VITAMIN A RICH FOODS CONSUMPTION OF WOMEN AND CHILDREN FROM SELECTED REGION IN UGANDA

VITAMIN A RICH FOOD CONSUMPTION AMONG WOMEN AND CHILDREN OF SELECTED REGIONS IN UGANDA

A Dissertation presented

by

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VITAMIN A-RICH FOOD CONSUMPTION AMONG WOMEN AND CHILDREN OF SELECTED REGIONS IN UGANDA

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This dissertation is dedicated to my husband Joshua and our children Tim, Titus, and Tina for the endless love, support and patience throughout the years I have been away. That time can never be recovered but I am so grateful this far.

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ABSTRACT

VITAMIN A-RICH FOOD CONSUMPTION AMONG WOMEN AND CHILDREN OF SELECTED REGIONS IN UGANDA

FEBRUARY 2022

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Vitamin A deficiency (VAD) remains a public health concern in low- and middle-income countries. Young children and women in the reproductive age group, particularly pregnant and lactating women, continue to experience vitamin A deficiency resulting in the risk of morbidity and mortality. Efforts to combat vitamin A deficiency have been tested with some success especially with school-based vitamin A supplementation programs. However, cost issues and reaching the most vulnerable individuals presents a formidable challenge. Globally, food-based approaches have been identified as a sustainable and effective strategy in improving vitamin A status and alleviating VAD.

This dissertation provides an overview of food-based approaches and vitamin A consumption among women and children from sweet potato growing households in selected regions in Uganda. Chapter one presents a systematic review on the effects of food-based approaches on vitamin A status of women and children. While some studies identified a positive effect of food-based approaches on vitamin A status others in this review did not find a statistically significant change in serum retinol levels. Chapter two describes vitamin A consumption and its predictors among women from sweet potato growing households from selected regions in Uganda. Plant sources of vitamin A including green leafy vegetables,

were the most common dietary sources of vitamin A. Knowledge regarding vitamin A was the only identified predictor of vitamin A consumption. Based on criteria provided in the Hellen Keller International guide which was used to compute vitamin A-rich food consumption, the studied community was identified as being at high risk of vitamin A deficiency.

Finally, chapter three analytically compared three different food security indicators by vitamin A-rich food consumption for 375 mother-child dyads. This study found that mothers had higher levels of vitamin A consumption than children in the same household. This difference was qualified by a significant interaction with the household wealth index, but not with the household dietary diversity score (HDDS) and the household food insecurity access scale (HFIAS). HDDS and the wealth index were correlated with the vitamin A-rich food consumption of mothers and not with that of children. In summary, although the evidence in the literature on the effects of food-based interventions on vitamin A status is inconclusive, there is some indication of the positive benefits of food-based approaches. Further, the communities included in this study are at high risk for vitamin A deficiency and knowledge of vitamin A being a salient determinant of women and children's consumption of vitamin A-rich food. Finally, mother's consumption of vitamin A-rich was greater than their children, with a positive correlation with HDDS, a negative correlation with the wealth index, and no statistically significant association with HFIAS. Initiatives targeting mother-infant dyads should also consider direct programming to reach children and maximize their nutritional benefits.

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ABBREVIATIONS

RBP-Retinol Binding Protein

OFSP- Orange-fleshed sweet potatoes

EAR- Estimated Average requirement

DRI – Daily Reference Intake

VAD-vitamin A deficiency

VA- vitamin A

BC beta carotene

WFSP white fleshed sweet potato

WM- white maize

CRP- C-reactive protein

CX- tangerine

TAG- Triacylglycerol

CRID- Continuous Radial Immunodiffusion

WHO-World Health Organization

HKI- Hellen Keller International

LMIC- Low and Middle-Income Countries

HDDS - Household Dietary Diversity Score

HFIAS - Household Food Insecurity Access Scale

CHAPTER I:

INTRODUCTION

1.1 Background

Vitamin A is an essential micronutrient for normal functioning of the visual system, growth and development, as well as maintenance of epithelial cellular integrity, immune function and reproduction (Claggett-Dame, 2011). The dietary needs for vitamin A typically preformed retinol and pro-vitamin A as carotenoids. Preformed Vitamin A in animal foods occurs as retinyl esters of fatty acids. During digestion, vitamin A derived from animal food sources is freed from the matrices more efficiently as compared to plant protein pro-vitamin A (Huang, Liu, Qi, Brand, & Zheng, 2018; Shannon, Moise, & Trainor, 2017).

The World Health Organization defines vitamin A deficiency as tissue concentrations of vitamin A low enough to have adverse health consequences even if there is no clinical evidence of disease (WHO, 2004). In addition to the specific signs and symptoms of late-stage vitamin A deficiency, such as xeropthalmia and the risk of irreversible blindness, non-specific symptoms include increased morbidity and mortality, poor reproductive health, increased risk of anemia, and delayed growth and development(ALASHRY & Morsy, 2021). However, these nonspecific adverse effects may also be caused by other nutrient deficiencies and co-morbidities (Sommer, 1995).

Micronutrient deficiencies especially vitamin A, iron, iodine and folate, highly prevalent in the low and middle-income countries, affects an estimated 2 billion people globally (WHO, 2018). Micronutrient deficiencies are a major contributor to infection and associated with severe illness and death (Regan L Bailey, Keith P West Jr, & Robert E Black, 2015a). Globally, the World Health Organization estimated that 3 million children have some form of xeropthalmia based on retinol blood levels and of these, Africa contributes to more

than a third of the cases (Justin C Sherwin, Mark H Reacher, William H Dean, & Jeremiah Ngondi, 2012a). Additionally, 250 million people are sub clinically deficient in Vitamin A with 52 million children coming from Africa (WHO, 1998; WHO, 2009).

Between 1995 and 2005, WHO estimated that 190 million preschool children and 19 million pregnant women were affected by vitamin A deficiency (World Health Organization, 2009b). However, the subclinical trend continues to be re-evaluated to establish the quantitative benchmark for measuring the prevalence trends. The actual number of subclinical deficiencies based on the prevalence of low serum levels of retinol remains uncertain because of the confounding and poorly quantified role of infections (WHO, 1998).

Although VAD can occur in individuals of any age, however children and women are more susceptible. VAD is a disabling and potentially fatal public health problem for children under 6 years of age. Blindness resulting from VAD is more prevalent in children under 3 years of age (World Health Organization, 2009b). This period is characterized by high vitamin A requirements to support rapid growth and the transition from breastfeeding to dependence on other food sources of the vitamin. Women are also vulnerable to VAD during pregnancy and lactation, often reporting night blindness and evidence indicating that their breast milk is frequently low in vitamin A (UNICEF/WFP/WHO, 2007).

VAD is most common in populations who primarily depend on plant sources for vitamin A and where minimal dietary fat is available in daily intake. About 90% of the ingested preformed vitamin A is absorbed whereas the absorption efficiency of pro-vitamin A carotenoid varies widely depending on the type of plant source and the fat content of the accompanying meal (K. M. Nair & Augustine, 2018). Where possible, an increased intake of dietary fat is likely to improve the absorption of vitamin A in the body. In populations where there is general food shortage and specific shortage of vitamin A rich foods, VAD peak incidence rates coincide with common childhood infectious diseases e.g. diarrhea, respiratory

infections, and measles. Similarly, food habits and taboos often restrict consumption of potentially good sources of vitamin A, for example mangoes and green leafy vegetables. Culture specific factors for feeding children, adolescent, pregnant, and lactating women are common. Such influences alter short and long-term food distribution within families. However, some cultural practices can be protective of vitamin A status and need to be identified and improved (WHO, 2009).

1.2 Sources of vitamin A

Plant foods rich in provitamin A represent more than 80 percent of the total food intake of vitamin A. It is mainly for this reason that carotenoids provide most of the vitamin A activity in the diets of economically deprived populations (Codjia, 2001). Preformed vitamin A is found almost exclusively in animal products such as human milk, glandular meats, liver and fish liver oils. Preformed vitamin A is also used to fortify processed foods, which may include sugar, cereals, condiments, fats and oils. Provitamin A carotenoids are found in orange sweet potatoes, green leafy vegetables e.g. spinach, amaranth and young leaves from various sources, yellow vegetables e.g. pumpkin, squash and carrots; and yellow and non-citrus fruits e.g. mangoes and papaya, as well as other plant sources (García-Closas et al., 2004). Although foods containing provitamin A carotenoids tend to have less biologically available vitamin A, they are more affordable than animal products (Padayatty, Espey, Levine, & Vitamin, 2010).

1.3 Explanation of Vitamin A Deficiency

Vitamin A deficiency is a systematic disease that affects cells and organs in the human body. The effects are more pronounced with pre-existing conditions such as measles, respiratory, or diarrheal diseases in children or significant protein-energy malnutrition. A gradual depletion if vitamin A stores manifests as night blindness, conjunctival xerosis and

bitotic spot, corneal xerosis and ulceration, as well as late stage VAD leading to xeropthalmia of increasing severity (Sherwin et al., 2012a).

1.4 Maternal Malnutrition

Maternal malnutrition is major determinant of adverse outcomes for mothers and offspring globally (Black et al., 2013). Food insecurity plays a significant role in maternal health outcomes (Black et al., 2013). Innovative food-based approaches have included production of beta-carotene rich orange-fleshed sweet potatoes as a preventive and therapeutic nutrition specific intervention targeting livelihoods that can also potentially prevent and mitigate vitamin A deficiency(Laurie, Faber, & Claasen, 2018). When it comes to vitamin A deficiency, there is an engendered and age subgroup emphasis of vulnerable groups such as women and children. These groups are considered particularly susceptible due to lack of dietary diversity, food insecurity, higher needs during periods of growth and development, and a high burden of infections (Keding, Schneider, & Jordan, 2013). In sub-Saharan Africa, dark green leafy vegetables, orange-fleshed sweet potatoes, carrots, and yellow fruits such as mangoes are the major sources of vitamin A particularly among resource constrained households who can only afford limited animal food sources such as eggs and meat.

1.5 Subclinical VAD definition and assessment

Subclinical vitamin A deficiency, which is likely to be more common given the prolonged efforts needed to eliminate VAD, is defined as tissue concentrations of vitamin A low enough to have adverse health consequences even when there is no evidence of clinical xeropthalmia (Organization, 1994). Nutritional indicators of subclinical VAD may include

breastfeeding patterns, anthropometric indicators of protein energy malnutrition, prevalence of low birth weight, household food availability, dietary patterns of the vulnerable groups, semi-quantitative and qualitative indicators of food consumption levels and beliefs and attitudes concerning food. Other health indicators include immunization coverage, measles case fatality rate and disease prevalence rates.

Various assessments have been used to establish the status of vitamin A at the population level. Liver reserves of vitamin A are considered the gold standard. Some biomarkers are more sensitive to change in liver vitamin A status than others. The biomarkers of vitamin A status can be broadly grouped into biological, functional, histological indicators, and biochemical indicators. Such biomarkers are not feasible or practical in many population-based studies (WHO, 2009). Broadly, over time xeropthalmia was used to determine vitamin A deficiency, and before the overt damage to the eye, individuals with vitamin A deficiency experience night blindness and longer vision rotation times (Tanumihardjo, 2012). This is an example of the ophthalmic signs of vitamin A deficiency, which is regarded as a biological and histological indicator. Night blindness is a functional indicator and results when the vitamin A pool in the eye becomes depleted and the concentration in the rod cells is lowered. This is reversible with vitamin A supplementation. In areas where marginal vitamin A status is marginal, night blindness may transiently occur during pregnancy of the contributor. The explanation for such an occurrence is still uncertain however, it is speculated that this could result from the increased demand during pregnancy or lowered concentration because of an increase in serum volume. If a population has a higher prevalence of night blindness, it should be considered to be at a higher risk for vitamin A deficiency.

Biologically vitamin A deficiency can be assessed through measurement of serum retinol and serum retinol binding protein with a cut off of <0.70 micro mol/L (20 micro g/dL) in ≤ 15% of the sampled population (De Pee & Dary, 2002). These values are applicable to

children six to 71 months of age. It is recommended that analysis should be done by high performance liquid chromatography (HPLC). The World Health Organization has put forward numerous indicators that can be used in monitoring and evaluation of programs including biological, socioeconomic, ecological, nutrition, and diet indicators. Where resources are limited, specific indicators can be used alone or in combination with other indicators to identify subclinical vitamin A deficiency(Haddad, Kennedy, & Sullivan, 1994; World Health Organization, 1994)

Biochemical indicators such as serum retinol concentration is the commonest method used to evaluate vitamin A deficiency, but it is homeostatically controlled until the liver reserves become extremely low. Because of this, serum retinol is not a reflection of the vitamin A liver stores. A number of factors including infection, inflammation and recent dietary intake affects serum retinol. Therefore, other biochemical methods that respond to liver reserves in the marginal category have been developed. Such as dose response tests and isotope dilution assays. In children certainly values <0.35 micro moles/litre and in women 0.7 micromoles /liter may indicate deficiency. As a population assessment tool, markers of inflammation should be used to adjust the serum retinol concentration (Tanumihardjo, 2012). In women, serum retinol concentrations have responded to vitamin A supplementation, if the values are initially low. However, in other population the serum retinol levels may not improve even with high doses of supplements (Tchum et al., 2006).

Whereas biological and chemical indicators are widely used to assess the prevalence and severity of vitamin A deficiency, literature puts forward another set of indirect indicators that can be use in the absence of direct indicators. Such indicators ecological and related indicators that have been associated with the clustering of vitamin A deficiency. These indicators help to identify populations where vitamin A deficiency is likely to be deficient by focusing on the factors that are responsible for, or contribute to, the problems occurrence.

Such indirect indicators do not replace biological indicators and cannot be used alone for determining vitamin A status of a given population. However, a composite based on them can be used to corroborate biological criteria to determine in there is a public health problem (World Health Organization 2014). The ecological and related indicators can be collected in the course any demographics, socioeconomic or health and nutrition surveillance activity. Such indicators include; nutrition status information, food availability, food consumption patterns and levels of intake among the vulnerable groups, illness related indicators, socioeconomic indicators. A composite of several from each of the three categories could be measured and evaluated. Relatively limited research has been done to evaluate the relationship between ecological and related indirect indicators and vitamin A deficiency. This study examined nutrition and diet indicators in the assessment of vitamin A deficiency/status.

1.6 Public health impact of vitamin A deficiency

Vitamin A is essential for health maintenance and represents one of the most prevalent micronutrient deficiencies in many parts of the world, particularly in Africa and Southeast Asia (WHO, 2020). Vitamin A deficiency mainly affects children and women during pregnancy and lactation due to their increased demands (Bailey et al., 2015a; Robert E Black et al., 2008). Vitamin A deficiency is responsible for over 600,000 deaths per year in mostly young children and pregnant women (Black et al., 2008). It can cause visual impairment in night blindness and an increased risk of illness and death from childhood infection, including measles and diarrheal diseases (Sahile et al., 2020) . It is estimated that about 30% of children (in developing countries) are vitamin A deficient, and 2% of under 5-child mortality is attributable to vitamin A deficiency (Stevens et al., 2015; WHO, 2020). Vitamin A deficiency can develop early in life, especially in populations that consume low provitamin A carotenoids and people prone to infection (Mitra, et al., 1998).

The body cannot synthesize Vitamin A and must provide it through the diet. Vitamin A is essential for iron mobilization, transport, and formation. Fortunately, Chronic insufficiency of vitamin A leads to reduced body stores that fail to meet the physiological needs that are tissue growth, normal metabolism, and resistance to infections (WHO, 2009). Persistence deficiency can lead to disorders such as dryness of the eyes (xeropthalmia leading to blindness), anemia, and increased risk of death due to reduced immunity (WHO, 2009). Women of reproductive age and children are at a greater risk of these health consequences (WHO, 2009).

Vitamin A is needed in small amounts for normal functioning of the visual system, maintenance of cellular function for growth, epithelial integrity, red blood cell production, immunity, and reproduction (Hassen Bennasir, Shanmugam Sridhar, & Tarek T Abdel-Razek, 2010). In much of the developing world, up to 90% of the vitamin A in the diets comes from plant sources, such as dark leafy green vegetables, deep yellow vegetables, and deep yellow fruits (Bloem, De Pee, & Darnton-Hill, 1998). These can be grown locally or subsistent. Therefore, homestead food production (HFP) is one of the community interventions that can contribute to combating vitamin A deficiency directly by increasing the intake of vitamin A-rich foods, thus contributing to the reduction of vitamin A deficiency (Iannotti, Cunningham, & Ruel, 2009). This also indirectly contributes to improved health and income, especially for women in the reproductive age group (A. W. Girard, J. L. Self, C. McAuliffe, & O. Olude, 2012) and to the overall nutrition status of the population (A. W. Girard et al., 2012).

1.7 Agricultural Interventions: Orange-Fleshed Sweet Potatoes

The agriculture-nutrition gap is systematic and presents an opportunity to bridge agriculture and health policies to enhance multi-sectoral initiatives aimed at improving

population health and development (Bose, Baldi, Kiess, & de Pee, 2019). Agricultural and income-generation interventions have traditionally focused on promoting the production of diverse foods, however, the focus on livelihoods often excludes examination of the nutritional and health impacts on targeted households. Food based approaches have been identified as one of the strategies necessary to improve micronutrient deficiencies and ensure sustainable progress in this effort (Gibson, 2011). Biofortication represents one approach within food-based strategies and is defined as the process of improving the nutrition quality of food (Khush, Lee, Cho, & Jeon, 2012). Breeding crops, such as sweet potatoes, with high levels of vitamins and minerals, as well as protein and fat content improve the nutrient density of the crops. Biofortication is a feasible and cost-effective complementary strategy of delivering micronutrients to low income households that may have limited access to diverse diets, micronutrient supplementation, and food fortification (Gibson, 2011).

Beta-carotene rich orange-fleshed sweet potatoes (OFSP) have emerged as an important member of the tropical tuber crops with a higher potential of being adopted as a regular diet of the consumer food chain to tackle the problem of vitamin A deficiency. Sweet potatoes are the second most produced root tuber and the seventh most produced food crop globally (Mitra, 2012). It represents one of the staple foods in East African countries. Uganda is the world's second largest producer of sweet potato after China (Mwanga & Ssemakula, 2011), with an annual production of 2.6 million tones from 578,000 hectares (Mwanga & Ssemakula, 2011). Often referred to as a ''poor man's food or famine crop'', OFSP have tremendous potential to contribute to a food based approach in promoting food security and economic wellbeing of communities because of its diverse range of positive attributes such as high yield with limited input, short duration for growth, high nutritional value, and tolerance to various production stresses (Mitra, 2012). With the aim of improving food security and livelihoods in SSA, specifically in Uganda, the International Potato Centre initiated the

Development and Delivery of Biofortified Crops to scale (DDBIO) project to increase production and consumption of OFSP. This study analyses the vitamin A consumption of among women and children from selected regions in Uganda.

1.8 Hypotheses tested

Specific Aim 1: Characterize vitamins rich foods consumption and associated factors of women from selected regions in Uganda

Hypothesis: Women in the reproductive age group who are knowledgeable about vitamin A and beta-carotene rich orange-fleshed sweet potatoes and its benefits are likely to consume vitamin A rich foods more frequently compared to women who are less knowledgeable.

Specific aim 2: To conduct a comparative analysis of food security indicators by vitamin A rich food consumption of women and children from selected households in Uganda.

Hypothesis 2a: Women are likely to consume diets that are different from those of the children in the household

Hypothesis 2b: Food influences vitamin A rich food consumption for women and children

1.9 Significance and innovation of the study

A food-based approach with a focus potential for orange-fleshed sweet potatoes in combating vitamin A deficiency remains untapped in sub-Saharan Africa. In Uganda, with the yields of white fleshed sweet potato varieties being ten times higher than that of orange fleshed sweet potato varieties, there is still need for the increased production and consumption of OFSP varieties that are high in beta-carotene to combat vitamin A deficiency (CIP, 2011) (Betty J Burri, 2011). This study will generate an evidence base to inform interventions aimed at increasing consumption of OFSP and subsequently improving vitamin A status in the Ugandan rural population.

The public health importance of vitamin A has widely been studied, and vitamin A intake interventions are low-cost, easy to scale-to-scale, with reductions in VAD-related disability and mortality (Series, 2008). Reducing the occurrence of VAD can profoundly benefit population health in low-income countries, leading to increased productivity, reduced disability life years, and greater life expectancy. National information on vitamin A intake patterns among women and children in Uganda is current outdated and such information is essential in informing national policy and action. There are limited nutritional epidemiology studies that examine Vitamin A deficiency in women of reproductive age in the East African context. This study specifically focuses on communities perpetrated by human-made disasters and will inform interventions within these targeted communities. The proposed study primarily focuses on women and children with an emphasis of pregnant and lactating women who are at a higher risk in susceptible populations.

1.10 Conceptual framework

This study utilizes two theoretical models, the socioecological model and the sustainable livelihood framework, in its conceptual framework. In characterizing vitamin-A rich food consumption and associated factors, we intend to utilize the socioecological model (SEM) to better understand factors influencing women and children's dietary intake of vitamin A rich foods in the Northern and Eastern regions in Uganda. The socioecological model has been used to understand the influence of multiple determinants of behaviour in previous research (Caperon et al., 2019; Townsend & Foster, 2013). An individual's vitamin A rich food consumption takes into consideration ones affliation to people, organisations and their community at large to be effective. The current study will focus on individual factors as well as relations with other people at the household and community levels. Understanding such factors helps to develop practical solutions in the improvement of dietary behaviour

with long term implications on the health of women and children. Thus, the proposed study will illuminate multilevel factors that influence dietary behaviour related to vitamin A intake among women and children in the northern and eastern regions of Uganda.

The sustainable livelihood framework (SLF) is a conventional approach poverty eradication that integrates the achievement of sustainable livelihoods as the broader goal for poverty eradication (Krantz, 2001)(UNDP, 2017). Household livelihood security represents adequate and sustainable access to income and resources to meet basic needs (Frankenberger, 1996). The production and consumption of vitamin A rich food with emphasis on OFSP is a component of the broader food security livelihood outcome. Additionally, livelihoods become sustainable when households can cope with and recuperate from stresses and shocks, as well as maintain or enhance their capabilities and assets without undermining the natural resource base (Krantz, 2001).

Earlier discussions of the livelihood models have primarily focused on rural areas and farmers or others making a living through some kind of self-managed production (Agrawal & Gibson, 1999). This study focuses on sweet potato growing households in two regions in Uganda. The unit of analysis is the individual as opposed to the resources generated. We posit those problems associated to development root in adverse institution structures that cannot be overcome by simple asset creation (GLOPP, 2008). Environmental conditions, such as serious and sustained droughts, exemplify the vulnerability of people and communities in rural developing economies to acute physical stresses (Connolly-Boutin & Smit, 2016). Such shocks impact communities whose vulnerability is largely affected by poverty and weak infrastructural support leading to devastating consequences for people's food security and livelihoods.

Food insecurity results from interactions of multiple stressors including socioeconomical and environmental factors (Connolly-Boutin & Smit, 2016; Laraia, Siega-

Riz, & Gundersen, 2010). Food security is considered a fundamental livelihood outcome and uncertainty in one's ability to acquire nutritious food in a safe and socially acceptable manner is largely associated with negative healthy consequences (Eisenmann, Gundersen, Lohman, Garasky, & Stewart, 2011; Hanson & Connor, 2014). Dietary diversity can be used as an entry component to food security (FANTA 2012-2018), with the understanding that linkages to food security based on the SL framework is often held in the context of household dietary diversity (J. Hoddinott, Ahmed, Ahmed, & Roy, 2017).

The sustainable livelihood model provides an analytical approach to facilitate a broad and systematic understanding of the various factors that constrain or enhance livelihood opportunities and how they relate to each other (Sheets, 1999). Vulnerability to food insecurity and micronutrient deficiency is linked to household composition, agricultural livelihood characteristics, and presence of livestock in a given household. However, an improvement in the economic status of a household may not necessarily lead to an improvement in the household's dietary diversity (Fraval et al., 2019). This model will also help in examining indicators of food security. This lays a foundation for the development and delivery of biofortified foods in Uganda which focuses on improving food security in these communities and seeks to enhance the livelihoods of these communities. The proposed study integrates the socioecological model with the sustainable livelihood framework (Figure 1. Conceptual Framework).

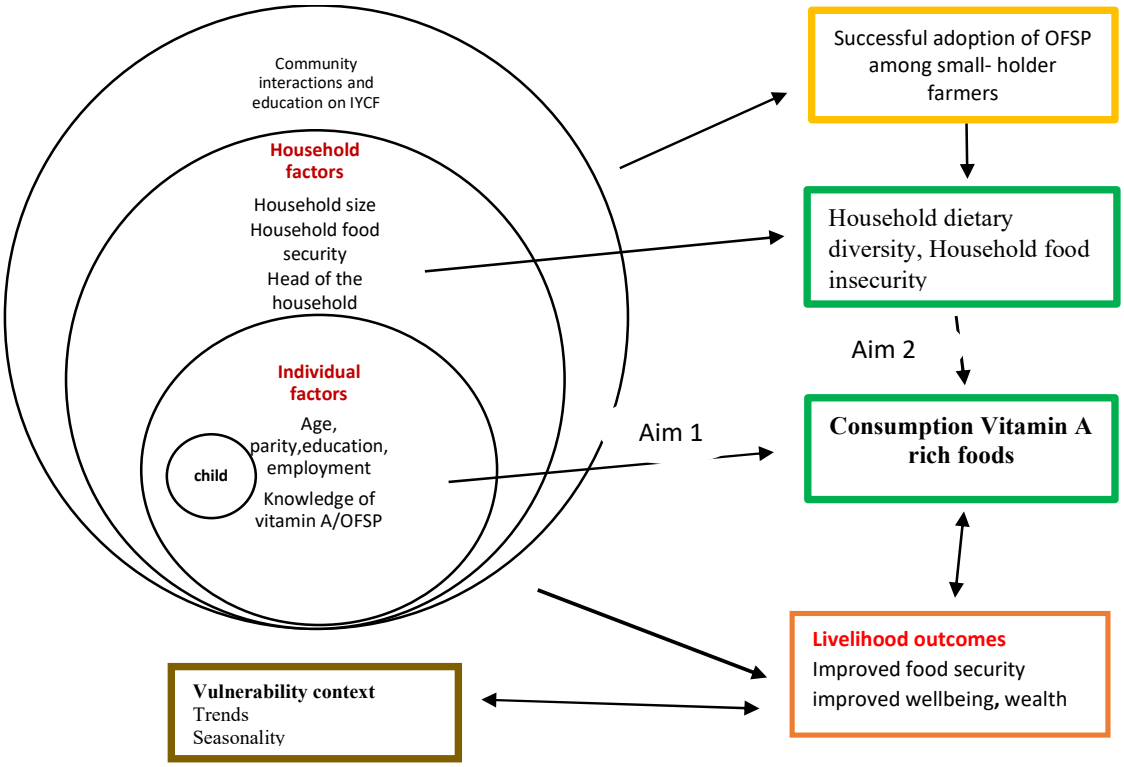

Figure 1.1: Conceptual framework

CHAPTER II

A SYSTEMATIC REVIEW OF THE EFFECTS OF FOOD-BASED APPROACHES ON VITAMIN A STATUS OF WOMEN AND CHILDREN

2.1 Abstract

Vitamin A deficiency (VAD) remains a worldwide public health concern. Women and children continue to experience vitamin A deficiency with increased risk of morbidity and mortality. Efforts to combat VAD, including vitamin A supplementation programs, often fall short due to their inability to reach the rural poor and high implementation costs. Food-based approaches have been identified as a strategy to improving vitamin A status. This systematic review assessed evidence of the effects of food-based approaches on vitamin A status of women and children. The review was reported using Prisma guidelines for systematic reviews. Searches were conducted on PubMed, CINHAL, Web of Science and Google Scholar from May to November 2021 with a search period between 2011 and 2021. Of the 27,323 identified references, 24 publications were included in the review.

Thirteen studies (54%) were experimental using biochemical measurements for vitamin A status. Other studies deduced vitamin A status from clinical examination or dietary intake of vitamin A rich foods. The predominant recruitment methods were randomization for the experimental studies or simple random sampling for the observational studies. Six studies reported a statistically significant difference in the level of vitamin A status or improvement of vitamin A deficiency. Four studies reported a significant association between dietary intake of vitamin A rich sources and vitamin A status. Based on this review, there is some indication of the positive benefits of food-based approaches. Due to methodological limitations of study and varying durations of the intervention periods across studies, results should not be interpreted as lack of evidence or the absence of an effect. Food based approaches could provide a safe and effective delivery mechanism for vitamin A.

2.2 Introduction

Vitamin A is an essential micronutrient needed for the normal functioning of the visual system, growth and development, as well as maintenance of epithelial cellular integrity, immune function, and reproduction (Hassen Bennasir, Shanmugam Sridhar, & Tarek T Abdel-Razek, 2010b). The dietary needs for vitamin A are provided as preformed retinol and provitamin A carotenoids (Dawson, 2000). Preformed Vitamin A in animal foods occurs as retinyl esters of fatty acids and during digestion, vitamin A is efficiently made free from the matrices compared to plant protein provitamin A (Huang et al., 2018; Shannon et al., 2017).

Preformed vitamin A is found almost exclusively in animal products such as human milk, glandular meats, liver, and fish liver oils. Preformed vitamin A is also used to fortify processed foods, which may include sugar, cereals, condiments, fats, and oils. Provitamin A carotenoids are found in Orange-fleshed sweet potatoes, green leafy vegetables such as spinach, amaranth, and young leaves from various plants; yellow vegetables like pumpkin, squash, and carrots; and yellow and non-citrus fruits including mangoes and papaya (García-Closas et al., 2004). Foods containing provitamin A carotenoids tend to have less bioavailable vitamin A but are more affordable than animal sources of the vitamin (Padayatty et al., 2010). Plant foods rich in provitamin A represent more than eighty percent (80%) of the total food intake of vitamin A. It is mainly for this reason that carotenoids provide most of the vitamin A activity in the diets of economically deprived populations in the world (Codjia, 2001).

The World Health Organization (WHO) defines vitamin A deficiency (VAD) as tissue concentrations of vitamin A low enough to have adverse health consequences even if there is no evidence of clinical xeropthalmia (WHO, 2004). In addition to the specific signs and

symptoms of xeropthalmia and the risk of irreversible blindness, non-specific symptoms include increased morbidity and mortality, poor reproductive health, increased risk of anemia, and contributions to slowed growth and development (WHO,2004). However, these nonspecific adverse effects may also be caused by other nutrient deficiencies such as iron, zinc and the B-vitamins (Ramakrishnan, Nguyen, & Martorell, 2009) which makes it difficult to attribute non-ocular symptoms to VAD in the absence of biochemical measurements reflective of vitamin A status (Ribeiro, Jaeger, & Ortiz, 2013; World Health Organization, 2004).

Vitamin A deficiency can occur in individuals of any age, with higher susceptibility among children and women. It is a disabling and potentially fatal public health problem for children under six years (Mannar & Hurrell, 2018; Stevens et al., 2015b). Blindness caused by VAD is more prevalent in children under three years of age (World Health Organization, 2009b). This early childhood period is characterized by high vitamin A requirements to support rapid growth and the transition from breastfeeding to dependence on other dietary sources of the vitamin (Ilich & Brownbill, 2010). Women of reproductive age are also vulnerable to VAD during pregnancy and lactation evidenced by reports of night blindness and low vitamin A levels in breast milk (UNICEF/WFP/WHO, 2007).

Globally, an estimated three million children have some form of xeropthalmia based on retinol blood levels, with Africa contributing to more than a third of these cases (World Health Organization, 2009b). Between 1995 and 2005, WHO estimated 190 million preschool children and 19 million pregnant women were affected by VAD (World Health Organization, 2009b). The actual number of subclinical deficiencies based on the prevalence of low serum levels of retinol remains uncertain because of the confounding and poorly quantified role of infections (WHO, 1998). As such, the subclinical trend continues to be re-evaluated to establish the quantitative benchmark for measuring prevalence trends. VAD, or

serum retinol < 0.70 μmol/L, is estimated to affect over 127 million children globally and more than one third of the children in sub-Saharan Africa (Bastos Maia et al., 2019a; Justin C Sherwin, Mark H Reacher, William H Dean, & Jeremiah Ngondi, 2012b).

In low and middle income countries (LMIC), up to 90% of the vitamin A in the diet is derived from plants such as dark leafy green vegetables, deep yellow vegetables, and deep yellow fruits (Bloem et al., 1998). Homestead food production (HFP) can contribute to combating vitamin A deficiency directly by increasing the intake of vitamin A-rich foods (Pee & Bloem, 2007). HFP also indirectly contributes to improved health and income, especially for women in the reproductive age group (Haselow, Stormer, & Pries, 2016), thus impacting the overall nutritional status of the population.

Food-based approaches, including biofortification, have been identified as a key strategy in improving multi-micronutrient deficiencies (Gibson, 2011). For example, biofortification is the process of improving the nutrition quality of food through plant breeding, biotechnology, or agronomic initiatives (WHO, 2019). Breeding crops, including sweet potatoes with high levels of vitamins and minerals, proteins, and fat content improves the nutrient profile of the crops. Biofortification is a feasible and cost-effective complementary strategy of delivering micronutrients to poor households that may have limited access to diverse diets and other micronutrient interventions such as supplementation and food fortification (Gibson, 2011).

Food-based interventions that focus on using foods that are naturally rich in vitamin A or other micronutrients provide a key strategy in combatting micronutrient deficiencies (Robert E Black et al., 2013; Nabarro, 2013). Specifically, growing fruits and vegetables that are rich in vitamin A forming carotenoids are a good alternative to providing vitamin A supplements or fortifying foods (Betty J Burri, 2011). Poor communities have limited access to animal sourced foods that are rich in vitamin A with higher bioavailability, such as fish oil,

liver, eggs, and butter. Considerable efforts are therefore made in low-income countries to promote vitamin A intake through increased production of affordable plant sources (Mitra, 2012).

A number of staple crops have been considered for biofortification in various settings including vitamin A enriched orange-fleshed sweet potatoes, yellow cassava, and orange maize; iron enriched beans and pearl millet; and zinc enriched rice and wheat (HarvestPlus, 2021). These micronutrient-rich crops have been released, tested, and grown in more than 30 countries worldwide (HarvestPlus, 2021). For example, sweet potato is the second most important root crop and the seventh most important food crop globally (Mitra, 2012). It is also one of the main staple foods in East Africa. Uganda is the world's second-largest producer of sweet potatoes after China (Mwanga & Ssemakula, 2011), with an annual production of 2.6 million tonnes from 578,000 hectares (Mwanga & Ssemakula, 2011).

Beta-carotene-rich orange-fleshed sweet potatoes have emerged as root crops with a higher potential of being adopted into regular diets and as a key strategy for addressing VAD in low income countries (Low et al., 2017). Often referred to as the "poor man's food or famine crop", consumption of orange-fleshed sweet potatoes has tremendous potential as a food-based approach in promoting food security, improving economic wellbeing, and alleviating VAD (Low et al., 2017). This crop has a diverse range of attributes such as high yield with limited input, short growth duration, high nutritional value, and tolerance to various production stresses (Mitra, 2012). The International Potato Centre's "Development and Delivery of Biofortified Crops at Scale" project (DDBIO) aims to improve food security and livelihoods in Uganda and throughout Sub-Saharan Africa by increasing the production and consumption of provitamin A biofortified sweet potatoes.

There is a dearth of information on the effectiveness of vitamin A intervention programs within the last decade, yet evidence-based nutrition interventions including food

biofortification offer an opportunity for effective and catalytic programming to achieve global development targets, eradicate malnutrition, and improve health outcomes at scale (Mandana Arabi, 2021). More specifically, there is no recent review that documents and evaluates the effectiveness of the various food-based approaches in combatting VAD.

The purpose of this systematic review is to document the scientific evidence on the effectiveness of food-based approaches on addressing VAD or improving vitamin A status of women and children. This review identifies, evaluates, and summarizes the findings of several studies in the improvement of vitamin A status.

2.3 Methods

The authors extensively reviewed and followed the systematic review process as reported by Crowther, Lim & Crowther (Crowther, Lim, & Crowther, 2010). This review adheres to the Prisma guidelines (Moher et al., 2015). Systematic searches and extractions were used to map the literature and identify key concepts and research opportunities. We conducted a literature search using four large databases including PubMed, CINHAL, Web of Science, and Google Scholar. The search strategy was developed over time in consultation with the University of Massachusetts Amherst health science librarian until we reached saturation in the results.

Two of the authors worked as a team to develop a complex search strategy using text words, index, truncation, and Boolean operators (Lefebvre et al., 2019). The framework employed the following search strategies in PubMed, CHNHAL, Web of Science and Google Scholar: ("Food-based approach*" OR "strateg*" OR" program*" OR "intervention*" OR "trial" OR experiment*") AND ("vitamin A status" OR ''vitamin A deficienc*") AND ("women" OR "young child*" OR "infant*" OR "toddler*"). The * symbol serves as a wildcat that stands in for any letters to finish the word. Additional searches were conducted

manually by looking at citations of full text reviews, thus serving as a reference list search (i.e., backward reference search) and cited reference search (i.e., forward reference search). All searches were conducted and logged from May 2021 to December 2021.

2.3.1 Eligibility and exclusion criteria

Studies with publication dates between 2011 and 2021 were included in this empirical study. The time period was selected as there are no reviews covering the past decade. We included research studies 1) that focused on interventions or programs of food-based approaches in improving vitamin A status or VAD of women and children under the age of five years or 2) cross-sectional studies that explored the relationship between diets and vitamin A status of women and children, as well as those that were 3) English language publications in scholarly peer-reviewed journals. Studies were excluded if they are single case studies, unpublished theses or dissertations, and not published in peer-reviewed journals.

2.3.2 Study selection

Detailed information about the study selection process is provided in the PRISMA flow diagram (Figure 2.1). A total of 27,323 studies were identified in the initial process (PubMed: 918 articles, CINAHL: 1330, Web of Science: 3674, Google Scholar: 21400 articles). The title and abstracts of the studies were examined and 26,898 studies were excluded due to unsuitability for the present review. A further 115 studies were excluded due to duplication and only having an abstract. Consequently, a total of 351 studies were selected for in-depth examination after which 286 studies were excluded for language limitations, being irrelevant to the main subject, and repetitive publication and single case reports. Following these procedures, 24 empirical studies were included in the final systematic review.

2.3.3 Quality assessment

Each study was assessed for quality by the two independent researchers. We assessed the risk of biases in each of the studies following recommendations of the Agency for Healthcare Research and Quality (AHRQ) Evidence-based Practice Center (EPC) Methods Guide for Effectiveness and Comparative Effectiveness Reviews on assessing the risk of bias of individual studies (Viswanathan et al., 2017). Among the recommendations applicable to this review were: using a tool that is specific to the study design being evaluated, showing transparency in how assessments are made, and avoiding the presentation of the risk of bias assessment as a numerical score. For the cross sectional studies, we used the AXIS tool for the correctional studies as described by Downes et al. (Downes, Brennan, Williams, & Dean, 2016), and for the intervention studies we referred to the revised tool to assess the risk of bias in randomized trials (Sterne et al., 2019).

2.3.4 Data extraction

A standard form was used to extract details from each article. The form included authors, year of publication, study design, study objective, sample size, recruitment method(s), sample eligibility criteria, geographical location of the study, measures of vitamin A status and or VAD, type of food-based approach, sample sociodemographic characteristics, statistical methods used, and the effects or relationship of the food-based approach/intervention and vitamin A status/VAD. Data were independently extracted from articles by two research team members. The independent data extractions were reviewed by a single member of the research team and reconciled by comparison of the extracted data with the original research articles.

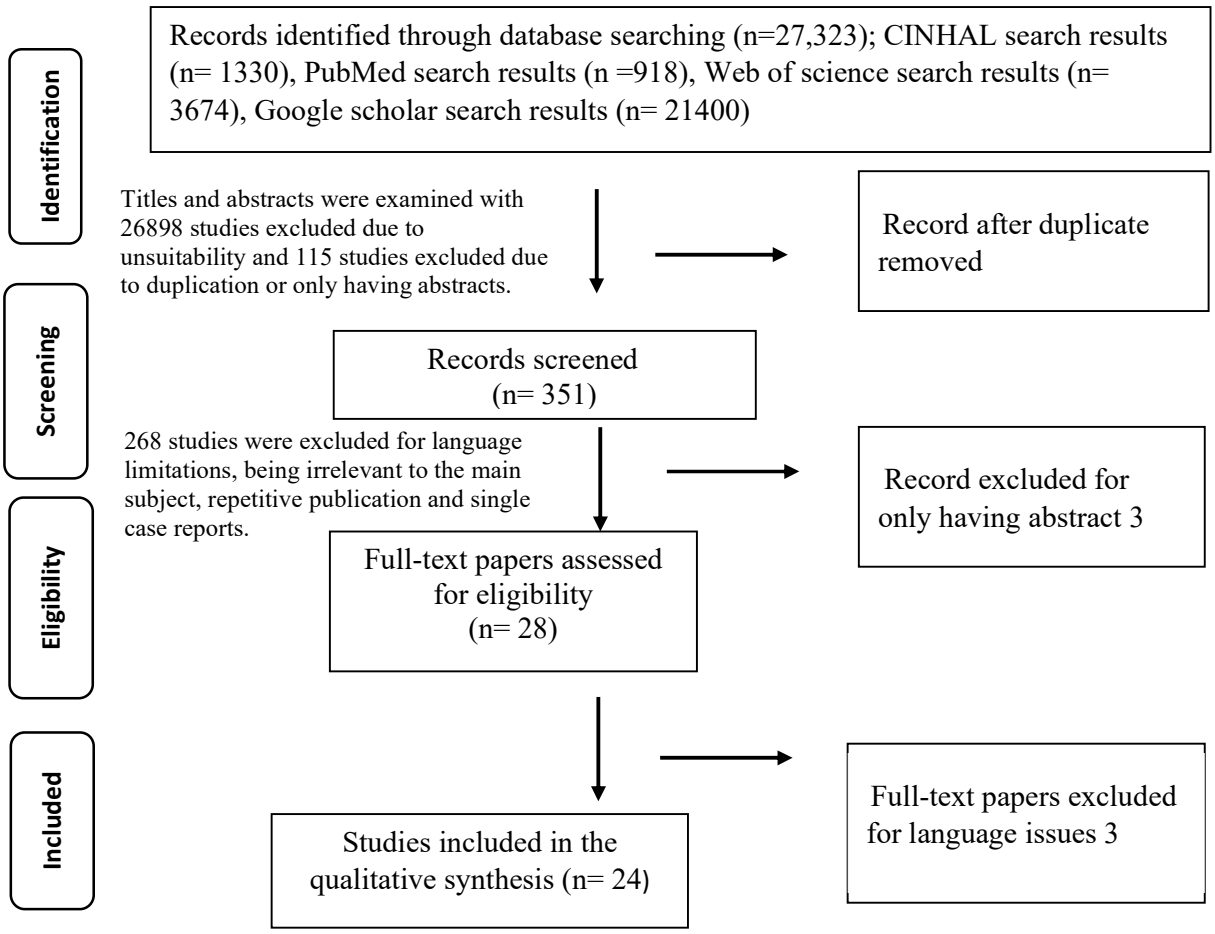

FIGURE 2.1. Systematic review flow diagram on the effects of food-based approaches in vitamin A-rich food consumption. The PRISMA flow diagram for the systematic review detailing the database searches, the number of abstracts screened, and the full texts retrieved.

2.4 Results

2.4.1 Study Characteristics

Information on the general characteristics and main methodological properties of the included 24 studies are shown in Table 2.1.

2.4.2 Geographical location of the studies

The studies included in the review were conducted in Africa, Asia, and the United States of America. One study was conducted in each of the following countries: Uganda (C. Hotz et al., 2012), Tanzania (Ndau et al., 2016b), Kenya (Girard et al., 2017), Cameroon (Engle-Stone et al., 2017), Mozambique (Christine Hotz, Cornelia Loechl, Alan de Brauw, et al., 2012), Mexico (Lopez-Teros et al., 2013), Philippines (Mason et al., 2011), and Thailand (Pinkaew, Udomkesmalee, Davis, & Tanumihardjo, 2021). Two studies were conducted in each of the following countries: Nigeria (Afolami et al., 2021; De Moura et al., 2015), Zambia (Palmer, Chileshe, et al., 2016; Palmer, Healy, et al., 2016), India (Sachdeva, Alam, Beig, Khan, & Khalique, 2011; Suri, Kumar, & Das, 2017), and United States of America (La Frano, Woodhouse, Burnett, & Burri, 2013; Zhu et al., 2015). Three studies were conducted in Bangladesh (Jamil et al., 2012b; Rahman et al., 2017; Turner, Burri, Jamil, & Jamil, 2013) and four studies were conducted in Brazil (Bastos Maia et al., 2018; Lima, Damiani, & Fujimori, 2018; Lira et al., 2018; Neves et al., 2019).

2.4.3 Participant Characteristics

The reviewed studies included 8 to 3,571 participants. Three studies recruited less than one hundred (N<100) participants, ranging from 8 to 70 participants (La Frano et al., 2013; Pinkaew et al., 2021; Zhu et al., 2015). The other studies recruited more than 100 participants, with the highest number being 3571 participants (Afolami et al., 2021; Bastos Maia et al., 2018; De Moura et al., 2015; Engle-Stone et al., 2017; Girard et al., 2017; Christine Hotz, Cornelia Loechl, Alan de Brauw, et al., 2012; Christine Hotz, Cornelia

Loechl, Abdelrahman Lubowa, et al., 2012; Jamil et al., 2012a; Jus'at et al., 2015; Lima et al., 2018; Lira et al., 2018; Lopez-Teros et al., 2013; Mason et al., 2011; Ndau et al., 2016b; Neves et al., 2019; Palmer, Chileshe, et al., 2016; Palmer, Healy, et al., 2016; Rahman et al., 2017; Sachdeva et al., 2011; Suri et al., 2017; Turner et al., 2013).

All women included in the studies were in the reproductive age group ranging from 15-49 years, with a mean of 34.0 ±0.5 years. Seven studies included children between zero months to nine years. Only one study included children from zero to 60 months (Sachdeva et al., 2011). Three studies recruited children beyond five years (Jus'at et al., 2015; Palmer, Healy, et al., 2016; Rahman et al., 2017). The other studies included children between six months and five years (De Moura et al., 2015; Christine Hotz, Cornelia Loechl, Abdelrahman Lubowa, et al., 2012; Suri et al., 2017). The lowest and highest reported mean ages for children were 20.8 ±0.5 months and 5.7 ± 1.3 years respectively.

Two studies recruited participants that were well-nourished with adequate vitamin A intake (La Frano et al., 2013; Zhu et al., 2015), whereas other studies reported that the participants had mild to moderate VAD (Afolami et al., 2021; De Moura et al., 2015; Christine Hotz, Cornelia Loechl, Abdelrahman Lubowa, et al., 2012; Jamil et al., 2012a; Mason et al., 2011; Palmer, Chileshe, et al., 2016; Palmer, Healy, et al., 2016; Pinkaew et al., 2021; Turner et al., 2013), or lower vitamin A breast milk concentrations (Engle-Stone et al., 2017; Girard et al., 2017).

Six out of the 24 studies included in this review included both women and children (Engle-Stone et al., 2017; Christine Hotz, Cornelia Loechl, Alan de Brauw, et al., 2012; Christine Hotz, Cornelia Loechl, Abdelrahman Lubowa, et al., 2012; Rahman et al., 2017), or mother-infant dyads (De Moura et al., 2015; Lira et al., 2018). Nine studies recruited only women (Bastos Maia et al., 2018; Girard et al., 2017; Jamil et al., 2012b; La Frano et al., 2013; Ndau et al., 2016b; Neves et al., 2019; Pinkaew et al., 2021; Turner et al., 2013; Zhu et al., 2015).

Five studies included only children (Lima et al., 2018; Mason et al., 2011; Palmer, Healy, et al., 2016; Sachdeva et al., 2011; Suri et al., 2017). All the children included in these studies were less than or equal to five years of age.

2.4.4 Risk of bias in individual studies

All the included studies were assessed for the risk of bias. Most of the studies explicitly stated the objective of the study as food-based approaches and vitamin A status or VAD; the population of interest; and the exposure and outcome of the study (Afolami et al., 2021; Engle-Stone et al., 2017; Girard et al., 2017; Christine Hotz, Cornelia Loechl, Abdelrahman Lubowa, et al., 2012; Jamil et al., 2012a; La Frano et al., 2013; Lima et al., 2018; Lopez-Teros et al., 2013; Mason et al., 2011; Palmer, Chileshe, et al., 2016; Palmer, Healy, et al., 2016; Pinkaew et al., 2021; Turner et al., 2013; Zhu et al., 2015). In the process of assessment, studies were identified as having a risk for sampling bias if they had loss to follow up (Girard et al., 2017; Christine Hotz, Cornelia Loechl, Abdelrahman Lubowa, et al., 2012; Pinkaew et al., 2021) and measuring the exposure or the outcome given recalling information increases bias (De Moura et al., 2015; Palmer, Chileshe, et al., 2016; Turner et al., 2013). Studies with stringent inclusion criteria or greater than 15 percent loss to follow up were considered to have a higher risk of sampling bias (Bastos Maia et al., 2018; Girard et al., 2017; Christine Hotz, Cornelia Loechl, Abdelrahman Lubowa, et al., 2012; Lopez-Teros et al., 2013; Mason et al., 2011; Pinkaew et al., 2021). One study explicitly reported a high risk of measurement bias as one of its limitations (Suri et al., 2017). Studies that evaluated vitamin A status were regarded having a risk of measurement bias (Suri et al., 2017). The evaluation of the risk of bias is detailed (Table 2.2).

2.4.5 Methodological features of the studies

All studies reviewed were empirical and quantitative in nature. Of the 24 studies, 13 studies (54%) were experimental studies including cluster randomized trials, randomized

trials, and randomized crossover studies (Afolami et al., 2021; Girard et al., 2017; Christine Hotz, Cornelia Loechl, Alan de Brauw, et al., 2012; C. Hotz et al., 2012; Jamil et al., 2012b; La Frano et al., 2013; Lopez-Teros et al., 2013; Mason et al., 2011; Palmer, Chileshe, et al., 2016; Palmer, Healy, et al., 2016; Pinkaew et al., 2021; Turner et al., 2013; Zhu et al., 2015). Nine of the experimental studies, were randomized control studies with two arms or groups (Afolami et al., 2021; De Moura et al., 2015; Girard et al., 2017; Christine Hotz, Cornelia Loechl, Alan de Brauw, et al., 2012; Christine Hotz, Cornelia Loechl, Abdelrahman Lubowa, et al., 2012; Lopez-Teros et al., 2013; Palmer, Chileshe, et al., 2016; Pinkaew et al., 2021; Turner et al., 2013). Three studies were randomized control trials with more than two arms; one study had three arms (Mason et al., 2011) and two studies had four arms (Jamil et al., 2012a; Turner et al., 2013). Two randomized crossover trials were included (La Frano et al., 2013; Zhu et al., 2015), with a minimum of two weeks between food-based treatments. One pre- and post-evaluation study was also included (Jus'at et al., 2015) (Table 2.1).

Eleven studies (46%) were nonexperimental (Bastos Maia et al., 2018; De Moura et al., 2015; Engle-Stone et al., 2017; Jus'at et al., 2015; Lima et al., 2018; Lira et al., 2018; Ndau et al., 2016b; Neves et al., 2019; Rahman et al., 2017; Sachdeva et al., 2011; Suri et al., 2017), with one study being a prospective cohort study (Neves et al., 2019). One study had a longitudinal design with an intended intervention (Ndau et al., 2016b) and the remaining ten were cross-sectional studies (Bastos Maia et al., 2018; De Moura et al., 2015; Engle-Stone et al., 2017; Jus'at et al., 2015; Lima et al., 2018; Lira et al., 2018; Ndau et al., 2016b; Rahman et al., 2017; Sachdeva et al., 2011; Suri et al., 2017).

2.4.6 Sampling techniques

The reviewed studies employed various sampling techniques at different stages of the design including multistage cluster sampling, random cluster sampling (De Moura et al., 2015; Christine Hotz, Cornelia Loechl, Alan de Brauw, et al., 2012; Christine Hotz, Cornelia

Loechl, Abdelrahman Lubowa, et al., 2012; Palmer, Chileshe, et al., 2016), systematic sampling at the household level, as well as simple random sampling of the participants (Jus'at et al., 2015; Pinkaew et al., 2021; Rahman et al., 2017; Suri et al., 2017; Turner et al., 2013). All the experimental studies employed randomization of participants to the study arms. Four studies purposively selected women who met the inclusion criteria (Girard et al., 2017; Jamil et al., 2012a; Mason et al., 2011; Sachdeva et al., 2011). In other studies, only children under the age of five years were included in the study (Afolami et al., 2021; Lima et al., 2018; Lopez-Teros et al., 2013; Mason et al., 2011; Palmer, Healy, et al., 2016; Sachdeva et al., 2011; Suri et al., 2017).

2.4.7 Food based approaches or diet

The food-based approaches identified in the review included examination of the following biofortified foods: orange-fleshed sweet potatoes (Girard et al., 2017; Christine Hotz, Cornelia Loechl, Alan de Brauw, et al., 2012; Christine Hotz, Cornelia Loechl, Abdelrahman Lubowa, et al., 2012; Jamil et al., 2012a; Turner et al., 2013), provitamin A-fortified cassava (Afolami et al., 2021; De Moura et al., 2015; La Frano et al., 2013; Zhu et al., 2015), tangerines (Turner et al., 2013), vitamin A fortified rice (Pinkaew et al., 2021), orange maize (Palmer, Chileshe, et al., 2016; Palmer, Healy, et al., 2016), vitamin A fortified milk (Lopez-Teros et al., 2013), palm oil (Zhu et al., 2015), vitamin A fortified cooking oil (Jus'at et al., 2015; Ndau et al., 2016b), and vitamin A fortified coconut oil (Engle-Stone et al., 2017; Mason et al., 2011). Fruits from the Amazon rain forest were included as an exposure in one study (Neves et al., 2019). Other studies focused on dietary intake of vitamin A-rich sources and associations with vitamin A status or VAD (Bastos Maia et al., 2018; Lima et al., 2018; Ndau et al., 2016b; Rahman et al., 2017; Sachdeva et al., 2011). Four studies included vitamin A capsules in the intervention for comparison with the food-based

approach or dietary intake of vitamin A-rich foods (Jamil et al., 2012a; Mason et al., 2011; Palmer, Chileshe, et al., 2016; Turner et al., 2013).

Interventions featured in studies included distribution of supplemental foods to communities or participants to add to daily consumption. Distribution of plant materials such as orange-fleshed sweet potato vines was also part of the intervention in three studies (Girard et al., 2017; Christine Hotz, Cornelia Loechl, Alan de Brauw, et al., 2012; Christine Hotz, Cornelia Loechl, Abdelrahman Lubowa, et al., 2012) and resulted in higher consumption of orange-fleshed sweet potatoes (Girard et al., 2017; Christine Hotz, Cornelia Loechl, Alan de Brauw, et al., 2012; Christine Hotz, Cornelia Loechl, Abdelrahman Lubowa, et al., 2012). Interventions designed as controlled experiments included 1) prepared meals distributed to participants on top of their daily diets (Afolami et al., 2021; La Frano et al., 2013; Lopez-Teros et al., 2013; Zhu et al., 2015); 2) dietary intake effects on vitamin A status (Jus'at et al., 2015; Lima et al., 2018; Lira et al., 2018; Ndau et al., 2016b; Sachdeva et al., 2011); 3) take-home uncooked foods for consumption with the other foods/meals (Pinkaew et al., 2021; Turner et al., 2013); or 4) vitamin A supplementation compared to dietary intake of Vitamin A-rich foods (Bastos Maia et al., 2018; Jamil et al., 2012a; Mason et al., 2011; Palmer, Chileshe, et al., 2016; Turner et al., 2013).

In randomized controlled trials, the intervention period ranged from three weeks to two years, with three interventions extending beyond 12 months (Christine Hotz, Cornelia Loechl, Alan de Brauw, et al., 2012; Christine Hotz, Cornelia Loechl, Abdelrahman Lubowa, et al., 2012; Mason et al., 2011). Two experimental studies included more than one intervention and comparison arm (Jamil et al., 2012a; Turner et al., 2013) where the exposure was dietary intake assessed through either a food frequency questionnaire (FFQ) (Engle-Stone et al., 2017; Christine Hotz, Cornelia Loechl, Alan de Brauw, et al., 2012; Lira et al., 2018; Neves et al., 2019; Rahman et al., 2017; Suri et al., 2017) or 24-hour recall (Girard et

al., 2017; Christine Hotz, Cornelia Loechl, Abdelrahman Lubowa, et al., 2012; Jus'at et al., 2015; La Frano et al., 2013; Sachdeva et al., 2011).

2.4.8 Vitamin A status/ Vitamin A deficiency

The outcome of interest in the reviewed studies was vitamin A status or vitamin A deficiency evaluated through estimation of serum retinol levels of the participants using different methods. Measurement methods included using high-performance liquid chromatography (HPLC) (Christine Hotz, Cornelia Loechl, Alan de Brauw, et al., 2012; Christine Hotz, Cornelia Loechl, Abdelrahman Lubowa, et al., 2012; Jamil et al., 2012a; La Frano et al., 2013; Lima et al., 2018; Lira et al., 2018; Lopez-Teros et al., 2013; Mason et al., 2011; Neves et al., 2019; Palmer, Chileshe, et al., 2016; Rahman et al., 2017; Turner et al., 2013); enzyme-linked immunosorbent assay (ELISA) (Engle-Stone et al., 2017; Girard et al., 2017; Jus'at et al., 2015; Ndau et al., 2016b); or the retinol isotope dilution (RID) (Pinkaew et al., 2021).

Vitamin A status was also estimated using postprandial plasma TAG retinol lipoprotein (La Frano et al., 2013; Zhu et al., 2015); response to grade light stimuli (Palmer, Healy, et al., 2016); xeropthalmia through ocular examination (Sachdeva et al., 2011); or post-ingestion and VAD deduced from dietary intake (Suri et al., 2017). Twelve of 24 studies reported adjusted serum retinol levels, where serum levels were adjusted for inflammation or subclinical infection (Bastos Maia et al., 2018; De Moura et al., 2015; Engle-Stone et al., 2017; Girard et al., 2017; Christine Hotz, Cornelia Loechl, Abdelrahman Lubowa, et al., 2012; Jamil et al., 2012a; Jus'at et al., 2015; Neves et al., 2019; Palmer, Chileshe, et al., 2016; Pinkaew et al., 2021; Rahman et al., 2017; Turner et al., 2013). Other studies did not report adjustment in serum retinol levels (La Frano et al., 2013; Lima et al., 2018; Lira et al., 2018; Lopez-Teros et al., 2013; Mason et al., 2011; Ndau et al., 2016b).

2.4.9 Effect of food-based approaches or diet on vitamin A status /Vitamin A deficiency of women and children

Ten out of the 24 studies (42%) reported a statistically significant ($p<0.05$) improvement in the vitamin A status or serum retinol levels (Jus'at et al., 2015; Mason et al., 2011; Turner et al., 2013), or improvement in TAG retinol lipoproteins (La Frano et al., 2013), or improvement in total body vitamin A stores (Lopez-Teros et al., 2013; Pinkaew et al., 2021), or increase in beta carotene (Zhu et al., 2015) of the participants in the intervention groups or a statistically significant positive association between dietary intake of vitamin A-rich sources with vitamin A status (De Moura et al., 2015; Neves et al., 2019; Sachdeva et al., 2011). In one study, a significant mean difference in retinol levels was noted in the children but not among the women who were also studied (Jus'at et al., 2015). In another study (Mason et al., 2011), a significant change in retinol levels was noted at 18 months as opposed to the three (3) month follow up period.

A closer examination of studies looking at sample sizes and the intervention period for studies that found a significant mean difference in the vitamin A status between the intervention and the control groups: 70 women in both the control and intervention arms for a 70-day intervention period (Pinkaew et al., 2021); 136 women in four intervention groups for three weeks intervention period (Turner et al., 2013); eight women for a two months study period (Zhu et al., 2015); 27 children for an intervention period of 3 months (Lopez-Teros et al., 2013); and 1,518 women for a pre- and post-evaluation with no comparison/control arm (Jus'at et al., 2015).

Among the cross-sectional studies, dietary intake of vitamin A-rich foods was associated with higher serum retinol levels (Lima et al., 2018; Neves et al., 2019; Rahman et al., 2017; Suri et al., 2017). Other studies reported a non-statistically significant change in vitamin A status or improvement of VAD of women and children (Afolami et al., 2021;

Engle-Stone et al., 2017; Girard et al., 2017; Christine Hotz, Cornelia Loechl, Abdelrahman Lubowa, et al., 2012; Jamil et al., 2012a). In eight studies, despite the non-statistically significant improvement or association with vitamin A status, there was an improvement of vitamin A intake or serum levels overall (Bastos Maia et al., 2018; Engle-Stone et al., 2017; Girard et al., 2017; Christine Hotz, Cornelia Loechl, Alan de Brauw, et al., 2012; Christine Hotz, Cornelia Loechl, Abdelrahman Lubowa, et al., 2012; Lira et al., 2018; Mason et al., 2011; Palmer, Chileshe, et al., 2016).

Retinol levels were adjusted for inflammation or subclinical infection in 12 of the 24 studies (Bastos Maia et al., 2018; De Moura et al., 2015; Engle-Stone et al., 2017; Girard et al., 2017; Christine Hotz, Cornelia Loechl, Abdelrahman Lubowa, et al., 2012; Jamil et al., 2012a; Jus'at et al., 2015; Neves et al., 2019; Palmer, Chileshe, et al., 2016; Pinkaew et al., 2021; Rahman et al., 2017; Turner et al., 2013). In three studies, although the vitamin A levels were higher in the intervention group compared to the control groups no statistically significant differences were observed (Jamil et al., 2012a; Palmer, Chileshe, et al., 2016; Palmer, Healy, et al., 2016).

2.4.10 Limitations of individual studies

Individual studies included in the review highlighted a number of design and sampling related limitations (Table 2.2). Cross-sectional studies could not establish a causal relationship (Bastos Maia et al., 2018; Lira et al., 2018; Neves et al., 2019; Sachdeva et al., 2011; Suri et al., 2017). Three studies noted an inadequate amount of time to observe effects in intervention studies (Afolami et al., 2021; Lopez-Teros et al., 2013; Mason et al., 2011). Four studies had low-powered designs with insufficient sample sizes to comprehensively examine the effects of food-based approaches on the retinol levels or vitamin A status of the populations (Engle-Stone et al., 2017; La Frano et al., 2013; Lopez-Teros et al., 2013; Zhu et al., 2015).

Three studies did not include biochemical measurements of serum retinol, and instead deduced vitamin A status from dietary intake or ocular examination thus increasing the likelihood of estimation error and bias associated with self-reports (Christine Hotz, Cornelia Loechl, Alan de Brauw, et al., 2012; Sachdeva et al., 2011; Suri et al., 2017). In another study, the possibility of overestimation of the outcome was noted as a limitation considering the nutrition contribution of breast milk was not measured (Suri et al., 2017). Similarly, the lack of precision in the estimation of the 600 microgram capsule of vitamin A in another study may have resulted in overestimated changes in retinol levels hence reducing the power to detect an effect (Palmer, Chileshe, et al., 2016). Two studies reported that additional confounding factors for vitamin A status was not measured (Lima et al., 2018; Ndau et al., 2016b), thus increasing the likelihood of over-estimation of the outcome.

In one study, the physiological status of the women (lactation) could have had an impact on the assumptions used in serum retinol determination method (RID) calculation (Pinkaew et al., 2021), hence suggesting a need to further validate the results due to issues with accuracy related to losses through breast milk.

Two studies identified the inability to delineate the effect of the intervention as the sole contributor to the vitamin A status as a limitation (Afolami et al., 2021; Christine Hotz, Cornelia Loechl, Abdelrahman Lubowa, et al., 2012). Two studies were conducted among adequately nourished women suggesting optimal vitamin A status compared to studies with participants experiencing VAD (La Frano et al., 2013; Zhu et al., 2015). Change in the initial methods of one study was documented as a limitation (Mason et al., 2011).

TABLE 2.1. Characteristics of the study included in the review

Study	Country	Study design	Sample size	Age range and Mean age	Exposure/intervention	Outcome
Hotz et al., 2012	Uganda	Randomized control trial with 2 arms; 2-year intervention	N= 1,416 children 843, women 573	Children 6-35 months; mean 20.8 ± 0.5 months 3-5yrs mean 51.4± 0.4 months, women 13-45 years; mean 34.0 ± 0.5 years	Orange Fleshed Sweet Potato (OFSP) distribution and consumption	Serum retinol adjusted for inflammation/infection
Girard et al., 2016	Kenya	intervention study with control, 1 year	N=505 women, 250 intervention arm, 255 control arm	Mean 24.3±5.5 years, prime gravidity at 30%	Distribution of OFSP vines, enhanced nutrition education about OFSP and vitamin A versus clinic-based nutrition only	Serum retinol adjusted for infection
De Moura et al., 2015	Nigeria	Cross sectional survey following a provitamin A biofortified cassava program	N= 578Mother-child dyads	Women 18-49 years; mean 28.2 ± 7.9 years, children 6-59months; mean 32.5 ± 14.9 months	Dietary intake including consumption of Provitamin A biofortified cassava, assessed using multiple 24-hour recall	Serum retinol
Turner et al., 2013	Bangladesh	Randomized placebo-controlled trial with 4 arms, 3-week intervention	N= 136 lactating women, 34 women in each of the 4 groups	Women 18-45 years; mean 24.0 ± 5 years	Vitamin A capsule + white fleshed sweet potatoes Vs tangerine +placebo capsule vs OFSP +placebo capsule vs white fleshed sweet potatoes +placebo capsule; assessed using FFQ	Serum retinol level

TABLE 2.1. Characteristics of the study included in the review

Study	Country	Study design	Sample size	Age range and Mean age	Exposure	Outcome
Pinkaew et al., 2021	Thailand	Randomized control trial, 70 days intervention	N=70 lactating women, recruited during pregnancy, 35 women in each group	20-40 year; mean 28.9±5.2	Rice consumption (50 mcg RAE/50g) with other foods vs unfortified rice	Change in Vitamin A status measured using the C-RID test
Palmer et al., 2016	Zambia	Randomized control trial, with 3 arms	N=149 lactating women with children 4-12 months,	20-30 years; mean 22 years	White maize and placebo verses orange maize (600ugRE/day) versus Vitamin A capsule (600ug) retinyl palmitate	Milk retinol concentration adjusted for CRP and AGP
Palmer et al., 2016	Zambia	Randomized control trial, with 2 arms	N= 1024 children	4-8 years; mean 5.7 ±1.3 years	Biofortified orange maize verses white maize	Serum retinol, response to grade light stimuli
La Frano et al., 2013	USA	Randomized, single blind cross over study	N= 12 non pregnant women	21-44 years; mean 29.3± 8.8 years	Biofortified cassava, each participant consumed 3 randomized cassava porridges, 3 meals separated by 2 weeks wash out	Post prandial plasma triacylglycerols retinol lipoprotein

TABLE 2.1. Characteristics of the study included in the review

Study	Country	Study design	Sample size	Age range and Mean age	Exposure	Outcome
Jamil et al., 2012	Bangladesh	Randomized control trial, with 4 arms	N=120 non pregnant, non lactating women	18-45 years; 28.4 ± 6.5 years	White fleshed sweet potato + a corn oil capsule (WFSP), 600ug of boiled OFSP+capsule 150uL corn oil (BOFSP); boiled WFSP + a capsule containing 600ugRAEof retinly palmitate; 600ug as boiled and fried OFSP and a corn oil capsule (FOFSP)	Plasma retinol concentrations
Zhu et al., 2015	USA	Randomized cross over trial	N= 8 Women	19-43 years; 27.1 ± 2.9 years	3 gari preparations separated by 2 weeks. washout periods; Treatments (containing 200 – 225.9 g gari) were: biofortified gari (containing 1 mg β-carotene); red palm oil-fortified gari (1 mg β-carotene), and unfortified gari with a 0.3 mg retinyl palmitate reference dose.	Post-ingestion Triacylglycerol-rich plasm and drawn six times from 0.5 – 9.5 h
Neves et al., 2018	Brazil	Prospective cohort study	N=442 pregnant women	24.7 ±6.4 years	Dietary intake including amazon fruits	Serum retinol
Suri et al., 2017	India	Cross sectional Survey	N= 750 children, 1-5 years	12-60 months; 33.45 ±12.7	Dietary intake assessed using the Hellen Keller FFQ	VAD as deduced from the dietary intake

TABLE 2.1. Characteristics of the study included in the review

Study	Country	Study design	Sample size	Age range and Mean age	Exposure	Outcome
Rahman et al., 2016	Bangladesh	Cross sectional survey	N=1176 women and children	Children 6-59 months, School age children 6-14 years, non pregnant, non lactating women 15-49 years	Dietary intake was assessed using the FFQ	serum retinol levels adjusted for CRP and AGP
Lima Braga et al., 2017	Brazil	National survey	N=3417 children	Children 6-59 months	Dietary intake	VAD as measured using serum retinol levels
Sachedva et al., 2011	India	Cross sectional survey	N=3571 children	0-60 months; mean 36.0 ± 21 months	Dietary intake and Vitamin containing foods	Xeropthalmia; ocular examination and proxy report from mothers
Engle-stone et al., 2017	Cameroon	Survey, 2 years before and 1 year after cooking oil fortification program	N=300 women 15-49 years and children 12-59 months	Children 12-59 months; mean 32.9± 0.8 months; women 15-49 years; mean 29.1 ± 0.4 years	Vitamin A fortified coconut oil intake measure using FFQ	Serum RBP, breast milk retinol adjusted for inflammation
Manson et al., 2011	Philippines	Randomized control study with 3 groups, 18 months intervention	N= 342 children	Children 1-5 years; mean 32.4 ± 9.8 months	6 monthly VAC dosing vs VACs for 3 monthly vs vitamin A fortified coconut oil +6 monthly VACs	Serum retinol
Lira et al., 2018	Brazil	Cross-sectional study	N = 134 pairs of mother-infant dyad, lactating women	Women 18-40 years 24.9 ± 6.6 years	Dietary intake in the last 3 months using an FFQ	Serum retinol and beta-carotene

TABLE 2.1. Characteristics of the study included in the review

Study	Country	Study design	Sample size	Age range and Mean age	Exposure	Outcome
Jus'at et al., 2014	Indonesia	Pre and post evaluation study	N =1518 women and children	Lactating mothers; mean 28.9 ± 6.7 years; children 12-23 months, mean 17.1 ± 3.8 months; 24-59 months; mean 38.3 ± 10·0 and women 15-29 years; mean 23.0 ± 6.6 years	Dietary intake of vitamin A and consumption of vitamin A fortified cooking oil	Serum retinol adjusted for subclinical infection of women and children
Lopez-Teros et al., 2013	Mexico	Randomized control trial, 3 months intervention	N= 27 children	Children 3-6 years; mean age 5.5 years	Daily consumption of 250mL of VA fortified milk providing 196 RE/d	TBVA; serum retinol
Bastos et al., 2018		Cross sectional survey	N=676 pregnant women	Pregnant women 15-45 years	Nutritional status and use of vitamin supplements	Serum retinol adjusted for CRP
Afolami et al., 2020	Nigeria	Randomized control trial, 93 days intervention	N= 176 preschool children	Children 3-5 years; mean age	Children were fed on either yellow or white cassava twice a day, 6 days a week for 93 days providing 221 RAEmcg/d of the yellow cassava vs 74 RAEmcg of the white cassava	Serum retinol adjusted for inflammation
Ndau et al., 2016	Tanzania	Longitudinal, Intervention design	N=569 lactating women	Lactating women 15-49 years	Consumption of vitamin A rich foods, knowledge about vitamin A and fortified oil	Serum Retinol
Hotz et al., 2012	Mozambique	Randomized control trial, 2.5 years	N= 432 women and children	Children 6-35 months; 3-5.5 years, mean 22.4±0.4 months, pregnant and women 28.9±0.5 years	Distribution of OFSP vine, intake of vitamin A foods including OFSP	OFSP consumption and vitamin A intake by children and women

TABLE 2.2. Main findings, study limitations, and risk of biases of studies reviewed (N=24)

Study	Main findings	Study limitations	Risk of biases
Hotz et al., 2012	Significant increase in OFSP consumption; no impact of intervention on serum retinol for women One-third reduction in serum retinol <0.7mmol/l, 9.5-point reduction in the prevalence of children with retinol <1.05mmol/L	Unable to tease out the contribution of vitamin A levels from other sources such as red palm oil	Sampling bias due to significant loss to follow up, potentially resulting into differential misclassification
Girard et al., 2016	No impact of the intervention on the mean RBP, however with reduced odds of RBP <1.17mmol/l (p=0.001) at 9 months. Higher odds of VA adequacy as measured by EAR or DRI (p<0.001)	Minimal bias due to geographical clustering, logistical constraints	Sampling bias due to losses to follow up in either group of the study
De Moura et al., 2015	Vitamin A intake was adequate with a high median of intake children 1038 µg RAE/day for children and 2441 µg RAE/day for women. VAD was 16.9% among children and 3.4% among women. Fortified cassava, Dark leafy vegs were the primary sources of vitamin A	Study limitations were not highlighted	Measurement bias as by design
Turner et al., 2013	Plasma retinol increased in the VA group. The plasma BC change was 250% in the OFSP group and 830% in the tangerine group. The mean change in plasma beta-carotene was significantly different in the vitamin A group compared to the control group (0.035±0.050umol/l).	Inability to measure the change in VA status directly, self-reporting of foods other than the treatment	measurement bias from the self-reporting of foods
Pinkaew et al., 2021	An increase in total body vitamin stores by 53umol/L was significantly higher than the control group, and with the liver reserves for the 2 group. There was a decrease in the CRP for the 2 groups and the prevalence of VAD decreased by 43% in the rice group.	Metabolic differences among women impacting on the assumptions used for the stable isotope technique (RID) equation. The necessity to validate the results since accuracy reduces as due to losses through breast milk	Sampling bias due to loss to follow-up

RBP-Retinol binding protein
OFSP orange fleshed sweet potatoes
EAR-estimated average requirement
DRI- Daily recommended intake
RAE- Retinoic acid equivalent
VA vitamin A

CRP- C-reactive protein
BC-beta carotene
TAG -triacyl glycerol
VAC vitamin A capsule
FFQ-Food frequency questionnaire

TBVA-Total body vitamin A
AGP- α-1-acid glycoprotein
OM- orange maize
WM-white maize

TABLE 2.2. Main findings, study limitations, and risk of biases of studies reviewed (N=24)

Study	Main findings	Study limitations	Risk of biases
Palmer et al., 2016	The mean milk retinol concentration was higher in the orange maize group versus the VA capsule group. However, the difference was not statistically significant	The intervention period was short, probably results would be different if longer	Measurement bias as a result of discrepancies in the outcome indicator, the milk sampling method has an effect on the retinol concentration
Palmer et al., 2016	Mean ± SD pupillary responsiveness to light stimuli was poorer at baseline in the Orange Maize group (16.1% 6 6.6%) than the White Maize group (18.1% 6 6.4%) (P = 0.02) but did not differ at follow-up (OM: 17.6% 6 6.5%; WM: 18.3% 6 6.5%). At baseline, 11.7% of the children had serum retinol <0.7 mmol/L, 14.4% had impaired dark adaptation (pupillary threshold$ 21.11 log cd/m2), and 2.3% had night blindness	Significant differences were identified in the subsample of children by intervention group including pupillary baseline response, this may have affected the results	Measurement bias due to differences in the two-intervention group were likely to regress the mean of the pupillary response
Frano et al., 2013	The plasma TAG retinol lipoproteins were higher with the biofortified meal compared to the other 2 meals. With similar bioavailability for the 3 meals, however, the rate at which beta carotene was detected in blood was significantly different	The participants in the study were well-nourished, probably with adequate vitamin A reserves, this affects the effect of the intervention	Measurement bias as a result of possible carry-over effects
Jamil et al., 2012	Mean plasma b-carotene concentrations were higher in groups that received OFSP (P < 0.0001), and final mean plasma b-carotene was marginally higher in the group that received fried OFSP compared with boiled OFSP (P =0.07). The differences in the mean plasma were not significantly different. Despite BC concentration, the impact of OFSP on vitamin A status appears to be limited	Differences in the diets for the 2 study populations may have painted a different picture of the results compared to if the 2 groups were initially as close as possible	Measurement bias due to differences in the diets for the 2 study population groups

TABLE 2.2. Main findings, study limitations, and risk of biases of studies reviewed (N=24)

Study	Main findings	Study limitations	Risk of biases
Zhua et al., 2015	There was an increase in beta carotene and alpha-carotene and retinyl palmitate at the end of the meal. The retinyl palmitate induced by the red palm oil was greater than that induced by the fortified treatment (4.12 ± 1.5 vs 2.4 ± 0.3)	The study was conducted among well-nourished American women, probably the results would have been different in a vitamin A deficient population	Measurement bias due to possible carry-over effects
Neves et al., 2018	Serum retinol levels were associated with the consumption of amazon fruits (β =0·087; 95% CI 0·012, 0·162)	Lack of data on other biochemical indicators such as the retinol binding protein, the actual nutrient intake was also not estimated	Sampling bias due to non-probability sampling techniques
Kumar & Das, 2017	Plant and animal sources such as eggs and butter were the major sources of vitamin A in the study population. Consumption of amaranth (2.7 days/week) and carrots (1.7 days/week) was moderate but that of animal foods rich in vitamin A was low to negligible (1.1 days/week for eggs and 0.2 days/week for liver and fish combined). There was inadequate intake of vitamin A-rich foods, thereby making subclinical VAD deficiency a public health problem	Possibility of overestimation of the outcome because breastmilk was not taken into consideration	Measurement bias as a result of the exclusion of other vitamin A sources
Lira et al., 2018	16 % of the women have insufficient intake of vitamin A and beta-carotene. Mean retinol levels were low in 8% of the mothers though they were adequate overall. Retinol and beta-carotene levels were positively associated in cord serum ($p = 0.004$), maternal serum ($p = 0.041$), and colostrum ($p < 0.001$) but was not associated with dietary intake.	use of mean retinol concentrations to support biochemical and nutritional risk of VAD can mask	Measurement bias due to possible errors recording dietary intake
Jus'at et al., 2014	Fortified oil improved vitamin A intake of children, lactating and non-lactating women. Serum retinol was 2–19 % higher at end-line than baseline (P <0·001). After adjusting for socioeconomic differences vitamin A intake from fortified oil predicted retinol status for children aged 6–59 months (P=0·003) and 5–9 years (P=0·03).	Uncertainty in the extrapolation of vitamin A content in oil from a subsample of households. Potential measurement errors in the measurement might have diluted the associations between vitamin A intake from oil and vitamin A status	Measurement bias due to possible errors recording dietary intake

TABLE 2.2. Main findings, study limitations, and risk of biases of studies reviewed (N=24)

Study	Main findings	Study limitations	Risk of biases
Rahman et al., 2016	VAD was highest among children; 20.5 vs 20.8 for preschool and school-age going children. Higher consumption of animal foods was associated with Vitamin A status. Increased consumption of leafy green vegetables was associated with lower retinol status	Inability to establish the cause-effect relationship given the study design, exclusion of foods from the FFQ which are part of the participants' diet	Measurement bias due to errors recording dietary intake
Lima Braga et al., 2017	After adjusting for confounders, consumption of meat at least once in the seven days was a protective factor [PR=0,24; 95%CI 0,13–0,42]	Overestimation of serum retinol levels since inflammation was not measured and controlled for	Measurement bias due to possible errors in dietary intake recording
Sachedva et al., 2011	Overall prevalence was at 9.1%. Low intake of proteins and vitamin A containing foods as well as predominant maize diet were significant dietary factors. Rural dwelling, lower social class, maternal illiteracy were significant antecedent socio-demographic risk factors.	Inability to determine cause and effect being a cross-sectional study	Measurement bias due to errors recording dietary intake
Engle-stone et al., 2017	Consumption of fortified oil that was consumed by 80% of participants in the past week did not detect an increase in serum retinol or milk retinol.	the sample size was probably inadequate, the picture would be different for a larger sample size	Measurement bias
Manson et al., 2011	No sustained increase in serum retinol was determined from the 3-month VAC dosing regimen and the prevalence of vitamin A deficiency as assessed by serum retinol remained around 30%. The difference was at 18months of VA fortified oil was associated with reducing the prevalence of VAD to <10%	Changes in the initial methods, the intervention arm of oil promotion picked momentum at a later point therefore at the end of 18 months, there was no comparison/control group. The results are not generalizable due to the lack of a comparison group	Sampling and measurement bias due to changes in study methodology along the course of the intervention

TABLE 2.2. Main findings, study limitations, and risk of biases of studies reviewed (N=24)

Study	Main findings	Study limitations	Risk of biases
Lopez-Teros et al., 2012	40% increase in total body vitamin A stores After 3 months, median changes in the serum retinol concentration for the intervention and control groups were 0.13 and 20.21 mmol/L, respectively (P = 0.009). Median changes in the TBVA stores were 0.06 and 0.01 mmol, respectively (P = 0.006) and estimated median changes in the liver VA concentration were 0.09 and 0.01 mmol/g, respectively (P = 0.002).	Very stringent inclusion criteria, excluding conditions that could be present in the general population	Sampling bias due to stringent inclusion criteria
Maia et al., 2018	Prevalence of VAD was 6.2% (4.5-8.3) and was associated with anaemia levels, being in the 3rd trimester and <12 years of schooling	Un clear, not mentioned in the study	Sampling bias due to nonprobability sampling techniques
Afolami et al., 2020	No significant treatment effect for adjusted beta carotene was detected (3.9%; 95%CI: −0.6%, 8.6%). But a significant effect for the haemoglobin concentration (adjusted effect: 3.08 g/L; 95% CI: 0.38,5.78 g/L).	Challenging to control for the foods consumed by the children outside the intervention meals. Low prevalence of VAD in the study population contributing to a nondetectable treatment effect	Measurement bias due to lack of control of other food consumed
Ndau et al., 2016	Mothers had a positive attitude towards vitamin A consumption though consumption of vitamin A rich foods was generally low; 40% of the mothers consumed animal products and 20 % consumed plant products; Residence was significantly associated with vitamin A status (p<0.000). Prevalence of VAD was highest in the younger age group 15-19 at 88.5 %,	subclinical infection/inflammation was not controlled for, possibly could have had an effect on the prevalence of VAD	Measurement bias due to lack of measurement for possible confounding factors
Hotz et al., 2012	There was a significant net increase in OFSP and vitamin A intake by children 6-35 months, 3-5.5 years, and women, OFSP provided 80% of the total vitamin A intakes	Biochemical or clinical indicators of vitamin A status were not included, therefore it was not possible to predict the impact of the increase of vitamin A intake on change in vitamin A status, instead relied on other smaller studies in the same area that reported improvement in serum retinol concentration	Measurement bias due to dietary intake assessment errors

2.4 Discussion

This systematic review examined and synthesized research on the effect of food-based approaches on vitamin A status or VAD of women and children. We discuss the overall effectiveness of food-based approaches in improving vitamin A or alleviating VAD for women in the reproductive age group. This review aims to improve understanding of the literature on this topic published in the past decade and serves as a reference for future research and policy development. The identified studies focused either on women who were pregnant or lactating, and/or children under five years of age. These are critical stages of the life cycle (Eilender, 2016), given fetal programming and growth during these periods resulting in a greater demand for vitamin A. During pregnancy, vitamin A is necessary for cell differentiation, organ formation, and for tissue repair in the postpartum period (Bastos Maia et al., 2019b; Wiseman, Bar-El Dadon, Reifen, & nutrition, 2017).

Evaluating interventions that can enhance nutrient intakes for desired health outcomes is worthwhile. In LMIC, there is high rate of mortality among children under five years (Li, Karlsson, Kim, & Subramanian, 2021; WHO, 2021). Almost three-fourths (72%) of children aged 6-23 months are not fed a minimally diverse diet to meet their nutrition needs and are at a higher risk of not meeting their vitamin A requirements (Hasman, Moloney, & Aguayo, 2021). Focusing on food-based approaches provides opportunities to integrate the delivery of successful evidence-based interventions in childhood programs for early identification, prevention, and control of VAD.

Almost half of the studies included in this review had a statistically significant improvement in serum retinol levels of participants following the intervention, while the rest of the studies noted a non-significant increase in the serum retinol levels. These findings suggest that food-based approaches focusing on vitamin A have a positive effect on the vitamin A status of affected populations. The benefits of food-based approaches are likely to

reach the poorest populations, while being more sustainable and environmentally friendly (Bouis & Saltzman, 2017). Additionally, such food-based approaches are less likely to cause toxicity compared to high dose vitamin A supplementation programs (Betty J Burri & Safety, 2011; Nguyen et al., 2012).

Nevertheless, there are challenges in the design and assessment of the multiple input variables that go into a comprehensive food-based intervention (Blasbalg, Wispelwey, & Deckelbaum, 2011). Considerations have to be made to assess the quality of studies with either statistically significant results or not. It is also important to note that a variety of approaches including biofortification of widely consumed staple foods such as rice, maize, orange-fleshed sweet potatoes, and cassava were identified in the review. As such, one of the recommendations of this review is for more comparative research on communities with intakes of similar staple foods. Targeting staple crops, while taking into consideration the dietary and cultural practices of the intended communities, can optimize the intended benefits such as improvement of vitamin A status resulting from biofortified crops (Garcia-Casal et al., 2016).

Of importance is the observation that study interventions resulted in improved levels of vitamin A as well as other benefits to the study communities. For example, one study reported improvement in the livelihood of communities after the distribution of orange-fleshed sweet potato vines due to extra income derived from selling part of the harvest (Christine Hotz, Cornelia Loechl, Abdelrahman Lubowa, et al., 2012). Secondly, there was an improvement in the intake of other micronutrients, such as iron, as a result of the increased intake of vitamin A (Afolami et al., 2021). Vitamin A has a regulatory role in the expression of genes involved in iron metabolism, and also supports the mobilization and transportation of iron (Wiseman et al., 2017). In this regard, such a finding is useful to both vitamin A and iron programs. In contrast to the findings of this systematic review, previously published

reviews did not find an improvement in the absorption of other micronutrients (Masset, Haddad, Cornelius, & Isaza-Castro, 2012b) and reported inconsistent results for improvements in vitamin A status (Amy Webb Girard, Julie L Self, Corey McAuliffe, & Olafunke Olude, 2012).

Cross-sectional studies identified a positive relationship between dietary intake and vitamin A status or serum retinol levels. Consumption of animal source foods was a protective factor for vitamin A status compared to dark leafy green vegetables (Rahman et al., 2017). In this regard, promoting a variety of vitamin A food sources is important for increased bioavailability derived from different foods. Household income and place of residence (urban versus rural) were also significant variables attributable to higher serum retinol levels, suggesting that a multitude of factors influence vitamin A intake.

Cross-sectional designs exclude assessing the temporality of relationships between variables and serum retinol levels or vitamin A status, and cannot ascertain causal pathways. Observational study designs can still provide some important information on predictors of vitamin A-rich food consumption. However, strategies such as food fortification have been primarily derived from non-observational studies (Satija, Stampfer, Rimm, Willett, & Hu, 2018; Trepanowski & Ioannidis, 2018).

Our examination of the quality of studies or risk of bias assessment is a strength of this review. Studies that included randomization or simple random sampling of the participants resulted in samples that were representative of the target population thus minimizing selection bias and sampling error. Although randomization can effectively capture allocation bias, it also counteracts preference effects and can decrease the potential generalizability of the study findings (Trepanowski & Ioannidis, 2018).

In addition to these quality issues, the inability to collect biochemical data to establish serum retinol levels or vitamin A status created a greater window for estimation errors from

the proxy indicators used. However, it is also important to acknowledge the challenges in collecting serum retinol concentration directly by methods such as high-performance liquid chromatography which is recommended by the World Health Organization. Such assays are expensive, technically demanding, and rarely available in developing countries (Talsma et al., 2015). Besides other methods such as estimating a combination of transthyretin, Retinol Binding Protein and C-reactive protein concentrations (Talsma et al., 2015), clinical examination for xeropthalmia (WHO, 2014), and the estimation of vitamin A status from dietary intake assessment, the Helen Keller International (HKI) assessment tool has also been seen to be effective (Haselow, Rosen, & Sloan, 1993). With the different approaches in estimating serum retinol levels across studies, the comparison of results in this review may be challenging due to inconsistencies.

2.5 Comparison with earlier review and Limitations

Our review corroborates previous reviews (Bassey et al., 2020) that there is a need for more randomized controlled trails on examining the effectiveness of food-based approaches on improving vitamin A status or alleviating VAD among women and children. In this review, intervention studies suggested a positive effect direction. This review offers new insights on the vast differences in the period of evaluation across various interventions, the different food approaches used, and the statistical power of the studies as possible explanatory factors of the lack of demonstrated effectiveness of food-based approached on vitamin A status. Previous reviews noted a lack of statistical power as one of several methodological weaknesses in studies (Bassey et al., 2020; Masset, Haddad, Cornelius, & Isaza-Castro, 2012a). In part, this is a consequence of the complexity of the settings in LMIC rather than the skill of the research team or the rigor of study designs.

Randomized trials of food-based approaches tend to be more complex during the implementation phase (Mirmiran, Bahadoran, & Gaeini, 2021). Evidence of efficacy, the

measure of the degree of success of an intervention, rather than effectiveness, the degree of success of an intervention in ideal conditions, might provide a more meaningful understanding of improvements in vitamin A status in population-based studies (Ruel & Alderman, 2013). The complexity of the chain of factors that lead from the implementation of a food-based approach program to the outcome of interest, vitamin A status or VAD, warrants a greater understanding of the circumstances under which people participate in such interventions, the immediate effects on their diets, and interpretation of findings.

In addition, confounding factors such as health and environmental conditions, as well as cultural beliefs and practices, can interfere with the implementation of food-based approaches at each stage of the study (Mirmiran et al., 2021). However, this review found that a significant number of studies considered the effects of health conditions such as inflammation in the interpretation of serum retinol levels of the participants. This systematic review concluded that there was an insufficient basis to attribute food-based approaches to improvement of vitamin A status or alleviation of VAD. The results of this review highlight the inconclusive evidence of food-based interventions in addressing VAD, especially in vulnerable populations of women and children and argues for more research in this area.

2.6 Conclusions

Overall, most studies presented in this review illustrated a positive trend towards improving vitamin A using food-based approaches allowing us to conclude that there is a case for recommending food-based approaches in improving vitamin A status. The lack of statistical significance in some of these studies, combined with mixed results on the effects of food-based approaches on vitamin A status or improvement in VAD among women and children indicates that more research is needed for a robust analysis of this relationship. Further research could improve the quality of literature by a continued application of rigorous

approaches to study design and extending the evaluation period of interventions. The wide variety of implementation methods and lengths of interventions create challenges in assessing effect size. Food-based approaches command large resources and improvements in their programmatic design has the potential to maximize the nutritional outcomes outlined in the Sustainable Development Goals. In conclusion, this systematic review asserts that food-based approaches could provide an important safety net for effective delivery of vitamin A to targeted communities.

CHAPTER III

PREDICTORS OF VITAMIN A-RICH FOOD CONSUMPTION AMONG WOMEN FROM SELECTED REGIONS IN UGANDA

3.1 Abstract

Vitamin A deficiency (VAD) has serious public health consequences for populations in low and middle-income countries (LMIC), especially for children under five years and pregnant women. LMIC are at a greater risk due to reliance on plant-based sources of vitamin A, which are less bioavailable compared to animal sources of the vitamin. Food based approaches, including biofortification, appear to be a potential solution to improving vitamin A and other micronutrient status. The objective of this paper is to characterize vitamin A-rich foods consumption and its predictors among women from selected regions in Uganda. A baseline cross-sectional survey was conducted by the International Potato Centre among 617 sweet potato growing households, focusing on women in the reproductive age group, from the northern and eastern regions of Uganda. Quantitative data was collected on a number of variables including vitamin A-rich food consumption, dietary intake using a food frequency questionnaire and a 24-hour recall. Vitamin A consumption was summarised using the Hellen Keller International guide.

The majority of women in this study were either pregnant (17 %) or lactating (80%). More than 70% of the study population had a weighted vitamin A-rich food consumption mean score of < 6 days per week, indicating high risk of vitamin A deficiency. Knowledge about vitamin A (b(SE) = -0.18 *(0.50),* $p < 0.001$) predicted vitamin A-rich food consumption. The study provides evidence on the association between nutrition knowledge and consumption of Vitamin A-rich foods, indicating development and delivery of biofortified foods including orange-fleshed sweet potatoes have the potential to further improve vitamin A status when combined with nutrition education.

3.2 Introduction

Micronutrient deficiencies, especially deficiencies in vitamin A, iron, folate and iodine, are highly prevalent in low- and middle-income countries (LMIC) and contribute to poor health (Regan L Bailey, Keith P West Jr, & Robert E Black, 2015b), retarded growth, low productivity, growth impairment, and unexpected death (Bailey et al., 2015a; Bain et al., 2013a; Ritchie & Roser, 2017; WHO, 2011). The burden of disease due to the health effects of micronutrient deficiencies has received increased attention in the last few decades (Bailey et al., 2015b).

Micronutrient deficiencies affect some of the most vulnerable members of society. Women are at a higher risk of developing micronutrient deficiencies, with pronounced effects during preconception, pregnancy, and lactation (Henjum et al., 2015; Torheim, Ferguson, Penrose, & Arimond, 2010). These conditions are exacerbated by low levels of household dietary diversity (Gernand, Schulze, Stewart, West, & Christian, 2016) and household food insecurity (Ruth Adisetu Pobee, Sixtus Aguree, Esi Komeley Colecraft, Alison D Gernand, & Laura E Murray-Kolb, 2020b).

Vitamin A deficiency (VAD) is considered to be one of the most serious public health concerns in LMIC. Young children and pregnant women especially in low-income, non-urban communities are more susceptible to VAD. Vitamin A is an essential micronutrient for normal functioning of the visual system, growth and development, as well as maintenance of epithelial cellular integrity, immune function and reproduction (Hassen Bennasir, Shanmugam Sridhar, & Tarek T Abdel-Razek, 2010a). VAD, defined as serum retinol concentrations below 0.825 µmol/l (World Health Organization, 2014), is estimated to affect two billion people globally (Muthayya et al., 2013; WHO, 2011). In Uganda, the prevalence of VAD is 8.3 percent and 9.0 percent in the urban and rural areas, respectively (Uganda Bureau of Statistics (UBOS), 2018). Higher prevalence rates have been reported in the

following regions of Uganda: Acholi (15.4%), Busoga (12.8%), and West Nile (11.2%) (Uganda Bureau of Statistics (UBOS), 2018).

The initial symptoms of VAD include impaired adaptation to the dark with serum retinol concentrations falling below 1.0 µmol/L (WHO, 2014). Xeropthalmia, an advanced condition of VAD that can lead to blindness, is a particular concern for pregnant women who experience greater vitamin A requirements (WHO, 2011). Limited studies have examined dietary patterns related to consumption of vitamin A-rich foods among women in low-income countries, particularly during pregnancy and the postpartum period (Abubakari & Jahn, 2016; Kavle & Landry, 2018). Better understanding of dietary patterns can lead to improved interventions aimed at preventing malnutrition and counteracting adverse maternal and child health outcomes related to VAD and other micronutrient deficiencies. Examination of dietary patterns also has implications for dietary guidelines (Tapsell, Neale, Satija, & Hu, 2016) which can subsequently lead to increased understanding of the mechanisms that facilitate higher consumption of vitamin A-rich foods and improved vitamin A status among women. This study characterizes the consumption of vitamin A-rich foods and documents the predictors of vitamin A-rich food consumption among women in Uganda.

3.3 Methods and Procedures

3.3.1 Study Design

This study examined baseline data on dietary intake and livelihoods among women residing in households that grew sweet potatoes in the selected regions in Uganda. Survey data was collected by the International Potato Centre (CIP) for monitoring and evaluation purposes of an initiative that involves the development and delivery of biofortified crops (i.e. the DDBIO project) in Uganda.

3.3.2 Study Setting

Data used in this analysis is from Uganda, a landlocked country in East Africa, with an estimated population 43 million people (UBOS, 2021). More than half (50.8 %) of the Ugandan population are women and nearly seven million are children aged 0-4 years (UBOS, 2016). Eighty percent of the Ugandan population is rural and the agricultural sector is the major economic backbone for 60% of the nation's population (FAO, 2021). Uganda is divided into four regions namely central, western, eastern and northern. This study undertook a secondary analysis of data collected by CIP from the eastern and the northern regions of Uganda, specifically nine out of the twelve districts considered for the DDBIO project including Pader, Lamwo, Gulu, Kitgum, Agago, and Adjumani in the northern region and Bugiri, Busia, Tororo, and Karamoja in the eastern region of Uganda.

3.3.3 Sample Size

The study size was determined based on a priori sample size calculations. The statistical power needed to detect small, medium, and large effects was calculated for chi-square, t-tests, and regression analyses. The power analyses were conducted using G* power 3.1.9.7 software (Faul, Erdfelder, Lang, & Buchner, 2007). Assuming a two-tailed test, 1-beta error probability of 0.8, and an alpha of 0.05. A sample size of 617 was determined to be sufficient to detect medium and larger sized effects for all tests, and to detect associations between selected independent variables and the outcome, vitamin A-rich food consumption, among women.

3.3.4 Study population and eligibility

The study population comprised women who resided in households that grew sweet potatoes in the eastern and northern districts in Uganda. The districts were selected based on higher prevalence of malnutrition as compared to other districts in Uganda, as well as minimal food-based interventions in the same districts. Baseline survey participants were

recruited from the communities at the household level. Eligible participants were women in each of the households who were either pregnant or lactating, as well as adolescent girls. Women were ineligible to participate in the survey if they were sick or mentally unwell or had not stayed in the household in the past three months.

3.3.5 Data collection

Data was collected using a comprehensive semi-structured household level survey. The tool comprised various sections including household characteristics; sweet potato variety, knowledge, and adoption; sweet potato production and utilization; knowledge of orange-fleshed sweet potatoes and its benefits; household food consumption; a 7-day food frequency questionnaire for vitamin A-rich foods including consumption of orange-fleshed sweet potatoes in the last seven days; knowledge about vitamin A; infant and young child feeding practices; maternal knowledge; meal frequency for the child; household water and sanitation; as well as household and livestock assets. The survey tool was administered at the household level in local languages by trained research assistants.

3.3.6 Assessment of vitamin A-rich food consumption

Food frequency questionnaire

Vitamin A food consumption was assessed using a 7-day food frequency questionnaire where participants were asked "How many days, in the past seven days, did (a selected reference child/adolescent girl/woman) eat (a specific food item)?". The food frequency questionnaire was semi-quantitative and consisted of 33 food items to capture vitamin A food intake.

Hellen Keller International (HKI) Food Frequency Method

An adjusted Hellen Keller International (HKI) guide was used to collect data on vitamin A-rich food consumption. The HKI Food Frequency Method, which has been

validated against WHO standards to classify VAD (Haselow et al., 1993), was used to evaluate frequency of intake of vitamin A-rich foods. The HKI method assesses the extent to which communities and populations are at risk of VAD. If at least 70% of the communities surveyed (11 out of 15) have a VAD problem, vitamin A is likely to be a public health problem in the entire area. Whether or not a community has a VAD problem is determined by either of two threshold values: ≤ 4 days per week for mean frequency of consumption of animal sources of vitamin A or ≤ 6 days per week for mean frequency of total consumption of animal and plant sources of vitamin A (weighted by the source) (El-Arab, Khalil, & Hussein, 2002; V. Persson, Greiner, Islam, & Gebre-Medhin, 1998).

Vitamin A consumption was computed based on responses to the question "How many days, in the past seven days, did (a selected reference child/adolescent girl/woman) eat (a specific food item)"? The frequency of vitamin A consumption score was calculated by first summing the number of days during the previous week the child or the caregiver consumed vitamin A rcih foods from the animal plant source. Then the number of days the child or the woman consumed vitamin A rcih food from the plant source summed and divided by six (6). The following formula was used in calculating the index.

Weighted total consumption days (C_w) = Total number of days animal sources of Vitamin A consumed (T_{VA}) + Total number of days plant sources of Vitamin A consumed (T_{AP}) divided by 6.

The weighted vitamin A consumption score (C) is equal to the total number of days the child or mother consumed Vitamin A rich food item from animal sources plus the adjusted consumption from the plant source.

3.3.7 Independent variables

Knowledge of vitamin A and orange-fleshed sweet potatoes

Knowledge of vitamin A was assessed using items that were part of the overall questionnaire for the survey. A score of one was allocated for each correct response. We summed up the individual responses of the section items with zero as the lowest and five as the maximum score. The summed responses were on a scale of 0-5, with 0 as a response for individuals who responded zero to not having heard about vitamin A or no correct answer for the rest of the items. The items in the scale included: "have you ever heard about vitamin A?"; "On a scale of 0 (no) - 1(yes), tell me two main reasons why vitamin A is important and name examples of foods that are rich in vitamin A".

Knowledge of orange-fleshed sweet potatoes

During the analysis, two scales were developed by running a series of exploratory factor analyses (principal axis factoring and direct oblimin rotation) to examine how many underlying factors explained women's knowledge of orange-fleshed sweet potatoes. Examination of the structural matrix allowed for the identification of items related to the underlying factors. Cut-off points of 0.32 were used for factor cross loading and 0.6 for a strong factor loading (Williams, Onsman, & Brown, 2010; Yong & Pearce, 2013). Items that had strong cross loadings or items that were shown to have factors that were not associated with knowledge, such as responses to gender-related measures such as "sweet potato is a woman's crop and you can't grow sweet potatoes and be considered a man", were eliminated.

Two factors were identified in this analysis. Factor one (misbeliefs about sweet potatoes) with items: 1. Sweet potato is not good for children less than 2 years old, 2. Sweet potato is not good for pregnant women, and 3. Sweet potato is not good for lactating women; and factor two (the general benefits of sweet potatoes) with items: 1. Sweet potato leaves are good for human being to consume and 2. Sweet potatoes that are orange inside are healthier

than the ones that are white inside. The reliability test for the two scales yielded a mean of 2.46 (*SD* 1.07) with a Cronbach's alpha of 0.362 for the general health benefit item and a mean of 3.90 (*SD* 0.831) with a Cronbach's alpha of 0.662 for the misconceptions about orange-fleshed sweet potatoes). Participants' responses to the generated items/scales were considered for comparison with vitamin A consumption.

Women Dietary Diversity Score

The woman dietary diversity represents the number of different food groups consumed by the household within a specified recall period (John Hoddinott & Yohannes, 2002). An indicator of the nutrition quality of the individual diet, HDDS was calculated by summing the number of food groups consumed by the individual respondent over the recall period using the nine food groups recommended by FAO (Faber, Schwabe, & Drimie, 2009; Steyn, Nel, Nantel, Kennedy, & Labadarios, 2006) and scores range from zero to nine. Extracted from the list of 20 possible food items in the questionnaire, the nine food groups included: (1) cereals/grains and root tubers, (2) vitamin A-rich fruit and vegetables, (3) fruit other than vitamin A-rich fruit, (4) vegetables other than vitamin A-rich vegetables, (5) legumes and nuts, (6) meat, poultry, and fish, (7) oils and fats, (8) diary, and (9) eggs. Other items such as tea, sugars, and beverages were not considered when calculating the HDDS for this study.

Other independent variables including age, education, employment, household food consumption, region and number of household members among others were also examined.

3.3.8 Data Analysis

Data analysis was conducted using SPSS version 26. Descriptive statistics and contingency tables were used to summarize household and participant characteristics and vitamin A-rich food consumption. These were reported as proportions, percentages, means and corresponding standard deviations. The means and standard deviations for Vitamin A

consumption data for the women were computed from the weighted score, as well as separately from the plant and animal sources of vitamin A. Exploratory factor analysis was conducted on knowledge items related to orange-fleshed sweet potatoes and summarized into two scales.

For comparative statistics, bivariate correlations were conducted to examine associations between continuous independent variables and vitamin A-rich food consumption. We conducted a one-way ANOVA and corresponding post hoc tests using Tukey correction to examine vitamin A-rich food consumption for the women across regions. Multivariate linear regression tested the association between the outcome and independent variables. Analysis of covariance was used to test associations between categorical variables. This process resulted in the development of two models, one with all the independent variables included and the second one considering only variables that were found to be significant at the bivariate level. We considered a 95% confidence interval and statistical significance was set at $p < .05$.

3.3. 9 Ethical Approval

Ethical clearance was obtained from the ethics committee of the Makerere University School of Health Sciences and research approval was granted by the Uganda National Council for Science and Technology. Human subjects' exemption status for secondary data analysis was received from the University of Massachusetts Amherst.

3.4 Results

3.4.1 Sociodemographic Characteristics

The mean age of women was 28.3 (SD 6.9) and over half of all participants were in the 20-34 age category. More than two-thirds of the women (80%) were lactating at the time of data collection and a majority (54.3%) had seven or less years of schooling. More than two

thirds of the participants were married. Most households had between 5-9 members and 75% of all households were engaged in farming. Seventy seven percent (77%) of the women consumed less than four food groups in the week preceding the survey (Table 3.1).

TABLE 3.1. Socio-demographic Characteristics of Households and Women

Variable	Categories	N (%)	Mean (SD)
Study sub-region	Eastern	216 (35)	
	Karamoja	137(22.2)	
	Northern	19(31.3)	
	West Nile	71(11.5)	
Household size	1-4	127 (20.6)	6.6 (2.5)
	5-9	411(66.5)	
	>9	80 (12.9)	
Sex of household head	Male	571(94.4)	
	Female	34(5.6)	
Relationship to household head	Household head	61 (10.5)	
	Spouse	494 (84.9)	
	Other	27 (4.7)	
Mother characteristics			
Age group (yrs)	15-19	44 (7.7)	28.3 (6.9)
	20-34	421 (73.2)	
	>35	110 (19.1)	
Marital status	Married with spouse	510 (88.1)	
	Married, spouse away	35 (6.0)	
	Divorced/separated	16 (2.8)	
	Widow	7 (1.2)	
	Never married	10 (1.7)	
Education (yrs of schooling)	No formal education	138 (23.9)	4.99 (3.64)
	1-7 years of schooling	321 (54.3)	
	>7 years of schooling	120 (20.8)	
Main Occupation	Farming (crops and livestock)	464 (80.3)	
	Household chores	62 (10.7)	
	Other	44 (8.3)	
Physiological state	Pregnant	97 (16.8)	
	Lactating	461 (79.6)	
	Non-pregnant, non-lactating	20 (3.5)	
Disability	Yes	22 (3.8)	
	No	557 (96.2)	
Woman DDS	≤ 4 food groups	443 (76.6)	3.4 (1.6)
	>4 food groups	135 (23.4)	

3.4.2 Knowledge of vitamin A and Orange-fleshed sweet potatoes

Eighty-two (82%) of the participants had heard about vitamin A and were able to identify the health benefits of this vitamin (Table 3.2). Almost a quarter of the women could identify the role of vitamin A in the prevention of infection and diseases. One fourth (25%) of the participants identified dark leafy green vegetables as a source of vitamin A, while only 3% identified orange-fleshed sweet potatoes as a source of vitamin A.

TABLE 3.2. Women's knowledge about vitamin A

Questions about knowledge on vitamin A	Yes (n)	%
Heard about vitamin A	507	82
Health benefits for vitamin A		
Good for eye sight	69	11.2
Prevents infections/diseases	140	22.7
Important in blood production	10	1.6
Other benefits (i.e., healthy skin, appetite)	145	23.4
Source of information about vitamin A		
Health Clinic	16	2.6
Media	27	4.4
Village Health Teams	26	4.2
School	17	2.8
Identified sources of Vitamin A		
Leafy green vegetables	152	24.6
Pumpkin/ripe mango/papaya	25	4.4
Orange-fleshed sweet potatoes	19	3.1
Eggs/Fish	132	21.4

For three items, participants were scored on a scale of 0-5, with zero having no information or never having heard about vitamin A and 5 representing a participant's ability to correctly identify three sources of vitamin A and health benefits of the vitamin. The mean score of vitamin A knowledge among participants was 2.1 (SD 1.8). Based on this three-item

scale, close to one third of the participants had no information about vitamin A and only 12% identified three sources and benefits of the vitamin (Table 3.3).

TABLE 3.3. Vitamin A Knowledge Scores

Score	Frequency (%)	Mean score
Score 0 (no information about vitamin A)	190 (30.7)	2.1±1.8
Scored 1	69 (11.2)	
Scored 2	96 (15.5)	
Scored 3	91 (14.7)	
Scored 4	98 (15.9)	
Scored 5 (identified 3 sources and health benefits of vitamin A)	74 (12.0)	

Two factors which informed the development of two scales presented in this analysis were derived from factor analysis of the knowledge items on orange-fleshed sweet potatoes included in the questionnaire. The first factor was awareness of the general health benefits of eating orange fleshed sweet potatoes and the second factor was misconceptions about orange-fleshed sweet potatoes (Table 3.3).

TABLE 3.4. Items and scale information from the exploratory analysis of knowledge about orange-fleshed sweet potatoes included in the questionnaire

Item	Factor loading				
	1	**2**	**1**	**2**	**3**
General health benefits					
Sweet potato leaves are good for human beings to consume	0.014	**0.726**	-0.066	**0.681**	0.365
Sweet potatoes that are orange inside are healthier than ones that are white inside	-0.027	**0.767**	-0.031	**0.8**	-0.266
Misconceptions					
Sweet potatoes are not good for the child	**0.723**	-0.23	**0.744**	-0.251	0.043
Sweet potatoes are not good for pregnant women	**0.816**	0.1	**0.837**	0.091	-0.063
Sweet potatoes are not good for lactating women	**0.771**	0.021	**0.749**	-0.032	0.302
Too much sweet potato can cause stomach problems	0.331	-0.229	0.309	-0.275	0.318

Vitamin A is found in all types of sweet potatoes	0.178	0.098	0.071	-0.009	0.848
Eigenvalue	1.94	1.23	1.94	1.23	1.07
Percentage of variance	27.6	17.5	27.6	17.5	15.3

Based on the identified orange-fleshed sweet potato knowledge scales, 45% of the women scored above the median in the knowledge scale for the general health benefits of orange-fleshed sweet potatoes and 61% scored below the median for misconceptions of orange-fleshed sweet potatoes.

TABLE 3.5. Participant scores on the scale dimensions derived from factor analysis of knowledge of orange-fleshed sweet potatoes

Scale component	Above median n (%)	Below mean n (%)	Mean	Median
General health benefits of OFSP	242 (45)	296 (55)	2.46 (1.07)	2.50
Misconceptions about OFSP	217 (37.9)	355 (61.3)	3.91(0.82)	4.0

3.4.3 Vitamin A-rich food consumption for women

Vitamin A consumption patterns were based on the Hellen Keller International (HKI) guide (V. Persson et al., 1998). Vitamin A consumption for women with dietary patterns inclusive of both plant and animal sources of vitamin A are presented in Figure 2.1. Dark green leafy vegetables were the most common source of vitamin A for the study population, with a mean consumption of 2.83 days per week and eggs were the least common vitamin A sourced foods consumed.

Orange-fleshed sweet potatoes were consumed at least once in the previous week by approximately 40% of the study population. Carrots, butter, vitamin A fortified margarine, and liver were the least available vitamin A sources for women in this study. Plant sources of vitamin A had the highest mean consumption in days per week compared to animal sources of Vitamin A (Table 2.6).

TABLE 3.6. Vitamin A-rich food group groups consumed at least once during the last week and meal frequency for women

Food groups	N (%)	Mean frequency of consumption (days/wk)
Any dark green leafy vegetables	450 (78.3)	2.84
Carrots	6 (1)	2.83
Ripe mango	46 (8)	2.32
Pumpkin or orange squash	153 (26.6)	1.9
Ripe pawpaw, fresh or juice	118 (20.5)	2.27
Passion fruit (or other fruit rich in vitamin A)	29 (5)	3.13
Orange-fleshed sweet potato	218 (37.9)	2.25
Eggs with yolk	110 (19.1)	1.9
Any fish, fresh	210 (36.5)	2.42
Liver from any animal	47 (8.2)	1.27
Butter	17 (3)	2.1
Vitamin A fortified margarine	8 (1.4)	2.25

There was a statistically significant difference in the mean number of days per week of consumption of plant (4.48) versus animal (1.45) sources of vitamin A (t, df = -20.3, 616 $p < .01$). The weighted score for vitamin A-rich food consumption among women in this study is presented in Figure 2.1.

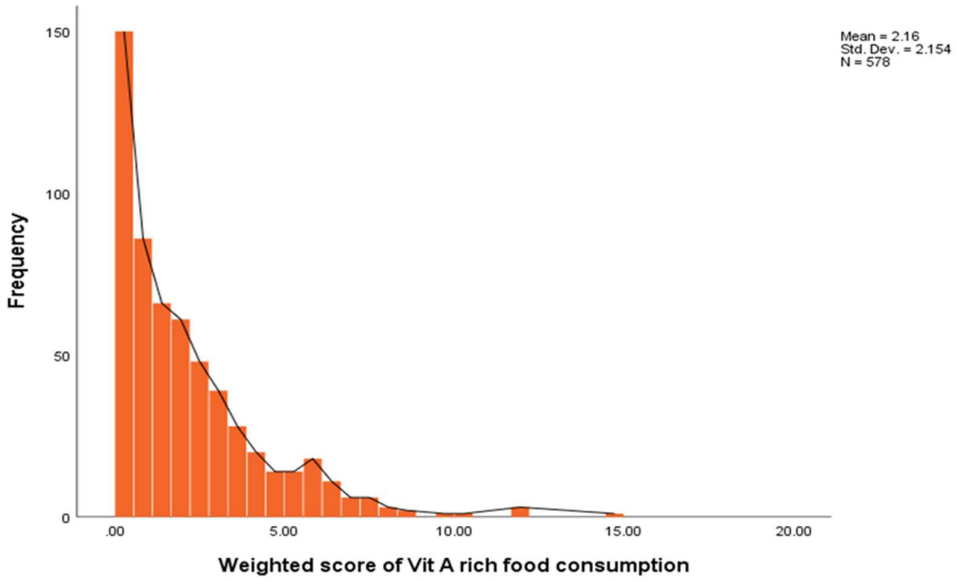

FIGURE 3.1. Distribution of vitamin A-rich food consumption weighted score for women in Uganda

Nearly all women (>95%) had less than or equal to 6 days per week for mean frequency of total consumption of animal and plant sources of vitamin A (weighted score). Based on the HKI guide, a community is considered to be at high risk of VAD when the mean weighted score is less than 6 days per week or less than 4 days of consumption of animal food sources of vitamin A.

3.4.4 Predictors of vitamin A-rich food consumption among women from selected regions in Uganda

One-way analysis of variance identified a statistically significant difference between the selected regions and vitamin A consumption in the study population (F (3,613) = 24.05, p<.001). Post Hoc comparison using Tukey correction identified that the eastern region (3.03, SD 2.67), Karamoja (1.46, SD 1.39), Northern (1.90, SD 1.80) and West Nile (1.50, SD 1.49) significantly higher in consumption of vitamin A-rich foods compare to the other three sub-

regions, all the p values <0.001 for the differences. There were no significant differences between the other regions (ps>0.05).

Pearson's correlation tested the associations between all variables considered in this study, including age, education, individual dietary diversity, vitamin A knowledge, knowledge of orange fleshed sweet potatoes, vitamin A-rich food consumption, and number of people in the household. Knowledge of vitamin A (correlation coefficient -0.15, $p<0.001$) and knowledge on benefits of OFSP (correlation coefficient 0.10, p=0.02) were identified having a statistically significant relationship with vitamin A-rich food consumption of women in this study.

Misconceptions about orange-fleshed sweet potatoes and other variables did not have a statistically significant association with vitamin A-rich food consumption of the women (Table 2.5). When we examined the correlation between vitamin A knowledge and vitamin A-rich plant food sources, and animal food sources rich in vitamin A independently, we noted a statistically significant inverse coefficient (correlation coefficient -0.16, p< 0.01) with the vitamin A-rich animal sources and a non-significant correlation with vitamin A rich plant sources (correlation coefficient 0.03, p=0.47).

A negative correlation between vitamin A knowledge and vitamin A-rich food consumption was observed in this study. Upon further examination of the data, no statistically significant association was observed between vitamin A knowledge and consumption of plant sources of vitamin A. However, there was a statistically significant and inverse association between knowledge and consumption of vitamin A-rich animal food sources.

Multivariate analyses examined two models using linear regression for the continuous outcome and analysis of covariance for the categorical outcome. In the full model, all the independent variables in the model were included irrespective of being significant at the

bivariate level. Knowledge of vitamin A remained statistically significant (unstandardised b coefficient (SE) = -0.18 *(0.50),* p< 0.001). In the reduced model, knowledge of vitamin A (b(*SE*), *p*-value) = -0.18(*0.49*), *p*<0.01) and knowledge of OFSP benefits (b(*SE*), *p*-value) = 0.21(*0.83*), *p*=0.012) were statistically significant predictors of vitamin A-rich food consumption. Misconception about OFSP did not remain statistically significant after adjusting for other covariates in the model (b(*SE*), *p*-value) = 0.18(*0.12*), *p*=0.09).

TABLE 3.7. Estimated correlation coefficient and unstandardised (b) coefficient for association between independent variables and vitamin A-rich food consumption for women

	Unadjusted model	**Full Model Model 1**	**Reduced Model Model 2**
Variable	**r(coefficient)**	**b(*SE*)**	**b*(SE)***
Household size	0.52	-0.04 *(0.04)*	
Education	0.05	0.05 *(0.03)*	-
Age	0.06	-0.008*(0.01)*	-
Knowledge of vitamin A	-0.15**	-0.18 *(0.50) §*	-0.18 (0.49) **
General Knowledge of benefits of orange-fleshed sweet potatoes	0.10*	0.18 *(0.09)*	0.21*(0.83)* *
Misconception about orange-fleshed sweet potatoes	0.65	0.20 *(0.11)*	0.18 *(0.12)*
Individual dietary diversity score	0.07	0.78*(0.11)*	-

*Significant at p<.05, **significant at p< .01, *§- p<.001*

3.4 Discussion

This chapter characterizes vitamin A-rich food consumption and its predictors among women from sweet potato growing households in selected regions of Uganda. The consumption patterns of vitamin A rich foods for women were relatively low with a mean weighted score below the adequate consumption. The study population was at a high risk for vitamin A deficiency. The women had relatively low knowledge about vitamin A given the

mean score observed in the study and the relatively high on the misconceptions about orange fleshed sweet potatoes. We also identified a significant an inverse correlation between knowledge and vitamin A rich food consumption. The studied regions are post conflict areas of Uganda with a greater need to improve food and nutrition security due to food shortages and disrupted economic activities. In Uganda, like in many other developing countries, large scale programs are needed to make a significant impact on high rates of malnutrition, including VAD. However, there has been limited experience and success in scaling up programs (M. K. Nair, Augustine, & Konapur, 2016). A rich-foods. This baseline survey was conducted in the eastern and northern regions of Uganda.

Most women in this study were lactating and 16% were pregnant at the time of data collection. These categories of women have higher vitamin A requirements compared to those who are not lactating and not pregnant. Low intakes during these periods of the life course are associated with adverse health consequences (R. E. Black, 2014). As such, the FAO/WHO recommends an extra 350 RE per day throughout pregnancy and lactation. Recommendations are based generally on the expected secretion of retinol into human breast milk as the concentration of vitamin A in breast milk is dependent on the mothers' status, and as such, their infants would also be expected to benefit (National Research Council, 1989). In addition, breast milk is the critical source of vitamin A especially in the first six months of life (Dror & Allen, 2018). Given the critical role of vitamin A in infant health and development, it is critical that women in the reproductive age group get adequate vitamin A (Bastos Maia et al., 2019a).

Based on the weighted consumption score, which found that nearly all women consumed low amounts of both animal and plant sources of vitamin A, the surveyed communities are considered to be at a high risk for VAD. Plant foods were more frequent sources of vitamin A compared to animal sources across all regions in this study. The vitamin

A-rich food consumption patterns of the study communities were not uniquely different and accentuated the reliance on plant source diets in limited resource settings in Sub Saharan Africa. Animal source foods are associated with higher serum retinol levels (Rahman et al., 2017), however, are less affordable for low income populations (Erokhin et al., 2021). Based on the observed dietary patterns, this study population was considered to be at high risk of VAD.

Previous studies corroborate our findings, suggesting that individuals from resource-constrained communities have limited access to foods containing preformed vitamin A from animal-based food sources and they do not commonly consume available foods containing beta-carotene due to poverty or lack of information on the importance of the food sources (Akhtar et al., 2013). Studies have identified plant sources as the most common sources of vitamin A (Akhtar et al., 2013). Hence, it is important to educate at-risk communities so that they can improve consumption of carotenoids in their diets, including orange-fleshed sweet potatoes, mangoes, papaya and dark leafy green vegetables (Gilbert, 2013).

Vitamin A-rich plant foods are readily available in these communities in Uganda, however, it is likely that they are underutilized. Furthermore, existing cultural practices that prohibit pregnant and lactating women from the consumption of potentially good sources of vitamin A need to be abated (Chakona & Shackleton, 2019; Ramulondi, de Wet, & Ntuli, 2021). Seasonal variation in food supply can be addressed by growth of drought-resistant and dry season crops, such as tubers, which can alleviate food insecurity, although they may not necessarily be the best sources of vitamin A (Underwood, Howson, Kennedy, & Horwitz, 1998).

Leafy green vegetables and orange-fleshed sweet potatoes were the commonly consumed sources of vitamin A in this population. There was limited consumption of vitamin A-rich fruits. Being seasonal crops, this translates into reduced consumption during the out of

season periods. Seasonality needs to be considered for consistent vitamin A intake across the year. Having the potential to purchase other sources in the market during off seasons is one strategy to be considered in program interventions. Education and peer mentoring on home-based gardens for alternative vitamin A sources during periods of food insecurity, especially in the dry season, would be instrumental in mitigating malnutrition (Faber & van Jaarsveld, 2007; Galhena, Freed, & Maredia, 2013).

Targeted nutrition education can be incorporated in food-based programs to increase community knowledge on ways to improve the bioavailability and maximize the absorption of vitamin A from plant sources (M. K. Nair et al., 2016; Ruel, 2001). This includes preparation methods that allows the addition of fat to increase bioavailability of vitamin A which is fat soluble and can be stored in the body (Jamil et al., 2012a). An intervention study including nutrition education, conducted in Bangladesh reported marginally higher beta carotene intake among individuals consuming fried orange-fleshed sweet potatoes versus boiled orange-fleshed sweet potatoes (p=0.07) (Jamil et al., 2012a).

This study observed low dietary diversity with 76.6% of women consuming less than four food groups. These results compare with a study on pregnant women (N=104) in the Damot Sore district of Southern Ethiopia which found that half of the women had dietary diversity scores less than three (Abebe, Abebe, Loha, & Stoecker, 2014). Another study in Ethiopia (N=300) reported that 23% of households had low dietary diversity (Schwei, Tesfay, Asfaw, Jogo, & Busse, 2017). Similar findings from another Ethiopian Study found that 70% of households reported low or medium dietary diversity (Aserese A D et al., 2020). However, another study among 624 lactating mothers attending an immunization clinic in Gondar town, Ethiopia found that women had adequate vitamin A consumption and a greater proportion of women consumed more than five food groups (Aserese A D et al., 2020). The difference in

the vitamin A-rich food intake in these Ethiopian communities can be explained by the latter being predominantly rural and post conflict, thus a higher level of food security.

The study found that only 12% of the women were knowledgeable about vitamin A, and a significant number had misperceptions about orange flashed sweet potatoes. In contrast to our study, knowledge was found to be higher among women attending an immunization clinic in Gondar town, Ethiopia (Aserese A D et al., 2020). A study conducted in Bangladesh identified knowledge as a predictor of vitamin A-rich food consumption (K. M. Jones, Specio, Shrestha, Brown, & Allen, 2005). However, no statistically significant association was found between knowledge of vitamin A and vitamin A-rich food consumption among lactating women in two regions of Tanzania (Ndau et al., 2016b).

Having a college degree, family size, and being from a higher economic class were identified as factors associated with vitamin A consumption in an Ethiopian study (Aserese et al., 2020). Given that the study settings were different, it is possible women who attended the clinic in a town setting were more educated, knowledgeable, and economically well off (Aserese et al., 2020) compared to women in our study who lived in post-conflict areas and relied on farming income. A study conducted in northern Benin where 33·6 % of women were identified as being at a greater risk of VAD, found that maternal education, maternal farming activity, maternal health status, low food diversity, lack of fruit and vegetable consumption, low protein food consumption, and high infection were associated with the vitamin A status (Alaofè, Burney, Naylor, & Taren, 2017). In a study of 569 lactating mothers in Tanzania, the prevalence of VAD was 88.5% and was associated with place of residence (Ndau et al., 2016a). Sixty eight percent of the lactating mothers lacked knowledge about vitamin A and fortified oil, however they had a positive attitude towards the consumption of vitamin A-rich foods (Ndau et al., 2016a). These findings suggest benefits of

nutrition education, specifically on vitamin A and its health benefits, in low-resourced communities (Ndau et al., 2016a).

Our study contributes to the body of literature on predictors of vitamin A-rich food consumption in low resource settings. It also informs the International Potato Centre's implementation and scaling up of initiatives related to orange-fleshed sweet potatoes in selected post conflict regions in Uganda. Study findings can help promote program effectiveness related to improved vitamin A-rich food consumption within these communities.

Limitations for this study include the lack of assessment of vitamin A status and measures of vitamin A-rich consumption. Although vitamin A consumption was computed from the Hellen Keller International guide which has been validated against acceptable standards, we consider that the potential for underestimation of vitamin A consumption may have occurred based on the vulnerable population of women in our study and the local environment. Since no biochemical tests were conducted, the lack of data on serum levels did not allow us to fully assess vitamin A status. This study may also have been prone to both recall and social desirability bias. Finally, food practices/patterns could be unique to these rural regions in this post conflict situation and results may not be generalizable to populations in other regions or urban areas of Uganda.

3.6 Conclusion

This study characterised vitamin A-rich food consumption and identified factors associated with the consumption among women of reproductive age in post conflict regions of Uganda. Findings indicated that the study population was considered to be at high risk for VAD. Intervention programs intended to improve vitamin A-rich food consumption through development and delivery of biofortified foods such as orange-fleshed sweet potatoes have the potential to improve vitamin A status and the livelihood of targeted communities by

included nutrition education programming. Nutrition education can increase dietary knowledge and address misconceptions about orange-fleshed sweet potatoes, thus improving utilization orange-fleshed sweet potatoes and micronutrient-rich foods in general.

CHAPTER IV

COMPARATIVE ANALYSIS OF FOOD SECURITY MEASURES BY VITAMIN A-RICH FOOD CONSUMPTION AMONG MOTHER-CHILD DYADS IN UGANDA

4.1 Abstract

Mother-child vitamin A intake is associated with household food security, and food security is a core component of the international movement to overcome hunger and poverty. While several studies evaluate the potential of household dietary diversity, self-reported food security, and other alternative indicators to predict food security outcomes accurately, few have conducted comparative analyses of multiple indicators by micronutrient intake. This study compared three different food security indicators, household dietary diversity (HDDS), household food insecurity access scale (HFIAS), and the wealth index, on the repeated household vitamin A-rich food consumption for 375 mother-child dyads from selected sweet potato growing households in Uganda. We aimed to determine mother-child differences in vitamin A-rich food consumption and conduct a comparative analysis of food security indicators by consumption. There was a statistically significant difference in the mean consumption of vitamin A-rich foods for women and children (F (1, 370) = 6.51, p = .011). Women had a higher vitamin A consumption (M = 2.08, SD =2.11) than children in the same household (M = 1.39, SD =2.17). This was qualified by a significant interaction with the household wealth index (F (1,370) = 4.31, p = .039), however not with household dietary diversity (F (1,370) = 3.16, p = .07), and household food insecurity access (F (1,370) = 0.32, p = .57). HDDS and the wealth index was associated with mother's consumption of vitamin A-rich food, however, not with that of the children**.** Initiatives that target mother-infant dyads should be aware of other factors, including intrahousehold food distribution and cultural practices, that may differentially impact child consumption of vitamin A-rich and other

micronutrient rich foods. As such, child-friendly initiatives are recommended to maximize nutritional benefits for children under five years.

4.2 Introduction

Maternal malnutrition is a major determinant of adverse outcomes for mothers and their children (R E Black et al., 2013). Poverty, combined with political problems, is the driving factor in the lack of resources to procure food leading to food insecurity and malnutrition, globally, with worsening scenarios in Africa (Bain et al., 2013b; Sasson, 2012). Food insecurity plays a significant role in maternal health and well-being (R E Black et al., 2013). Women who are food insecure have lower educational attainment and are less likely to access health care (Belachew et al., 2011; Hadley, Stevenson, Tadesse, & Belachew, 2012). They also have greater vulnerability to being exposed to and infected by infectious diseases such as human immunodeficiency virus (HIV), primarily through the pathway of nutrient deficiencies (Friis, 2006; Gillespie & Kadiyala, 2005). Food insecurity increases women's engagement in risk behaviors and early marriage (Masa, Graham, Khan, Chowa, & Patel, 2019; Miller et al., 2011; Pellowski, Huedo-Medina, & Kalichman, 2018; Tsai & Weiser, 2014). In addition, food-insecure mothers had 2.2 times higher rates of mental health issues than those who were food-secure (Gundersen & Ziliak, 2015). And for children, the odds of behavioral problems were 2.1 times higher among those who were food insecure compared to their food secure peers (Gundersen & Ziliak, 2015; Whitaker, Phillips, & Orzol, 2006).

It is crucial to understand that household food security may not guarantee food security for all its individual members as household preferences may not prioritize food acquisition (Pinstrup-Andersen, 2009), and intrahousehold food distribution may favor some household members over others (Pinstrup-Andersen, 2009). Evidence suggests that food security is a determinant of child and maternal dietary intake (Bonis-Profumo, Stacey, &

Brimblecombe, 2021). In these regards, women and children are at a greater risk of food insecurity within households, leading to adverse health and nutritional outcomes (Ivers & Cullen, 2011; Lawlis & Jamieson, 2016). Previous studies suggest women experience higher levels of food insecurity relative to men (L. A. Persson, Rasmussen, & Yang, 2019), raising public health concerns of nutrient deficiencies across the life-course. Other studies found that compared to men, women invest and expend greater household resources on food and child health, and hence their access to resources can potentially mitigate food insecurity and malnutrition(Doss, Njuki, & Mika, 2020; Duflo, 2003; Hossain, Asadullah, & Kambhampati, 2021; Quisumbing & Maluccio, 2000).

Vitamin A deficiency (VAD) is considered one of the most prevalent micronutrient deficiencies worldwide, mainly affecting children and pregnant women in LMIC (World Health Organization, 2009a). Globally, approximately 30% of children under five years of age are vitamin A deficient, contributing to 2% of mortality in this age group (Stevens et al., 2015a; United Nations System Standing Committee on Nutrition, 2010). Micronutrients, including vitamin A, are critical for growth and development (Singh, 2004), as well as immune function (Gombart, Pierre, & Maggini, 2020) and the prevention of illness (Marcos, 2021).

There is evidence linking VAD to indicators of food security (Pobee et al., 2020b); poor socioeconomic status (West Jr & Mehra, 2010); less frequent intake of vegetables, fruit, dairy, products, fish, and meat (Gittelsohn et al., 1998; Mele et al., 1991); a less varied household diet (Wirth et al., 2017); and household food rationing (Hombali, Solon, Venkatesh, Nair, & Peña-Rosas, 2019). There is a dearth of studies focusing on differences in food consumption patterns, especially micronutrient consumption, in mother-child dyads (Thakwalakwa, Flax, Phuka, Garcia, & Jaacks, 2020). In addition, household food allocation patterns relevant to mother-child dyads and in the context of

scarcity remain poorly understood (Harris-Fry, Shrestha, Costello, & Saville, 2017; Patnaik, 2009).

Numerous studies examining food security and nutritional status in mother-child dyads have found differences between women and children in the same household (Bonis-Profumo et al., 2021; Ling, Robbins, & Xu, 2019; Wojcicki, 2014). There is a dearth of research on the strength of associations of various measures of food security and vitamin A-rich food consumption (Faber et al., 2009), as well as comparative analysis of food security measures and malnutrition, especially in resource-limited settings (Cordeiro, Wilde, Semu, & Levinson, 2012; Faber et al., 2009). More evidence is needed to delineate the effect of food insecurity on micronutrient intake, and the causal pathways of this relationship.

This study presents a comparative analysis of food security measures by vitamin A-rich food consumption of mother-child dyads in selected regions of Uganda. Unique in examining and documenting the mother-child differences in vitamin A consumption, this study posited that mothers' vitamin A-rich food consumption was greater than their children. This study also examined the strength of various food security indicators in predicting vitamin A consumption for mothers, children, and the difference mother-child consumption.

4.3 Methods and Procedures

4.3.1 Study Design

This study examined baseline data on food security, dietary intake, and livelihoods among mother-child dyads residing in households that grew sweet potatoes in the selected regions in Uganda. Survey data were collected by the International Potato Centre (CIP) for monitoring and evaluation purposes of an initiative that involves the development and delivery of biofortified crops (DDBIO) at scale in Uganda.

4.3.2 Study Setting

Data used in this analysis were collected in Uganda, a landlocked country in East Africa, with an estimated population of 43 million people(UBOS, 2021). Half (50.8 %) of the Ugandan population are women and nearly seven million are children aged 0-4 years (UBOS, 2016). Eighty percent of the Ugandan population is rural, and the agricultural sector is the major economic backbone for 60% of the nation's population (FAO, 2021). The country is divided into four regions, namely central, western, eastern, and northern. This study examined data from the eastern and the northern regions of Uganda, specifically nine out of the twelve districts considered for the DDBIO project, including Pader, Lamwo, Gulu, Kitgum, Agago, and Adjumani in the northern region and Bugiri, Busia, Tororo, and Karamoja in the eastern region of Uganda.

4.3.3 Sample Size

The sample size for this study was determined based on a priori sample size calculations. The statistical power needed to detect small, medium, and large effects was calculated for Student's t-tests, Pearson's correlations, and regression analyses. The power analyses were conducted using G* power 3.1.9.7 software (Faul et al., 2007). Assuming a two-tailed test, 1- beta error probability of 0.8, and an alpha of 0.05. The analytical dataset had 375 woman-child dyads which was sufficient to detect medium and larger sized effects for all tests and to detect associations between selected independent variables (i.e., Household Dietary Diversity Score (HDDS), Household Food Insecurity Access Scale (HFIAS), and the wealth index) and the outcome variable, vitamin A-rich food consumption, among women and children.

4.3.4 Study population and eligibility

The study population comprised mother-child dyads who resided in households that grew sweet potatoes in the eastern and northern districts in Uganda. These districts were

selected based on higher levels of malnutrition as compared to other districts in Uganda, as well as minimal food-based interventions in the same districts. Participants were recruited from the communities at the household level and included women who were either pregnant or lactating, as well as women with children 6-24 months. Women were ineligible to participate in the survey if they were sick or mentally unwell or had not stayed in the household in the past three months.

4.3.5 Data collection

Data were collected at a household level in the selected communities using a comprehensive semi-structured household-level questionnaire developed by CIP. The tool comprised various sections, including household food security status and other household characteristics; sweet potato variety, knowledge, and adoption; sweet potato production and utilization; knowledge of orange-fleshed sweet potatoes and its benefits; household food consumption; a 7-day food frequency questionnaire for vitamin A-rich foods; consumption of orange-fleshed sweet potatoes in the last seven days; knowledge about vitamin A; infant and young child feeding practices; maternal knowledge; meal frequency for the child; household water and sanitation; household livestock assets and belongings. The survey tool was administered at the household level in local languages by trained research assistants.

4.3.6 Measures

Vitamin A-rich food consumption patterns

An adjusted Hellen Keller International (HKI) guide was used to collect data on vitamin A-rich food consumption. The analysis of this data, determines if the community in question has a problem of public health importance. The HKI tool was validated against the World Health Organization standards to classify VAD. (Haselow et al., 1993). If at least 70% of the communities surveyed (11 out of 15) have a VAD problem, vitamin A is likely to be a public health problem in the entire area. Community level VAD is determined by either two threshold values, ≤ 4 days per week for mean frequency of consumption of animal sources of vitamin A or ≤ 6 days per week for mean frequency of total consumption of animal and plant sources of vitamin A (weighted by the source).

The HKI tool was computed based on the question, "How many days, over the past seven days, did (a selected reference child/adolescent girl/woman) eat (a specific food item)?''. The frequency of vitamin A consumption score was calculated by first summing the number of days during the previous week the child or the caregiver consumed Vitamin A rich food from animal source. Then the number of days the child or caregiver consumed Vitamin A rich food from a plant source summed and divided by six (6). The following formula was used in calculating the index:

Weighted total consumption days (C_w) = Total number of days animal sources of Vitamin A consumed (T_{VA}) + Total number of days plant sources of Vitamin A consumed (T_{AP}) divided by 6.

The weighted vitamin A consumption score (C) is equal to the total number of days the child or mother consumed Vitamin A rich food item from animal sources plus the adjusted consumption from the plant source

Assessment of Food Security

This study examined three indicators of household food security available in the dataset: Household Dietary Diversity Score, the Household Food Insecurity Access Scale, and the wealth index. These indices have been used in multiple countries as proxy indicators of the household food access components of food security (Eze, Mbah, Davidson, & Grace, 2019; Kennedy et al., 2010; Leroy, Ruel, Frongillo, Harris, & Ballard, 2015).

Household dietary diversity score (HDDS)

The HDDS represents the number of different food groups consumed by the household within a specified recall period (John Hoddinott & Yohannes, 2002). An indicator of the nutrition quality of the individual diet, HDDS was calculated by summing the number of food groups consumed by the individual respondent over the recall period using the nine food groups recommended by FAO (Faber et al., 2009; Steyn et al., 2006) and scores range from zero to nine. Extracted from the list of 20 possible food items in the questionnaire, the nine food groups included: (1) cereals/grains and root tubers, (2) vitamin A-rich fruit and vegetables, (3) fruit other than vitamin A-rich fruit, (4) vegetables other than vitamin A-rich vegetables, (5) legumes and nuts, (6) meat, poultry, and fish, (7) oils and fats, (8) diary, and (9) eggs. Other items such as tea, sugars, and beverages were not considered when calculating the HDDS for this study.

Household food insecurity access scale (HFIAS)

Data were collected using a modified version of HFIAS measurement tool. Participants were asked to consider if any of the nine listed food insecurity-related conditions had occurred in the last 30 days. If the response was affirmative, the response for each was recorded (never =0; rarely =1; sometimes = 2; and often=3). The HFIAS was calculated by summing the frequency for the nine-food insecurity related conditions with higher scores

reflecting greater household food insecurity. The data was transformed into a continuous indicator of food security with a range from 0-27 (Coates et al., 2007). Food security status was then categorized into four categories by setting HFIAS score value thresholds to segment the entire distribution of the HFIAS scores (Chakona & Shackleton, 2018):

1) Food secure: HFIAS score 0-1
2) Mildly food insecure: HFIAS score 2-7
3) Moderately food insecure: HFIAS score 8-11
4) Severely food insecure: HFIAS score 12-27

Wealth Index

The wealth index is often used in food security assessments (Hjelm, Mathiassen, & Wadhwa, 2016). It provides information on the household's ability to access food, the potential for food insecurity, and the economic situation of food insecure households (Hjelm et al., 2016).Selected variables for this index included household and livestock assets, as well as household belongings. Households were classified into wealth quintiles by ranking their assigned wealth index values. This study employed principal component analysis (PCA), a method typically used to reduce the dimensionality of multiple factors in a dataset. PCA involves replacing a set of correlated variables within a set of correlated variables with a set of uncorrelated “principal components” while minimizing information loss (Jolliffe & Cadima, 2016).

The PCA method extracts the most important information that can identify patterns in the data in the form of principal components. The first principal component comprises the wealth index (Hjelm, Mathiassen, Miller, & Wadhwa, 2017). The criteria for the variables selected for inclusion in the PCA were those with a prevalence between 5% and 95%, as well as variables that were not largely correlated or entirely correlated with each other. Following the creation of the wealth index and quintiles, variables that did not show a clear pattern in

increasing ownership between each wealth quintile were also excluded in the frequentative process.

4.3.7 Ethical approval

Ethical clearance was obtained from the ethics committee of the School of Health Sciences, Makerere University, and approved by the Uganda National Council for Science and Technology. Human subjects' exemption for this secondary data analysis was received from the University of Massachusetts Human Research Protection Office

4.3.8 Statistical analysis

Data analyses were conducted using SPSS version 26 (IBM Corp, 2019). Continuous data from the computed indices, vitamin A-rich food consumption for women and children, HDDS, HFIAS, and the wealth index, was used to run the statistical tests described below. Data were stratified by woman or child to allow for within- and between-person variances in vitamin A-rich food consumption. The HDDS, HFIAS, and wealth index were normally distributed.

Dependent sample Student's t-tests were used to compare vitamin A-rich food consumption between women and children. Pearson's correlation analysis at the bivariate level determined if vitamin A-rich food consumption for women and children correlated with food security indicators. Using a general linear model, a repeated measure analysis of covariance (ANCOVA) was conducted. Presence of differences in the vitamin A-rich food consumption for women and children was assessed, along with interactions between vitamin A-rich food consumption and independent variables. Statistical significance was set at 0.05 with a 95% confidence interval.

4.4 Results

The northern (33%) and eastern (32%) subregions had a considerably larger proportion of participants compared to the other regions (<20%). The mean number of

household members in this sample was 6.7 (SD 2.5), and only 11% of households were female-headed (Table 3.1).

TABLE 4.1. Socio-demographic characteristics of the study participants (N = 375)

Variable	Categories	n (%)	Mean *(SD)*
Study Region	Eastern	118 (31.5)	
	Karamoja	76 (20.3)	
	Northern	125 (33.3)	
	West Nile	56 (14.9)	
Household size (No. of people)	1-4 people	62 (16.6)	6.7 (2.5)
	5-9 people	261(69.5)	
	>9 people	52 (13.9)	
Sex of Household Head	Male	354(94.4)	
	Female	21(5.6)	
Relationship to Household Head	Household head	13 (3.5)	
	Spouse	303 (84.9)	
	Other	38 (10.1)	
Woman Age Group (Years)	15-19	21 (5.9)	28.5 (6.9)
	20-34	274 (77.4)	
	>35	57 (16.7)	
Child Age group (Months)	6-12	135 (36.0)	
	13-24	240 (64.0)	
Marital Status	Married with spouse	312 (88.4)	
	Married, spouse away	20 (5.7)	
	Divorced/separated/widowed	22 (5.9)	
Education (Years of schooling)	No formal education	80 (22.6)	4.99 (3.64)
	1-7 years	194 (51.8)	
	>7 years	80 (25.5)	
Occupation	Farming (crop and livestock	290 (82.2)	
	Household chores	35 (10.7)	
	Other	26 (7.1)	
Reproductive Status	Pregnant	49 (13.9)	
	Lactating	291(82.4)	
	Non-pregnant, non-lactating	13 (3.7)	
Disability Status	Yes	14 (4.0)	
	No	340 (96.0)	
Food Security Status	Food Secure	89 (15.4)	
	Mild Food Insecurity	181 (31.3)	
	Moderate Food Insecurity	161 (27. 8)	
	Severe Food Insecurity	148 (25.6)	
Wealth Quintiles	1 (Low)	76 (20.3)	3.01(1.41)
	2	87 (23.2)	

3	73 (19.5)
4	63 (16.8)
5 (High)	76 (20.3)

There was a relatively higher consumption of vitamin A-rich foods among mothers compared to their children. The mean weighted score for vitamin A-rich food for women was 2.08 days (*SD* = 2.11) and 1.39 days (*SD* = 2.17) for children, respectively (Table 3.2). Dependent samples t-test results revealed a statistically significant difference in the mean weighted score for vitamin A-rich food consumption among mother-child dyad (t (373) = 7.46 $p < .001$).

TABLE 4.2. Scores for vitamin A rich food consumption for women and children

	Consumption	**N**	**Mean *(SD)***	**Median**
Women	Total score for Vitamin A-rich animal foods	374	1.32 (1.90)	0.00
	Total score for Vitamin A-rich plant foods	374	4.5 (3.64)	4.00
	Total weighted consumption score	374	2.08 (2.11)	1.33
Children	Total score for Vitamin A-rich animal foods	374	0.89(1.85)	0.00
	Total score for Vitamin A-rich plant foods	374	3.01 (3.81)	2.00
	Total weighted consumption score	374	1.39 (2.17)	0.50

More than two-thirds of the households (77%) reported consuming ≤ four food groups in the 24 hours preceding the survey, with higher consumption of carbohydrate-dense foods than protein-dense foods (Figure 4.1).

FIGURE 4.1. Food groups consumed by households in 24 hours preceding the survey

Food security categories based on the HFIAS revealed 16% percent of the households as food secure and 27.2% as severely food insecure (Figure 4.2). There was nearly an equal distribution of food security/insecurity status across the selected regions.

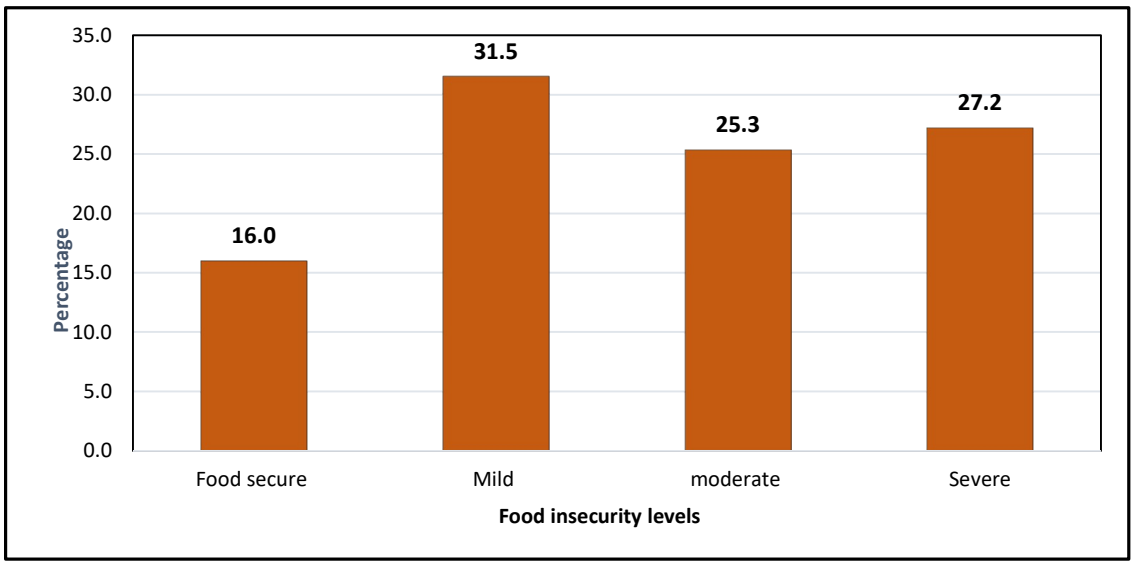

FIGURE 4.2. Distribution of food security/food insecurity

Affirmative responses to the nine questions of the HFIAS ranged from 19.6% to 77.6% (Table 4.3). The responses were highest for items showing mild to moderate forms of food insecurity such as Q1. worrying about food, Q2. not able to eat preferred food, Q3. eating a limited variety of food, and Q4. eating foods that you did not really want to eat. Affirmative responses for Q7 to Q9, indicative of severe forms of food insecurity, were relatively lower. More than half of the participants reported a frequency of three times or more in the past four weeks for affirmative responses to Q1 to Q6.

TABLE 4.3. Affirmative responses to questions on the Household Food Insecurity Access Scale (HFIAS) N= 375)

	HFIAS questions	n	% Yes	>3 times in past 4 wks. n (%)
Q1	Worry about food	271	72.3	171 (63.1)
Q2	Not able to eat the preferred foods	291	77.6	171 (58.8)
Q3	Eat a limited variety of foods	257	68.5	167 (65.0)
Q4	Eat foods that you did not really want to eat	269	71.7	143 (53.2)
Q5	Eat smaller meal	228	60.8	136 (59.7)
Q6	Eat fewer meals in a day	235	62.7	133 (56.6)
Q7	No food of any kind to eat in the household	119	31.7	60 (16.0)
Q8	Go to sleep at night hungry	125	33.3	57 (15.2)
Q9	Go a whole day and night without eating anything	62	19.6	21 (5.6)

Mean (SD) and median scores for HDDS and HFIAS, as well as the mean and median wealth index is presented in Table 3.3. Both HDDS and wealth index were negatively correlated with HFIAS (Table 4.4).

TABLE 4.4. Mean, SD, and median values for the household food security indicators

Food Security Indicators	N	Mean	SD	Median
HDDS	374	3.40	1.56	3.5
HFIAS	375	8.22	5.64	8.0
Wealth index	375	2.94	1.42	3.0

A strong positive correlation between the vitamin A-rich food consumption of mothers with that of the children (r (371) =.651, p< .001) was observed in this study (Table 3.5). There were no significant associations between HDDS and vitamin A-rich food consumption for women (r (371) = .26, p = .12) or with vitamin A-rich food consumption for children (r (371) =.04, p =.44). HFIAS was not correlated with either the vitamin A-rich food consumption for mothers (r (371) = .07, p = .20) or children (r (371) = .00, p = .99). A weak significant inverse correlation was observed between the wealth index and women's vitamin A-rich food consumption (r (372) = -.15, p = .05), but not with the children's vitamin A-rich food consumption (r (372) = -.04, p = .40) (Table 4.5).

TABLE 4.5. Correlation between vitamin A-rich food consumption, household food security, and wealth index (N= 374)

Variable	VA Weighted score women	VA Weighted score children	HFIAS	HDDS	Wealth index
VA Weighted score women	1				
VA Weighted score children	.651**	1			
HFIAS	.066	.000	1		
HDDS	.115*	.040	-.077	1	
Wealth Index	-.145**	-.044	-.179**	.005	1

Test of significance based on Pearson's correlation (2 tailed), p<0.05
* Correlation significant at the 0.05 level (2-tailed).
** Correlation significant at the 0.01 level (2-tailed).

The three food security covariates were included in the general linear model against a 2-level dependent variable (vitamin A-rich food consumption for mothers and children). There was a significant within-subject effect of the difference between mother and child vitamin A-rich food consumption (F (1, 370) = 6.51, p = .011). Mothers had higher vitamin A consumption (M = 2.08, SD =2.11) than children in the same household (M = 1.39, SD =2.17). This difference was qualified by a statistically significant interaction with household wealth index (F (1,370) = 4.31, p = .039). While children's vitamin A consumption was not

predicted by household wealth (*b* = -.11, *SE* = .08, *p* .15), the woman's vitamin A consumption was negatively predicted by household wealth (*b* = -0.25, *SE* = .08, *p* = .001). In addition, there was a statistically significant between-subject effect of the household wealth (*F* (1,370) = 6.66, *p* = .01) (Table 4.6).

A marginally significant interaction was observed between HDDS and the difference in vitamin A consumption of women and children (*F* (1,370) = 3.16, *p* = .07). Children's vitamin A consumption was not predicted by HDDS (*b* = .06, *SE* = .07, *p* .4), while women's vitamin A consumption was positively predicted by HDDS (*b* = .17, *SE* = .07, *p* = .02). There was no statistically significant between subject effect of HDDS (*F* (1,370) = 3.16, *p* = .08) (Table 4.6).

A non-significant interaction between HFIAS and the mother-child difference of vitamin A-rich food consumption was determined in this study (*F* (1,366) = 2.39, *p* = .14). Neither women's (*b* = .018, *SE* = .019, *p* = .37) nor children's vitamin A consumption (b= -.004, *SE*= .002, *p* = .83) were associated with HFIAS (Table 4.6). No statistically significant between subject effect of HFIAS was observed (*F* (1,370) = 0.32, *p* = .57).

TABLE 4.6. Parameter estimates in the general linear model for vitamin A-rich food consumption and household food insecurity indices

Dependent variable	Independent variable	B (unstandardized coefficient)	*SE*	*p*-value	95% CI, lower bound	95% CI, lower bound
Women	Intercept	2.064	0.396	0.000	1.284	2.843
Vitamin A weighted score	HFIAS	0.018	0.019	0.366	-0.021	0.056
	HDDS	0.170	0.069	0.014	0.034	0.306
	Wealth index	-0.237	0.077	0.002	-0.388	-0.087
Children	Intercept	1.575	0.417	0.000	0.756	2.395
Vitamin A weighted score	HFIAS	-0.004	0.02	0.829	-0.045	0.036
	HDDS	0.059	0.073	0.416	-0.084	0.202
	Wealth index	-0.117	0.081	0.148	-0.275	0.041

4.5 Discussion

Food insecurity and micronutrient deficiencies are public health concerns affecting millions of the global population (IFAD, UNICEF, WFP, & WHO, 2021). Evidence suggests that consuming a diverse diet improves nutritional health and well-being (Chakona & Shackleton, 2017; Cordeiro et al., 2012). However, household food insecurity has often resulted in monotonous diets deficient in micronutrients, including vitamin A (Chakona & Shackleton, 2017). This study undertook a comparative analysis of food security indicators and vitamin A-rich food consumption in mother-child dyads. We posit that understanding food security in the context of vitamin A-rich food consumption is one of the gateways to establishing or documenting any relationships between food security and micronutrient consumption, and more broadly optimal health. The study provides new information on food security and vitamin A intake among women and children from limited-resource settings.

A considerable number of households were categorized as food insecure by the three food security indicators, suggesting that these indicators were all able to illustrate trends or occurrences of food security in these communities. These results are consistent with previous studies (Omuemu, Otasowie, & Onyiriuka, 2012; Sharafkhani, Dastgiri, Gharaaghaji, Ghavamzadeh, & Didarloo, 2010; Wambogo, Ghattas, Leonard, & Sahyoun, 2018). The weak correlations between household food security indicators and vitamin A-rich food consumption found in this study is corroborated by studies on the association of multiple food security indicators and undernutrition in Vietnam (Mahadevan & Hoang, 2016) Tanzania (Cordeiro et al., 2012)or micronutrient status in Ghana (Ruth Adisetu Pobee, Sixtus Aguree, Esi Komeley Colecraft, Alison D Gernand, & Laura E Murray-Kolb, 2020a).

This study found that HDDS and the wealth index were associated with vitamin A-rich food consumption among mothers, but not children. HFIAS was not associated with

vitamin A-rich food consumption in this study. A study conducted in Ethiopia also identified a positive correlation between reported food security and dietary diversity (Schwei et al., 2017). A study conducted in Ghana among mother-child dyads identified the wealth index as a predictor of mother and child dietary intake (Kubuga, Shin, & Song, 2020). Studies elsewhere have also identified correlations between wealth indices and food consumption (Decuyper et al., 2014; Hjelm et al., 2016). However, the wealth index in this study was inversely and significantly associated with vitamin A-rich food consumption of mothers but not children. The interpretation here is that households with fewer assets were likely to consume more vitamin A-rich foods than households with more assets. We suggest that communities may have rooted food practices that were related to food consumption and not altered by increased wealth (Chakona & Shackleton, 2019). There is also a possibility that these communities are unaware of the food sources and benefits of vitamin A, affecting consumption patterns despite their ability to access these foods (Angeles-Agdeppa, Lenighan, Jacquier, Toledo, & Capanzana, 2019; Mshanga, Martin, & Petrucka, 2020). Furthermore, it is possible that intrahousehold distribution of resources did not change with increased household wealth, and either food expenditures may have been maintained at pre-wealth levels or intrahousehold food distribution patterns could have negatively affected children's consumption of vitamin A-rich foods. Finally, this study may have not accounted for other potential confounders in the region for which data were not collected. Alternatively, the possibility of unexplained analytical pitfalls of the methods used is also relevant to study findings (Aggarwal & Ranganathan, 2016).

HFIAS was not a predictor of vitamin A-rich food consumption for mothers and their children in this study. These findings contrast with a Canadian study that established associations between food insecurity and micronutrient inadequacies (Kirkpatrick & Tarasuk, 2008). Differences in the findings of our study and the Canadian study can be explained by

vast differences in the place of residence, socio-demographics, and examination of micronutrients in totality in the Canadian study as opposed to vitamin A in particular

This study identified a difference in household consumption of vitamin A-rich foods, with mothers consuming these foods relatively more frequently compared to children in the same households. However, the overall intake of vitamin A-rich foods of the household was generally low. In contrast, a study among mother-infant dyads in Brazil found an adequate intake of vitamin A-rich foods or beta-carotene intake (Lira et al., 2018). Given that women are likely to select from a variety of sources of vitamin A-rich foods, there is a possibility that children may have a limited number of sources as predetermined by the mother. For example, a common practice in Uganda is where green leafy vegetables commonly consumed by the household may not be given to children under five years due to the taste, preparation, and presentation issues (Mennella & Bobowski, 2015; Scaglioni et al., 2018). At the same time, women may perceive particular vitamin A-rich foods as not good for children due to their texture or knowing that children don't like such foods, or because children are commonly given softer and easily digested foods(Benakappa, Shivamurthy, & Medicine, 2012).

A study in India found that foods are classified according to their hot or cold properties, with certain foods selected for child consumption (Benakappa et al., 2012). Different taboos and cultural beliefs about food vary across communities and shape what foods are provided to children (Lokossou, Tambe, Azandjèmè, & Mbhenyane, 2021). Studies examining the dynamics of food choice within households found that choices can be based on personal preferences, gender, contextual issues, and resources available to the household (Evans et al., 2011; Yaktine & Caswell, 2013). Differences in mother-child vitamin A-rich food consumption can also be explained by commonly acceptable beliefs that the dietary patterns and food preferences are not yet well established for children under five years (Farrow & Blissett, 2012).

The lack of association between food security indicators and vitamin A consumption of children could be explained by the fact that breast milk consumption was not taken into consideration, hence underestimating vitamin A-rich food consumption (V. Persson et al., 1998). It is possible that breastfeeding could reduce or alter other food intake, including vitamin A-rich food consumption, for some children (Specht, Rohde, Olsen, & Heitmann, 2018). One significant limitation is that the tool used to assess vitamin A consumption was prone to recall bias and social desirability bias (Hebert et al., 2008). This study would have benefited from the collection of serum retinol levels, however, this biomarker of vitamin A status was not collected due to a lack of required laboratory facilities, as well as issues with storage and transportation.

The present study contributes to establishing strategies and promoting healthy diets and optimal nutritional outcomes by examining associations between food security and vitamin A-rich food consumption among mother-child dyads in Uganda. Monotonous diets high in carbohydrates and low in nutrient-rich foods are typical in developing countries, even among households that can afford better (Chakona & Shackleton, 2017; Mekuria, Wubneh, & Tewabe, 2017). Diets high in carbohydrates but low in protein and micronutrients can result in malnutrition, even if one's daily energy supply is adequate. Earlier studies in sub-Saharan Africa have found household dietary diversity to be a promising indicator, and household food security status was seen to be a positive predictor of dietary diversity (Faber et al., 2009; Schwei et al., 2017). Hence, selecting appropriate measures of household food security is critical is assessing the impact of food and economic aid, as well as for program evaluation purposes, and for informing multisectoral policies (A. D. Jones, Ngure, Pelto, & Young, 2013).

4.6 Conclusion

This study identified a strong and statistically significant correlation between mother and child vitamin A-rich food consumption. HDDS and wealth index was found to be associated with vitamin A-rich food consumption of mother but not children, while HFIAS was not associated with either mother or child consumption. Based on the findings of this study, programs that target mother-child dyads should be aware that interventions may not impact or reach children, and child-specific interventions should also be considered. Finally, improving the vitamin A status of women and children requires improving the dietary intake of vitamin A for the whole family. Achieving this goal will require a combination of strategies, including increasing the availability of vitamin A-rich foods, improving maternal knowledge on vitamin A-rich food sources and their preparation, and alleviating poverty.

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