EFFECTS OF INFORMATION ON KNOWLEDGE GAPS ABOUT MICRONUTRIENTS DEFICIENCIES AND BIOFORTIFIED FOOD IN TANZANIA

by

Pius Lwiyiso Kilasy

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Approved: ____

Brandon R. McFadden, Ph.D.
Professor in charge of thesis on behalf of the Advisory Committee

Approved: ____

Martin D. Heintzelman
Chair of the Department of Applied Economics and Statistics

Approved: ____

Calvin L. Keeler Jr., Ph.D.
Interim Dean of the College of Agriculture and Natural Resources

Approved: ____

Louis F. Rossi, Ph.D.
Vice Provost for Graduate and Professional Education and
Dean of the Graduate College

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ABSTRACT

Micronutrients include significant vitamins and minerals needed for better growth and strong immunity. Pregnant women are vulnerable due to their role of bearing child's. The risk of maternal and neonatal deaths globally is between 2.5 to 3.4 million yearly. Vitamins is crucial for energy production, immune function and blood clotting. Minerals play essential roles in growth, bone health, fluid balance which are essential to a good start in life and robust growth and development of the child before they are born. Biofortification seems to be a cost-effective methods where potential nutrients are added to food after production from factories or through conventional breeding for benefiting rural populations. An online survey was conducted in Tanzania to understand the knowledge gaps associated with micronutrients deficiency especially for vitamin A, iodine, iron, and zinc. The survey included six treatments i.e., Control, Information, FlagInformation, Named, NamedInformation and NamedFlagInformation. Results shows variation among respondents who heard about micronutrients deficient with 78.48% for iron, 76.1% for Vitamin A, 68.1% for iodine and 54.86% for zinc. Also, the score for females and high-poverty households assigned to the control group was over 60% for correctly identifying the negative health effects associated with vitamin A deficiency and between 34-48% for the other micronutrients. Respondents randomized to an information treatment scored between 24-45% higher for vitamin A, iron, and zinc.

Keywords: *Micronutrient's deficiency, Neonatal, Anemic, Maternal, Infant, Vitamins, Minerals*

Chapter 1

INTRODUCTION

1.1 Background and Motivation

Micronutrients are significant groups of nutrients needed by every person worldwide for assurance of better growth with strong immunity. Although vitamins and minerals are needed in small amounts, they are very potential towards ensuring the sustainability of children growth and development as well as to women of reproductive age, pregnant women and breast-feeding mothers especially vitamin A, iodine, iron and zinc as they play a fundamental role in sustaining a healthiness and productive populations (Micronutrient Initiative, FFI, GAIN, THE WORD BANK, UNICEF and USAID, 2009) Micronutrient malnutrition is regarded as a hidden hunger because its symptoms have few warning signs that can alert individuals on their severity (Birol, Meenakshi, Oparinde, Perez, & Tomlins, 2015) Over the world, micronutrients deficiency is a problem affecting more than two billion people (FAO and FHI 360., 2016; FAO, IFAD, WFP, and WHO., 2021). The essential micronutrients include vitamins and minerals. In particular, vitamin A, iodine, iron, zinc and folate play pivotal roles in maintaining healthy and productive populations (HarvestPlus, 2021; Merz, 2018)

The world population as estimated by the department of economic and social affairs of the United Nations is 7.7 billion, with the expectation of increasing to 8.5 billion by 2030, 9.7 billion by the year 2050 and 10.9 billion by 2100 (United Nations, 2019) Tanzania is among the sub-Saharan African country with a rapid population growth with approximately 60 million people by 2021. Micronutrients being essential it should be incorporated in various policies working to support women of reproductive age and children with ≤ 59 months to reflect the world population increase.

For solving micronutrients deficiencies, it is recommended to adopt and use biofortification intervention that may be achieved through industrial fortification, where nutrients are added to food after production. For example, iodized salt that provides iodine and low-fat milks having vitamins A&D added after the fat is removed or it can be through crop improvement where potential traits having all essential nutrients like vitamin A, iron, zinc and iodine developed by conventional or genetic engineering techniques are selected to fulfil consumers and producers' requirements. Furthermore, the survey conducted two experiments: the first was an experiment to identify the impact of including the name of a micronutrient in a biofortified food (e.g., vitamin A cassava versus biofortified cassava) to determine whether people will show higher sense of understanding various food types with respective micronutrients, while the second was an experiment to identify the effect of information on knowledge gaps of negative health and food, risk perceptions, and the likelihood of purchase of biofortified.

The requirement for vitamins is crucial for energy production, immune function, blood clotting and related functions, consuming orange maize, yellow cassava and orange-fleshed sweet potatoes may provide up to 100% of the estimated average requirements (Centers for Disease Control and Prevention, (CDC), 2020; HarvestPlus, 2021; Shenkin, 2006). Globally, more than 4 million children under age five are affected by xerophthalmia, which is a severe eye illness caused by moderate to severe deficiency leading to blindness. Large numbers of children do not show external signs of vitamin A deficiency, but generally, they are living with dangerously low vitamin A stores. Those children are vulnerable to infection because of reduced immunity to fight common childhood diseases. Worldwide, about 127 million pre-school children in South Asia and Sub-Saharan Africa have been affected by vitamin A deficiency (The United Nations Children's Fund, (UNICEF), 2007). Also, vitamin A deficiency contributes to between 1.3-2.5 million child deaths annually with the highest risk in developing countries (Humphrey, West, & Sommer, 1992).

Iron is a leading causative of anemia, contributing to low haemoglobin concentration. Anemia is affecting 43% of children with age below five (5) years and 38% of pregnant women worldwide (Centers for Disease Control and Prevention, (CDC), 2020; Wessells & Brown, 2012) During pregnancy, an increase in anemia contributes to the risk of death for the mother and low birth weight for the infant. Worldwide, the risk of maternal and neonatal deaths is between 2.5 million and 3.4 million each year (Centers for Disease

Control and Prevention, (CDC), 2020). The other survey on anemia found that children between ages between 6-59 months have an anemia prevalence of about 58% with 26% mildly anemic; 30% moderately anemic; and 2% severely anemic. According to the statistics, various districts are worrying, for example, Shinyanga at 71% of children were anemic. Moreover, as per the survey about half (45%) of Tanzanian women of reproductive age (18-49 years) are anemic; with 33% being mildly anemic; 11% moderately anemic and 1% severely anemic. Results from Zanzibar shows that anemia prevalence was higher than (60%), especially in the Kaskazini Pemba region (72% (SARI, ARI Uyole, ARI Maruku & CIAT, 2018). Globally, each year more than 17,000 deaths occurs to women of reproductive age attributed to iron deficiency anemia out of which 70% occurs in Africa. Additional effects of iron deficiency include decreased physical performance and physical activity, cognitive performance, depression and fatigue (SARI, ARI Uyole, ARI Maruku & CIAT, 2018). The use of iron beans can be an alternative to eliminate its deficiency by approximately 60% of the estimated average requirement of iron (HarvestPlus, 2021). According to the Global Nutrition Report of 2014; approximately 40% of women of reproductive age suffer from anemia due to iron deficiency (International Food Policy Research Institute, 2014)

Moreover, 17.3% of the world population is zinc deficiency due to an inadequacy diet; some regions experience a higher deficiency of 30% of people who are at risk (Luke Maxfield1, Samarth Shukla2, & Jonathan S. Crane3., 2021; Luke Maxfield1 et al., 2021;

Wessells & Brown, 2012). WHO data Global, zinc deficiency accounts for about 16% of lower respiratory tract infections, 18% of malaria and 10% of diarrheal disease (Caulfield, 2004; Caulfield, 2004; Kumera et al., 2015; Kumera et al., 2015; WHO, 2002).

The Government of Tanzania developed its National Nutrition Strategy (NNS) with a five-year plan from July 2011 to June 2016 aiming to achieve its objectives of ensuring the nation and its people are appropriately sustained (Tanzania Ministry of Health and Social Welfare, 2011).Part of the strategy was focused on reducing the prevalence of Vitamin A deficiency among children between 6 and 59 months from 24% in 1997 to 15% in 2015, reducing anemia prevalence among pregnant women from 48.4% in 2004/5 to 35% in 2015, reducing the prevalence of anemia among children age 6-59 months from 71.8% in 2004/5 to 55% in 2015 and maintaining low rates of iodine deficiency among children age 6-12 at <50% (Ministry of Health, Community Development, Gender, Elderly and Children - MoHCDGEC/Tanzania Mainland, Ministry of Health - MoH/Zanzibar, National Bureau of Statistics - NBS/Tanzania, Office of Chief Government Statistician - OCGS/Zanzibar, and ICF, 2016).

In 2016 the Government of Tanzania developed and adopted a new National Multisectoral Nutrition Action Plan (NMNAP) 2016-21 which replaced the 2011-2016 National Nutrition Strategy (NNS). The NMNAP was developed to work as a multi-stakeholder’s process focusing on seven priority areas, including 1) Maternal, infant and young child and adolescent nutrition, 2) Prevention and control of micronutrients deficiencies, 3) Integrated management of acute malnutrition; 4) Nutrition-related non-communicable diseases; 5) Nutrition sensitive interventions; 6) Multi-sectoral Nutrition Governance; 7) Multi-sectoral Nutrition Information System. For ensuring attainment of planned strategy and follow-up of all seven key priority nutrition agenda the government of Tanzania started the implementation of the National Nutrition Survey (NNS) using SMART (Standardized Monitoring and Assessment of Relief and Transitions) (Ministry of Health, Community Development, Gender, Elderly and Children (MoHCDGEC) [Tanzania Mainland], Ministry of Health (MoH) [Zanzibar], Tanzania Food and Nutrition Centre (TFNC), National Bureau of Statistics (NBS), Office of the Chief Government Statistician (OCGS) [Zanzibar] and UNICEF. 2018. Tanzania National Nutrition Survey using SMART Methodology (TNNS) 2018. Dar es Salaam, Tanzania: MoHCDGEC, MoH, TFNC, NBS, OCGS, and UNICEF., 2019).

Domestic consumption of cereals in Tanzania is very high. The introduction of new varieties resulting from biofortification which is tested for nutrient availability such as vitamin A, Iron, Zinc and Iodine will be motivational to consumers, and they may be motivated even to consume such food products frequently upon understanding the benefits they are getting from it. Currently, biofortified food varieties and their products are becoming widespread in Tanzania's Consumers interests with an example to the yellow sweet potatoes that has increased since their introduction recently (Talsma, Melse-

Boonstra, & Brouwer, 2017a). With such high micronutrient's deficiency, it is necessary to increase awareness to the community to consume biofortified cereal products which could aid in combating micronutrients deficiencies. Example consumption of wheat in Tanzania is more than one million metric tons per year, with an approximated increase of 2.1% annually due to population growth and urbanization. Corn consumption is about 5.4 million metric tons, with an expected increase of 2.4% annually, and rice consumption is 2.3 metric tons with a forecasted increase of 1.5% annually (The United Republic of Tanzania, 2019). We expect those nutrients which are necessary for human growth and development, to be available at a required amount in most food products consumed regularly. Nutrient supplementation might be one among various alternatives available to ensure that all essential micronutrients are accessible through biofortification either in plants varieties during productions that undergo conventional breeding or during processing before they consume final products. Moreover, we generally know that consumption of biofortified food is potential as it will strengthen the human immune system and nutrition, which will be a remedy to various diseases.

Compared to other methods, bio-fortification is having two key comparative advantages, i.e., its long-term cost-effectiveness and its ability to reach underserved, rural populations (Bouis & Saltzman, 2017). Bio-fortification is cost-effective when compared to other methods because it involves breeding varieties which are having sufficient nutrients. Application of bio-fortification technology in different geographical locations will have a potential positive impact once adopted successfully. It is onetime costs that do not involve farmers at the initial stages.

Because of its importance in building a strong and stable working force, Tanzania like most governments has strategies and formed various task forces to implement nutrition matters. Multiple experts are working with countries agricultural research institutes which develop and test varieties in different locations. Then after their release, such new varieties from conventional breeding with necessary micronutrients are disseminated to farmers in rural areas.

Researching *on the effect of information on knowledge gaps about micronutrient deficiencies and biofortified foods in Tanzania is crucial towards developing a strong and stable future community.* In order to understand clearly the effect of information on knowledge gap the survey was designed to have six treatments i.e., Control, Information, FlagInformation, Named, NamedInformation and NamedFlagInformation where respondents were randomized and few of them view the Tanzanian flag without names of specific micronutrients i.e., Biofortified Maize against box with names i.e., Vitamin A maize. The Tanzanian flag was used to motivate respondents that the research belongs to them and not someone else. Evaluation and combating micronutrients deficiency aim at having people with better health, which is a priority of most Tanzanians towards the reduction of frequency visitation in medical services and to reduce costs associated with treatments once diseases occur due to micronutrient deficiency.

Tanzania has set various development aspirations that are outlined in the Tanzania Development Vision 2025 (TDV 2025) that were developed in the late 1990s for guiding economic and social development efforts up to the year 2025 (The United Republic of Tanzania, 2017) The targets of Transforming Tanzania into a middle-income country which has been achieved in July 2020 earlier than its plan, have been permeated by five main national attributes of a) High-quality livelihood; b) Peace, stability and unity; c) Good governance; d) A well-educated and learning society, and e) A competitive economy suitable for creating sustainable growth and collective benefits (The United Republic of Tanzania, 2009). Achieving the development plan attributes will be realized by the guarantee of production and consumption of food with essential micronutrients. The objective of all countries worldwide is to have people with active growth, stable immune system, efficient memory, attention and physical activity hence able to work efficiently.

1.2 Problem statement and justification

As introduced earlier, micronutrient's deficiency is a problem affecting more than two billion people globally (FAO and FHI 360., 2016; FAO, IFAD, WFP, and WHO., 2021)

Such micronutrient deficiencies associated with vitamin A, iron, zinc and iodine are also affecting Tanzanians.

Iron deficiency is leading, causing significant death to pregnant women's and children's even though it is possible to supplement. According to a micronutrient survey conducted in the year 2011, its results show that 35% of children were iron deficient, and 59% had anemia with the overall prevalence of iron deficiency anaemia (IDA) among children being 24%. The rate of iron deficiency without anemia was 11% (National Bureau of Statistics (NBS) [Tanzania] and ICF Macro, 2011). Moreover, from the same survey, about 30% of women between 18-49 years were iron deficient, and 41% had anaemia, with the occurrence of iron deficiency deprived of anaemia being 16%, while the prevalence of IDA with anemia is 14%. Another survey found that a total of 5,124 children found to have a prevalence of anemia, with 145 severe anaemia and 2,628 moderate anaemia and also a total of 2,338 women found to have a prevalence of anaemia, with 88 severe and 1,309 moderate anaemia (Ministry of Health, Community Development, Gender, Elderly and Children - MoHCDGEC/Tanzania Mainland, Ministry of Health - MoH/Zanzibar, National Bureau of Statistics - NBS/Tanzania, Office of Chief Government Statistician - OCGS/Zanzibar, and ICF, 2016).

According to the survey by the National Bureau of Statistics (Tanzania) and ICF Macro (2011), Children with age 6-11 and ages 12-23 months have the highest prevalence of iron deficiency and anemia. However, the incidence of both tends to decline with age, indicating such deficiency might have occurred since before weaning age or they were born with iron deficiency. About 50% or more of children with age between 6-59 months in Arusha, Singida, and Kigoma was having an iron deficiency, with observable differences to children in the Mtwara region with only 13%. The percentage of children with IDA in Arusha, Shinyanga, and Unguja North was higher (39%), than the lowest IDA results obtained in Iringa (10%)(National Bureau of Statistics (NBS) [Tanzania] and ICF Macro, 2011). Iron intake during pregnancy at least for 90 days or more is very crucial, it helps to reduce unnecessary death in case of excessive bleeding during delivery. In the study that was conducted, the Kigoma region had the lowest percentage (7%) of women who took iron during their pregnancy. Some regions such as Lindi, Unguja North and Unguja South had the highest percentage (33%) of women taking iron during their pregnancy period for 90 days or more (Ministry of Health, Community Development, Gender, Elderly and Children - MoHCDGEC/Tanzania Mainland, Ministry of Health - MoH/Zanzibar, National Bureau of Statistics - NBS/Tanzania, Office of Chief Government Statistician - OCGS/Zanzibar, and ICF, 2016). In, the case of women, the highest anemia incidence without iron deficiency was in Lindi, Mtwara, and Pemba North (56-58%). Women aged 20-29 have the highest prevalence of iron deficiency as well as iron deficiency with or without anemia. Pregnant women who are most susceptible have the highest rate of iron deficiency and anemia with or without ID. The highest rates of iron deficiency are experienced in various regions like Tabora (50%), Shinyanga (46%), and Kigoma and Arusha (45% each). Some regions showed the lowest ID prevalence, for example, Mtwara (7%) and Pemba North (10%). The regions with the overall pervasiveness of anaemia (IDA) with 50% or higher were Arusha, Tabora, Shinyanga, and Manyara (National Bureau of Statistics (NBS) [Tanzania] and ICF Macro, 2011). Adequate iron is essential for ensuring better motor and cognitive development, and the world health organization (WHO) recommends supplementation of iron to infants and children with 6 to 24-month age in all areas where anaemia prevalence ranges between 20% to 30% or higher (INACG, 2015; Saraceno, 2002).

As it is known that vitamin A is vital for vision, growth and reproduction, and is involved in the control and differentiation of epithelial tissues (Thurnham, 1989) meaning that any deficiency will impact the body and subject to various risks including being susceptible to diseases. Vitamin A deficiency (VAD) is recognized as a leading cause of all-cause morbidity and mortality among children (Fawzi, Herrera, & Nestel, 2000; Sommer, 1998). VAD upsurges the severity of infections, like measles and diarrheal diseases in children, and reduces recovery from illness. Referring to the research done by the National Bureau of Statistics of Tanzania it shows that the prevalence of VAD for all children about 6,295 were reduced from 38% to 33% after adjustment from infection/Inflammations (National Bureau of Statistics (NBS) [Tanzania] and ICF Macro, 2011). There is a recommendation from the German Nutrition society that pregnant women need to consume about 40% of additional vitamin A and 90% for breastfeeding mothers. Also, the American Academy of Pediatrics Committee on nutrition (1998) indicates that vitamin A is the most important vitamin during pregnancy and breastfeeding for lung functioning and maturation.

In the case of zinc, it is vital as it promotes immune functions and helps people resist infectious diseases including diarrheal, pneumonia and malaria. Pregnant women's need zinc for ensuring healthy pregnancies. Examples of factors contributing to having zinc deficiency include dietary intake, inadequate absorption, increased loss, or increased body system utilization. Reduced dietary intake is the most common causative. By complementing zinc; there is a possibility to reduce child mortality by 9% and reduce the incidence of childhood diarrheal by 23% (Brown et al., 2009; Kries, Müller, Niggli, Ruby, & Ruby, 2017).

Bearing in mind current Tanzania's focus of expanding its economic sectors such as agriculture, tourism and industries, there is a need to consider and invest in micronutrients intervention for assurance of having a healthy and energetic future generation. Supplementing micronutrients especially Iron, Zinc, vitamin A and iodine to children's and pregnant women's who are the most vulnerable to those consequences is essential and promoting consumption of bio-fortified food with vitamin A, iron, zinc and iodine has become a cost-effective intervention approach worldwide (Hirschi, 2008).

Tanzania's economy currently dependents on agriculture which is the backbone of the country that employs more than 70% of the total Tanzania population. Linking micronutrients intervention through biofortification of agricultural produces will accommodate almost all Tanzanians because the remaining group are those depending on food purchase which will have all the required micronutrients that are missing. Thus, with such micronutrients deficiency and demand, bio-fortification application and adoption in the agricultural sector become vital for achieving the intended objective of economic transformation by 2025 (The United Republic of Tanzania, 2017).

1.3 Purpose

The main purpose of the research is to determine the knowledge gaps about micronutrient deficiencies with particular attention given to women of reproductive age. The specific micronutrients of interest were vitamin A, iron, zinc and iodine.

1.4 Objective

1. To identify the knowledge gaps about vitamin A, iron, zinc and iodine.
2. To contribute to the improved health and nutrition status of women of reproductive age in Tanzania (i.e., 18-49), which also improves the health of children below 59 months.
3. To determine Tanzanian’s consumers ’likelihood of purchasing biofortified crops.

1.5 Research questions and hypotheses

The overall objective of this study is to identify the current levels of awareness and identify knowledge gaps about micronutrient deficiencies. Survey questions were asked to measure perceived risk, knowledge about the negative health outcomes, knowledge of food that reduce the risk of being deficient, and likelihood of purchasing biofortified crops that decreases the risk of being deficient. The survey was having six treatments i.e., Control, Information, Flginformation, Named, Namedinformation and NamedFlagInformation. The micronutrient deficiencies of interest are iodine, iron, vitamin A, and zinc.

The specific hypotheses for each series of questions asked were:

1. Does awareness of micronutrient deficiencies differ among vitamin A, iron, zinc and iodine?

   Ho: Awareness of micronutrients deficiency is equal across micronutrients

   Ha: Awareness of micronutrients deficiency is not equal across micronutrients.

2. Does awareness of micronutrient deficiencies not lower for females and high poverty households?

   Ho: Awareness of micronutrients deficiency is similar for females and high poverty households.

Ha: Awareness of micronutrients deficiency is not similar for females and high poverty households.

3. Does awareness of micronutrient deficiencies for vitamin A, iron, zinc and iodine differ between men and women?

   Ho: Awareness of micronutrients deficiency is equal between men and women

   Ha: Awareness of micronutrients deficiency is not equal between men and women.

4. Does awareness of micronutrient deficiencies differ across treatments?

   Ho: Awareness of micronutrients deficiency is equal across treatments

   Ha: Awareness of micronutrients deficiency is not equal across treatments.

5. Does the perceived risk of micronutrients deficiencies differ among vitamin A, iron, zinc and iodine?

   Ho: Perceived risk of micronutrients deficiency is equal across micronutrients.

   Ha: Perceived risk of micronutrients deficiency is not equal across micronutrients

6. Does the perceived risk of micronutrients deficiencies differ across treatments?

   Ho: Perceived risk of micronutrients deficiency is equal across treatments.

   Ha: Perceived risk of micronutrients deficiency is not equal across treatments

7. Does knowledge about the negative health outcomes associated with micronutrient deficiencies differ among vitamin A, iron, zinc and iodine?

   Ho: Knowledge about the negative health outcomes is equal across micronutrients.

   Ha: Knowledge about the negative health outcomes is not equal across micronutrients.

8. Does knowledge about the negative health outcomes associated with micronutrient deficiencies differ across treatments?

   Ho: Knowledge about the negative health outcomes is equal across treatments.

   Ha: Knowledge about the negative health outcomes is not equal across treatments.

9. Does knowledge about foods that decrease the risk of being micronutrients deficiencies differ among vitamin A, iron, zinc and iodine?

   Ho: Knowledge of foods that decrease the risk of being a deficiency is equal across micronutrients.

   Ha: Knowledge of foods that decrease the risk of being a deficiency is not equal across micronutrients.

10. Does knowledge about foods that decrease the risk of being micronutrients deficiencies differ across treatments?

Ho: Knowledge of foods that decrease the risk of being a deficiency is equal across treatments.

11. **Ha:** Knowledge of foods that decrease the risk of being a deficiency is not equal across treatments. Does the likelihood of purchasing foods that decrease the risk of being micronutrients deficiencies differ among vitamin A, iron, zinc and iodine?

    Ho: The likelihood of purchasing foods that decrease the risk of being a deficiency is equal across micronutrients.

    Ha: The likelihood of purchasing foods that decrease the risk of being a deficiency is not equal across micronutrients.

12. Does the likelihood of purchasing foods that decrease the risk of being micronutrients deficiencies differ across treatments?

    Ho: The likelihood of purchasing foods that decrease the risk of being a deficiency is equal across treatments.

    Ha: The likelihood of purchasing foods that decrease the risk of being a deficiency is not equal across treatments.

Chapter 2

LITERATURE REVIEW

Tanzanian women of reproductive age (18 – 49) and children under 59 months are highly susceptible to micronutrients deficiency. For pregnant women's, the most necessary micronutrients commonly provided as supplements, include vitamins A, D, E, folate, B12, B6, and C, iron, zinc, iodine, copper and selenium (Gernand, Schulze, Stewart, West, & Christian, 2016). Vitamin D, vitamin B12, folate, and ferritin are crucial for child growth and development; Vitamin D regulates calcium metabolism, promotes bone health (Bellows et al., 2017). All such essential micronutrients may be obtained from agricultural produces which undergoes biofortification through traditional or conventional breeding of varieties that seem to be preferred and consumed mostly within the country (HarvestPlus, 2021). Biofortified types and food products is a new intervention, and most Tanzanians may have little knowledge about it, without having any additional information. Therefore because of its necessity, it is essential to create awareness to the community the way biofortification can be substantial. Reaching out to the sparse rural population in a sustainable way should be the first and vital strategy, as it will assure the acceptability and adoption hence improving on the outcome of micronutrients malnutrition rehabilitation (De Groote et al., Oct 27, 2016).

Research is done by HarvestPlus in India and Pakistan since 2014 and commercialization of zinc from wheat as first and iron as a secondary micronutrient has a potential outcome towards fighting against micronutrients deficiency. A total of nine wheat varieties (BHU 1, BHU 3, BHU 5, BHU 6, BHU 17, BHU 18, NR-419, NR-420 and NR-421) were released and currently tested in other countries like Bangladesh, Brazil, China, Ethiopia, and Nepal (HarvestPlus, 2014)

Also, as an example, the Indian Council of Agricultural Research developed different varieties of crops with promising high content of micronutrients like iron and zinc which are supporting pregnant women's and children to overcome the problem of micronutrients deficiency. Some of the types are Wheat: HPBW 01 with 40.0 ppm of iron and 40.6 ppm of zinc compared to other popular types with less iron (28.0 – 32.0ppm) and zinc (32.0 ppm), and Wheat: WB 02 with 40.0 ppm of iron and 42.0 ppm of zinc compared to other popular varieties with less iron (28.0 – 32.0 ppm) and less zinc (32.0 ppm) (Yadava D.K., P.R. Choudhury, Firoz Hossain and Dinesh Kumar, 2017).

For ensuring efficient and successful biofortification, it is necessary to consider three critical aspects. First, conducting successful breeding like those done by HarvestPlus and Indian Council of Agricultural research with high nutrient concentration and high yields that will be of high profitability to end-users (Producers and consumers) (Bouis & Saltzman, 2017; HarvestPlus, 2014). Second, the effectiveness of micronutrients must be verified with improvement when bio-fortified varieties are consumed as compared to customarily eaten food products. Third, awareness creation for the biofortified crops for greater adoption among farmers and consumed by those suffering from micronutrient malnutrition in significant numbers (Bouis, Hotz, McClafferty, Meenakshi, & Pfeiffer, 2011).

2.1 Perception and attitudes among Tanzanians

Tanzania is experiencing problem of micronutrients deficiencies and as a strategy of the government to fight against it have introduced various interventions including supplementation. But supplementation is not feasible always as it has a cost implication. Adoption of biofortification may be a best and one time cost that does involve producers and consumers but once such technology is adopted it may have a larger impact throughout the country within a short time. And with current reports, biofortified food varieties and their products are becoming widespread in Tanzania. Due to the potentiality of biofortified foods consumers has shown interests' of using it, for example, the availability of yellow sweet potatoes with additional Vitamin A across the country has increased since its introduction recently (Rao, 2020; Talsma, Melse-Boonstra, & Brouwer, 2017b; Waized, Ndyetabula, Temu, Robinson, & Henson, 2015). Also, trials on beans for testing consumer acceptance and their WTP for high iron beans were conducted on the northern part of

Tanzania in 2019, and its Results shows that 95% of consumers were WTP premium price of $ 1.09 (Tsh 2500) per 0.25kg of high iron beans against $ 0.91 (Tsh 2100) per 0.25kg of non-high iron beans (Rubyogo et al., 2019). With those researches above, there is evidence showing consumer acceptance of bio-fortified varieties or their products which will help combat micronutrients deficiency to women of reproductive age, and children's below 59 months.

Therefore, having new varieties tested for nutrient availability such as vitamin A, Iron and Zinc will be motivational to consumers, and they may be motivated even to consume frequently upon understanding the benefits they are getting from those products. The biofortification method may be more useful in sub-Saharan Africa and a developing country like Tanzania, where smallholder farmers may be interested in various innovations. However, their economic capability is insufficient for them to be able to adopt it (Boru Douthwaite, Nicoline C. de Haan, Victor Manyong, & Dyno Keatinge, 2002; Collier & Dercon, 2014).

Chapter 3

METHODOLOGY

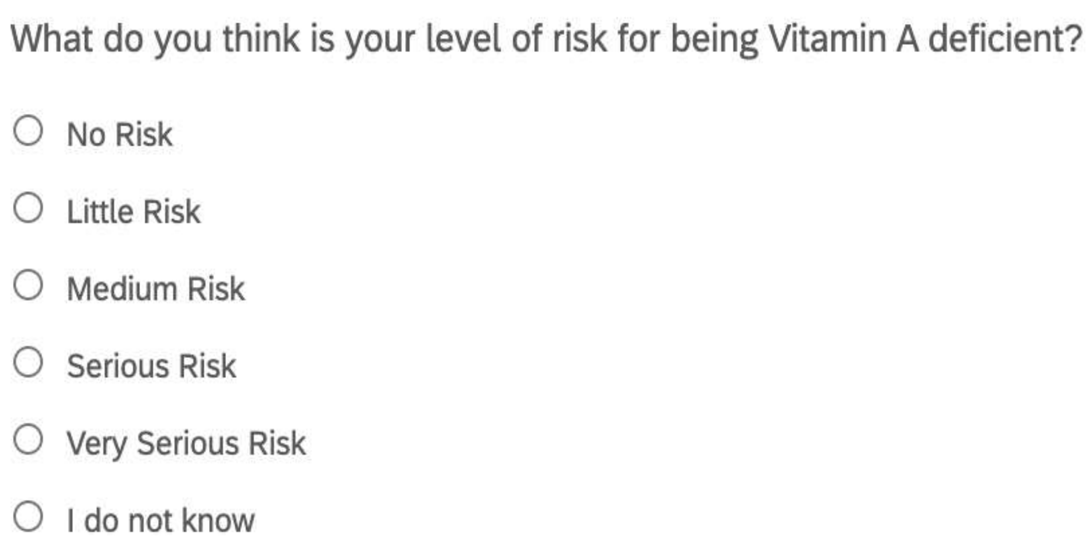
3.1 Study design

The survey was approved by the Institutional Review Board (IRB) at the University of Delaware before distributing it to respondents. Tanzania has a total of 31 regions that include that Tanzania mainland with 26 regions and Tanzania Island (Zanzibar) with 5 regions. During our survey, data were collected from all regions of Tanzanian mainland and 4 regions of Tanzania island (Zanzibar). The survey was online and were reached through the services of Qualtrics®, which maintains online panels of respondents, although this was somehow a disadvantageous to most susceptible to micronutrients deficiencies living rural areas where technologies is not advanced and cannot have an internet access to complete questionnaires and this has happened because of covid-19 pandemic hence have restrictions to collect data directly from human subject as per IRB rules. The population of interest was Tanzanian citizens aged 18 to 49 and females was oversampled since they are the one at higher risk for micronutrient deficiencies compared to males. Respondents were asked questions to determine their knowledge with Vitamin A, Iron, Zinc and Iodine in regards to: 1) awareness of micronutrient deficiencies (Figure 3.1), 2) perceived risk of being micronutrient deficient (Figure 3.2), 3) knowledge about negative health outcomes associated with micronutrient deficiencies (Figure 3.3), 4) knowledge about foods that decrease the risk of being micronutrients deficient (Figure 3.4), and 5) likelihood of purchasing biofortified foods that decrease the risk of micronutrient deficiency (Figure 3.5).


Have you heard about Vitamin A deficiency ?

- Yes
- No

Figure 3.1: Knowledge about Micronutrients Deficiency


What do you think is your level of risk for being Vitamin A deficient?

- No Risk
- Little Risk
- Medium Risk
- Serious Risk
- Very Serious Risk
- I do not know

Figure 3.2: Perceived risk of being micronutrient deficient

What health problems do you think are associated with Vitamin A deficiency? (check all that apply)

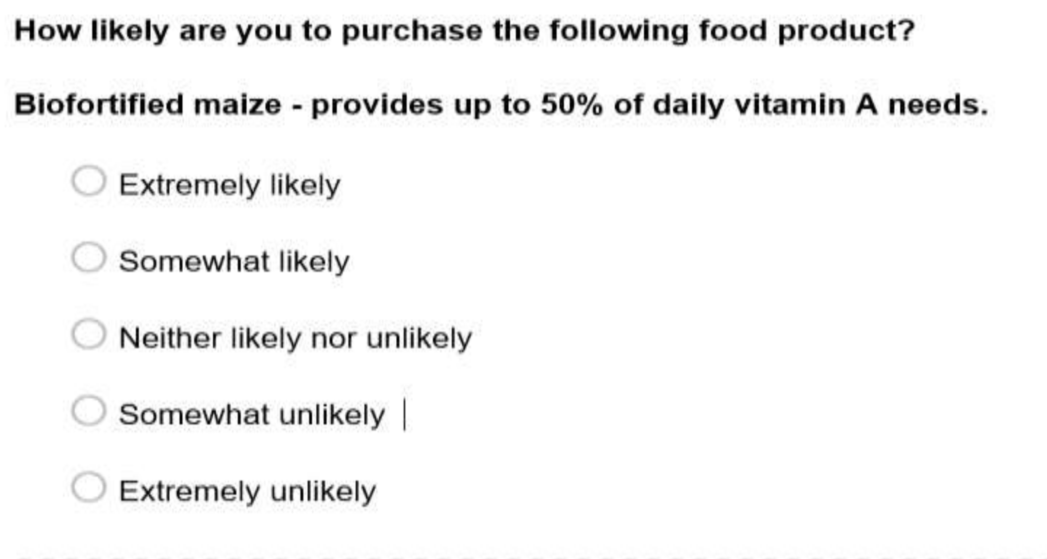
- ☐ Increased death risk for pregnant women
- ☐ Night blindness
- ☐ Permanent blindness
- ☐ Increased risk of death for children who have measles and diarrhoea
- ☐ Reduced ability to do physical labor
- ☐ Impared mental development and learning capacity
- ☐ Anemia
- ☐ Stunted growth
- ☐ Chronic and severe diarrhea
- ☐ Poor immune function
- ☐ Decreased thyroid hormone production
- ☐ Swelling in the neck
- ☐ Increased infant mortality

Figure 3.3: Knowledge of negative health outcomes associated with micronutrient deficiency.

Which of the following foods decrease the risk of being deficient from Vitamin A? (Check all that apply)

- ☐ Meat
- ☐ MilkYogurt/Cheese
- ☐ Biofortified Sweet Potatoes
- ☐ Biofortified Maize
- ☐ Biofortified Cassava
- ☐ Supplements
- ☐ Biofortified beans
- ☐ Biofortified millet
- ☐ Fortified flour
- ☐ Biofortified rice
- ☐ Biofortified maize
- ☐ Biofortified wheat
- ☐ Seafood
- ☐ Eggs
- ☐ Fortified Salt

Figure 3.4: Knowledge of foods that decrease the risk of micronutrients deficiencies



How likely are you to purchase the following food product?

Biofortified maize - provides up to 50% of daily vitamin A needs.

- Extremely likely
- Somewhat likely
- Neither likely nor unlikely
- Somewhat unlikely
- Extremely unlikely

Figure 3.5: Likelihood purchase of foods that decrease the risk of micronutrient deficiency.

Respondents were also asked demographic questions about their household including the Simple Poverty Scorecard®. As it is known by its name, a Simple Poverty Scorecard® is a tool that uses ten cost indicators in a household budget to assess their poverty relative to others and determine whether they are below a given poverty line (Schreiner, 2016). The specific questions asked are shown below in Figure 3.6.

Simple Poverty Scorecard® Poverty-Assessment Tool

Interview ID:			Name	Identifier
Interview date:		Participant:		
Country:	TZA	Field agent:		
Scorecard:	002	Service point:		
Sampling wgt.:		Number of household members:		

Indicator	Response	Points	Score
1. How many household members are 18-years-old or younger?	A. Six or more	0	
	B. Five	2	
	C. Four	5	
	D. Three	11	
	E. Two	14	
	F. One	17	
	G. None	28	
2. Are all household members ages 6 to 18 currently in school?	A. No	0	
	B. Yes	3	
	C. No members ages 6 to 18	5	
3. What is the main building material used for the walls of the main building?	A. Baked bricks	0	
	B. Poles and mud, grass, sun-dried bricks, or other	6	
	C. Stones, cement bricks, or timber	13	
4. What is the main building material used for the roof of the main building?	A. Grass/leaves, mud and leaves, or other	0	
	B. Iron sheets, tiles, concrete, or asbestos	6	
5. What is the main fuel used for cooking?	A. Firewood, coal, solar, gas (biogas), wood/farm residuals, or animal residuals	0	
	B. Charcoal, paraffin, gas (industrial), electricity, generator/private source, or other	9	
6. Does your household have any televisions?	A. No	0	
	B. Yes	15	
7. Does your household have any radios, cassette/tape recorders, or hi-fi systems?	A. No	0	
	B. Yes	4	
8. Does your household have any lanterns?	A. No	0	
	B. Yes	4	
9. Does your household have any tables?	A. No	0	
	B. Yes	4	
10. If the household cultivated any crops in the last 12 months, does it currently own any bulls, cows, steers, heifers, male calves, female calves, or oxen?	A. No crops, and no cattle	0	
	B. No crops, and cattle	0	
	C. Crops, but no cattle	5	
	D. Crops, and cattle	12	

SimplePovertyScorecard.com — Score:

Figure 3.6. Simple Poverty Scorecard® Poverty Assessment Tool.

3.2 Target Population and Study sample

The data was collected from respondents in the age range age 18 to 49, and women were oversampled because they were the population of interest. Tanzania has approximately 29,883,000 females out of which 10,920,000 are under reproductive age among which data was collected for the study (United Nations. Department of Economic and Social Affairs. Population Division, 1998).

3.3 Ethical Consideration

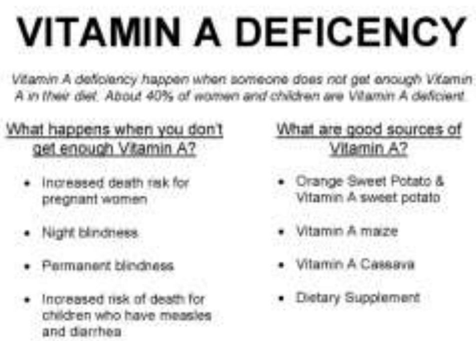
The Institutional Review Board approved of the University of Delaware, DE, USA (IRB, UD, DHHS (IORG No. 0000279)) reviewed and approved the survey to ensure it lies within the rules and regulations that are stipulated when dealing with human subjects. Participants were allowed to review and sign consent forms as a way to declare to participate in the study. The questionnaires were completed only by those who completed the electronic consent form before completing the survey.

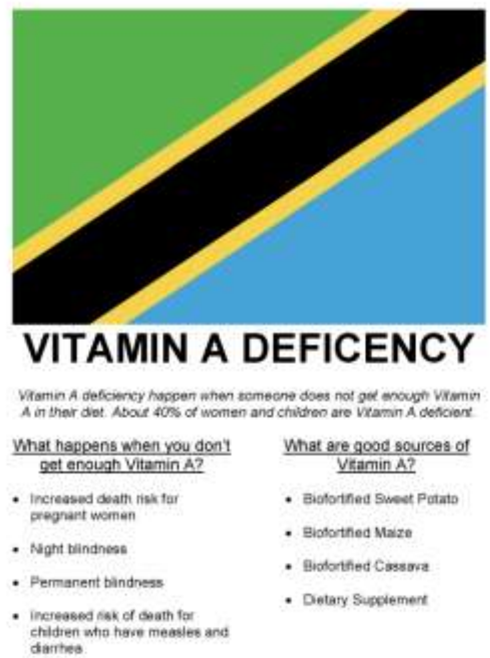
3.4 Sample size

Data was collected from 1,050 respondents between the ages of 18 to 49 with 809 being female, 225 male, and 16 respondents preferred not to answer. Respondents had the choice to complete the questionnaire in one of two languages, English or Swahili. The translation of the questionnaire into Swahili was completed by a professional translation service which is in the U.S.

3.5 Questionnaire Design

Within the survey there were two experiments conducted: 1) an experiment to identify the impact of including the name of a micronutrient in a biofortified food (e.g., vitamin A cassava versus biofortified cassava), and 2) an experiment to identify the effect of information on knowledge gaps, risk perceptions, and the likelihood of purchase. Moreover, when presenting information to respondents randomly assigned to receive information, half will see an information sheet accompanied by the Tanzanian flag to let them understand that the study they are participating is focusing Tanzanians.

<table>
<tr><th>Control (No flag)</th><th>Treatment (Flag)</th></tr>
<tr><td>


</td><td>


</td></tr>
</table>

Figure 3.7:Tanzania flag versus box on infographics.

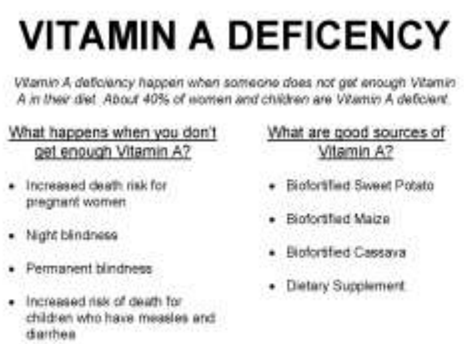
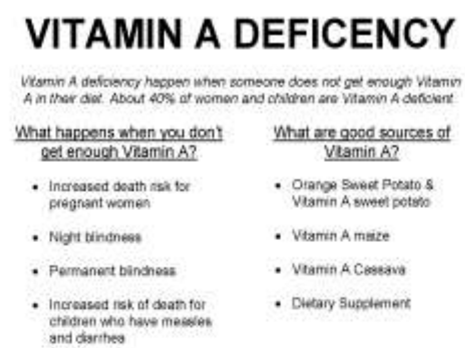
<table>
<tr><th>Control (Unnamed)</th><th>Treatment (Named)</th></tr>
<tr><td>
</td><td>
</td></tr>
</table>

Figure 3.8. Named versus unnamed crops on infographics

Figure 3.9 below illustrates how respondents were randomized into different treatments i.e., Control, Information, Flginformation, Named, Namedinformation and NamedFlagInformation Treatment for iron, vitamin A, and zinc, and randomization for iodine is in Figure 10. Respondents answer questions for all micronutrients, and respondents remain in a "Named" treatment and/or "Information" treatment after the initial randomization. Within the survey, there was no information treatment for iodine because it was left out as a control to measure the within subject treatment effects of information. This design allows us to test the effect of information between subjects (i.e., the effect of information on other measurements, like knowledge, and effect of including the Tanzanian flag) and within-subjects (i.e., using iodine as a control to test the effect of information on other measurements, like knowledge). This design also allows us to test whether including the name of a micronutrient in a biofortified food (e.g., vitamin A cassava versus biofortified cassava) implicitly improves knowledge about biofortified foods.

Iron/Vitamin A/Zinc

~1,000 Respondents

~500 Respondents

Named

(e.g., vitamin A cassava)

~200 Respondents view information with Tanzanian Flag

~200 Respondents views information without Tanzanian Flag

~100 views no information (control)

~500 Respondents

Non-named

(e.g., biofortified cassava)

~200 Respondents view information with Tanzanian Flag

~200 Respondents view information without Tanzanian Flag

~100 views no information (control)

Figure 3.9. Respondent Randomization for Iron, Vitamin A, and Zinc

Iodine

~1,000 Respondents

~500 Respondents

Named

(e.g., iodine salt)

~500 Respondents

Non-named

(e.g., fortified salt)

Figure 3.10. Respondent Randomization for Iodine

3.6 Statistical Methods

3.6.1 Hypothesis 1. Testing whether the awareness of micronutrient deficiencies differ among vitamin A, iron, zinc and iodine.

A test of differences in proportions was used to examine if awareness of micronutrients deficiency was equal across vitamin A, iron, zinc and iodine. If the null hypothesis is rejected, then it can be determined relative awareness and provide insight into which micronutrients require more communication to increase awareness.

3.6.2 Hypothesis 2. Testing whether the awareness of micronutrient deficiencies is not lower for females and high poverty households

A binary logit model was estimated to determine if awareness about the micronutrient deficiencies was the same for females and high poverty households. The estimated binary logit model can be mathematically represented by:

(1) $Awareness_i = a_1 + b_1 Female + b_2 PSC$,

where $Awareness_i$ is an indicator variable equal to 1 if a respondent had heard of the i^{th} micronutrient deficiency, Female is equal to 1 if a respondent self-identified as a female, and PSC is the respondent score from the Simple Poverty Scorecard® developed for Tanzania. The estimated coefficients, b_1 and b_2, represent the relative difference in awareness for females and high poverty households.

3.6.3 Hypothesis 3. Testing whether the awareness of micronutrient deficiencies for vitamin A, iron, zinc and iodine differ between men and women

A binary logit model was estimated to determine if awareness about the micronutrient deficiencies for females and males as well as and high poverty households. The estimated binary logit model for both male and female can be mathematically represented by:

(1) $\text{Awareness}_i = a_1 + b_1\text{Female} + b_2\text{PSC}$,

(2) $\text{Awarenes}_i = a_1 + b_1\text{Male} + b_2\text{PSC}$

where Awareness_i is an indicator variable equal to 1 if a respondent had heard of the i^{th} micronutrient deficiency, Female/Male is equal to 1 if a respondent self-identified as a female/male, and PSC is the respondent score from the Simple Poverty Scorecard® developed for Tanzania. The estimated coefficients, b_1 and b_2, represent the relative difference in awareness for females/males and high poverty households.

3.6.4 Hypothesis 4. Testing whether the awareness of micronutrient deficiencies differ across treatments.

Respondents were randomized where few of them were subjected on information treatments and others were not. The hypothesis intended to identify whether such awareness exist between Information, FlagInformation, Named, NamedInformation and NamedFlagInformation

3.6.5 Hypothesis 5. Testing whether the perceived of micronutrient deficiencies differ among vitamin A, iron, zinc and iodine.

Respondents tested to understand their overview about perceived risk of being micronutrients deficiency, it was rated from no risk, little risk, medium risk, serious risk, very serious risk and I do know option. With such response it helps to determine whether difference among respondents exists or not.

3.6.6 Hypothesis 6. Testing whether the perceived risk of micronutrients deficient was not influenced by treatment

Ordinary least squares were estimated to examine the treatment effects on perceived risk, and the estimated regression model can be mathematically represented by:

$$(2)\ PerceivedRisk_i = a_2 + c_1 Info + c_2 FlagInfo + c_3 NamedInfo + c_4 NamedFlagInfo,$$

where $PerceivedRisk_i$ varies from 0 to 100, and Info, FlagInfo, NamedInfo, and NamedFlagInfo are all indicator variables equal to 1 if a respondent was randomized to the respective information treatment. The estimated coefficients, c_1, c_2, c_3, and c_4, represent the relative difference in perceived risk for respondents randomized to the respective treatments.

3.6.7 Hypothesis 7. Testing whether negative health outcomes associated with micronutrients deficiencies differ among vitamin A, iron, zinc and iodine.

Each micronutrient i.e., vitamin A, iodine, iron and zinc has specific negative health outcome associated with its deficiency. Looking at its proportional it can help to identify those who are aware. Respondents' knowledge or awareness is crucial towards taking precaution to overcome such negative health outcome associated with micronutrients deficiency

3.6.8 Hypothesis 8. Testing whether the negative health outcomes associated with micronutrients deficiencies were affected by treatment information (differ across treatments)

An average score was calculated for each micronutrient, instead of summing the number of correctly identified health outcomes, so that respondent scores were penalized for selecting negative health outcomes associated with a particular micronutrient deficiency. Ordinary least squares were estimated to examine the treatment effects on the average score, and the estimated regression model can be mathematically represented by:

$$(3)\ NegativeHealth_i = a_3 + c_5Info + c_6FlagInfo + c_7NamedInfo + c_8NamedFlagInfo,$$

where $NegativeHealth_i$ is the average score and varies from 0 to 1 for the i^{th} micronutrient deficiency and the indicator variables are the same as previously described, and the estimated coefficients c_5, c_6, c_7, and c_8, indicate the treatment effect on the average score.

3.6.9 Hypothesis 9. Testing whether the knowledge of foods that decrease the risk of being micronutrients deficiencies differ among vitamin A, iron, zinc and iodine.

Respondents were allowed to identify different food varieties in response to specific nutrients, it was having similar procedure as was in the negative health outcomes.

3.6.10 Hypothesis 10. Testing whether the knowledge of food that reduces the risk of being micronutrients deficient were influenced by treatment (differ across treatments)

The treatment effects on identifying foods that decrease micronutrient deficiency were estimated in the same manner as was done for negative health outcomes. The regression model estimated to examine the treatment effects on the average score of risk-reducing foods can be mathematically represented by:

(4) $FoodKnowledge_i = a_4 + c_9 Info + c_{10} FlagInfo + c_{11} NamedInfo + c_{12} NamedFlagInfo$,

where $FoodKnowledge_i$ is the average score and varies from 0 to 1 for the i^{th} micronutrient deficiency risk-reducing foods and Info, FlagInfo, NamedInfo, and NamedFlagInfo are indicator variables, while the estimated coefficients c_9, c_{10}, c_{11}, and c_{12}, indicate the treatment effect on the average score.

3.6.11 Hypothesis 11. Testing whether the likelihood of purchasing foods that decrease the risk of being micronutrients deficiencies differ among vitamin A, iron, zinc and iodine.

Biofortified foods are potential for reducing micronutrients deficient. An ordered probit model used to assess significance of preference of respondents between food sources providing vitamin A, iodine, iron and zinc

3.6.12 Hypothesis 12. Testing whether the likelihood of purchasing foods that decrease the risk of being micronutrients deficiencies differ across treatments.

As explained about the likelihood of purchasing biofortified foods across micronutrients deficient, it also used to test across treatments. An ordered probit model used to assess significance of preference of respondents between food sources providing vitamin A, iodine, iron and zinc across treatments i.e., Information, FlagInformation, Named, NamedInformation and NamedFlagInformation treatments

Within-subjects tests for hypotheses 7 and 9

Respondents assigned to an information treatment were not provided information about iodine, this allows for a within-subject test of treatment effects on correctly identifying negative health outcomes and risk-reducing foods. For example, a within-difference model determining the treatment effects of information about the risk-reducing foods for vitamin A can be mathematically represented by:

i) $(FoodKnowledge_{vitaminA} – FoodKnowledge_{iodine}) = a_5 + c_{13}Info + c_{14}FlagInfo + c_{15}NamedInfo + c_{16}NamedFlagInfo.$

where the dependent variable is the difference between respondent average score for vitamin A and iodine. Now, the estimated coefficients c_{13}, c_{114}, c_{15}, and c_{16}, reflect the impact of information within a treatment instead of the relative difference between a treatment and the control group. A similar model was estimated for the within difference for risk-reducing foods.

Chapter 4

RESULTS AND DISCUSSION

4.1 Hypothesis 1. Testing whether the awareness of micronutrient deficiencies differ among vitamin A, iron, zinc and iodine

Generally, most of the respondents were aware of micronutrients deficiency with 78.48% having heard about iron deficiency. 76.1% of respondents heard about vitamin A deficiency, while having lower percentage for iodine with 68.1% and zinc having 54.86% as shown in table 4.1. With such results, we can see the knowledge gap of hearing about micronutrients deficiency exist for zinc and iodine when compared to iron and vitamin A. Such results may have an implication that promotion efforts among micronutrients are higher for iron and vitamin A compared to zinc and iodine. Considering the roles of Iodine and Zinc for child development during the initial stages of pregnancy, there is a need to increase efforts of education and awareness campaign to ensure that adequate precaution is taken as a remedy of such micronutrient's deficiency.

Table 4.1. Proportions of respondents that heard about micronutrients deficiency

Iron***	Vitamin A***	Iodine**	Zinc*
78.48	76.1	68.1	54.86

Following the results about of micronutrient deficiencies i.e., vitamin A, iron, zinc and iodine, we reject our null hypothesis (Ho) which stated that the awareness of micronutrients deficiency is equal across vitamin A, iron, zinc and iodine and conclude that variations on awareness about micronutrients deficiency exist across vitamin A, iron, zinc and iodine.

4.2 Hypothesis 2. Testing whether the awareness of micronutrient deficiencies is not lower for females and high poverty households.

The results of the binary logit models estimated to test Hypothesis 1 (b) are shown in Table 4.2. An odds ratio more (less) than one indicates an increase (decrease) in the probability of awareness. The odds ratio for PSC is significant and less than one for iodine, iron, and zinc, indicating that high-poverty households had relatively less awareness about these micronutrient deficiencies. The odds ratios were not significantly different from one for females, indicating that females and males had a similar level of stated awareness about these micronutrient deficiencies.

Table 4.2. **Awareness – Binary Logits and Odds Ratios Reported for Female**

	Vitamin A	Iodine	Iron	Zinc
1.female	1.094	1.013	1.250	1.106
PSC	0.990*	0.977***	0.985***	0.985***
_cons	4.249	4.931	5.310	1.922
Chi-Square Stat	4.40	25.13***	10.73***	12.84***
# Of observations	1,050	1,050	1,050	1,050

***p-value < 0.01 and *p-value < 0.10

4.3 Hypothesis 3. Testing whether the awareness of micronutrient deficiencies for vitamin A, iron, zinc and iodine differ between men and women

Comparing results from table 4.2 with binary logits and odds ratios reported for female and table 4.3 with binary logits and odds ratios reported for male it appears that female has odds ratio more than one indicating an increase in the probability of awareness compared to males having odds ratio less than one meaning that there is a decrease in probability of awareness among male , hence we reject our (Ho) and conclude that the awareness of micronutrients deficiency differs between male and females.

Table 4.3. Awareness – Binary Logits and Odds Ratios Reported for male.

	Vitamin A	Iodine	Iron	Zinc
Male	0.937	0.920	0.774	0.846
PSC	0.990*	0.978***	0.985***	0.986***
_cons	4.636	5.035	6.674	2.144
Chi-Square Stat	4.26	25.38***	11.17***	13.58***
# Of observations	1,050	1,050	1,050	1,050

***p-value < 0.01 and *p-value < 0.10

4.4 Hypothesis 4. Testing whether the awareness of micronutrient deficiencies differ across treatments

In reference to the data from table 4.1 with proportinal of respondents who heard about micronutrients deficiency which differ among vitamin A, iodine, iron and zinc it has an implication of causing differences across treatments i.e., Information, FlagInformation, Named, NamedInformation and NamedFlagInformation.

4.5 Hypothesis 5. Testing whether the perceived of micronutrient deficiencies differ among vitamin A, iron, zinc and iodine.

Respondents perceived risk about micronutrient deficiencies is around 50% of all respondents with nor risk or little as shown in table 4.4. But somehow strange for iodine and zinc having higher responses for the I do know option.

Table 4.4. Examining the Uncertainty about Perceived Risk

	Vitamin A	Iodine	Iron	Zinc
No risk (1)	27.33	23.9	26.29	25.24
Little risk (2)	32.19	30.19	31.24	28.29
Medium risk (3)	17.05	15.62	19.9	20.29
Serious risk (4)	10.48	10.86	10.67	11.33
Very serious risk (5)	7.24	3.81	6.57	4.29
I don't know	5.71	15.62	5.33	10.57
Weighted averages with IDKs removed	2.34	2.29	2.37	2.84

4.6 Hypothesis 6. Testing whether the perceived risk of micronutrients deficient was not influenced by treatment

The results from the regression to test hypothesis 6 are shown in Table 4.5. Looking at the coefficients from the regression for all treatments, it shows that all are not significant. Following the results about the perceived risk of being micronutrient deficient across treatments, we **fail to reject our null hypothesis (Ho**) which stated that the perceived risk of micronutrients deficiency is equal across treatments and conclude that by using only the regression there is no evidence to support any variation among respondents perceived risks about micronutrients deficient.

Table 4.5. Perceived risk regression coefficients.

Treatments	Vitamin A	Iodine	Iron	Zinc
Info	-0.101	-0.114	-0.150	-0.114
Flaginfo	-0.150	-0.222	-0.201	-0.195
NamedInfo	-0.266	-0.299	-0.263	-0.153
NamedFlagInfo	-0.098	-0.126	-0.216	-0.078
_cons	2.466	2.447	2.532	2.450
F stat	1.400	2.480	1.590	0.980
# Of Observation	1,050	1,050	1,050	1,050

4.7 Hypothesis 7. Testing whether the negative health outcomes associated with micronutrients deficiencies differ among vitamin A, iron, zinc and iodine.

The results from the regression to test Hypothesis 7 are shown in Table 4.6. Considering the coefficients among vitamin A, iodine, iron and zinc, it appears to be much more knowledge about the negative health effects associated with vitamin A deficiency compared to the others. For example, females and high-poverty households assigned to the control group scored over 60% for correctly identifying negative health effects associated with vitamin A deficiency, while scoring between 34-48% for the other micronutrients.

Information was very effective. Respondents randomized to an information treatment scored 24-45% higher for vitamin A, iron, and zinc. Differences observed on iodine is a result of not having any information provided on it which tend to highlight the impact of the information on the knowledge gap among respondents. Even when we look at the F statistic, we found that the overall iodine model for females was not significant. On concluding from our results about knowledge of the negative health outcomes associated with micronutrient deficiencies (i.e., Vitamin A, Iron, Zinc and Iodine) about the stated hypothesis, we reject our null hypothesis (Ho) which stated that the Knowledge about the negative health outcomes is equal across micronutrients and conclude that respondent knowledge on the negative health outcomes differs across micronutrients.

4.8 Hypothesis 8. Testing whether the negative health outcomes associated with micronutrients deficiencies were affected by treatment information (differ across treatments)

The results from the regression to test Hypothesis 8 are shown in Table 4.6. Considering the coefficients among treatments it appears that the NamedFlagInformation treatments respondents were having more knowledge about the negative health effects compared to other treatments.

Table 4.6. Negative health outcomes correctly identified averages regression and coefficients

	Female only Sample				**Highest Poverty households (40th Percentile)**			
	Vitamin A	**Iodine**	**Iron**	**Zinc**	**Vitamin A**	**Iodine**	**Iron**	**Zinc**
Info	0.236***	-0.041	0.405***	0.418***	0.244***	0.025	0.451***	0.462***
Flaginfo	0.240***	-0.304***	0.399***	0.391***	0.253***	-0.196***	0.426***	0.442***
NamedInfo	0.286***	0.007	0.431***	0.448***	0.292***	0.067	0.437***	0.437***
NamedFlagInfo	0.276***	0.008	0.381***	0.349***	0.297***	0.160***	0.395***	0.440***
_cons	0.635***	0.477***	0.403***	0.415***	0.607***	0.361***	0.340***	0.347***
F stat	32.35***	21.95	53.72***	45.74***	15.63***	9.54***	26.33***	25.77***
# Of Observations	809	809	809	809	428	428	428	428

4.9 Hypothesis 9. Testing whether the knowledge of foods that decrease the risk of being micronutrients deficiencies differ among vitamin A, iron, zinc and iodine.

The results from the regression to test hypothesis 9 are shown in Table 4.7. Considering the coefficients in all treatments it appears to be much more knowledge about the foods that reduce the risk of being deficient from vitamin A deficiency compared to the other micronutrients. For example, females and high-poverty households assigned to the control group scored over 66% for correctly identifying food that reduce the risk of being vitamin A deficiency, while scoring 44-66% for the other micronutrients.

The method of naming food with the specific micronutrient shows to be an effective communication approach. Respondents randomized to an information treatment scored 6-35% higher for vitamin A, iron, and zinc. Looking at the F statistic as well, we found that the overall iodine model for females was not significant. Conclusion from our results about knowledge of food that reduce the risk of being deficiencies (i.e., Vitamin A, Iron, Zinc and Iodine) and with the stated hypothesis, we reject our null hypothesis (Ho) which stated that the Knowledge about foods that decrease the risk of being micronutrients deficiency is equal across micronutrients and conclude that respondent knowledge on the foods that decrease the risk of being deficiency differs across micronutrients.

4.10 Hypothesis 10. Testing whether the knowledge of foods that reduces the risk of being micronutrients deficient were influenced by treatment (differ across treatments)

The results from the regression to test Hypothesis 10 are shown in Table 4.7. Considering the coefficients among treatments it appears the flaginformation treatments respondents were having more knowledge about the correct foods that reduce the risk of being micronutrients deficiency hence we reject our null (Ho) and conclude that the knowledge of food that reduces the risk of being micronutrients deficient were influenced by treatments.

Table 4.7. Risk-reducing foods correctly identified averages regression and coefficients

	Female only Sample				Highest Poverty households (40th Percentile)			
	Vitamin A	**Iodine**	**Iron**	**Zinc**	**Vitamin A**	**Iodine**	**Iron**	**Zinc**
Info	0.063**	-0.013	0.241***	0.053	0.110***	-0.004	0.319***	0.097***
Flaginfo	0.044*	0.059	0.213***	0.101***	0.112***	0.061	0.253***	0.189***
NamedInfo	0.239***	-0.013	0.357***	0.341***	0.303***	-0.016	0.442***	0.359***
NamedFlagInfo	0.213***	0.008	0.295***	0.317***	0.254***	0.029	0.339***	0.392***
_cons	0.741***	0.701***	0.542***	0.584***	0.669***	0.664***	0.444***	0.507***
F stat	33.28***	1.21	36.43***	47.40***	17.58	0.57	24.89***	22.93***
# Of Observation	809	809	809	809	428	428	428	428

Within Tests for Hypotheses 7 and 9

The results from the regression for testing within difference models for hypothesis 7 are shown in Table 4.8. Considering the coefficients in all treatments by excluding iodine (Minus iodine) i.e., finding the difference within the coefficients it appears to be much more knowledge about the negative health effects associated with vitamin A deficiency compared to the other micronutrients deficiency. For example, females and high-poverty households assigned to the control group scored over 24% for correctly identifying negative health effects associated with vitamin A deficiency, while scoring (-2.2) to (-1.5) % for iron and zinc micronutrients. There also appears that there is slightly more knowledge about Iodine, compared to Iron and Zinc. We can conclude that when iodine was included in the model our results about knowledge of the negative health outcomes associated with micronutrient deficiencies (i.e., Vitamin A, Iron, Zinc and Iodine) in reference to the stated hypothesis, we reject our null hypothesis (Ho) which stated that the Knowledge about the negative health outcomes is equal across micronutrients and conclude that respondent knowledge on the negative health outcomes differs across micronutrients.

Referring to table 4.6 in comparison with table 4.8, it appears that high-poverty respondents randomized to the FlagInfo and NamedFlagInfo treatments scored higher than other respondents for iodine even though there was no information provided about iodine. Those results indicate how respondents randomized to an information treatment did compared to a control group. By subtracting the iodine scores from the scores of other micronutrients, we can control for treatments that may have respondents who have generally more knowledge about micronutrient deficiencies.

Table 4.8. Negative health outcomes correctly identified averages regression coefficients

	Female only Sample			Highest Poverty households (40th Percentile)		
	Vitamin A	**Iron**	**Zinc**	**Vitamin A**	**Iron**	**Zinc**
Info	0.277***	0.446***	0.459***	0.219***	0.426***	0.436***
Flaginfo	0.544***	0.703***	0.694***	0.449***	0.621***	0.638***
NamedInfo	0.279***	0.424***	0.441***	0.225***	0.370***	0.370***
NamedFlagInfo	0.268***	0.373***	0.341***	0.137***	0.235***	0.280***
_cons	0.159***	-0.073***	-0.061***	0.246***	-0.022	-0.015
F stat	32.78***	51.19***	46.78***	10.50***	20.37***	20.01***
# Of Observations	809	809	809	428	428	428

The results from the regression for testing within difference models for hypothesis 9 are shown in Table 4.9. In view of the coefficients in all treatments by excluding iodine (Minus iodine) i.e., finding the difference within the coefficients it appears to be much more knowledge about the foods that reduce the risk of being deficient from vitamin A deficiency compared to the other micronutrients. For example, females and high-poverty households assigned to the control group scored about 0.5% for correctly identifying food that reduce the risk of being vitamin A deficiency, while scoring -22% to -16% for iron and zinc micronutrients.

As per results from the analysis about the knowledge of foods that decrease the risk of being micronutrient deficiency (i.e., Vitamin A, Iron, Zinc and Iodine) while excluding iodine (Minus iodine) towards finding respondents knowledge about the foods that reduce the risk of being deficient i.e., finding the difference within the coefficients we also notice that still there is relatively more knowledge about the foods that reduce the risk of being deficient from vitamin A than on Iron and Zinc and by naming those foods has become an effective method to increase awareness among respondents. With such results and consideration of the stated hypothesis, we reject our null hypothesis (Ho) which stated that the Knowledge about foods that decrease the risk of being micronutrients deficiency is equal across micronutrients and conclude that respondent knowledge on the foods that decrease the risk of being deficiency differs across micronutrients.

Table 4.9. Risk-reducing foods without iodine correctly identified averages regression and coefficients.

	Female only Sample			Highest Poverty households (40th Percentile)		
	Vitamin A	**Iron**	**Zinc**	**Vitamin A**	**Iron**	**Zinc**
Info	0.076	0.254***	0.066	0.115*	0.323***	0.101
Flaginfo	-0.015	0.154***	0.042	0.052	0.192***	0.128*
NamedInfo	0.252***	0.370***	0.355***	0.319***	0.459***	0.376***
NamedFlagInfo	0.221***	0.303***	0.325***	0.226***	0.311***	0.363***
_cons	0.040	-0.159***	-0.118***	0.005	-0.220	-0.157
F stat	14.11***	17.70***	23.31***	7.26***	12.34***	10.87***
# Of Observations	809	809	809	428	428	428

4.11 Hypothesis 11. Testing whether the likelihood of purchasing foods that decrease the risk of being micronutrients deficiencies differ among vitamin A, iron, zinc and iodine.

Some coefficients estimate from the ordered logit model were significant showing respondents' likelihood of purchasing food products with additional micronutrients to reduce deficiency as shown in table 4.10. From the results, while testing hypothesis 11 it appears that the named treatment with information has 51.6% of respondents likely to purchase Maize with 50% DN and also the named treatment with flag and information has 50.7% and 42.4% of respondents likely to purchase Maize with 50% DN and Cassava with 100% DN respectively.

Given the results about the likelihood of purchasing biofortified food products (i.e., Vitamin A Maize, Vitamin A Cassava, Iron beans etc.) that supplement micronutrients deficiency and regarding the stated hypothesis, we reject our null hypothesis (Ho) which stated that the likelihood of purchasing foods that decrease the risk of being deficiency is equal across micronutrients and conclude that respondent interests and preference of biofortified food products differ across micronutrients.

4.12 Hypothesis 12. Testing whether the likelihood of purchasing foods that decrease the risk of being micronutrients deficiencies differ across treatments.

The results from the regression to test hypothesis 12 are shown in Table 4.10. Considering the coefficients estimate from the ordered logit model which were significant and respondents from the information treatments shows their likelihood of purchasing food products with additional nutrients (biofortified foods) to reduce deficiency, hence we reject our null (Ho) and conclude that the respondent's likelihood of purchasing biofortified foods were influenced by treatments

Table 4.10. Likelihood of purchase of biofortified food products.

	Vitamin A			Iodine	Iron		Zinc		
Treatments	Maize with 50% DN	Cassava with 100% DN	Sweet Potatoes with 100% DN	Fortified Salt with 30% DN	Beans with 80% DN	Pearl millet with 80% DN	Maize 70% DN	Wheat with 50% DN	Rice with 40% DN
Info	0.332	0.064	0.190	-0.172	-0.223	0.183	0.220	-0.081	0.173
Flaginfo	0.156	0.056	-0.379	-0.288	-0.066	0.323	0.363	-0.119	0.118
NamedInfo	0.516**	0.325	0.219	0.111	0.258	0.282	0.123	-0.129	-0.138
NamedFlagInfo	0.507**	0.424**	0.298	0.046	0.041	0.313	0.231	-0.011	0.135
Chi-Squre statistic	8.97	6.49	14.82***	4.79	5.75	3.25	3.26	0.65	3.10
Log likelihood	-949	-1012	-977	-849	-958	-1145	-1022	-1043	-977
#Of Observation	809	809	809	802	809	802	802	802	802

Chapter 5

CONCLUSION AND RECOMMENDATIONS

This study used an online survey fielded to respondents in Tanzania to examine the risk perception of micronutrients deficiency among women of reproductive age, and the effects of knowledge gaps about micronutrients deficiency and preference for consuming biofortified foods. Considering the results obtained it appears that most respondents appear to have knowledge of Vitamin A compared to Iron, Iodine and Zinc. This has been an improvement to previous research that were assessing consumer risk perception of vitamin A deficiency and the acceptance of biofortified rice in Morogoro region of Tanzania in 2018, where its results shows that approximately half of the respondents were not knowing the risk of being vitamin A deficiency as shown in figure 5.1 (Domonko, McFadden, Mishili, Mullally, & Farnsworth, 2018).

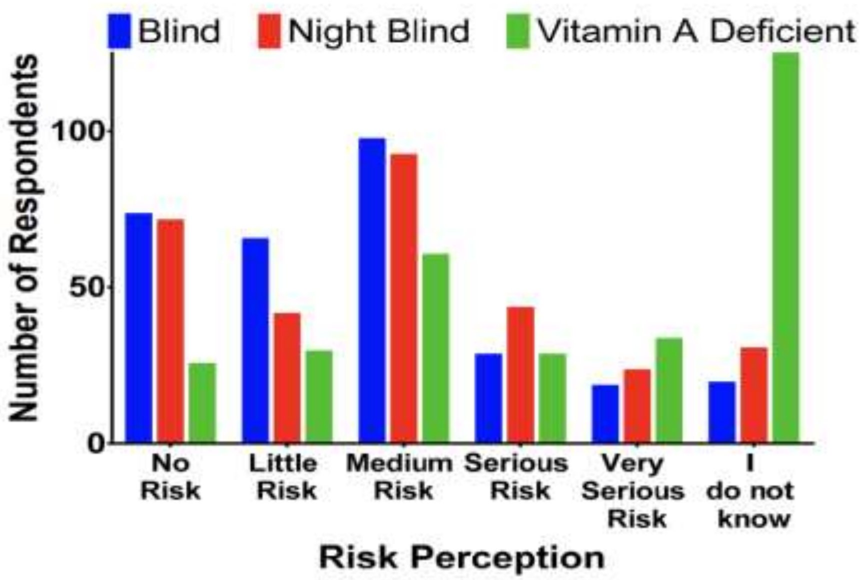


Figure 5.11. Perceived risk of vitamin A deficiency (VAD)

On average, respondents were more aware about micronutrients deficiency of iron with 78.48% followed by Vitamin A with 76.1% while iodine was 68.1% and zinc was 54.86%, while respondents were aware of the negative health outcomes associated with vitamin A than iron and zinc. From the results zinc has the lowest proportional of respondents that are aware of it, and we know that zinc, is vital for promoting immune functions and helps people resist infectious diseases including diarrheal, pneumonia and malaria while pregnant women's need zinc for ensuring healthy pregnancies. Therefore, with the obtained results there is a need to have much promotion efforts of zinc to the community for combating health problems associated with zinc deficiencies. We know for development of strong and health community it is necessary to devote more resources to increase awareness to community especially women and children who are at risk than others, without neglecting those living in rural villages which are in remote areas and sometimes too difficult to access technologies.

On average, respondents had more aware about the risk reducing food for vitamin A as well than foods for reducing zinc and iron deficiency. Also, within our results respondents were not aware of the negative health outcome associated with iodine deficiency but seems to know that fortified salt helps to reduce the risk of being deficient from iodine.

Looking up across treatment effects it shows us that naming foods with specific names i.e., Vitamin A maize has become a better approach to increase their awareness and interest of their willingness to purchase those products as a result of being knowledgeable.

With this study, we identified the most challenging limitation especially to rural households in the access to technology. So, with online data collection as a result of the Covid-19 pandemic, we were unable to collect data physically from the rural community. Even though we managed to collect data from 30 regions out of 31 within Tanzania mainland and the island (Unguja and Pemba) still most of the respondents were those living in urban and suburban, hence we didn't manage to capture knowledge gaps within rural households for understanding their awareness about micronutrient deficiencies, their knowledge about who is the at-risk population, knowledge about the negative health outcomes associated with micronutrient deficiencies and knowledge about the food sources that reduce the risk of being micronutrient deficient.

Whenever future studies will be planned it is better to oversample rural households by visiting villages and collecting data directly from respondents that will represent clearly whether there are gaps on not.

My research has added efforts which the Tanzania government initiated as an effort to implement the 2016-2021 National Multisectoral Nutrition Action Plan with seven strategies for ensuring maternal, infant and young child and adolescent nutrition is achieved, ensuring prevention and control of micronutrients deficiencies among those who are at risks, mainatining integrated management of acute malnutrition, working on nutrition-related non-communicable diseases; initiating nutrition sensitive interventions; involving stakeholders to coordinate and under multi-sectoral nutrition governance and initiating follow-up of all intervention using multi-sectoral nutrition information system. Whenever awareness campaign is increased it will be an effective method to ensure the achievement of the goals planned.

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Appendix

A.1 INSTITUTIONAL REVIEW BOARD

UNIVERSITY OF DELAWARE

Institutional Review Board
210H Hullihen Hall
Newark, DE 19716
Phone: 302-831-2137
Fax: 302-831-2828

DATE:	January 13, 2021
TO:	Brandon McFadden
FROM:	University of Delaware IRB
STUDY TITLE:	[1695318-1] Eliciting Risk Perception of Micronutrients Deficiency in Tanzania
SUBMISSION TYPE:	New Project
ACTION:	DETERMINATION OF EXEMPT STATUS
EFFECTIVE DATE:	January 13, 2021
REVIEW CATEGORY:	Exemption category # *(2)*

Thank you for your New Project submission to the University of Delaware Institutional Review Board (UD IRB). According to the pertinent regulations, the UD IRB has determined this project is EXEMPT from most federal policy requirements for the protection of human subjects. The privacy of subjects and the confidentiality of participants must be safeguarded as prescribed in the reviewed protocol form.

This exempt determination is valid for the research study as described by the documents in this submission. Proposed revisions to previously approved procedures and documents that may affect this exempt determination must be reviewed and approved by this office prior to initiation. The UD amendment form must be used to request the review of changes that may substantially change the study design or data collected.

Unanticipated problems and serious adverse events involving risk to participants must be reported to this office in a timely fashion according with the UD requirements for reportable events.

A copy of this correspondence will be kept on file by our office. If you have any questions, please contact the UD IRB Office at (302) 831-2137 or via email at hsrb-research@udel.edu. Please include the study title and reference number in all correspondence with this office.

INSTITUTIONAL REVIEW BOARD

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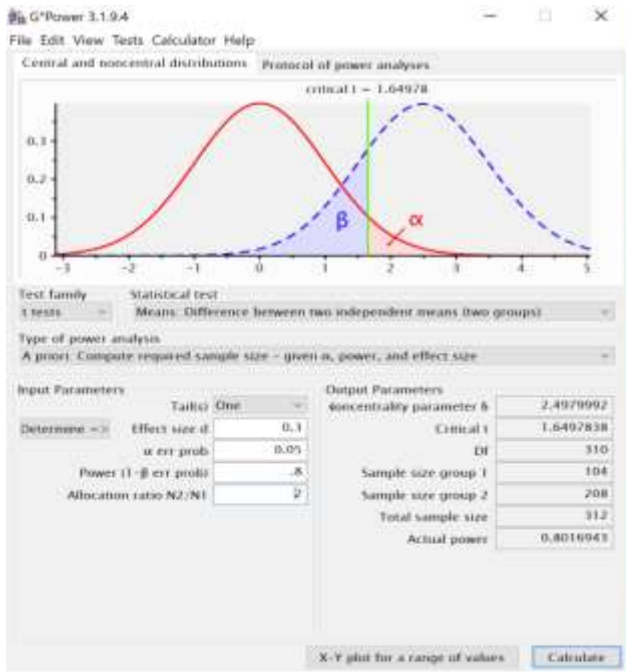
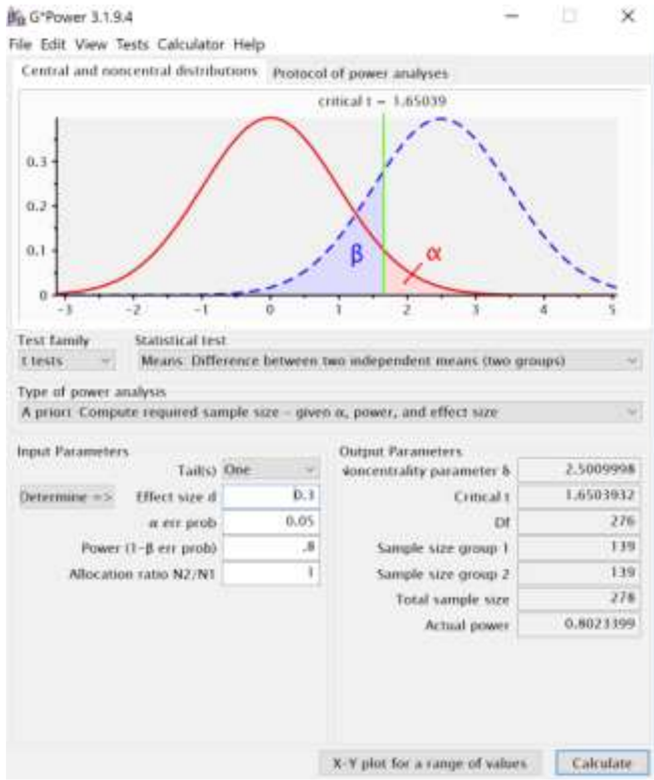
- 1 -

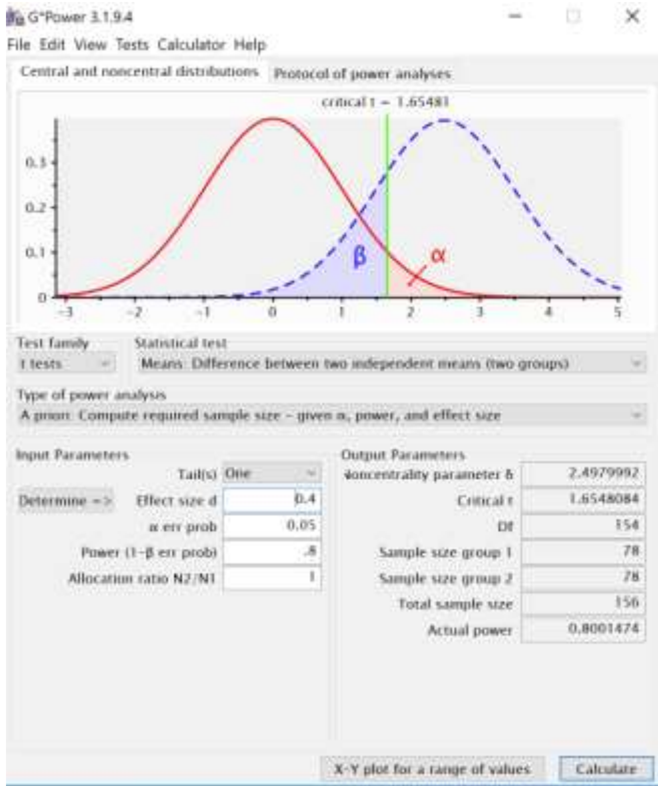
A.2 POWER ANALYSIS



Comparing Treatments



Comparing Controls


G*Power 3.1.9.4
File Edit View Tests Calculator Help
Central and noncentral distributions
Protocol of power analyses
critical t = 1.65481
β
α
Test family
t tests
Statistical test
Means: Difference between two independent means (two groups)
Type of power analysis
A priori: Compute required sample size – given α, power, and effect size
Input Parameters
Tail(s) One
Determine =>
Effect size d 0.4
α err prob 0.05
Power (1-β err prob) .8
Allocation ratio N2/N1 1
Output Parameters
Noncentrality parameter δ 2.4979992
Critical t 1.6548084
Df 154
Sample size group 1 78
Sample size group 2 78
Total sample size 156
Actual power 0.8001474
X-Y plot for a range of values
Calculate

A.3 COMPARISONS OF FEMALES WHO HEARD ABOUT MICRONUTRIENTS DEFICIENCY AND HIGHER POVERTY HOUSEHOLDS

	Vitamin A	Iodine	Iron	Zinc
	Odds Ratio			
Female	1.131	1.006	1.245	1.169
PSC	0.995	0.981	0.992	0.989
Age	1.010	1.034	1.011	1.049
Rural	0.879	0.844	0.723	0.829
Urban	0.959	0.876	0.877	0.875
Education	1.054	1.070	1.149	1.072
Employed	1.352	0.807	1.432	1.332
Seeking employment	0.969	0.670	1.018	0.838
Bilingual	1.083	1.062	1.001	1.417
Arusha	1.020	0.886	1.210	0.657
Dar	1.013	0.830	0.840	0.861
Married	1.756	1.053	2.032	1.001
Single	1.480	1.384	2.153	0.834
Christian	1.909	2.256	2.695	1.619
Muslim	1.513	1.727	1.261	1.436
_cons	0.667	0.736	0.352	0.213
Chi-Squre	26.49	52.92	70.30	81.140
Log likelihood	-554	-620	-504	-667
Number of observations	1,029	1,029	1,029	1,029

A.4 POVERTY SCORE SUMMARY

Variable	Obs	Mean	Std. Dev.	Min	Max
psc1	1,050	14.14	8.36	0	28
psc2	1,050	3.10	1.55	0	5
psc3	1,050	9.75	5.44	0	13
psc4	1,050	5.65	1.40	0	6
psc5	1,050	5.97	4.26	0	9
psc6	1,050	12.96	5.15	0	15
psc7	1,050	3.22	1.59	0	4
psc8	1,050	2.25	1.99	0	4
psc9	1,050	3.70	1.05	0	4
psc10	1,050	2.91	3.98	0	12
psc	1,050	63.64	14.66	11	100