.23	Inadequate	
SOB ²	0.24 ^a \pm 0.24	Inadequate	
SOB ³	0.36 ^a \pm 0.02	Inadequate	<0.001 ^{***}
SOD ¹	0.66 ^a \pm 0.03	Inadequate	
SOD ²	0.46 ^b \pm 0.04	Inadequate	
SOD ³	0.32 ^c \pm 0.02	Inadequate	

Values are mean \pm SD; n = 3. Values are on liquid 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. POE = Palm oil from company E; POF = Palm oil from company F; POG = Palm oil from company G; SOA = Sunflower oil from company A; SOB = Sunflower oil from company B; SOC = Sunflower oil from company C; SOD = Sunflower oil from company D.

¹ Fortification quality for oil: “Not-fortified” 0 mg/100g vitamin A, “Inadequately fortified” <2 mg/100g vitamin A, “Adequately fortified” \geq 2- 4 mg/100g and “Over fortified” >4 mg/100g.

Table 7: Fortification quality among flour samples for folic acid levels (mg/kg)

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

Values are mean \pm 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.

WFA = Wheat flour from company A; WFB = Wheat flour from company B; WFC = Wheat flour from company C; WFD = Wheat flour from company D; MFA = Maize flour from company A; MFB = Maize flour from company B.

¹ Fortification quality for folic acid in wheat flour: “Not-detected” 0 mg/kg folic acid, “Inadequately fortified” <1.1 mg/kg folic acid, “Adequately fortified” \geq 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-detected” 0 mg/kg folic acid, “Inadequately fortified” <0.6 mg/kg folic acid, “Adequately fortified” \geq 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.

Based on the present analysis, we noted that unlike Fe 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 Zn, folic acid and vitamin A. The

observed levels of fortification compliance for Zn, Fe and folic acid are still low, negating the impact of the current national fortification projects in Tanzania.

Similar to previous fortification assessment programs (GAIN, 2015), we had hypothesized that the adequacy of Fe as a “marker” could reflect likely fortification of other micronutrients such as Zn, folic acid and B₁₂ but this was not the case. The reasons for the observed difference in fortification adequacy between Fe and other micronutrients in the mandatory food vehicles are not much clear. However, some nutrients, especially vitamins that are sensitive to heat, oxidizing and reducing agents might have been lost during food processing or preparation, extrusion moisture, and other micronutrients in the premix and the fortified food vehicles (Allen *et al.*, 2006). Additionally, 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). Moreover, micronutrient sachets that are termed multiple nutrients that are shipped to Africa contain fewer or no other fortificants other than Fe, which in reality is very rare.

Similar results of inadequate fortification have been reported in a previous national survey that revealed inadequacy fortification for vitamins and Fe in the mandatory fortified food vehicles such as vegetable oils, and wheat and maize flours in Tanzania (GAIN, 2015). Similar results of inadequate fortification were also reported in Nigeria where an analysis revealed no traces of vitamin A and Fe in fortified vegetable oils, sugar, and cereal flour samples (Ogunmoyela *et al.*, 2013). Furthermore, inadequate fortification of iodine, Fe, Zn, folic acid or 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).

Contrary to the present study which revealed that a majority of the wheat flour samples (83.3%) and maize flour samples (80%) were adequately fortified with Fe, a study in Abidjan, Côte d’Ivoire revealed a low level of Fe fortification compliance in wheat flour samples (32%) (Rohner *et al.*, 2016). A similar national survey conducted in Nigeria also revealed significant low levels of compliance for Fe (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 oils and cereal flours, respectively, met the minimum fortification levels for vitamin A and Fe (Ogunmoyela *et al.*, 2015).

Based on the present analysis, it is evident that since the first survey, there has not been much improvement in the adequacy of micronutrient fortification in Tanzania. The prevalence of anemia is still high despite the reported improvements in Fe 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 difficult to get Fe-fortified flour especially in rural communities, where 80% of the population relies on hammer mills. Most of the people in rural areas consume their home-grown maize/wheat, milled at small hammer mills that have limited capacity to fortify flour (Penarosa *et al.*, 2014). Moreover, the high cost of premix micronutrients and fortified flour has a limited majority of companies and consumers from constant access to premix micronutrients and the consumption of fortified products. This might be the reason for 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 on 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 (Kavishe & Harris, 2017; Towo *et al.*, 2015), in Zambia (Darnton-Hill & 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 and her colleagues (Luthringer *et al.*, 2015). On the other hand, the fortification assessment coverage conducted by GAIN and the Oxford Policy Management (OPM) in Nigeria in 2018 established a significant improvement in the mandatory fortified food vehicles (GAIN & OPM, 2018). Their assessment showed that 67%, 89%, 46%, 86% and 80% of 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, except for Fe 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). This has been also supported by this study in which 75% of the respondents believed that government incentives on fortification premixes can improve the program. Another 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 and 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 and according to this study, only 1 company was penalized and about 75% viewed penalties as an effective measure to improve compliance of food fortification.

Micronutrient fortification programs are still facing challenges especially in the area of compliance, hence the need for sustainable plans from both the private sector and government in order to alleviate the observed challenges.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 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 Fe fortification in maize and wheat flours comply with the East Africa fortification standards but Fe should not be used as a marker to reflect fortification of other micronutrients in the flour. On the other hand, the current levels of micronutrient fortification for vitamin A in cooking oil, and for folic acid and Zn in wheat and maize flours are still far lower from the established standard specifications. This study highlights that food fortification is still facing some challenges in developing countries and needs to be quantified for solutions. Some of these challenges are the high cost of premixes, low consumer awareness and poor laboratory facilities. Additionally, inadequate and ineffective monitoring and evaluation of fortification compliance by the government regulators due to inadequate resources may also contribute to this. Therefore, the outputs of this study call for a review of the current fortification strategies concerning the standards, training, consumer awareness, monitoring and enforcement

5.2 Recommendations

The provision of government incentives for premixes and laboratory facilities, creation of consumer awareness on health benefits of fortified foods, frequent inspection at both the market place and factories and an emphasis on mandatory fortification to all food processing companies regardless of the size can facilitate the success of micronutrients fortification in the country. Additionally, folic acid and Zn levels in wheat and maize flours should be monitored and analyzed independently instead of relying on Fe to represent them. The enforcement of laws and penalties by the government regulatory authorities as well as effective and adequate monitoring and evaluation is very crucial in improving fortification programs. This can be achieved by the government in cooperation with the private sectors, food processors, and consumers to ensure its proper implementation and sustainability. The major limitation of this study includes its convenience sampling methodology and small sample sizes which may not accurately represent current levels of fortification in Tanzanian food vehicles. Further surveys with larger sample sizes and random sampling methods are therefore warranted.

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APPENDICES

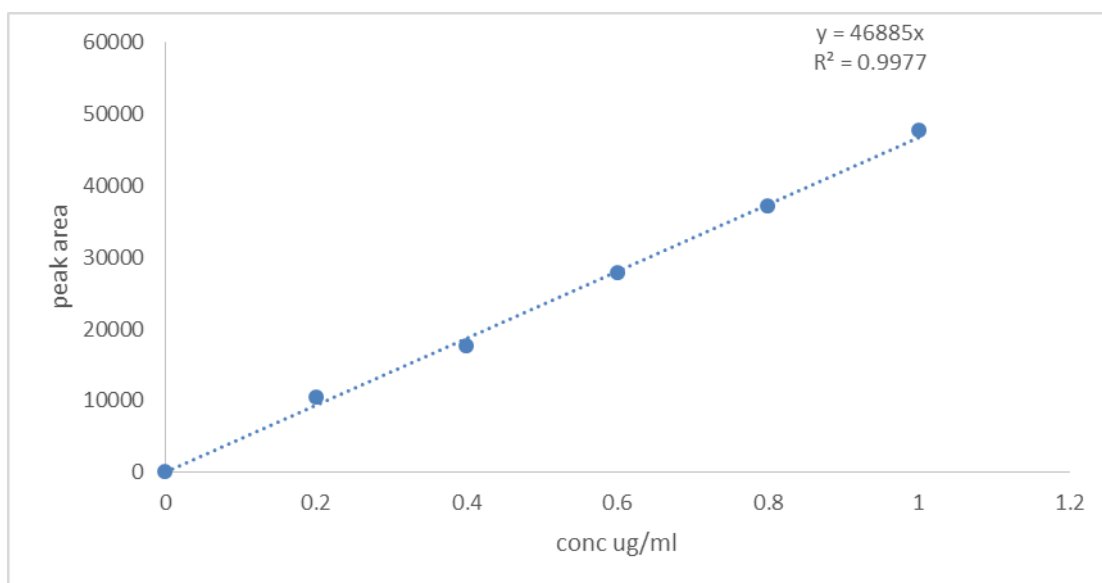
Appendix 1: A questionnaire on challenges facing food processors in implementing a food-fortification program

1. Company name.....
2. Address.....
3. Name of the respondent
4. Age
 - a) 20 - 30
 - b) 31 - 40
 - c) 41 - 50
 - d) > 50
5. Sex.....
6. Education level
 - a) Primary
 - b) Secondary
 - c) College
 - d) University degree
 - e) Postgraduate degree
7. Job title.....
8. Are you aware of food-fortification?
 - a) Yes
 - b) No
9. Is it mandatory for this company to do food-fortification for any of the foods you are processing?
 - a) Yes (Evidence)
 - b) No
10. If “YES” what type of food products do you fortify?
 - a) Wheat flour
 - b) Maize flour
 - c) Cooking oil
11. What micronutrients do you fortify with?
 - a) Wheat flour.....
 - b) Maize flour.....

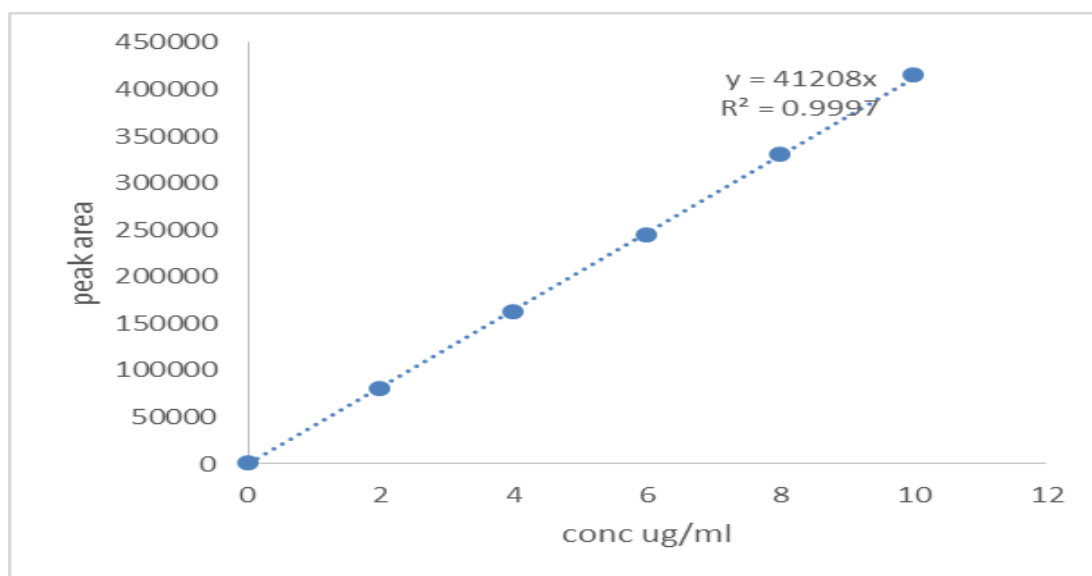
- c) Cooking oil.....
- 12. Why fortification of.....
 - a) Wheat flour.....
 - b) Maize flour.....
 - c) Cooking oil.....
- 13. What is the status of food fortificants?
 - a) Always available
 - b) Not always available
- 14. Do you receive any government incentives in the following?
 - a) Inputs/premixes
 - b) Equipment
 - c) Both
 - d) Others.....
- 15. What are your views on government incentives in improving effectiveness in fortification?
 - a) Very effective
 - b) Moderate effective
 - c) Slightly effective
 - d) Not at all effective
- 16. Have you ever received any food fortification inspection visits from regulatory agencies?
 - a) Yes (with evidence)
 - b) No
 - c) I do not know
- 17. If “YES” how many inspections per year?
 - a) Once
 - b) Twice
 - c) Thrice
- 18. Do you receive inspection feedback and share the results?
 - a) Yes
 - b) No
 - c) I do not know
- 19. Have you ever received training from government personnel on food-fortification?
 - a) Yes (with evidence)

- b) No
 - c) I do not know
20. Have you ever been penalized for incompliance with food-fortification standards?
- a) Yes
 - b) No
 - c) I do not know
21. If “YES” what was the penalty/penalties?
- a) Fines
 - b) Operating licensing suspension
 - c) Plant closure
 - d) Others.....
22. What are your views on the current use of penalties in food-fortification incompliance?
- a) Very effective
 - b) Moderately effective
 - c) Slightly effective
 - d) Not at all effective
23. Do you face competition with non-fortifying producers?
- a) Yes
 - b) No
 - c) I do not know
24. What other challenges do you face in ensuring food-fortification compliance?
.....
25. What are your recommendations?

Appendix 2: Standard curves for retinol and folate



A: Retinol standard curve



B: Folate standard curve

RESEARCH OUTPUTS

(i) Publication

Kiwango, F. A., Chacha, M., & Raymond, J. (2020). Adequacy of micronutrient fortification in the mandatory fortified food vehicles in Tanzania. *Nutrition and Food Science*, 2020, 1-11. <https://doi.org/10.1108/NFS-04-2020-0141>

(ii) Poster presentation

An investigation of adequacy of the current micronutrient fortification in the mandatory fortified food vehicles in Tanzania

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

Micronutrient
fortification

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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 Kenyatta 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 pyrogalllic 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

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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 A₂₈₃ 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 B₁₂, 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,

Food vehicle	Nutrient	Fortificant compound	Regulatory levels	
			Min	Max
Wheat flour	Folate	Folic acid	1.1 ¹	3.2 ¹
	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: ¹Regulatory levels are in mg/kg for wheat and maize flour; ² mg/100 g for edible cooking oil

Table 2.
Micronutrient
fortification
compliance levels
adopted from EAS

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	Mean \pm SD	Level of fortification				<i>p</i> -value
		Inadequately (%)	Adequately (%)	Not-fortified (%)	Overfortified (%)	
<i>Vitamin A fortification in cooking oil samples¹</i>						
Cooking oil (n = 19)	0.659 \pm 0.872	89.5	10.5	0	0	< 0.001***
<i>Micronutrient fortification in wheat flour samples²</i>						
Folic acid (n = 12)	0.28 \pm 0.3	0	16.7	41.7	41.7	< 0.001***
Iron (n = 12)	36.61 \pm 17.52	8.3	83.3	8.3	0	0.004**
Zinc (n = 12)	27.92 \pm 15.80	75	25	0	0	0.011*
<i>Micronutrient fortification in maize flour samples³</i>						
Folic acid (n = 5)	0.31 \pm 0.28	0	20	0	80	< 0.001***
Iron (n = 5)	20.28 \pm 7.68	20	80	0	0	0.002**
Zinc (n = 5)	23.60 \pm 9.3	60	40	0	0	0.001**

Notes: Values are mean \pm 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%).

¹Fortification 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” \geq 2–4 mg/100 g and “Overfortified” >4 mg/100 g.

²Fortification 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” \geq 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” \geq 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” \geq 40–80 mg/kg zinc and “overfortified” > 80 mg/kg. ³Fortification 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” \geq 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” \geq 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” \geq 33–65 mg/kg zinc and “overfortified” > 65 mg/kg zinc.

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

Notes: Values are mean \pm 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%).

¹Fortification 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" \geq 2–4 mg/100 g and "Overfortified" > 4 mg/100 g.

²Fortification 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" \geq 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" \geq 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" \geq 40–80 mg/kg zinc and "overfortified" > 80 mg/kg. ³Fortification 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" \geq 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" \geq 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" \geq 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

Food vehicle	Sample ID	Mean \pm SD	Fortification quality ¹ levels	p-value	Micronutrient fortification
Cooking oil	POE ¹	0.40 \pm 0.02	Inadequate	< 0.001***	<hr/>
	POE ²	1.84 \pm 0.14	Inadequate		
	POE ³	0.27 \pm 0.14	Inadequate		
Cooking oil	POF ¹	0.24 \pm 0.02	Inadequate	0.007**	
	POF ²	0.34 \pm 0.03	Inadequate		
Cooking oil	POG ¹	3.14 \pm 0.1	Adequate	< 0.001***	
	POG ²	0.27 \pm 0.01	Inadequate		
Cooking oil	SOA ¹	2.19 \pm 1.90	Adequate	0.12 ^{ns}	
	SOA ²	0.38 \pm 0.37	Inadequate		
	SOA ³	0.07 \pm 0.00	Inadequate		
Cooking oil	SOC ¹	0.62 \pm 0.04	Inadequate	< 0.001***	
	SOC ²	0.25 \pm 0.02	Inadequate		
	SOC ³	0.21 \pm 0.02	Inadequate		
Cooking oil	SOB ¹	0.26 \pm 0.23	Inadequate	0.72 ^{ns}	
	SOB ²	0.24 \pm 0.24	Inadequate		
	SOB ³	0.36 \pm 0.02	Inadequate		
Cooking oil	SOD ¹	0.66 \pm 0.03	Inadequate	< 0.001***	
	SOD ²	0.46 \pm 0.04	Inadequate		
	SOD ³	0.32 \pm 0.02	Inadequate		

Notes: Values are mean \pm 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. ¹Fortification 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

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

Table 4.
Fortification quality levels among sample batches for vitamin A (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/

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

Notes: Values are mean \pm 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. ¹Fortification quality for folic acid in wheat flour: “Not-fortified” 0 mg/kg folic acid, “Inadequately fortified” < 1.1 mg/kg folic acid, “Adequately fortified” \geq 1.1– 3.2 mg/kg folic acid and “overfortified” > 3.2 mg/kg folic acid. ²Fortification quality for folic acid in maize flour: “Not-fortified” 0 mg/kg folic acid, “Inadequately fortified” < 0.6 mg/kg folic acid, “Adequately fortified” \geq 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

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

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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Poster presentation



AN INVESTIGATION OF ADEQUACY OF THE CURRENT MICRONUTRIENT FORTIFICATION IN THE MANDATORY FORTIFIED FOOD VEHICLES IN TANZANIA

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INTRODUCTION

- Globally, more than 2 billion people are micronutrient deficiency (Bailey, 2015).
- Micronutrient fortification of cooking oil, wheat and maize flours is mandatory in Tanzania since 2011 (Food Fortification) Regulations, 2011).
- Apart from the first national food fortification assessment in Tanzania in 2015, up-to-date information regarding the compliance of micronutrient fortification is limited in the country.
- This present study aimed at updating the information on the current status of micronutrient fortification in the mandatory fortified food vehicles in Tanzania

Research objectives

General objective: To authenticate compliance with the current mandatory food fortification practices with regard to the national standards and regulations in Tanzania



- To evaluate the adequacy of current fortification levels of wheat and maize flour (Fe, Zn, and folate), and vegetable oils (vitamin A) from large food-processing companies in Tanzania
- To investigate the constraints facing large-scale food-processing companies in implementing the food-fortification programs in Tanzania



Results and Discussion

	Level of fortification					
	Mean ± SD	Inadequately (%)	Adequately (%)	Not-fortified (%)	Over fortified (%)	p-value
Vitamin A fortification in cooking oil samples						
Cooking oil (n = 19)	0.659 ± 0.872	89.5	10.5	0	0	<0.001*
Micronutrient fortification in wheat flour samples						
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						
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*

Values are mean \pm 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%).

