INCORPORATING OFSP IN RECIPES CONTRIBUTES TO ERADICATING VITAMIN A DEFICIENCY AMONG WOMEN OF REPRODUCTIVE AGE AND PRESCHOOL CHILDREN IN SUB-SAHARAN AFRICA: AN EXCEL BASED SIMULATION MODEL

Nyangaresi Annette [1], Moyo Mukani [1], Abong' George[2], Miiro Richard [3], Grant Fredrick [4], Hareau Guy[5], Muzhingi Tawanda [1*]

[1] International Potato Center (CIP), SSA Regional Office, ILRI Campus, Nairobi, Kenya

[2]Department of Food Science, Nutrition and Technology, University of Nairobi, Nairobi, Kenya

[3] Department of Food and Nutrition, Makerere University, Kampala, Uganda

[4] International Potato Center (CIP), Kampala, Uganda

[5] International Potato Center (CIP), Lima, Peru

Abstract

Vitamin A Deficiency (VAD) is one of the leading contributors to hidden hunger globally, with poor African communities being the most affected. This study sought to explore the commonly consumed foods in three Sub-Saharan African (SSA) countries; Uganda, Kenya, and Malawi, and to assess the possible contribution of Orange Fleshed Sweet Potato (OFSP) in meeting the daily Vitamin A (VA) demands for the normal functioning of the body in pre- and school going children aged between seven months and 8 years and women of reproductive age. Secondary data from Food Composition Tables (FCT) and common food recipes in the specific countries was analyzed using an excel based simulation model. VAD was determined based on the recipes and estimations on the amounts of OFSP sufficient to meet the deficiencies. There were significant differences, ($p<0.05$), in VA quantities in the foods across the three countries. Recipes incorporating OFSP generally had higher VA content. Interestingly, in recipes combining equal or lesser mounts of OFSP with other ingredients or other sweet potato varieties, OFSP contributed the highest amounts of VA regardless of the cooking method. Furthermore, recipes with OFSP as the only ingredient and/or sole source of VA, VA content surpassed the daily requirements for children with an excess contribution of 92.6-295.6mcg, 292.6-495.6mcg and 192.6-395.6mcg for children aged 7-12 months, 1-3 years and 4-8 years, respectively. For pregnant and lactating women, the VA contribution by OFSP was between 9-106% and 5-66% of the RDA, respectively. The OFSP quantities needed to meet deficiencies in the recipes were 5.6-53.9g for children aged 7-12 months, 3.2-32.3g for children aged between 1-3 years and 4.4-43.1g in the children aged between 4-8 years. The OFSP needs estimates for pregnant and lactating mothers were 8.2-83.1g and 43.7-140.3g, respectively.

Keywords: Orange Fleshed Sweet Potato, Vitamin A Deficiency, Hidden Hunger, Food Composition Tables

Corresponding Authors:

Muzhingi Tawanda: International Potato Center, CIP-SSA Regional Office, ILRI Campus, Old Naivasha Road, Nairobi, Kenya, t.muzhingi@cgiar.org

1 INTRODUCTION

Vitamin A (VA) is a fat-soluble vitamin responsible for normal vision, gene expression, reproduction, embryonic development, growth, and immune function in the human body (McLaren et al., 2012, Gester H, 1997). Vitamin A Deficiency (VAD) is considered a serious global health problem (Kiharason, J.W. et al., 2014, Hawkes, C., 2017) and continues to affect many vulnerable groups especially women of reproductive age and children of school going age (Fiedler et al., 2010). VAD is manifested through night blindness, stunted growth, impaired cognitive development and high morbidity and mortality especially in children below the age of five (Padmavathi, 2016, Beaton G.H et al., 1993).

VAD is estimated to affect 190 million preschool children and 19 million pregnant and lactating women worldwide, mainly in Asia and Africa (WHO, 2009; Stevens et al., 2015) with countries such as Uganda, Kenya and Malawi displaying high numbers. A study by Uganda Demographic and Health Survey (UDHS, I., 2011), showed that up to 38% of children and 36% of women in Uganda are VA deficient. A similar trend is reflected in different regions of SSA with Ghana reporting 20.18% VAD in children aged between 6-59 months and 1.5% in non-pregnant women in the year 2017, (UNICEF, 2017). In the same year, Malawi reported that close to 60% of children under the age of five had sub-clinical VAD whilst 60% of preschool and 38% of school children had VAD (NSO, Malawi, 2017). The country also reported 57% of women of reproductive age and 48% of non-pregnant women had VAD in the year 2001. Kenya, despite having a lower prevalence, reported a combined 4.5% prevalence, with preschool children having a prevalence of 9.2%, pregnant women 5.4% and non-pregnant women 2.0% (MoH, K., 2018). These statistics show how deeply rooted VAD is in the continent with a projection that in Uganda alone, 221,430 lives could be lost between 2013 and 2025 (FANTA, 2010) through VAD.

Previous studies have shown that food-based strategies are effective in reducing micronutrient deficiencies (Ruel, 2001). Furthermore, dietary based approaches to combating VAD are viewed as healthy, affordable, and sustainable (Underwood B.A., 2000, Low, Jan W., et al., 2017, Mitra et al., 2012). In order for these strategies to be effective and sustainable in relatively poor SSA communities, focus should be on promoting locally grown crops such as sweet potato. Sweet potato is a crop that grows in diverse climatic and environmental conditions and requires minimum farm input, making it ideal for enhancing food security in poor African communities (Laban, T.F., et al., 2015). Uganda is ranked as the second largest producer of sweet potato globally after China (FAOSTAT, 2014), with Eastern Uganda being the highest producer followed by Western and Central, respectively (George O. et al., 2016). In Malawi, sweet potato is grown by small holder farmers across a wide range of environments (Kathabwalika, D.M., 2016) whilst in Kenya, the western and Nyanza regions are the highest producers of the crop (Kaguongo, W., 2012). The biofortified orange fleshed sweet potato (OFSP) varieties (*Ipomoea batatas*) are amongst the most promising crops for combating VAD (Low, Jan W., et al., 2017:2007, Waized, Betty, et al., 2015). OFSP is rich in pro-VA carotenoids such as beta-çarotene (precursor of VA in the body), (Kapinga, Regina, et al., 2005), with as low as 125g being able to supply the daily VA requirements for preschool children, (van Jaarsveld, Paul J., et al., 2005).

For a long time, dietary practices, and food choices in most African communities, were founded on culture, household food sources, resource sources and allocations and not necessarily on informed nutritional needs, especially for the micronutrients (Eva C., et al., 2020, Kittler P.G., et al., 2016, WHO, 2000). Other culture associated food practices exclude VA rich foods hence high prevalence of VAD (WHO, 2009). For years, sweet potato has been a common meal and ingredient on the African plate (Woolfe, J.A., 1992), and is considered an important food security crop in Africa (Loebenstein, G., et al, 2003, Wheatley, C. et al., 2008), with an annual production capacity of up to 1.7 million tonnes (Mmasa, J., 2012). However, conventional varieties, particularly the purple, white and cream varieties have consumer preferred traits such as high dry matter (Kathabwalika, D.M., et al., 2016), whilst lacking sufficient levels of VA to meet the dietary needs (Aywa, A.K., 2013, Burri, B.J., 2011). A number of studies have shown that consuming the OFSP, undoubtedly contributes to reducing VAD prevalence (Neela S. et al., 2019, Low, Jan W., 2017, Laurie, S.M., et al., 2018). The OFSP varieties (Table 1) which are relatively newly adopted in some countries, are VA dense (Low, J.W., 2000).

TABLE 1. Table showing OFSP varieties adopted and cultivated in Uganda, Kenya and Malawi and their attributes

OFSP Variety	**Country adopted**	**Orange Color**	**Mean Yield (T/Ha)**	**Dry matter /100g (%)**	**Beta Carotene /100g Fresh weight (mcg)**	**RAE Content/100g Fresh weight (mcg)**	**Suitability**
Anaakwanine	Malawi	Intermediate	25	25.2	40.78	3398.33	B.P, J
Chipika	Malawi	Pale	35	28.4	12.47	1039.17	B.P, J
Zondeni	Malawi	Intermediate	-	32.4	15.85	1320.83	B.P, J
Kaphulira	Malawi	Pale	35	27	34.83	2902.5	B.P, J
Kadyaubwerere	Malawi	Intermediate	30	26.4	20.15	1679.17	B.P, J
VITA/Naspot 9-O	Uganda/ Kenya	Intermediate	17	25	38.3	3191.67	B.P, J, P, F, D.U

Naspot 8	Uganda	Pale	17.8	26.2	15.11	1259.17	B.P, J, P, F, D.U
Kabode/Naspot 10-O	Uganda/ Kenya	Intermediate	16	24	21.3	1775	B.P, J, P, F, D.U
Gerald	Uganda	Intermediate	24	28	29.39	2449.17	B.P, J, P, F, D.U
Tuweria	Uganda	Intermediate	38	27.2	48.75	4062.5	B.P, J, P, F, D.U
Ejumula	Uganda	Intermediate	19	29.8	34.6	2883.33	B.P, J, P, F, D.U
Irene/ Kakamega-7	Kenya	Immediate	19.6	26	33.32	2776.67	P, D.U
Kenspot 5	Kenya	Pale	10.0-23.0	26.8	21.29	1774.17	-
SPL 031	Kenya	Dark	20-30	24.4	20.94	1745	-

Key: *B.P-Baked products, J-juice, P-Puree, F-Fries, D.U-Diverse utilization*

Source: *2019 Sweet potato Catalogue for Sub-Saharan Africa-International Potato Center*

Given the aforementioned and the great potency of OFSP to end VAD, an understanding of the VA content in OFSP varieties and its VA contribution as a meal and an ingredient is crucial to assist policymakers and implementers in the formulation of policies and programs that would encourage and prioritize its consumption as a practical and sustainable solution to ending VAD. Therefore, the study developed an excel based simulation model for estimating the potential contribution of OFSP consumption in women of childbearing age and children of pre and school going age and recommend appropriate measures to reducing VAD in SSA. The model will explore the dietary practices in Uganda, Kenya and Malawi, based on commonly consumed foods, establish VAD as calculated from the total sum of VA content in the foods, estimate the contribution of OFSP in the foods using Food Composition Tables and project the quantities of OFSP sufficient to eradicate the deficiencies.

2 METHODS

2.1 Study design and criteria

Findings from a systematic review and analysis of technical reports, peer reviewed papers, nutrition fact sheets, food composition tables and scientific blogs were consolidated (Snyder, H., et al. 2019). Scientific papers published between 2000-2020 in peer reviewed journals were reviewed. Forward citation was employed for the study. Keywords used on search engines were ‘Vitamin A Deficiency’, ‘night blindness’, ‘prevalence’, ‘Africa’, ‘Malawi’, ‘Kenya’, ‘Uganda’, ‘orange fleshed sweet potato’, ‘sweet potato’, ‘children’, ‘women of reproductive age’, ‘food-based approaches’, ‘recipes’, ‘food composition’, ‘hidden hunger’, and ‘micronutrient deficiencies’. The search combined at least four keywords, whereby the words VAD, hidden hunger, night blindness, micronutruient deficiencies were used interchangeably, Africa, Kenya, Uganda and Malawi were interchanged, OFSP or food based approaches were interchanged whilst children and women of reproductive age were used together or in separate searches. Over 20,000 scientific papers were available for review, however, due to the large number, a further trimming down was done by selecting those promoting OFSP as a food based strategy to ending VAD. Forward citation was used to identify related work thereby eliminating irrelevant articles. In estimating the VA content in the assessed foods, The most current Food Composition Tables (FCT) and recipe publications in the three countries were used; FCT, 2012 for Uganda, FCT, 2018 for Kenya and FCT, 2019 for Malawi.

2.2 Information source and sites

On desk information search for relevant studies was done through different online databases. These were Google Scholar, Web of Science, Sweetpotato Knowledge Portal, PubMed and Hinari.

2.3 Development of the Excel Simulation Model

Data from FCT and recipes was used to develop the simulation model. The data was only used for purposes of the simulation and did not include individual consumption levels, individual portions or varieties consumed thereby limiting the computation of individual daily vitamin A (RAE) intake. A total of sixteen recipes of commonly consumed foods from Uganda, Kenya and Malawi, six from each country, were randomly selected, analyzed and presented for this study.

2.4 Data extraction and cleaning

Data extracted from the FCT included the name of commonly consumed recipes, their ingredients, the ingredient portions and beta-carotene content. Sixty two, seventy seven and forty recipes from Uganda, Kenya and Malawi, respectively were simulated for VA content, VAD, and the amounts of OFSP sufficient to meet the deficit as obtained from the simulation.

2.5 Selection of Recipes for presentation

The available recipes consisted of mainly roots, tubers, cereals, legumes, dairy and poultry products, vegetables and cooking oil and mainly used boiling, frying and stewing as the main cooking methods. Recipes containing main ingredients considered as staple foods in the three countries and had the preparation method as either boiling or frying, were selected for presentation in this article. Additionally, at least one recipe from each country that had either OFSP only, or in combination with other ingredients at different ratios were included in the data presented herein. The model used a standard 100g for each recipe to arrive at the findings. This may not be the actual amounts, frequencies or only meal consumed at individual level and may be slightly more or less for each age cluster. For simplicity, the recipes were coded as UG_1-UG_6, KE_1-KE_6 and MAL_1-MAL_6 .

2.6 Determination of Vitamin A Deficiency levels

VAD analysis was done based on the Daily Recommended Allowances for the different age clusters. The RDA used for the simulation model are as in Table 2 below:

TABLE 2. Table showing the recommended daily allowances for Vitamin A

	Age Cluster	VA RDA (mcg)
Children	7-12 months	500
	1-3 years	300
	4-8 years	400
Pregnant Mothers	14-18 years	750
	19-50 years	770
Lactating Mothers	14-18 years	1200
	19-50 years	1300

Source: Krinsky et al., 2000

2.7 Determination of VA Content in the Recipes

VA content was presented as Retinol Activity Equivalent (RAE) in micrograms (mcg). The retinol, beta-carotene and beta-carotene equivalent values for each ingredient were obtained from the FCT for each country with the average RAE for OFSP, 926mcg per 100g OFSP (Malawian FCT, 2019), being standardized for the three countries. Where total RAE (tRAE) was not given but carotenoid content was available in the FCT:

2.7.1 Conversions of beta-carotene and beta-carotene equivalent of the ingredients from FCT

RAE_{1a} *(mcg) = Beta-carotene (x) (µg)* ÷ 12*

Where, * is the beta-carotene content in 100g of ingredient as given in the FCT or

RAE_{1b} *(mcg) = Beta-carotene equivalent (y)(µg)* ÷ 24*

Where, * is in the beta-carotene equivalent content in 100g of ingredient as given in the FCT.

$RAE_1 = RAE_{1a} + RAE_{1b} + Retinol_1$

2.7.2 RAE calculations in each ingredient portion in 100g recipe (RAE2)

RAE_2 *(mcg) = Weight of ingredient (w)(g) ÷ 100g* ×* RAE_1

Where * is the weight used to calculate RAE in the FCT

2.7.3 tRAE calculations in 100g recipe (tRAE)

$tRAE\ ((mcg)) = \sum RAE_2\ (mcg)$

Ingredients with a RAE_2 content of less than 0.01mcg ($RAE_2 \leq 0.01$ mcg) were considered to have no significant contribution to VA content in the recipes hence excluded from the data set used for this analysis.

2.7.4 Estimation of OFSP amounts needed to meet VA Deficits

$OFSP\ (g) = VAD\ (mcg) \div 926^*\ (mcg) \times 100\ (g)$

Where, * is the VA content in 100g of OFSP from the Malawian FCT

2.8 Illustration of the steps to developing the simulation model

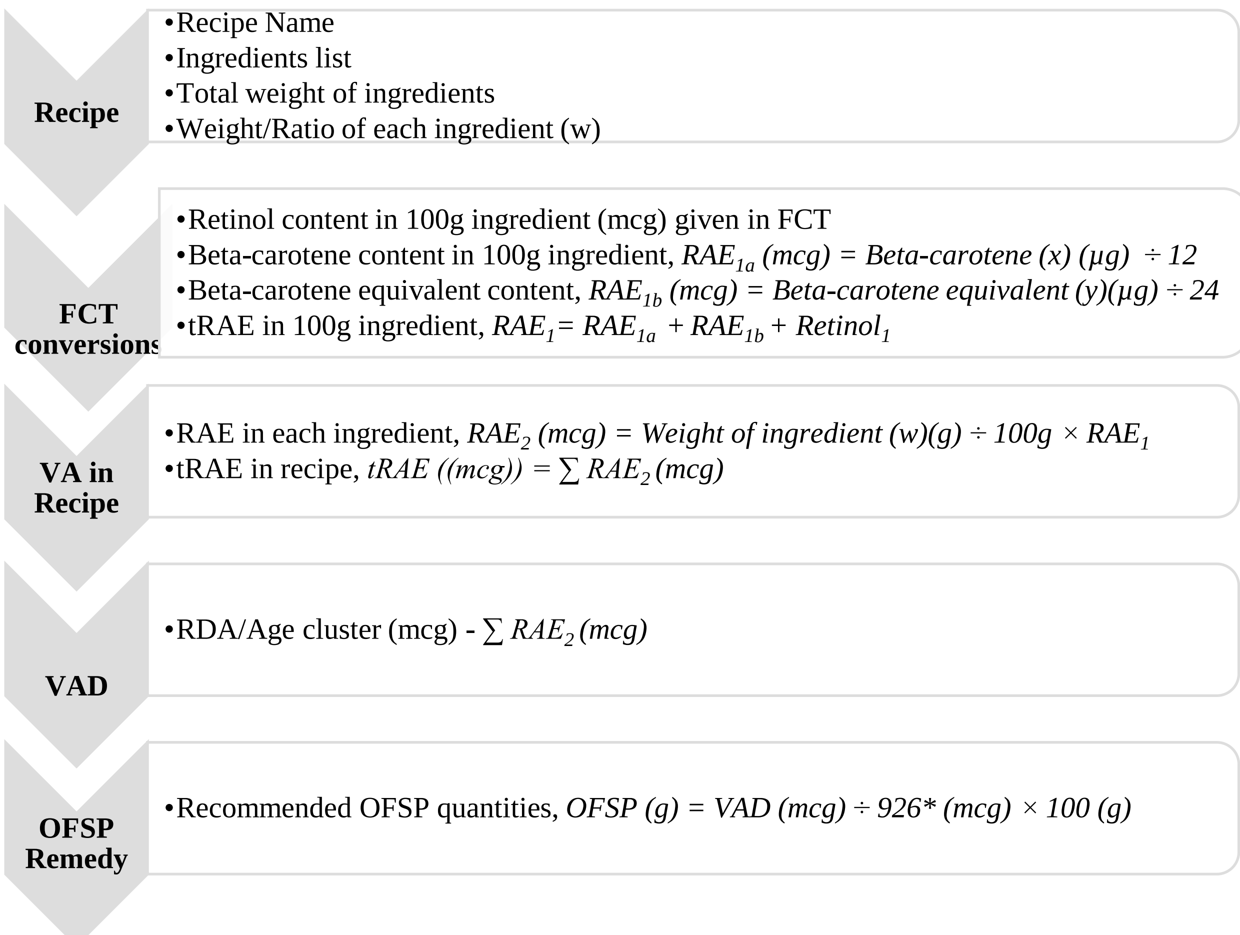

FIGURE 1. A summarized illustration of the steps involved in developing the excel simulation model

2.9 Statistical Analysis and Synthesis

All data was analyzed on Microsoft Excel, 2016 using the equations developed above. Differences in the VA content in the eighteen recipes was done using single factor analysis of variance on Microsoft Excel Analysis ToolPak, 2016. General descriptive analysis was done using the same tool.

3 RESULTS AND DISCUSSIONS

3.1 Recipes, Ingredients, Portions and VA contributions

It was observed that the commonly consumed foods in the three countries constituted of bananas, rice, wheat and maize as the main ingredients. These also coupled as the staple foods (Mango, N.,et al., 2018, Amaral, M.M. et al., 2018, and Mohajan, H., 2014). Other main ingredients were cassava, sorghum, yam, millet, sweet potato and beans. Of the ingredients in the presented recipes, cassava, green banana, yam, yellow and orange fleshed sweet potatoes had significant VA contributions (RAE≥0.01mcg) which is in line with studies done by Englberger, L. et al., 2003, and De Moura, F.F. et al., 2015. Tomato, onion and fortified cooking oil also contributed significantly to VA content in the fried foods, particularly, UG_2, UG_5 and UG_6 in Uganda and MAL_1, MAL_2 and MAL_6 in Malawi. Elizalde-González, M.P. and Hernández-Ogarcía, S.G., 2007 and Daood, H.G. et al., 2014 conducted and quantified beta-carotene content from tomatoes under different conditions, placing tomato as a good source of pro-VA carotenoids. The VA contribution by the cereals and legumes was nil. In his research on cereals in 2004, McKevith reported that cereals neither have VA nor beta-carotenes. Recipes that incorporated the yellow and orange sweet potato generally had higher levels of VA content. Notably, the OFSP cultivar had a higher VA content compared to the yellow cultivar. The white variety on the other hand did not contribute at all to the VA content in the recipes. In relation to this, Burri, Betty J. , 2011, reported that OFSP varieties had high beta-carotene content. MAL_6 which did not have any OFSP had significant VA contribution, 73.92mcg, from pumpkin leaves and tomato. Previous studies including that of Van Jaarsveld, P. et al., 2014 and Schönfeldt, H.C et al., 2011, reported pumpkin leaves as having considerable amounts of VA. Table 3 below, shows a summary of the eighteen recipes, that were analyzed in this study, their main ingredients, ingredients significantly contributing to VA content (RAE_2 ≥0.01), the weights of the ingredients, the total VA content in the recipe (tRAE) and the contribution of OFSP if any is also indicated.

TABLE 3. Table of selected commonly consumed foods, ingredients, portions and VA content

Recipe Code	Recipe Name	Main Ingredients	Ingredients contributing VA	Weight of VA contributing ingredient (g)	Total VA (mcg)	VA from OFSP (mcg)	VA from OFSP in Recipe (%)
UG_1	ATAP, Cassava, Millet & Sorghum flour	Cassava, Sorghum, Millet	Cassava	33.95	2.38	0	0
UG_2	Bean Sauce (Pinto)	Beans, Onion,Tomato, Vegetable oil	Tomato	6.61	2.75	0	0
UG_3	Mugoyo, Sweet Potato (W & Y)	White and Yellow S.P	YSP	50	88.42	0	0
UG_4	Mugoyo, Sweet Potato, (W, Y & O), Beans	White , Yellow, OFSP	YSP, OFSP	15,15	92.06	65.53	71
UG_5	Katogo, Matooke	Green Banana, Onion, Tomato	Banana, Tomato	47.31, 3	22.76	0	0
UG_6	Katogo, Yam, Beans, Tomato	Yam, Onion,Tomato	Tomato	3	1.25	0	0
KEN_1	Pilau	Rice, Beef	Beef	-	5.25	0	0
KEN_2	Mukimo wa Njahi (Raw & Ripe Bananas)		-	-	1.00		0
KEN_3	Wukunu (Sweet Potatoes & Dehulled Black Beans	S.P (White), Beans	S.P	-	0.67	0	0
KEN_4	Kimanga cha Ndizi (Smoked Green Bananas and Kidney Beans	Banana, Beans	Banana	-	1.67	0	0
KEN_5	Pan Fried Sweet Potatoes (Orange Fleshed)	OFSP	OFSP	100	795.58	795.58	100
KEN_6	Sweet Potatoes (Orange Fleshed) with Peanut Butter	OFSP, Peanut Butter	-	-	237.08	-	-
MAL_1	Cassava stew, with pigeon pea, (Chinangwa chophika ndi nandolo	Cassava, Pigeon pea, Tomato	All	33, 13, 7	4.31	0	0
MAL_2	Plantain and bean casserole, (Mbalagha za nyemba	Green Banana, Tomato, Sunflower oil	Banana, Tomato	46, 12	22.52	0	0

MAL$_3$	Pumpkin fritters, (Mandasi a maungu	Pumpkin, Egg, Cooking oil, Sugar	All	76, 11, 3	151.04	0	0
MAL$_4$	Sweet potato fritters, (Zitumbuwa za mbatata	OFSP, Egg, Margarine	All	62, 22, 10	673.86	574.12	85
MAL$_5$	Sweet potatoes, boiled, with groundnut flour	OFSP	OFSP	64	592.64	592.64	100
MAL$_6$	Pumpkin leaves stew, (Nkhwani wokazingira	Pumpkin leaves, Tomato	Pumpkin leaves, Tomato	48, 32	73.92	0	0

Key: *- (No information)*

3.2 OFSP Contribution to the VA requirements of the different age group

OFSP recipes had among the highest VA content. Table 5 below gives a summary of the role the OFSP in the overall VA needs of the age sets under the study

TABLE 4. Table of showing percentage contribution of OFSP in the foods' VA content as well as to the overall Vitamin A requirements for pre and school going children and women of the reproductive age.

				CONTRIBUTION TO OVERALL RDA (%)						
				Children			**Pregnant Women**		**Lactating Women**	
Recipe Code	**Total VA (mcg)**	**VA from OFSP (mcg)**	**In recipe (%)**	**7-12 months (500mcg)**	**1-3 years (300mcg)**	**4-8years (400mcg)**	**14-18 years (750mcg)**	**19-50 years (770mcg)**	**14-18 years (1200mcg)**	**19-50 years (1300mcg)**
UG$_1$	2.38	0	0	0	0	0	0	0	0	0
UG$_2$	2.75	0	0	0	0	0	0	0	0	0
UG$_3$	88.42	0	0	0	0	0	0	0	0	0
UG$_4$	92.06	65.53	71	13	22	16	9	9	5	5
UG$_5$	22.76	0	0	0	0	0	0	0	0	0
UG$_6$	1.25	0	0	0	0	0	0	0	0	0
KEN$_1$	5.25	0	0	0	0	0	0	0	0	0
KEN$_2$	1.00		0	0	0	0	0	0	0	0
KEN$_3$	0.67	0	0	0	0	0	0	0	0	0
KEN$_4$	1.67	0	0	0	0	0	0	0	0	0
KEN$_5$	795.58	795.58	100	159	265	199	106	103	66	61
KEN$_6$	237.08	-	-	-	-	-	-	-	-	-
MAL$_1$	4.31	0	0	0	0	0	0	0	0	0
MAL$_2$	22.52	0	0	0	0	0	0	0	0	0
MAL$_3$	151.04	0	0	0	0	0	0	0	0	0
MAL$_4$	673.86	574.12	85	115	191	144	77	75	48	44
MAL$_5$	592.64	592.64	100	119	198	148	79	77	49	46

MAL_6	73.92	0	0	0	0	0	0	0	0	0

The Mugoyo of Uganda (UG_4), Pan-fried sweet potato of Kenya (KEN_5), and the Sweet potato fritters of Malawi (MAL_3) are some of the recipes that utilized the OFSP. In equal portions, OFSP contributed more than twice the VA contributed by the yellow cultivar which supports the findings of Burri, Betty J. , 2011. The Mugoyo recipe (UG_4), whose main ingredients are the white, yellow and orange fleshed sweet potatoes, just 15g of OFSP contribute to 13, 16 and 22% of the VA needs in the children's clusters and 5 and 9% to the lactating mothers and pregnant women respectively. In Kenya, the Pan fried sweet potatoes (KEN_5) recipe, with OFSP as the only ingredient fried in unfortified oil, the contribution is 159, 199 and 265% in the children's three groups, 103-106% in pregnant women and 61-66% for the lactating mothers. These results indicate, that lower amounts of the OFSP in children's diets are enough to meet the needs. Similar observation is made in the study conducted by Jan L. et al, 2017 whereby she reported that 100 g of a medium intensity OFSP variety which has a high beta-carotene retention ratio of 80%, can meet the daily vitamin A needs of a young child. Lastly, in Malawi, two OFSP recipes were analyzed. The Sweet potato fritters (MAL_4) which mainly constitute of OFSP, eggs and margarine, the OFSP's contribution was 115, 144 and 191% for children categories, 75-77% for the pregnant women's needs and 44-48% for the lactating mothers. This recipe is densely rich with VA due to the contribution from the egg and margarine. However, animal sources of VA are often considered expensive and unsustainable to poor rural households (Bai, Y. et al, 2020). In the OFSP boiled with groundnut flour recipe, (MAL_5), whereby 64g of the OFSP was used, only OFSP contributed to the VA content with a contribution of 119, 148 and 198% for the children's cluster. For the pregnant women, the contribution was 77-79% and 46-49% for lactating mothers.

3.3 VAD simulation and Estimation of OFSP Quantities Sufficient to meet the Vitamin A Deficits

The set of data analyzed simulated a high level of Vitamin A deficit in majority of the recipes with significant differences ($P \leq 0.05$) between the recipes as shown in Table 4 below.

TABLE 5: Table showing variation under one factor Analysis of Variance

Groups	*Count*	*Sum*	*Average*	*Variance*
UGANDA	6	209.6215	34.93692	1900.485
KENYA	6	1041.25	173.5417	101697.2
MALAWI	6	1518.29	253.0483	89982.34

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	146210.4	2	73105.18	1.132945	0.348151	3.68232
Within Groups	967900.1	15	64526.67			

Total	1114110	17

The deficiencies were particularly highest in pregnant and lactating mothers aged between 14-50 years owing to their high VA demands. This may not be the practical case as adults usually consume higher portions of food compared to children. Children's VA needs which are relatively lower compared to the women's, were significantly catered for in the foods as summarized in Tables 6 and 7 below. The OFSP amounts that can be incorporated in the assessed recipes varied significantly ($p \leq 0.05$) among within the recipes and between age clusters. The simulation clearly demonstrates that lower quantities of OFSP are needed to curb VAD in children. For example, in the KEN_5 recipe, a reduction of up to 53.5g of OFSP for children aged between 1-3 years is necessary. In the MAL_5 recipe of Malawi, up to 10g of OFSP reduction in the recipe is advisable for children aged between 7-12 months. The proposal to reduce the OFSP portions is not to mean that the VA intakes exceed the Tolerable Upper Intake of 6460mcg in a day for children (Trumbo, P. et., al, 2001) but rather an indication that lower quantities are sufficient especially for poor households. Far from the reductions, an inclusion and raising the OFSP portion by up to 53.9g in majority of the recipes is recommended .

TABLE 6. Table showing VAD levels and estimated quantities of OFSP needed to meet the Vitamin A gaps in the recipes, for pre and school going children.

	VAD (mcg)			**OFSP QUANTITY NEEDED (g)**		
Recipe Code	**7-12 months**	**1-3 years**	**4-8 years**	**7-12 months**	**1-3 years**	**4-8 years**
UG_1	497.6	297.6	397.6	53.7	32.1	42.9
UG_2	497.2	297.2	397.2	53.7	32.1	42.9
UG_3	411.6	211.6	311.6	44.4	22.8	33.6
UG_4	407.9	207.9	307.9	44.1	22.5	33.3
UG_5	477.2	277.2	377.2	51.5	29.9	40.7
UG_6	498.8	298.8	398.8	53.9	32.3	43.1
KEN_1	494.8	294.8	394.8	53.4	31.8	42.6
KEN_2	499.0	299.0	399.0	53.9	32.3	43.1
KEN_3	499.3	299.3	399.3	53.9	32.3	43.1
KEN_4	498.3	298.3	398.3	53.8	32.2	43.0
KEN_5	-295.6	-495.6	-395.6	-31.9	-53.5	-42.7
KEN_6	237.1	37.1	137.1	25.6	4.0	14.8
MAL_1	495.7	295.7	395.7	53.5	31.9	42.7

MAL_2	477.5	277.5	377.5	51.6	30.0	40.8
MAL_3	349.0	149.0	249.0	5.6	3.2	4.4
MAL_4	-173.9	-373.9	-273.9	-18.8	-40.4	-29.6
MAL_5	-92.6	-292.6	-192.6	-10.0	-31.6	-20.8
MAL_6	426.1	226.1	326.1	46.0	24.4	35.2

In the women of reproductive age category, the model simulated up to 83.1g of OFSP quantities required to alleviate VAD in pregnant women aged 19-50 years, in the KEN_3 recipe. For lactating mothers, the needs ranged from 43.7-129.5g for women aged 14-18 years and between 54.5-140.3g for the older lactating mothers across the different recipes. The analysis noted that, as the number of ingredients increases in the recipes, and the portion of OFSP reduces, its contribution to the daily requirements reduces. Burri, 2012 stated that, it is unlikely that OFSP or most other carotenoid-rich foods that are used to prevent VAD could be consumed in large enough quantities to be harmful hence higher portions of OFSP recommended for the recipes.

TABLE 7. Table showing estimated quantities of OFSP needed to meet the Vitamin A gaps in the recipes, for pregnant women and lactating mothers.

	VAD (mcg)		**OFSP QUANTITY NEEDED (g)**		**VAD (mcg)**		**OFSP QUANTITY NEEDED (g)**	
	PREGNANT WOMEN				**LACTATING MOTHERS**			
Recipe Code	**14-18 years**	**19-50 years**	**14-18 years**	**19-50 years**	**14-18 years**	**19-50 years**	**14-18 years**	**19-50 years**
UG_1	747.6	767.6	80.7	82.9	1197.6	1297.6	129.3	140.1
UG_2	747.2	767.2	80.7	82.9	1197.2	1297.2	129.3	140.1
UG_3	661.6	681.6	71.4	73.6	1111.6	1211.6	120.0	130.8
UG_4	657.9	677.9	71.1	73.2	1107.9	1207.9	119.6	130.4
UG_5	727.2	747.2	78.5	80.7	1177.2	1277.2	127.1	137.9
UG_6	748.8	768.8	80.9	83.0	1198.8	1298.8	129.5	140.3
KEN_1	744.8	764.8	80.4	82.6	1194.8	1294.8	129.0	139.8
KEN_2	749.0	769.0	80.9	83.0	1199.0	1299.0	129.5	140.3
KEN_3	749.3	769.3	80.9	83.1	1199.3	1299.3	129.5	140.3
KEN_4	748.3	768.3	80.8	83.0	1198.3	1298.3	129.4	140.2
KEN_5	-45.6	-25.6	-4.9	-2.8	404.4	504.4	43.7	54.5
KEN_6	487.1	507.1	52.6	54.8	937.1	1037.1	101.2	112.0
MAL_1	745.7	765.7	80.5	82.7	1195.7	1295.7	129.1	139.9

MAL_2	727.5	747.5	78.6	80.7	1177.5	1277.5	127.2	138.0
MAL_3	599.0	619.0	-0.5	-0.3	1049.0	1149.0	43.7	54.5
MAL_4	76.1	96.1	8.2	10.4	526.1	626.1	56.8	67.6
MAL_5	157.4	177.4	17.0	19.2	607.4	707.4	65.6	76.4
MAL_6	676.1	696.1	73.0	75.2	1126.1	1226.1	121.6	132.4

4 CONCLUSION

The study sought to evaluate the possible contribution of OFSP to curbing VAD and estimate quantities sufficient to eradicate deficiencies in commonly consumed foods in Uganda, Kenya and Malawi, using simulated data. Based on the Excel Generated Simulation Model, where OFSP is seen to have considerable contribution to both preschool and lower primary children and women of reproductive age, we reached the conclusion that OFSP has immense potential in the fight against Vitamin A Deficiency. Applying the model, consuming at least 100 g of OFSP daily would provide more than adequate VA amounts required by children below the age five while staying within the Tolerable Upper Intake Levels (Low J., 2007). For Women of reproductive age, both pregnant and lactating, a larger serving is required to meet their higher needs. The model offers a guide to monitoring VAD needs at household levels for the different age groups and can be customized to evaluate other nutritional requirements. Given the affordability and accessibility of OFSP, it makes it ideal for utilization among poor rural communities who are most vulnerable to VAD. On varietal considerations, there is no information on the varieties of OFSP used in the recipes making it difficult to conduct varietal comparisons but generally OFSP varieties are reported to have high pro-VA content (Low J., 2017). The findings of this study support the development and implementation of policies and programs that promote the cultivation and consumption of OFSP varieties to enhance vitamin A intakes in the region, while also empowering smallholder farmers through market access and value chain development in Africa (Carey, E. E., et al.,1998). However, the consumption of OFSP alone is not a silver bullet to eradicating VAD and must be complemented through diet diversification and with other nutritious foods like the green leafy vegetables (Carey et al., 2014, IFPRI, 2001).

Recommendations

The developed model is simple yet effective in estimating VA content in foods and VAD arising from food recipes given the ingredient portions or quantities. It can therefore be adopted to estimate quantities of VA rich ingredients or foods that can be incorporated in given recipes to eliminate VAD occurrence in different age sets. We strongly recommend its adoption as an implementation tool in programs fighting VAD. For precise and accurate estimations, we recommend that the tool is used together with other food intake assessment tools like the Food Frequency Questionnaires, 24-Hour Dietary Recall and Dietary Records

Author contributions

Nyangaresi Annette: Concept development, Article search and review, Data extraction, Conversions and Analysis, Methodology, Original manuscript writing, review & editing. **Moyo Mukani**: Data verification, Manuscript review and editing. **Abong' George**: Draft and final Manuscript review and editing. **Miiro Richard:** Final Review and editing. **Grant Fredrick:** Co-supervision, review and editing. **Hareau Guy:** Co-funding, Concept Development, review and editing. **Tawanda Muzhingi:** Main supervision, Concept development, review and editing.

Declaration of Conflict of Interest

The authors declare no conflict of interest.

Acknowledgments

The authors would like to acknowledge the International Potato Centre (CIP), Kenya, International Potato Center, Lima, Peru and the BioInnovate Research Project for supporting the research.

References

1. Abong, George Ooko, et al. "A review of production, post-harvest handling and marketing of sweetpotatoes in Kenya and Uganda." *Current Research in Nutrition and Food Science*4.3 (2016): 162.
2. Amaral, M.M., Herrin, W.E. and Gulere, G.B., 2018. Using the Uganda National Panel Survey to analyze the effect of staple food consumption on undernourishment in Ugandan children. *BMC public health*, *18*(1), p.32.
3. Aywa, A.K., Nawiri, M.P. and Nyambaka, H.N., 2013. Nutrient variation in colored varieties of Ipomea batatas grown in Vihiga County, Western Kenya. *International Food Research Journal*, *20*(2).
4. Bai, Y., Alemu, R., Block, S.A., Headey, D. and Masters, W.A., 2020. Cost and affordability of nutritious diets at retail prices: Evidence from 177 countries. *Food Policy*, p.101983.
5. Beaton GH Martorell R Aronson KJ Edmonston B McCabe G Ross AC Harvey B *Effectiveness of vitamin A supplementation in the control of young child morbidity and mortality in developing countries.*United Nations Administrative Committee on Coordination, Sub-committee on Nutrition State-of-the-Art Series: nutrition policy discussion paper no. 13, Geneva,United Nations,1993

6. Burri, B.J., 2012. Evaluating global barriers to the use of red palm oil as an intervention food to prevent vitamin A deficiency. *Comprehensive Reviews in Food Science and Food Safety*, *11*(2), pp.221-232.
7. Burri, Betty J. "Evaluating sweet potato as an intervention food to prevent vitamin A deficiency." *Comprehensive Reviews in Food Science and Food Safety* 10.2 (2011): 118-130.
8. Carey, E. E., et al. "Using orange-fleshed sweetpotato varieties to combat vitamin A deficiency and enhance market opportunities for smallholder farmers in sub-Saharan Africa." *Food Security and Crop Diversification in SADC Countries: The Role of Cassava and Sweetpotato* (1998): 17-19.
9. Daood, H.G., Bencze, G., Palotas, G., Pek, Z., Sidikov, A. and Helyes, L., 2014. HPLC analysis of carotenoids from tomatoes using cross-linked C18 column and MS detection. *Journal of chromatographic science*, *52*(9), pp.985-991
10. De Moura, F.F., Moursi, M., Lubowa, A., Ha, B., Boy, E., Oguntona, B., Sanusi, R.A. and Maziya-Dixon, B., 2015. Cassava intake and vitamin A status among women and preschool children in Akwa-Ibom, Nigeria. *PLoS One*, *10*(6), p.e0129436.
11. Elizalde-González, M.P. and Hernández-Ogarcía, S.G., 2007. Effect of cooking processes on the contents of two bioactive carotenoids in Solanum lycopersicum tomatoes and Physalis ixocarpa and Physalis philadelphica tomatillos. *Molecules*, *12*(8), pp.1829-1835.
12. Englberger, L., Darnton-Hill, I., Coyne, T., Fitzgerald, M.H. and Marks, G.C., 2003. Carotenoid-rich bananas: a potential food source for alleviating vitamin A deficiency. *Food and Nutrition Bulletin*, *24*(4), pp.303-318.
13. Eva C., et al. "Sociocultural influences on food choices and implications for sustainable healthy diets." *Food and Nutrition Bulletin* 41.2_suppl (2020): 59S-73S.
14. FANTA-2. The Analysis of the Nutrition Situation in Uganda. Food and Nutrition Technical Assistance II Project (FANTA-2), Washington, DC: FHI 360, 2010.
15. FAO/Government of Kenya. 2018. Kenya Food Composition Tables. Nairobi, 254 pp. http://www.fao.org/3/I9120EN/i9120en.pdf
16. FAO/Government of Kenya. 2018. Kenyan Food Recipes. A recipe book of common mixed dishes with nutrient value. Nairobi, FAO. 349 pp. http://www.fao.org/3/I8897EN/I8897en.pdf
17. FAO/INFOODS (2012). FAO/INFOODS Guidelines for Checking Food Composition Data prior to the Publication of a User Table/Database-Version 1.0. FAO, Rome.
18. Fiedler, John L., and Ronald Afidra. "Vitamin A fortification in Uganda: comparing the feasibility, coverage, costs, and cost-effectiveness of fortifying vegetable oil and sugar." *Food and nutrition bulletin* 31.2 (2010): 193-205.

19. Gerster, Helga. "Vitamin A-functions, dietary requirements and safety in humans." *International journal for vitamin and nutrition research* 67.2 (1997): 71-90.
20. Hawkes, C., 2017. *Global nutrition report 2017: Nourishing the SDGs*. Development Initiatives.
21. Kaguongo, W., Ortmann, G., Wale, E., Darroch, M. and Low, J., 2012. Factors influencing adoption and intensity of adoption of orange flesh sweet potato varieties: Evidence from an extension intervention in Nyanza and Western provinces, Kenya. *African Journal of Agricultural Research*, *7*(3), pp.493-503.
22. Kapinga, Regina, et al. "Vitamin A partnership for Africa: A food based approach to combat vitamin A deficiency in sub-Saharan Africa through increased utilization of orangefleshed sweetpotato." *Chron Horticult* 45 (2005): 12-4.
23. Kathabwalika, D.M., Chilembwe, E.H.C. and Mwale, V.M., 2016. Evaluation of dry matter, starch and beta-carotene content in orange-fleshed sweet potato (Ipomoea batatas L.) genotypes tested in three agro-ecological zones of Malawi. *African Journal of Food Science*, *10*(11), pp.320-326.
24. Kiharason, J.W. and Isutsa, D.K., 2014. Potential of Orange-Fleshed Sweet Potato in Increasing Vitamin A Dietary Intake in Up to 60-Month-Old Children in Laikipia, Kenya. *Journal of Chemical, Biological and Physical Sciences (JCBPS)*, *4*(2), p.1188.
25. Kittler, Pamela Goyan, Kathryn P. Sucher, and Marcia Nelms. *Food and culture*. Cengage Learning, 2016.
26. Krinsky, Norman I., et al. "Dietary reference intakes for vitamin C, vitamin E, selenium, and carotenoids." *Institute of Medicine* (2000).
27. Laban, Turyagyenda F., et al. "Participatory agronomic performance and sensory evaluation of selected orange-fleshed sweet potato varieties in south western Uganda." *Global J. Sci. Frontier Res* 15 (2015): 25-30.
28. Laurie, Sunette M., Mieke Faber, and Nicole Claasen. "Incorporating orange-fleshed sweet potato into the food system as a strategy for improved nutrition: The context of South Africa." *Food Research International* 104 (2018): 77-85.Monterrosa,
29. Loebenstein, G., et al. "Sweet potato." *Virus and virus-like diseases of major crops in developing countries*. Springer, Dordrecht, 2003. 223-248.
30. Low, J.W., Uaiene, R.N., Andrade, M.I. and Howard, J.A., 2000. *Orange-flesh sweet potato-promising partnerships for assuring the integration of nutritional concerns into agricultural research and extension* (No. 1092-2016-87680).
31. Low, Jan W., et al. "A food-based approach introducing orange-fleshed sweet potatoes increased vitamin A intake and serum retinol concentrations in young children in rural Mozambique." *The Journal of nutrition* 137.5 (2007): 1320-1327

32. Low, Jan W., et al. "Tackling vitamin A deficiency with biofortified sweetpotato in sub-Saharan Africa." *Global food security* 14 (2017): 23-30.
33. Low, Jan, Thomas Walker, and Robert Hijmans. "The potential impact of orange-fleshed sweet potatoes on vitamin A intake in Sub-Saharan Africa." *A paper presented at a regional workshop on food based approaches to human nutritional deficiencies*. 2001.
34. MAFOODS. 2019. Malawian Food Composition Table. 1st Edition. Averalda van Graan, Joelaine Chetty, Malory Jumat, Sitilitha Masangwi, Agnes Mwangwela, Felix Pensulo Phiri, Lynne M. Ausman, Shibani Ghosh, Elizabeth Marino-Costello (Eds). Lilongwe, Malawi.
35. Mango, N., Makate, C., Mapemba, L. and Sopo, M., 2018. The role of crop diversification in improving household food security in central Malawi. *Agriculture & Food Security*, *7*(1), p.7.
36. McKevith, B., 2004. Nutritional aspects of cereals. *Nutrition Bulletin*, *29*(2), pp.111-142.
37. McLaren, Donald Stewart, and Klaus Kraemer, eds. *Manual on vitamin A deficiency disorders (VADD)*. Karger Medical and Scientific Publishers, 2012.
38. Mitra, Surajit. "Nutritional status of orange-fleshed sweet potatoes in alleviating vitamin A malnutrition through a food-based approach." *J. Nutr. Food Sci* 2.8 (2012): 160.
39. Mmasa, J. and Msuya, E.E., 2012. Mapping of the sweet potato value chain linkages between actors, processes and activities in the value chain: A case of “Michembe” and “Matobolwa” products–A case study of Shinyanga and Mwanza regions.
40. MoH, K., 2018. KNBS.(2013). The Kenya National Micronutrient Survey 2011.
41. Mohajan, H., 2014. Food and nutrition scenario of Kenya.
42. National Statistical Office (NSO), Community Health Services Unit (CHSU) of the Ministry of Health, and Department of Nutrition, HIV and AIDS (DNHA) jointly with the 2015-16 Malawi Demographic and Health Survey
43. Neela, Satheesh, and Solomon W. Fanta. "Review on nutritional composition of orange-fleshed sweet potato and its role in management of vitamin A deficiency." *Food science & nutrition* 7.6 (2019): 1920-1945.
44. Padmavathi, Mrs KV. "Nutritional Deficiency Disorders in Childhood Perspectives and Future Challenges Dr. Mrs. KV Padmavathi." *Chief Patron*: 3, 2016
45. Ruel, Marie T. *Can food-based strategies help reduce vitamin A and iron deficiencies?*. No. 5. International Food Policy Research Institute (IFPRI), 2001.
46. Schönfeldt, H.C. and Pretorius, B., 2011. The nutrient content of five traditional South African dark green leafy vegetables—A preliminary study. *Journal of food composition and analysis*, *24*(8), pp.1141-1146.

47. Snyder, Hannah. "Literature review as a research methodology: An overview and guidelines." *Journal of Business Research* 104 (2019): 333-339.
48. Sweet potato Catalogue, 2019
49. Trumbo, P., Yates, A.A., Schlicker, S. and Poos, M., 2001. Dietary reference intakes: vitamin A, vitamin K, arsenic, boron, chromium, copper, iodine, iron, manganese, molybdenum, nickel, silicon, vanadium, and zinc. *Journal of the Academy of Nutrition and Dietetics*, *101*(3), p.294.
50. UDHS, I., 2011. Uganda demographic and health survey. *Uganda Bureau of Statistics, Kampala Uganda*.
51. Underwood, Barbara A. "Overcoming micronutrient deficiencies in developing countries: is there a role for agriculture?." *Food and nutrition bulletin* 21.4 (2000): 356-360.
52. University of Ghana/GroundWork/University of Wisconsin-Madison/KEMRI-WellcomeTrust/UNICEF, 2017. Ghana Micronutrient Survey 2017.
53. van Jaarsveld, Paul J., et al. "β-Carotene–rich orange-fleshed sweet potato improves the vitamin A status of primary school children assessed with the modified-relative-dose-response test." *The American journal of clinical nutrition* 81.5 (2005): 1080-1087.
54. Waized, Betty, et al. *Promoting biofortified crops for nutrition: Lessons from orange-fleshed sweet potato (OFSP) in Tanzania*. No. IDS Evidence Report; 127. IDS, 2015
55. Wheatley, C. and Loechl, C., 2008. A critical review of sweetpotato processing research conducted by CIP and partners in Sub-Saharan Africa.Burri, B.J., 2011. Evaluating sweet potato as an intervention food to prevent vitamin A deficiency. *Comprehensive Reviews in Food Science and Food Safety*, *10*(2), pp.118-130.
56. Woolfe, J.A., 1992. *Sweet potato: an untapped food resource*. Cambridge University Press
57. World Health Organization, 2009. Global prevalence of vitamin A deficiency in populations at risk 1995-2005: WHO global database on vitamin A deficiency.