THE POTENTIAL OF FRESHLY BRED ORANGE-FLESHED SWEET POTATO VARIETIES IN COMBATING VITAMIN A DEFICIENCY

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A THESIS SUBMITTED IN FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE HUMAN NUTRITION OF THE OPEN UNIVERSITY OF TANZANIA

2020

CERTIFICATION

The undersigned certifies that he has read and hereby recommends for acceptance by the Open University of Tanzania a thesis titled: ***"The Potential of Freshly Bred Orange-Fleshed Sweet Potato Varieties in Combating Vitamin A Deficiency"***, in fulfillment of the requirements for the degree of Master of Science Human Nutrition Administration of the Open University of Tanzania.

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Dr. Leonard W. T. Fweja

(Supervisor)

……..

Date

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DECLARATION

I, **Badi Mwalimu Bao**, do hereby declare that this thesis is my own original work and that it has not been presented for a similar or any other award to any other university.

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Signature

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Date

DEDICATION

This thesis work is dedicated to the Almighty Allah, who gave me all the strength and courage. I, Badi Mwalimu Bao dedicate this work to my family for their moral and encouragement in the study period in particular and throughout my life in general.

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ABSTRACT

The aim of the study was to evaluate the potential of freshly bred Orange-fleshed sweet potato (OFSP) varieties in combating vitamin A deficiency. Two OFSP varieties (Mataya and Kiegea) and two white-fleshed sweet potato (WFSP) varieties (Sinia and Vumilia) were used for the study. Estimation of moisture, fat, ash, protein, carbohydrates and crude fibre was conducted using standard AOAC procedures. The β carotene of OFSP was determined by UV Spectrophotometric method. The findings revealed that there is high moisture content in the OFSP varieties which ranged from 71.68 ± 0.46% to 72.10 ± 0.25% for Mataya and Kiegea respectively. Crude protein (0.91 ± 0.02) g and ash content (0.44 ± 0.02) g content was high in Kiegea and were the least in WFSP varieties. However, the Mataya variety recorded the highest amount of crude fibre (0.15 ± 0.01) g/100g and the least was observed in WFSP varieties. Fat content was high in Kiegea (0.25 ± 0.02) g while Mataya had the least fat content (0.19 ± 0.05) g. OFSP variety (Kiegea) recorded lowest carbohyadrates, which contains (26.27 ± 0.46) g/100g. The other task was to determine the β-carotenes of the unprocessed and processed OFSP varieties. The retention rate of β-carotene, (78.97% - 80.44%) was higher in boiled OFSP potatoes than in fried OFSP potatoes (62.88% - 67.83%). Results on sensory quality of locally available WFSP and OFSP varieties indicated insignificant differences in overall acceptability between Mataya, Kiegea and Vumilia. The optimum amount of OFSP (g/day) required to meet Vitamin A (VA) requirements for different age groups (7-12 months to 10-13 years) varied from 98.91 and 144.27 to 148.36 and 216.41g/day for Kiegea and Mataya varieties respectively. This implies that Kiegea variety is a richer source of β-carotene than Mataya variety suggesting its great potential in combating VAD.

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LIST OF ABBREVIATIONS

CIP	Centro Internacional de la Papa
DMC	Dry Matter Content
FAO	Food and Agriculture Organization
HIV/AIDS	Human Immunodeficiency Virus/ Acquired Immunodeficiency Syndrome
IDD	Iodine Deficiency Disorders
IU	International Units
LDPE	Low-density polyethylene
MAFC	Ministry of Agriculture Food Security and Cooperative
NBS	National Bureau of Statistics
NGOs	Non-Government Organizations
OFSP	Orange-Fleshed Sweet Potatoes
PEF	Pulsed Electric Field
RAE	Retinol Activity Equivalent
SNAP	Singida Nutrition and Agro-ecology Project
SPSS	Statistical Package for the Social Sciences
SPVD	Sweet Potato Virus Disease
TFDA	Tanzania Food and Drugs Authority
UNICEF	United Nations Children's Fund
URT	United Republic of Tanzania
USA	United States of America
VAD	Vitamin A Deficiency
WFSP	White Fleshed Sweet Potatoes
WHO	World Health Organization

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Vitamin A Deficiency (VAD) is a serious prevalent public health problem in many developing countries (WHO, 1995). It mainly affects the poor, young children under five years, pregnant and lactating women (Low *et al.,* 1997). In children, VAD causes millions of deaths, poor growth and development, increased risk of infection and severity of infection, and blindness. About 140 millions children are affected from VAD worldwide, 100 millions live in sub-Saharan Africa (Mason *et al.,* 2001). Vitamin A Deficiency (VAD) also enhances several risks to pregnant women including; death during pregnancy, miscarriage, night blindness, pre-mature birth, giving birth to low weight children and also it may increases the risk of spread of HIV/AIDS virus infections (Tumwegamire *et al.,* 2004). In Tanzania, VAD is categorized as a problem of public-health significance. Likewise, the health agencies worldwide, they promote the usage of vitamin A capsules, supplements, fortifying processed and packaged foods to children, pregnant and lactating women especially in hospitals and health centers, in order to reduce the effect of VAD. These efforts have proven to reduce cases of the deficiency. For example, the vitamin A supplements delivered twice a year to children less than 5 years have been shown to reduce child mortality by 24%. Also, the children blindness cases related to VAD have significantly been reduced (Imdad *et al.,* 2010).

Currently, the cheapest and cost-effective method for combating VAD is through food-based strategies by promoting consumption of locally available vitamin A-rich

foods that can be grown in home gardens. Orange-fleshed sweet potatoes (OFSP) can be a very good target crop for food-based strategy (Low *et al.* 2007).

Orange-Fleshed Sweet potatoes (OFSP) are high in carotenoids and β-carotene (Takahata *et al.,* 1993). Consumption of OFSP can provide sustainable vitamin A, which plays crucial role in preventing night blindness (Ndirigue, 2004). The introduction of OFSP in East Africa was done by an International Potato Centre (known as CIP from its Spanish-language name Centro Internacional de la Papa). Initially two types of OFSP species were grown namely Mataya which is red skinned and deep orange inside and Kiegea which is white skinned and orange inside. They are readily available in few regions. And other three varieties were released later; Ejumula; cream skinned and deep orange inside, Kakamega; purple red skinned intermediate orange inside and Naspot 90; purple red skinned deep orange inside (Kapinga *et al*., 2010). In Tanzania, two varieties of OFSP, Mataya and Kiegea were released in 2010 for use (MAFC, 2010). These varieties of OFSP have moderate yield (12-15t/ha), are tolerant to Sweet Potato Virus Disease (SPVD), and have moderate dry matter content. Therefore, the aim of this study was to evaluate the potential of the released OFSP varieties, in combating vitamin A deficiency.

1.2 Research Problem

Vitamin A Deficiency (VAD) is one of the most serious health problems affecting children, and women of reproductive age in Tanzania (WHO, 2009). It occurs when the intake of vitamin A is less than the body needs or if the body cannot absorb vitamin A properly due to disease or infection. In Tanzania, VAD is categorized as a problem of public-health significance. A national prevalence survey which was

conducted by the National Bureau of Statistics (NBS) in 2010 indicated that 33 percent and 37 percent of children under 5 years' old and lactating women respectively are affected by VAD. Most developing countries usually try to offer vitamin A supplements and capsules in order to combat the deficiency. Also, fortification programs are implemented in food products like flour, milk and vegetable oil. However, these vitamin A supplements and capsules are not sufficient and easily accessed by poor families in villages.

In Tanzania for example, about 74% of the total Tanzanians (55 million), lives in rural areas, characterized by very scattered pattern, poor network of roads and undeveloped health system (UNICEF, 2004). Dietary diversification seen as a more sustainable method for combating VAD in the long term compared with food supplementation and fortification. Research findings (Low *et al.,* 2007) have established that a small amount of 100-150 grams of OFSP varieties can supply daily recommended allowance for children less than 5 years of age. For many years, farmers in Tanzania have been growing the common WFSP varieties due to their high yielding capacity, high dry matter and acceptability by consumers though they have low beta-carotene levels.

The consumer acceptability study done in the Lake Zone in Tanzania (Tomlins *et al.,* 2007) found that beta-carotene-rich sweet potato was more acceptable to consumers than cream-fleshed sweet potato, however the study did not examine the nutrients contents and sensory quality of the OFSP (Mataya and Kiegea) currently cultivated in Tanzania. This study aimed at evaluating the potential of OFSP varieties in combating VAD. The findings of this study will give an insight on nutritional quality and potential intervention for VAD.

1.3 Research Objectives

1.3.1 General Objectives

To evaluate the potential of orange fleshed sweet potato varieties in combating vitamin A deficiency.

1.3.2 Specific Objectives

(i) To determine the proximate composition of the OFSP and WFSP cultivated in Tanzania

(ii) To examine the β-carotenes content of the unprocessed and processed OFSP and WFSP varieties

(iii) To assess sensory quality of locally available WFSP and OFSP varieties

(iv) To evaluate the optimum amount of OFSP needed to supply vitamin A to children (7 month-13 years)

1.4 Hypothesis

The research hypotheses of this study are as follows:

1. **H_0**: There is no difference in proximate composition between OFSP and WFSP varieties cultivated in Tanzania.

2. **H_0:** The β-carotenes contents of OFSP and WFSP varieties are independent of the treatments (boiling and frying).

3. **H_0:** There is no difference in sensory quality between WFSP and OFSP varieties

4. **H_0:** The amount of OFSP required to supply the optimum amount of vitamin A to a child is the same as that of WFSP.

1.5 Significance of the Study

Data on the nutritive value of OFSP cultivars are sparingly documented. The findings of this study would enrich the available data and thus help consumers to understand the nutritional potential of OFSP varieties. Data on vitamin A and carotenoid contents of the OFSP generated from the current study would also assist the government and other stakeholders in the nutritional subsector to weigh out and make informed decision regarding the interventions and its scaling up in other regions in combating VAD.

CHAPTER TWO

LITERATURE REVIEW

2.1 General Nutrition Overview in Tanzania

Nutrition can be defined as the intake of an adequate amount of energy and nutrients in relation to the body's needs for normal growth, development, active and a healthy life (FAO/WHO, 2002). Undernutrition remains one of Tanzanians greatest human development challenges. Tanzanians main nutrition challenges are related to under nutrition such as Iron Deficiency Anemia (IDA), Iodine Deficiency Disorders (IDD) and vitamin A deficiency (VAD) among children below five years of age and pregnant women. More 27,000 infant deaths per annum in Tanzania are due to micronutrients deficiencies including vitamin A (Noor *et al.*, 2017). Causes of malnutrition are numerous ranging from inadequate access to food, inadequate caring practices and poor access to basic health services. Table 2.1 provides the levels of malnutrition among children aged less than 5 years and women in Tanzania.

Table 2.1: Malnutrition for Children and Women in Tanzania

Children below 5 years of age	**%**	**Women**	**%**
Stunting	46	Low body mass index	11
Underweight	17	Iron deficiency	36
Anaemia	58	Anaemia	455
Iron deficiency	35	Iron deficiency	30
Vitamin A deficiency	33	Vitamin A deficiency	37

Source: TDHS, (2015)

2.2 Worldwide Sweet Potatoes Production

Sweet potato (*Ipomoea batatas* L. Lam), is an important root crop that is grown all over the world spreading throughout the tropical and subtropical countries. Asia as a

whole accounts for about 78% of the world area under this crop and about 92% of the world production. India is one of the leading producers of this crop along with China, America, Brazil, Peru, Mexico and Thailand. China is the largest producer and consumer of sweet potato in the World accounting about 67% of global area and about 86% of the global production.

African farmers produce about 7 million tons of sweet potatoes annually, mostly for human consumption. Projections indicate that productions will more than double by 2020 (Scot *et al.,* 1999). It is one of the most staple crops grown in highly populated areas of Eastern Africa (Tumwegamire *et al*; 2004).

2.3 Sweet Potato Production in Tanzania

Major staple foods in Tanzania include maize, paddy rice and cassava while sorghum, wheat, millet and sweet potatoes are categorized as other staples. Tanzania is the second largest producer of sweet potato in East Africa (after Uganda) with an annual production of just under one million tons (URT, 2011). Sweet potato currently ranks as the World's seventh most important food crop and the fifth most important food crop on fresh weight basis in developing countries, after rice, wheat, maize and sorghum (FAO, 2004). In Tanzania, sweet potato is considered as the classic household food security crop (Minde *et al*., 1998).

This is due to the fact that, the crop has short maturing period (3-5 months), ability to grow under marginal conditions, low demand on soil nutrients, less labor intensive, flexible planting and harvest times. It is adaptable to a wide ecological range of 0-2000 mm above sea level and 30^0N to 30^0S. In Tanzania, sweet potato is the third

most important root and tuber crop after cassava and Irish potato. The crop is grown almost in all agro-ecological zones (Lake Zone, Western Zone, Southern Highlands Zone, Eastern Zone and Northern Zone) because of its hardy nature and broad adaptability, hence providing a sustainable food supply when other crops fail (Ndunguru and Rajabu, 2000). In terms of volume produced, sweet potato is the most important in the Lake Zone (330,600 tons/year), Southern Highlands Zone (271,000 tons/year), Eastern Zone (107,400 tons/year) and Southern Zone (37,400 tons/year) (URT, 2011).

Sweet potato is grown by smallholders, especially youth and women, and occupies approximately 14% of total arable land of the farms surveyed in Tanzania (Kapinga *et al*., 1995). Sweet potatoes are commonly consumed fresh, mostly just boiled or roasted. Sweet potatoes have white, yellow or orange flesh and their skin may either be white, yellow, orange, red or purple depending on the caretonoids type and concentration. Table 2.2 provides data on sweet potato production in Tanzania.

Table 2.2: Sweet Potato Production in Tanzania

Year	Area harvested (hectares)	Production in metric tons	Yields in metric tons per hectares
2003	135,470	207,830	1.5
2004	517,530	1,501,620	2.9
2005	469,110	1,414,820	3.0
2006	480,000	1,396,400	2.9
2007	450,000	1,322,000	2.9
2008	460,000	1,379,000	2.9
2009	465,000	1,381,120	2.9
2010	480,000	1,392,000	2.9

Source: FAOSTAT, 2010

2.3.1 Sweet Potato Varieties Grown in Tanzania

Tanzania has a wide collection of sweet potato varieties but most of them have low yield and vulnerable to pests and diseases. This has affected the production and utilization of sweet potatoes in Tanzania. However, the National variety release committee of Tanzania has approved several varieties such as Simama, Sinia, Vumilia, Juhudi, Kandoro, Kinahaha and others which are white fleshed sweet potatoes and Kiegea, Mataya, Ejumula, Kakamega, Naspoti 90 and Mayai as orange fleshed varieties. The major criteria applied by the committee during the release of new varieties are high yield, good root shape, storability, starchiness and less or no fibre.

2.4 Nutritional Composition of Sweet Potatoes

Nutritive value of sweet potato tubers in comparison with other tubers contains an average amount of proteins and carbohydrates mainly starch. They also contain pro-vitamins A, vitamins B and C in significant amounts and some free sugars, which give the tuber its sweet taste (Amajor *et al*., 2011). It has also been reported that sweet potato leaf contain protein and crude fibre which are important for addressing protein deficiency diseases and colon diseases. Other studies also revealed that both sweet potato tuber and leaf contain micro nutrients necessary for healthy body and in addition contain ant-nutrients such as phytate, oxalate and tannin (Olayiwola *et al*., 2009).

2.5 Processing of Sweet Potato Roots

Food processing is the transformation of raw ingredients, by physical or chemical means into food or of food into other forms. Food processing combines

raw food ingredients to produce marketable food products that can be easily prepared and served by the consumer. The processing is subdivided into two main groups, viz: processing of foods with non-thermal methods such as high-pressure processing, pulsed electric field (PEF), electronic beams, and processing of foods with the application of heat such as blanching, pasteurization, sterilization, evaporation or concentration, drying or dehydration, microwave and infra-red heating.

2.5.1 Processing of Sweet Potato Roots by Heat Treatment

Heat treatment is one of the important methods used in food processing to extend the shelf life of foods either by destroying the enzymatic and microbial activity or by removing water to inhibit deterioration that results from higher water activity. Fellows (2000) enumerated the advantages of heat processing as: (i) Simple control of processing conditions; (ii) Production of shelf-stable products that need no refrigeration; (iii) The destruction of anti-nutritional factors (e.g. trypsin inhibitor in some legumes); and (iv) The enhancement of availability of nutrients for human consumption (e.g. improves digestibility of proteins and gelatinization of starches).

Processing by application of heat that can be used in product development from sweet potato can be carried out using four methods including: (a) Heat processing with the use of hot air e.g. dehydration, baking, roasting (b) Heat processing with the use of water or steam e.g. blanching, pasteurization (c) Heat processing with the use of hot oils e.g. frying (d) Heat processing using radiated and direct energy e.g. ohmic heating, di-electric heating, infrared heating (Doymaz, 2012).

2.5.2 Sweet Potato Processed Products

The traditional methods of processing sweet potato in most countries have been limited to washing, peeling and boiling. The development of processed products from sweet potato presents one of the most important keys to the expanded utilization of the crop. Fresh-market sweet potatoes can be microwaved, boiled, grilled, and baked. In some countries alcohol is distilled from sweet potatoes, and also used to make pasta sauces. They can be processed as follows: Dried/dehydrated; flour, flakes, chips, Frozen: dices, slices, patties, french fries, and Canned; candied, baby foods, mashed, cut/sliced, pie fillings. Sweet potatoes are also used as an ingredient in cakes, ice creams, icing, pie fillings, cookies, custards and various other bread products.

2.6 Consumer Preference for Sweet Potatoes

There are two main types of sweet potato, the traditional WFSP and the OFSP. The WFSP is widely produced among small farmers, but the OFSP was recently introduced and is being promoted by the agriculture authorities and their partners in Tanzania. Only the OFSP provides an inexpensive source of β-carotene, the precursor of Vitamin A (Van Jaarsveld *et al*., 2003; Tsou and Hong, 1992). OFSP was primarily introduced in Tanzania as part of an integrated approach to mitigate Vitamin A deficiency. These benefits have prompted both public and private sectors to promote OFSP. Despite the advantages of OFSP, most consumers apparently prefer eating traditional WFSP as evidenced by the fact that traders predominantly sell WFSP. Also traditionally, sweet potatoes are commonly consumed boiled and preference is to varieties with high dry matter content (DMC), hence, consumers do not enjoy boiled OFSP due to its low DMC. In fact, Mazuze (2004) found that despite a comprehensive awareness campaign on the superior nutritional value of OFSP varieties, the price

differences observed between white/cream-fleshed and orange-fleshed varieties have not been significantly affected; both types are typically sold at the same price in a market.

2.7 Adoption of OFSP in Tanzania

Adoption of a new technology by farmers is usually driven by a combination of many factors. One important aspect is farmer's perception, attitudes, and knowledge towards the technology.

For combating VAD, sustained adoption is required for OFSP varieties that fit to the agro-ecological conditions of the country and which meet local preferences of farmers, processors and consumers. Farmer adoption decision depend on access to OFSP planting varieties, compatibility with existing farming system, any possible improvements to farming system and marketing possibilities. Processor adoption decision depend on access to quality OFSP roots, compatibility with existing processing system, any possible improvements to processing system and product possibilities. Consumer adoption decision depends on perceivable sensory attributes, sensory qualities, texture, colour and flavor (Pal *et al.*, 1995).

According to FAO statistics, Tanzania has 76 percent of its land suitable for sweet potatoes production. Out of the 940,565 Sq km of land in Tanzania, 199,942 is moderately suitable, 264,595 sq km is suitable, while 246,265sqkm is highly suitable. The data also indicates that only 8% of the land is not suitable for sweet potatoes production in the country; this means that a large part of the land resources in Tanzania is suitable for production for all types of sweet potatoes including the OFSP.

2.8 Carotenoids Content of Sweet Potatoes

Carotenoids are plant pigments responsible for bright red, yellow and orange hues in many fruits and vegetables. They are a class of plant chemicals and are found in the cells of a wide variety of plants, algae, and bacteria. They help plant absorb light energy for use in the photosynthesis. There are more than 600 types of carotenoids, the most common ones are beta-carotene, alpha-carotene, beta-cryptoxanthin, lutein, zeaxanthin and lycopene. Sweet potatoes differ in colour and carotenoids concentration. The highly found provitamin A in sweet potatoes is beta carotene, although small concentration of beta-cryptoxanthin and alpha-carotene can also be found in some varieties (Burri *et al*., 2011).

2.8.1 Effects of Cooking and Storage on Carotenoid Content of Sweet Potatoes

In the OFSP the major carotenoid present is β-carotene. The roots are usually consumed after processing like boiling, baking or making fried chips. In order to alleviate the vitamin A deficiency, it is necessary to get information regarding the retention of the total carotenoids and β-carotene in the different processing methods. Orange fleshed varieties varied significantly in their carotenoid content and retention capabilities (Ameny and Wilson,1997). Food processing, drying and storage have been previously reported (Rodriguez and Amaya, 1997) to have a major effect on pro-vitamin A retention because of the nature of unsaturated, unstable provitamin A carotenoids that are easily degraded by light, oxygen, ultra-violet and heating leading to significant losses. The highest retention of total carotenoids (90%–91%) β-carotene (89%–96%) was observed in the oven drying method followed by boiling (85%–90% and 84%–90%) in all the clones. In the frying method, the retention of total carotenoid was 77%–85% and β-carotene was 72%–86%. On the other hand, the least retention

of total carotenoids (63%–73%) β-carotene (63%–73%) was recorded in the sun-drying process. Variation in retention of carotenoids may be due to the difference in the enzymatic oxidation during processing (Ameny and Wilson, 1997).

2.8.2 Beta-Carotene contents in White Fleshed Sweet Potatoes and Orange Fleshed Sweet Potatoes

Beta-carotene is the provitamin A carotenoids highly capable of turning into vitamin A twice as much than does alpha-carotene. The Beta-carotene content in OFSP varieties vary, ranging from < 100 μg/100 g to 26,600 μg/100 g in raw sweet-potato (Kidmose *et al*., 2007). Cream and white varieties of sweet-potato contain very little amount of Beta-carotene.

OFSP is one among the rare indigenous species of the sweet potatoes rich in Beta-carotene developed by research scientists working on this root crop (Woolfe, 1992). Currently OFSP are being encouraged for adaption by farmers in Tanzania for both domestic and commercial use. In comparison to the common white fleshed sweet potatoes, the OFSP has additional Vitamin A, C, E and K nutritional benefits. OFSP is extremely rich in bioavailable beta-carotene, which the body converts into vitamin A (retinol).

The levels of beta-carotene in OFSP are extremely high in many varieties [100-1600 mg retinol activity equivalent (RAE)/100 g for varieties in Africa] and it is generally well accepted by young children (Hagenimana *et al*., 2001). Recently emphasis has been made on promoting growth, processing and consumption of OFSP as a fight measure against VAD and food insecurities.

2.8.3 Absorption and Transportation of Vitamin A in the Body

According to **(**Ong, 1994), the amount of vitamin A absorbed from the gut depends on a number of factors:

(i) Dietary protein, which is required for synthesis and release of pancreatic and intestinal enzymes involved in proteolysis, lipolysis and conversion of carotenes to retinol.

(ii) Dietary fat, which stimulates secretion of bile acids and pancreatic lipase thus increasing the absorption of lipids, retinoids and carotenoids.

(iii) Dietary nitrites and nitrates, which destroy carotenes in the gut.

(iv) Intestinal disease which reduce the chance of absorption of vitamin A by reducing the transit time of food through the gut and altering mucosal structure and function.

Vitamin A is transported from the gut bound to fatty acids as retinyl esters, which are dissolved in particles of lipid referred to as chylomicrons. These particles are the form in which lipid is absorbed from the gut. The chylomicrons containing the retinyl esters are transported by the lymphatic system into the jugular vein and the retinyl esters are taken up by the liver. The esters are split (hydrolysed) on entering the liver and are then again re-esterified to form retinyl esters which are the storage form of vitamin A in the liver.

Vitamin A measurement is done as retinol equivalents for both carotene and retinol types of vitamin A. The conversion is 1μg retinol is equal to 1μg retinol equivalent = 1 RE, and 6 μg β-carotene is equal to1 μg retinol equivalent = 1RE. Some vitamin supplements are still measured in International Units (IU), as follows;

1 RE=3.33 IU or 10 IU β-carotene

1 IU retinol= 0.3 RE

1 IU β-carotene= 0.1 RE

2.8.4 Conversion of Beta-Carotene to Vitamin A

Nutritionally carotenoids can be grouped into provitamin A and non-provitamin A. Provitamin A carotenoids can be turned into vitamin A (retinol) in the intestine or liver. Examples of pro-vitamin A are alpha carotene, beta carotene and beta-cryptoxanthin (Ukpabi and Ekeledo, 2009), while lutein, zeaxanthin and lycopene are non-provitamin A. Dietary provitamin A carotenoids are a major source of our vitamin A needs. The conversion of beta carotene varies considerably among people.

Researchers (Lin *et al.,* 2000) revealed that some people could achieve adequate vitamin A nutritional status from β-carotene alone, but 45% would not. Beta-carotene is called a provitamin A because human body can convert it into vitamin A or retinol when storage levels in the liver are low. Other carotenoids such as alpha-carotene also can be converted. Once in the small intestine, beta-carotene is cleaved or cut by a specific enzyme called beta-carotene-15, 15'-monooxygenase (BCO) into two molecules of retinol.

The conversion and absorption efficiency of retinol is relatively low between 9-22 % and depends on many factors, such as the need for vitamin A, intestinal health, bile production and the amount of dietary fat in the intestines. Retinol is a fat-soluble vitamin, which means it needs some fat to be absorbed and stored in the body. If retinol is not needed by your body, beta-carotene is not cleaved in half within the

small intestine. Instead, its absorbed intact and stored mainly within subcutaneous fat just beneath your skin.

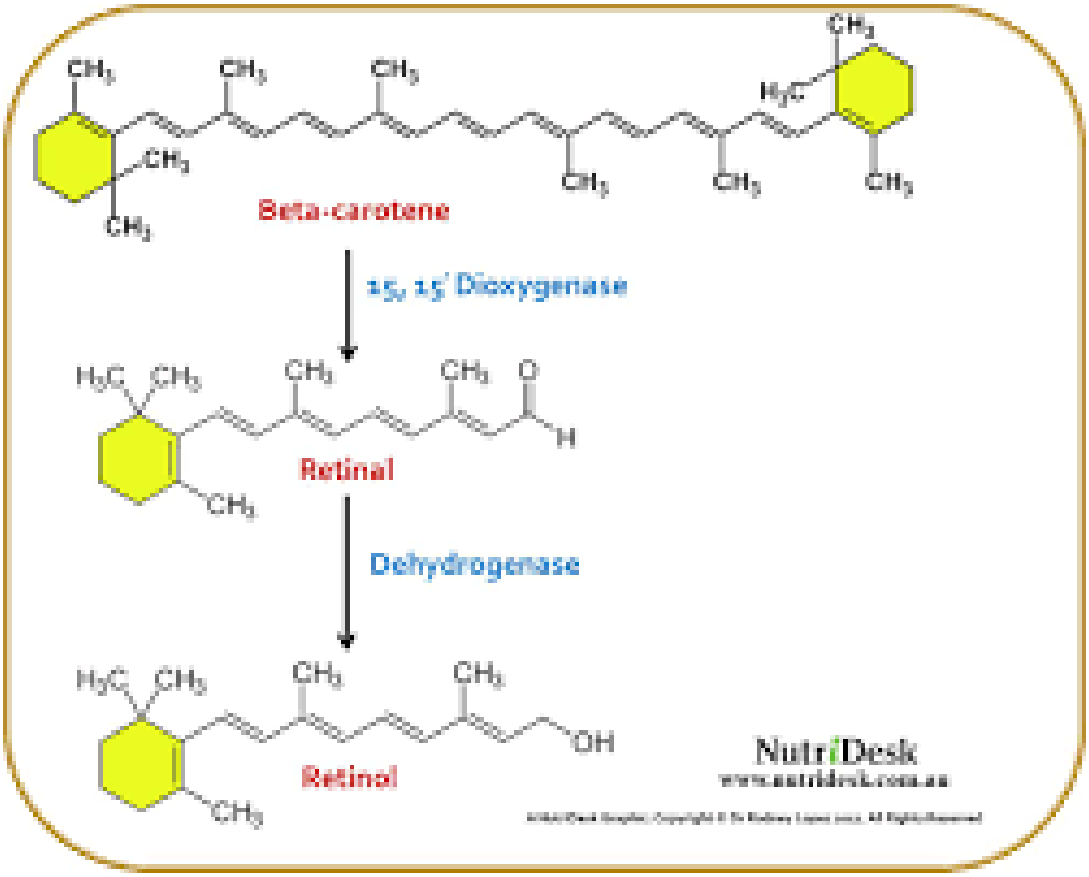


Figure 2.1: Conversion of Beta-carotene to Vitamin A
(Lin *et al*, 2000).

2.8.5 Important Dietary Sources of Vitamin A

Vitamin A is found, in large amounts, in a relatively small number of foods. Vitamin A in animal foods is mainly in the form of retinol, and consumed directly in meat products, and is produced in the body if person consumes sufficient of a precursors (pro-Vitamin A) known as β-carotene and other carotenoids derived from plants (Rao, 2000). Vitamin A from animal sources is most easily used by the body, but there are few good sources---liver from animals, birds and fish, breast milk (especially colostrums), animal milk, eggs, and butter and animal ghee. Among the plant sources,

vitamin A from yellow maize, yellow sweet potatoes, OFSP, cassava, red palm oil, dark orange fleshy fruits and vegetables, appears to be more bio-available (absorbed and utilized) than the vitamin A from dark leafy greens (Khan *et al*. 1997).

2.8.6 Sweet Potato as a Source of ß-carotene

Depending on the variety (Booth *et al*. (2001), 100g of sweet potato can provide ß-carotene quantities that are sufficient to yield from 0 to 100% of the suggested daily vitamin A requirement (Table 2.7), which is at least 350µg per day for infants and 400µg per day for young children (1-6 years). This is because the body cannot convert all ß-carotene, which translates to about 2400 µg of ß-carotene (Kapinga *et al*., 2010). This amount can easily be supplied by about 100g of orange-flesh sweet potato. Small quantities of OFSP, which may contain from 300 to over 3,000 µg RE per 100g fresh weight, can easily provide such Recommended Daily Allowances (RDAs) while also serving as a rich source of other vitamins and nutrients (Woolfe, 1992).

Table 2.3: Recommended Dietary Intakes for Vitamin A

Human age / reproductive status	Basal (µg retinol equivalent)	Safe (µg retinol equivalent)
Infants	180	350
1-6 years	200	400
6-15 years	250-350	400-600
Males	300-400	500-600
Females	270-330	500
Pregnancy	100	100
Lactation	180	350

Source: Booth *et al*. (2001)

2.8.7 Global Vitamin A Deficiency and the Amount of OFSP Required to Supply the Needed amount of Vitamin A Per Year

In most tropical countries where the consumption of animal products is relatively low, the main sources of vitamin A in the diet comes from plant sources. Some foods have vitamin A added to them such as margarine's, vegetable ghee and dried milks. The people most at risk for Vitamin A deficiency (WHO 2009) are the 190 million preschool children and 19.1 million pregnant women from low-income, food-deficit countries estimated to have low VA status. According to (Burri, 2015) the smallest amount of OFSP needed for the 208.1 million people most at risk is: 2.083×10^{12}g OFSP/y, or 2.083 million metric tons/y. The higher and probably more realistic amount of OFSP needed for these 208.1 million people is: 11.681×10^{12} g OFSP/y, or 11.681 million metric tons/y.

2.9 Vitamin A Deficiency (VAD) and Related Diseases

Vitamin A deficiency is one among the malnutrition condition, under the classification of Vitamin and Mineral Deficiencies (VMDs). Vitamin A Deficiency (VAD) occurs when too little vitamin A is present in the food over a long period. Vitamin A is fat soluble and excessive vitamin A can be stored in the liver, so VAD does not occur immediately when there is no vitamin A in the food, but when the storage in the body has been exhausted (FAO/WHO 2002). Vitamin A deficiency is the leading cause of preventable childhood blindness; it can also lead to impaired immune function, cancer, measles, birth defects, child mortality and maternal mortality. It is considered to be a serious public health problem when the prevalence of the blood indicator, serum retinol, is below 0.70 umol/l. VAD can be produced in

number of ways other than through a shortage of vitamin A or provitamin A in the diet. These include:

(i) Low conversion of provitamin A (e.g. β-carotene) to vitamin A, a process, which occur in the gut wall.

(ii) Impaired uptake of vitamin A from the gut or impaired delivery to the target tissues.

(iii) Increased metabolism and excretion of vitamin A especially during febrile illnesses such as measles or malaria.

(iv) Insufficient vitamin A at target tissues and to meet increased demands such as for repair after tissues damage (measles and herpes virus).

2.9.1 Vitamin A Deficiency (VAD) among Women and Children

VAD can occur to individuals of all age. However, it is particularly relevant to children under 6 years of age. VAD-related blindness is most prevalent in children under the age of 3, because this period is characterized by high requirements of vitamin A to support growth, the transition from breastfeeding to other food, and increased numbers of infections (FAO/WHO 2002). An estimated 250,000 to 500,000 children worldwide become partially or totally blind each year due to VAD, and about half of them die within a year of losing their sight (WHO, 2003).

It also contributes up to 25% of child mortality due to related diseases such as malaria, diarrhoea associated diseases, acute respiratory infections and vaccine preventable diseases (Micronutrient Initiative, 2004). Most of the 100 to 140 million children affected by VAD worldwide have sub-clinical manifestations (WHO 2003). It is

estimated that, in Africa and South East Asia, about 40% of pre-school aged children are at risk, have the highest burden of this form of micronutrient malnutrition. The number of malnourished children is projected to rise from 33 million in 1997 to somewhere between 39 and 49 million in 2020 (Rosengrant *et.al.* 2001).

VAD is also common in pregnant women, because pregnant and breast-feeding women have higher demands of vitamin A. It exposes them to a higher risk of death during or shortly after giving birth. Nearly 600,000 women die from childbirth-related causes every year, the vast majority of them from complications that could be reduced through better nutrition including provision of vitamin A (WHO 2009). In addition, children born by mothers with VAD start their life with precious little vitamin A stored in their bodies.

2.9.1.1 Magnitude of VAD and Related Diseases in Tanzania

The area under study is located in Eastern Zone, which is characterized by having high production of sweet potatoes (107,400 tons/year). The selected area (Kibaha) is the capital centre of Coast region. According to data from National Bureau of Statistics, the prevalence of vitamin A deficiency among children age 5-59 months was 45 percent in Coast region, which is above the average national level prevalence, which was 33 percent. Also the large percentages of people living in Coast region have low income; the per capita income of the residents of Coast region was TShs. 752,192 (equivalent to US $ 470) in 2012. This amount was lower than that of Tanzania Mainland, which was estimated at Tshs. 1,025,038 (equivalent to US$ 640) in 2012; hence most of them cannot afford daily to buy expensive sources of vitamin A from animal products like meat, and milk.

2.10 Interventions to Combat VAD

World Health Organization (WHO, 1995) goal is the worldwide elimination of VAD and its tragic consequences, including blindness, disease and premature death. Combating VAD requires action at several different levels: on individual/household and on population level; on daily and on long-term basis; with preventative and with remedial treatment. In combating VAD, short-term interventions are backed up by long-term sustainable solutions. The most common strategies for addressing VAD are:

2.10.1 Vitamin A Supplementation

Supplementation refers to periodic administration of pharmacological preparations of vitamin A in capsules to groups at risk, mainly to young children (FAO/WHO 2002). In contrast to other vitamins, the body can store vitamin A quite easily in the liver. Sufficient vitamin A can be given to children by giving them one, preferably two high-dose capsules per year (WHO 2003, MI & UNICEF 2004). Vitamin A supplementation is considered to be a 'highly cost-effective child survival intervention' (IVACG, 2003).

For deficient children, the periodic supply of high-dose vitamin A in swift, simple, low-cost, high-benefit interventions has also produced remarkable results through distribution done by health agencies. It is estimated that more than 12 million children received Vitamin A supplements in 1997 (Kapinga *et al*., 2001). Vitamin A supplementation programs have been enormously successful of global basis for many years. Examples are Ethiopia, Thailand, Tanzania, Peru and Kenya (Hagenimana et al., 2001). However, the impact of supplementation on vitamin A

levels does not address VAD over the long term. Rather, they should be seen as initial steps towards better overall nutrition.

2.10.2 Food Fortification

Fortification is the enrichment of food products with specific vitamins and minerals, such as vitamin A. In this intervention, vitamin A is added to products that are widely consumed such as milk, sugar, vegetable oil, and flour. Food fortification is not restricted to developing countries, but a normal procedure in food production in developed countries. About 25 to 50% of additional vitamin A in the diet of the average European now comes from fortified food products (MI & UNICEF 2004).

Fortification requires the co-operation of food processors, but governments can have some influence on food processing. For example, governments can make fortification compulsory, introduce subsidies, reduce duties for imported vitamins and/or offer storage facilities for vitamins below costs (MI & UNICEF 2004). Recent legislation makes it mandatory for private food processors in Tanzania to start fortifying wheat, maize and oil with essential vitamins and minerals. According to TFDA (2011) food fortification regulation "No person shall be authorized to manufacture for sale, importation, or expose for sale any food regulated under these regulations unless that food meets the minimum requirements for fortified food".

The Tanzania's National food fortification programme is targeting to fortify food with essential vitamins and minerals which Tanzanians lack: iron, zinc, Vitamin A, B12 and folic acid (National Nutritional Strategy, 2011). The program is funded by UK government, and implementation is done under the Non-Governmental Organization

Helen Keller International. Also there is another non-governmental organization called ‘TUBORESHE CHAKULA’ which is working with small food processors in villages found in Manyara, Dodoma and Morogoro regions, in order to fortify sun-flower oils and maize flour. Fortification programs, though cost effective, can take many years to initiate, as they require policy change and significant investment by the private sector. This programme can take even longer to reach target groups especially in the rural areas. In Tanzania, access to fortified foods may be limited by the availability of and access to fortified industrial foods and purchasing power. Most of packed foods are fortified but people living in the villages may not afford to buy packed food. In addition, even when fortified foods are available, children 6-59 months of age may not consume enough to reach their daily vitamin A requirements.

2.10.3 Dietary Diversification

Food-based approaches are broad-based projects. They offer assistance in setting up homestead food production, improving the productivity of home gardens, and in keeping small and dairy animals. However, they also raise awareness about VAD and give education about storage and food processing. Successful projects works with local NGOs in the village level were implemented like the Singida Nutrition and Agro-ecology Project (SNAP) (Young *et al*., 2016), NAFAKA project, and Chickpea project (Ronner *et al.*, 2012).

Once the gardens are established they prove to be sustainable in providing all-year-round availability of diverse food. This does not only improve the vitamin A status, especially of women and children, but it also improves the status of other essential vitamins and minerals. Homestead food production often generates additional small

incomes, which can be spent (often by the women who produce them) on other food products, education or assets to improve the gardens.

The diet improvement is the essential approach for reducing VAD in a population and is more sustainable in the long-term. For vulnerable rural families, growing fruits and vegetables in home gardens complements dietary diversification and fortification and contributes to better lifelong health. Within this approach, orange-fleshed sweet potatoes provide a locally-available, vitamin-A rich food which can assist in combating VAD amongst supplies the recommended daily allowance of vitamin A for children under-five years of age (Low *et al*., 2007).

2.10.3.1 Factors Influencing the Effectiveness of OFSP for preventing Vitamin A Deficiency

Various factors might be important variables for determining the effectiveness of sweet potatoes as a food-based intervention to prevent Vitamin A deficiency. Most of these factors influence the carotenoid concentration of the sweet potato. These factors include variety of sweet potato and growing, harvesting, storage conditions and cooking method and conditions. In addition, the food matrix and the presence or absence of fat influences carotenoid bio-accessibility. The effect of sweet potato variety on carotenoid concentrations is very crucial, ranging from negligible to ≥22000 μg/100 g. This would account for about 98.6% of the variability in the effectiveness of sweet potato interventions.

CHAPTER THREE

MATERIALS AND METHODS

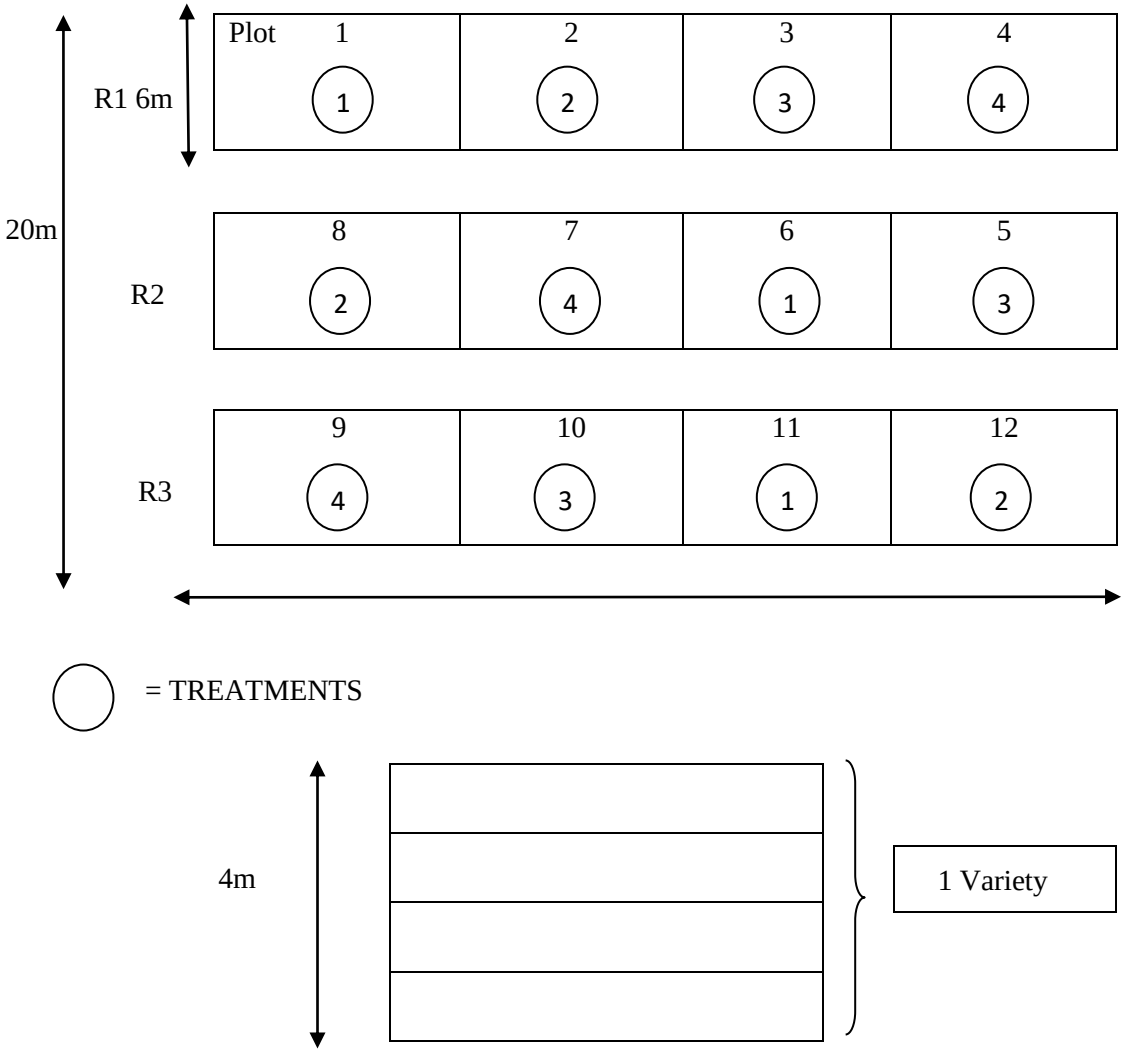
3.1 Description of Study Area

The study was carried out in Kibaha District at Maili Moja Ward. The district is one of the six districts of the Coast Region, Tanzania. Other districts are Rufiji, Mafia, Mkuranga, Bagamoyo, and Kisarawe. The district is bordered to the North by the Bagamoyo District, to the East by Dar-es-Salaam Region, to the South by the Kisarawe District and to the West by the Morogoro Region. Kibaha district covers an area of about 1,812 total Sq. Kms. According to the 2012 census, Kibaha district has a population of 198,697 people. It located within the latitude -6.7813^0 S and longitude 38.9929^0 E. The Region experiences a typical tropical climate with an average temperature of 28 degree Centigrade, with rainfall ranging from 800mm to 1000mm per annum. It has a bimodal rainfall pattern, a short rainy season from October to December and long rains between March and June. Typical of coastal areas, the region has hot and humid conditions.

3.2 Research Design

This study was a semi-experimental design. The vine cuttings of sweet potatoes for the trial were propagated in a field multiplication block at the National Root Crops Research Institute (NRCRI). Each clone was planted in a plot size of 6.0×4.0 m in randomized block design with 3 replications. The distance between and within the ridges were 100 and 30 cm respectively. All of the varieties were harvested in the same experimental field, the usual cultural practices such as early planting and delaying harvest hold were observed.

FIELD PLAN



Spacing Row*Row =1m

Plant*Plant= 3cm

Rigde length 6m

Plot ⟶ 4 rigde

3.3 Collection of Sweet Potato Samples

The two OFSP varieties, Mataya and Kiegea and two WFSP varieties, Sinia and Vumilia analysis were collected from the plots of the sweet potatoes for laboratory. Mataya is red skinned and deep orange inside while Kiegea is white skinned and

orange inside. Vumilia is white skinned and white inside while Sinia is purple skin colour and yellow flesh colour. From each replicated plot, four (4) plants were selected randomly per clone. From each plant, three (3) roots of different size (large, medium and small) were selected. The collected samples were transported to the laboratory while packaged in polythene bags for immediate sample preparation.

3.3.1 Preparation of Sweet Potato Samples for Laboratory Analyses

The fresh sweet potatoes were collected from the field and then cleaned with tap water to remove dirt and other field damaged portion. The surface water was wiped off by using tissue papers, and then air dried and weighed. The cleaned sweet potatoes were peeled, chopped into small pieces with knife, quartered and then ground in a food processor. The food processor was previously rinsed with sodium hypochlorite solution (2% in boiled water). Cleaning of food processor was done prior to processing of each potato variety. The sample processing operation was carried out rapidly to avoid enzymatic degradation. Grated samples were thoroughly mixed and packed as 1 kg samples in plastic bags and sealed. Each sample was clearly coded and dispatched to the analytical laboratory for analyses, where the samples were frozen and then stored at -20°C.

3.4 Laboratory Analysis

3.4.1 Proximate Composition of OFSP and WFSP

Chemical analysis

The method of AOAC (2016) was used to determine the moisture, ash, protein, fibre along with the total reducing sugars, carbohydrates, and fat content. All experimental procedures were carried out at IITA laboratory.

3.4.1.1 Determination of Moisture Content

The moisture content was determined by an oven dry method (AOAC, 2016). The sample was weighed and oven dried at 105°C till constant weight was attained. The amount of moisture was calculated and expressed in percentage.

3.4.1.2 Determination of Protein Content

Kjeldahl procedure was used for the determination of protein using block digestion and steam distillation (KjeltecTM 8200 Auto distillation unit 2012) (AOAC, 2016). A weight of 0.25 g of the sample was weighed and transferred into a digestion flask to which approximately 2g of catalyst mixture (CuSO4, K2SO4) was added followed by approximately 6 ml of concentrated sulphuric acid.

The contents of the flask were digested in a fume chamber and then the resultant fume chamber content was connected to the nitrogen distillation unit. The distillate was titrated with 0.1M HCl until when the colour changed from blue to dirty green or orange endpoint. The volume of acid used for neutralization was noted. The percentage of crude protein was calculated using the following formula:

$$\%\ N = \frac{1.401\ x\ (titre - blank) mls\ x\ concentration\ of\ acids\ in\ molarity}{Sample\ weight\ (g)}$$

$$\%\ Crude\ \mathrm{Pr}otein = \%\ Nitrogen\ x\ Conversion\ Factor\ (6.25)$$

Whereby; 14.01= Atomic weight of nitrogen

6.25= Standard Kjeldahl factor for assumption that nitrogen is derived from protein containing 16 % nitrogen.

3.4.1.3 Determination of Fat Content

The fat content was determined by solvent extraction method using SoxtecTM 2055 (AOAC, 2016). About 3 g each of the samples were taken into extraction thimble and covered with defatted cotton wool. The thimble support holder was used to insert the thimbles into the extraction unit, then the cup holder was used to insert the extraction cup containing 70 ml of solvent (40- 60°C petroleum ether). The extraction process involved three stages; boiling (15 min), rinsing (45 min) and recovery (10 min). The cup containing extracted fat was dried in an oven at 105°C for 30mins, cooled in a desiccator and then weighed. The fat content was expressed in percentage.

3.4.1.4 Determination of Ash Content

The ash content was determined by heating a sample in a muffle furnace (AOAC, 2016). 5 grams of sample was weighed and transferred to a furnace at 550°C. The ash was weighed and content expressed as percentage of the original sample weight on dry weight basis.

3.4.1.5 Determination of Crude Fibres

Crude fibre was determined using dilute acid and alkali hydrolysis using Fibertec 2010 by Weende method. Exactly 1.00 g of the sample was accurately taken into glass crucible and about 200 ml of boiled 1.25% H_2SO_4 was poured into the flask and the mixture boiled for 30 minutes under reflux condenser. The insoluble matter was washed with boiling 4 times until the residue was free from acid. About 200 ml of boiling 1.25% KOH solution was added into the residue and then heated for 30 min. under reflux condenser. The residue was filtered, washed with boiling water and then the crucible was transferred to the cold extraction unit and washed with acetone. After

digestion, the residue was dried at 105°C in an air-convectional oven, cooled in a desiccator until constant weight was obtained. The residue was incinerated in an electric furnace at 525°C until all the carbonaceous matter was burnt. The crucible was left to cool down to below 250°C, then removed from the furnace and transferred to the desiccator, cooled to room temperature and weighed. The crude fibre was calculated and expressed as percentage.

3.4.1.6 Determination of Carbohydrates

The carbohydrates content was calculated by difference method as follows:

$$\%Carbohydrate = DM - \left(crude\,Fibre\,Dmb + Ash\,Content\,Dmb + Lipid\,Dmb + \Pr otein\,Dmb\right)$$

Where by: - $DM = Dry\,Matter\,Content$ and $Dmb = Dry\,Matter\,Basis$

3.4.2 Determination of β-carotene Content in Raw, Boiled and Fried OFSP and WFSP Varieties

3.4.2.1 Determination of β-carotene in Raw OFSP and WFSP Varieties

From 300g of raw sample, exactly 3g was measured using an analytical balance scale (Mettler, Switzerland) and transferred into a mortar. The sample was ground with 50 ml of cold acetone (acetone refrigerated at 4°C for 2 h prior to use) being added slowly and was then filtered using Filter (porosity 3; pore size 20-30 µm) with sunction through a sintered glass funnel in a fume chamber. Acetone was used as an extraction medium. The extraction was repeated until the sample from the mortar was devoid of colour. About 40 ml of petroleum ether was put in a 500 ml separating funnel containing the filtrate with teflon stop-cock and 1-2 ml of acetone was added. Distilled water 300 ml was added slowly along the neck without shaking to avoid

emulsion formation. The two phases were then left to separate and the lower aqueous layer discarded. The sample was washed 3-4 times with distilled water (approx. 200 ml) each time to remove residual acetone. In the last phase, washing was done in such a way that the upper phase was not discarded. Upper layer was then collected into 50 ml flask using anhydrous sodium sulphate filter to remove residual water. The absorbance of the extract was then determined at 450nm using UV-visible spectrophotometer model BioMate-6 (sigma Adrich) Rodriguez-Amaya and Kimura (2004).

The concentration of beta carotene was calculated using the below equation as described by Rodriguez-Amaya and Kimura (2004).

$$Carotene\,content\,(mg/100g) = \frac{A\,x\,volume\ (mL)\,x10^3}{Ac\ x\,Sample\,weight\,(g)}$$

Whereby:- $A = Absorbance$

$Volume = Total\,Volume\,of\ Extract = 50ml$

$Ac = Absorption\,Coefficient\,of\ \beta - carotene\,in\,petroleum\,ether = 2592$

3.4.2.2 Determination of β-carotene of Boiled OFSP and WFSP Varieties

Raw samples of each variety (300g) were cleaned using portable water; 500 ml water was added and then boiled unpeeled in stainless steel saucepans with the lid on to boiling point (100°C). Keeping the skin on helps retain the nutrients and enhances the nutritional quality (Rodriguez-Amaya, 2002). Sweet potatoes were cooked until soft for approximately 40 minutes. When the core temperature reached approximately 100°C, the sweet potatoes were soft based on the test which was done by inserting a stainless steel probe. Samples were then cooled to room temperature and peeled (skin was easily peeled off from cooked potato samples). The flesh (peeled potatoes) were

mashed with a spoon, thoroughly mixed and then packed in plastic bags and sealed. Samples were coded and stored after freezed in the analytical laboratory at -20°C. β-carotene content was then determined by weighing 3g of each sample out of 300g, following the same procedures used for determination of β-carotene in raw samples.

3.4.2.3 Determination of β-carotene of Fried OFSP and WFSP

Peeled raw samples (300g) were dried shortly for 5 minutes in open air and then immersed in 300ml of preheated unfortified sunflower oil for 10min at 170^{o}C. Samples were then cooled to room temperature. The fried samples were then mashed in a clean plastic container with a fork, thoroughly mixed and were packed in plastic bags and sealed for analysis of β-carotene. Out of 300g prepared, exactly 3g of the fried sample was measured and the same procedure used for determination of β-carotene in raw potato samples was applied (Rodriguez-Amaya and Kimura, 2004).

3.4.3 Determination of the Optimum amount of OFSP Needed to Supply Recommended Vitamin A to a Child

The optimum amount of OFSP was determined based on the concentrations of bio-accessible beta-carotene. The weight of 1 cup of sweet potato usually is used to calculate the amount (in cups/day) of OFSP needed to supply the VA requirements of a person. One cup of OFSP weighed 255g (USDA ARS 2010). Therefore, to calculate the cups/day of OFSP that would supply 100% of the requirement for VA, the amount of OFSP in g/day will be divided by 255g/cup. This amount corresponded to the amount of OFSP needed by an individual with marginal VA status. A child who is 5years-old or younger needs to consume only 100 g OFSP/day (almost half a cup) of OFSP roots in order to receive the recommended daily amount of vitamin A (Tsou

and Hong, 1992). The amount in grams/day of OFSP needed to meet the requirements for a child at different life stages with good Vitamin A status was calculated following the formula deduced by Burri (2011).

$$Grams\ perday = (\mu gRE / day) \Big/ (\mu g\ \ beta\,carotene / gram\,sweet\ potato / 12)$$

Where by: µgRE represents microgram retinol equivalents and 12 represents µg β-carotenes as conversion ratio.

3.5 Sensory Study

3.5.1 Sampling of the Panelists

Twenty (20) consumers of sweet potatoes at Maili moja ward market were drawn randomly as panelists to analyse particular sensory attributes, which are aroma, colour, texture and overall acceptability.

3.5.2 Preparation of Samples for Sensory Analysis

Samples for sensory analysis were prepared by taking about 5 kg of intact potato roots (free from diseases and insect damage) of each variety from experimental plots. The varieties were OFSP varieties (Mataya and Kiegea) and local varieties (Sinia and Vumilia). The samples were then washed, peeled and chopped into roughly equal sized small pieces which were kept in containers labeled with codes.

3.5.3 Cooking Methods of Sweet Potatoes

The chopped potatoes (approximately 25mm slices) were processed by boiling in water with a lid of the cooking vessel on for 20 minutes, followed by simmering heat (lid of cooking vessel off) for 10 additional minutes. The doneness of the potatoes was checked by piecing with a fork. Little resistance to piecing was an indication of the readiness to eating. During sensory analysis boiled potatoes were served on plates

when still warm. Potatoes meant for frying were cut into 10 mm pieces and afterwards were deep-fried with unfortified sunflower oil at 180 °C for ± 2 minutes, placed on oil-absorbing sheets to soak up oil and the potato chips packed in Low-density polyethylene (LDPE).

3.5.4 Sensory Evaluation

A 7-point Hedonic scale was used for organoleptic evaluation (Binbridge *et al*., 1996). This scales ranges from 6 to 0 where, 6 represents like extremely, 5 represent like very much, 4 represent like much, 3 represent neither like nor dislike, 2 represent dislike much, 1 represent dislike very much and 0 represent dislike extremely. The evaluation included various sweet potatoes attributes like attractiveness of the flesh color of the boiled root (root appearance), acceptance of root texture and texture characteristic from very watery to very dry, and taste/flavor of the root, and overall opinion on the acceptability of the variety.

3.6 Statistical Analysis of Data

The data which were collected were coded and entered into a computer file for further analysis. Statistical Analysis was done by using SPSS (version 12.0 SPSS Inc, IL, USA). Descriptive statistics were performed and values expressed as mean, standard deviation and percentage. ANOVA analysis at the 5% level of least significance was used to determine any differences in the mean values between different sweet potato cultivars and the specific differences between pairs of means were separated by using Duncan’s Multiple Range Test.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Proximate Composition

The proximate composition results of the OFSP varieties (Mataya & Kiegea) and WFSP varieties (Sinia & Vumilia) are presented in Table 4.1.

Table 4.1: Proximate Composition of OFSP and WFSP Varieties

Variety		Proximate parameter					
		Moisture (%)	**Protein (N×6.25) g**	**Fibres (g/100g)**	**Ash (g)**	**Fat (g)**	**Carbohydrate (g/100g)**
OFSP	Kiegea	72.10±0.25^{a}	0.91±0.02^{a}	0.13±0.05^{a}	0.44±0.02^{a}	0.25±0.02^{a}	26.27±0.46^{a}
	Mataya	71.68±0.46^{a}	0.81±0.02^{b}	0.15±0.01^{a}	0.41±0.02^{b}	0.19±0.05^{b}	27.31±0.50^{b}
WFSP	Sinia	62.56±0.02^{b}	0.80±0.01^{b}	0.12±0.01^{a}	0.41±0.01^{b}	0.21±0.01^{b}	35.87±0.03^{c}
	Vumilia	64.33±0.03^{c}	0.81±0.01^{b}	0.12±0.01^{a}	0.39±0.02^{b}	0.20±0.01^{b}	34.12±0.01^{d}

Values are means of triplicate experiments and values for the same nutrient in the same column with different superscript letters are significantly different at $P < 0.05$

Values are means of triplicate experiments and values for the same nutrient in the same column with different superscript letters are significantly different at $P < 0.05$. The moisture content varied significantly ($p< 0.05$) between OFSP and WFSP varieties. Significant variations ($p< 0.05$) were also observed between WFSP varieties (Sinia and Vumilia) but the variations were insignificant ($p \geq 0.05$) between OFSP varieties (Kiegera and Mataya). The moisture contents recorded for those four varieties are however lower than those reported in previous studies (Wenkam, 1983) for fresh sweet potatoes (77.8%). The variations in the moisture content among sweet potato varieties can be due to the differences in the genetic composition and agro-cultural practices.

However, comparing with other roots and tubers, sweet potatoes have higher moisture contents and thus low dry matter content. The normal dry matter content of sweet potatoes is around 30%, but differs widely depending on variety, geographic area, climate, and amount of light, soil and cultivation practices. It has been reported (Woolfe, 1992) that the application of fertilizer significantly reduces the moisture content in sweet potatoes. The low moisture content signifies high dry matter content and, thus, more carbohydrates and, consequently, higher energy content (Table 4.1).

Fat contents results showed significant variations ($p < 0.05$) between OFSP varieties (Mataya and Kiegea) and also between Kiegea and WFSP varieties. However the differences within WFSP varieties (sinia and vumilia) were insignificant ($P < 0.05$). Like other roots and tubers, sweet potato is well recognized for its low-fat content. The results of fat contents were similar to those of other studies (Ishida *et al.*, 2000), which documented 0.2% to 0.33% fat contents.

In terms of protein contents, the OFSP varieties (Mataya and Kiegea) showed significant ($p<0.05$) differences (Table 4.1), however, the WFSP varieties (Vumilia and Sinia) on the other hand showed insignificant differences ($P \geq 0.05$) between them. The difference between OFSP and WFSP was clearly indicated by Kiegea (OFSP variety) which varied significantly ($p < 0.05$) with both WFSP varieties (Vumilia and Sinia). Nevertheless, the protein contents of those two OFSP varieties (Mataya and Kiegea) were lower than those reported in previous studies (Senanayake *et al.,* 2013). In their study (Senanayake *et al,* (2013) recorded between 1.2 and 3.3% protein contents on dry weight basis in five varieties of sweet potato. Some studies (FAO, 2001) have indicated sweet potato to contain about 1.6% protein content. The

deviation of the current results from available literature data could be due to genetical variations between varieties or clones.

The crude ash contents results between OFSP varieties (Mataya and Kiegea) indicated significant variations ($p < 0.05$), however the differences between the WFSP varieties (sinia and vumilia) were insignificant ($P \geq 0.05$). Furthermore, the crude ash content for Kiegea also varied significantly ($p < 0.05$) with the WFSP varieties (sinia and vumilia) but no significant variations ($P \geq 0.05$) were observed between mataya (OFSP variety) and WFSP varieties (sinia and vumilia). The crude ash contents of these varieties ranged from 0.39±0.02 to 0.44±0.02%, which compares well with those reported for fresh sweet potato tubers, which varied between 0.40% and 0.44% (Ingabire and Vasanthakaalam, 2011).

The crude fibre contents results showed no significant ($p<0.05$) difference between both OFSP and WFSP varieties. The current results on crude fibre content, which ranged from 0.12±0.01 to 0.15±0.01 compared well with those obtained by Ingabire and Vasanthakaalam (2011) for Rwandan varieties which had crude fibre contents ranging between 0.11% to 0.14%. On the other hand the results of crude fibre obtained from this study are not comparable to those obtained in the study which was carried in Sirilanka which ranged between 2.1 and 13.6 % on dry matter basis (Senanayake et al., 2013). This difference in crude fibres content may be attributed to genetical and cultivar differences and / or environmental conditions. Dietary fibre has recently gained much importance as it is indicated to reduce the incidences of colon cancer, diabetes, heart diseases and certain digestive diseases (Ingabire and Vasanthakaalam, 2011).

The result of carbohydrate content showed significant variations ($p<0.05$) between OFSP and WFSP varieties. A previous study (Wenkam, 1983) indicated fresh sweet potato had 27% of carbohydrate content whereas FAO (2001) reported 28% carbohydrate content for fresh samples. Those earlier results compare well with the carbohydrate contents recorded for the OFSP varities in the current study but are lower than those of the WFSP varieties.

4.2 β- carotene Content of Unprocessed and Processed OFSP and WFSP

The results of β- carotene content of differently treated sweet potatoes are presented in Table 4.2.

Table 4.2: β - carotene Contents of Differently Treated OFSP (Kiegea and Mataya) and WFSP (Sinia and Vumilia) Varieties

Variety		Treatment		
		Fresh (mg/100g)	**Boiled** (mg/100g)	**Fried** (mg/100g)
OFSP	Kiegea	21.57±0.45[a]	17.35±0.20[a]	14.63±0.30[a]
	Mataya	14.79±0.19[b]	11.68±0.45[b]	9.30±0.16[b]
WFSP	Sinia	BD	BD	BD
	Vumilia	BD	BD	BD

Values are means of triplicate experiments and values for the same treatment within the same column with different superscript letters are significantly different at $P < 0.05$. BD = Below Detection level <0.04µg/mL

The current results indicate that β-carotene was not detectable in WFSP varieties (Sinia and Vumilia) but was detectable in OFSP varieties (Kiegea and Mataya)

regardless of the treatments (Table 4.2). The treatments (boiling and frying) on the other hand had negative effects on β-carotene contents for the OFSP varieties. The β-carotene contents varied significantly ($P < 0.05$) between the OFSP varieties and between processing treatments. The results generally showed negative effects of both treatments (boiling and frying) on β-carotene contents. The results further indicated variation in β-carotene retention rate, which varied with the processing treatment. The retention rate of β-carotene (78.97% - 80.44%) was higher in boiled OFSP potatoes than in fried OFSP potatoes (62.88% - 67.83%). The variation could be due heating intensity and shielding effect of the heating media. β - carotene is fat soluble but is water insoluble.

Furthermore, the variation in β-carotene retention could also be due to the difference in the enzymatic oxidation during processing (Ameny and Wilson, 1997). Adelaide *et al*. (2007) moreover indicated that variations during processing could also be attributed to the temperature, duration of frying, and stage of maturity. The β-carotene contents recorded in the present study fall within the range reported by Takahata *et al*. (1993) which varied between 0.01 and 26.6 mg/100g on fresh weight basis (fwb). Generally, cooking and processing have a degrading effect on β-carotene content. Vimala *et al*. (2011) indicated variations in β-carotene retention due to treatment e.g. sun drying retained 63 - 73%, oven drying 89 – 96%, boiling 84–90% and frying 72–86% β-carotene among OFSP varieties.

The results in the present study compare well with the findings of Vimala *et al*. (2011) in terms of β-carotene retention rate due to heat treatments (frying and boiling). While the effect of the various treatments on β-carotene contents is appreciated however the

variations in β-carotene contents between varieties in the present study could also be attributed to other factors such as genetic variations (Adelaide *et al*., 2007).

4.3 Sensory Quality of boiled WFSP and OFSP Varieties

The results in Table 4.3 shows the sensory evaluation results for WFSP varieties (Vumilia and Sinia) and OFSP varieties (Kiegea and Mataya) which was done by using a 7 point hedonic scale method.

Table 4.3: Sensory Quality of WFSP and OFSP Varieties

Attribute	**Varieties**		**Mean±SD**	**Rank**	**p-value**
Color	OFSP	Kiegea	5.35^{a}±0.75	1	0.00
		Mataya	5.30^{a}±0.57	2	
	WFSP	Sinia	1.45^{b}±1.19	4	
		Vumilia	3.30^{c}±1.17	3	
Texture	OFSP	Kiegea	2.85^{a}±1.09	4	0.00
		Mataya	3.25^{a}±1.25	3	
	WFSP	Sinia	4.75^{b}±0.97	1	
		Vumilia	4.60^{b}±1.14	2	
Aroma	OFSP	Kiegea	3.30^{a}±0.92	1	0.00
		Mataya	2.90^{a}±0.97	2	
	WFSP	Sinia	1.70^{b}±1.03	3	
		Vumilia	2.40^{b}±0.88	4	
Overall acceptability	OFSP	Kiegea	4.05^{a}±1.00	2	0.00
		Mataya	3.65^{a}±1.14	3	
	WFSP	Sinia	2.65^{b}±1.14	4	
		Vumilia	4.15^{a}±0.81	1	

Sensory evaluation of the OFSP varieties was conducted alongside the WFSP varieties (Table 4.3) in order to evaluate their acceptability. Four attributes were captured in the evaluation including colour, texture, aroma and the overall acceptability. The results indicate that the OFSP varieties ranked higher in terms of colour and aroma (as first and second) with Kiegea variety leading in either cases followed by Mataya. The OFSP varieties (Kiegea and Mataya) developed a deep orange colour after boiling.

However, in terms of texture the OFSP varieties (Kiegea and Mataya) ranked lower (as third and fourth) with Kiegea variety ranking last. On the other hand, the WFSP variety Sinia variety ranked first in terms of texture followed by Vumilia variety. This could be due to the low moisture content and high starch content (Table 4.1). In all attributes the results indicated significant differences ($P < 0.05$) between the OFSP and WFSP varieties but were insignificant ($P \geq 0.05$) between OFSP varieties.

However, in terms of overall acceptability Vumilia was the highest ranked and Sinia the lowest ranked. Generally the ranking was in the following descending order: Vumilia > Kiegea >Mataya > Sinia. The differences in the overall acceptability was similarly significant ($P < 0.05$) between Sinia and all the other three varieties but were insignificant ($P \geq 0.05$) among the first three leading varieties (Vumilia, Kiegea and Mataya). The findings by Oyunga *et al.,* (2015) on sensory evaluation of OFSP varieties (Kabode and Vita) against a local variety indicated that the overall acceptability of the local variety was higher than that of the two new OFSP varieties.

In the present study one of the two local WFSP varieties (Vumilia) had the highest overall acceptability score while the other one had the lowest overall acceptability

score. The findings of previous studies (Kapinga *et al.*, 2003) described firmness as an indicator of high dry matter content which is a preferred sweet potato root quality. This could partially explain the overall acceptability of Vumilia variety, which had 34.12±0.01 g/100g carbohydrate content as compared to 26.27±0.46 g/100g and 27.31±0.50 g/100g of Kiegea and Mataya respectively but lower than Sinia which had 35.87±0.03 g/100g carbohydrate contents suggesting the interplay of other factors.

The OFSP cultivars have often been rated poorly regarding finger-feel firmness (Leksrisompong *et al.*, 2012) probably due to their generally, low dry matter (20 to 24%) contents (Tomlins et al., 2012; Vimala et al., 2013). The two OFSP varieties (Kiegea and Mataya) ranked second and third respectively. This implies the potential of OFSP varieties and its likely acceptability due to the superiority in colour and aroma and also richness in β-carotene, which is a precursor for vitamin A.

4.4 Optimum Amount of OFSP Needed to Supply the Required Amount of Vitamin A for the Different Age Groups

The amount and availability of vitamin A in OFSP is influenced by several factors including genetic variability and soil composition a few to mention. Though dietary reference intakes for VA are available however due to inherent variations among varieties it was deemed important to establish the optimum amount needed to meet individuals demand based on the richness of vitamin A contents in OFSP varieties (Kiegea and Mataya). Vitamin A (VA) determination was done for the various age groups as presented in Table 4.4 (from 7-12 months to 10-13 years of age) as age is among the determining factors.

Table 4.4: Indicates the Amount of OFSP Needed to Supply Optimum amount of VA among Children of Different Age Groups

OFSP Variety	Estimated beta carotene content of OFP varieties* (mg/100g)	Recommended VA intake for different age groups		Computed Optimum amount of OFSP (g/day) required to supply the optimum Recommended amount of VA	P-value
		Age groups (Months/years)	Recommended VA intake (µg RE/day)		
Kiegea	17.35	7-12 Months	400	98.91	0.001
Mataya	11.68			144.27	
Kiegea	17.35	1-3 years	400	98.91	0.001
Mataya	11.68			144.27	
Kiegea	17.35	4-6 years	450	111.27	0.001
Mataya	11.68			162.31	
Kiegea	17.35	7-8 years	500	123.63	0.001
Mataya	11.68			180.34	
Kiegea	17.35	9 years	500	123.63	0.001
Mataya	11.68			180.34	
Kiegea	17.35	10-13 years	600	148.36	0.001
Mataya	11.68			216.41	

The amount of OFSP (grams/day) needed to meet VA requirements varies with both age and concentration of beta-carotene in the OFSP varieties. The results in Table 4.4 generally indicate that a much higher amount of Mataya variety is needed to supply the required optimum amount of vitamin A compared to Kiegea variety among children age groups. These variations are attributed to the variations in the amount of β-carotene contents between the two varities.

On the other hand the amount of OFSP variety that should be consumed to attain the optimum VA demands of a child are dependent on the age group. The optimum amount of OFSP (g/day) required to meet VA requirements for different age groups (7-12 months to 10-13 years) varied from 98.91 and 144.27 g/day to 148.36 and 216.41g/day for Kiegea and Mataya varieties respectively (Table 4.4). This implies

that Kiegea variety is a richer source of β-carotene than Mataya variety suggesting its great potential in combating VAD.

According to Tsou and Hong (1992), a child who is 5 year old or younger needs to consume only 100 g OFSP/day (half-cup) of OFSP roots per day in order to receive the recommended daily amount of vitamin A. This amount corresponds with–the optimum amount established for Kiegea variety required to supply the needed VA at 7-12 month, 1-3 years and 4-6 years.

Burri (2011) showed that the amounts of OFSP needed for consumption ranged from 31 to 176 g/d for a 10-13 year old child with good Vitamin A status. The estimated optimum amount for a child aged 10-13 years in the present study were 148.36 and 216.41 g/d for Kiegea and Mataya varieties respectively which falls within the ranges by Buri (2011) for the respective age. Any difference in the estimated values of OFSP needed to meet VA requirements that might be observed could be due to either / both age group and the concentration of beta-carotene in the OFSP varieties understudy. The results generally indicate significant differences between OFSP varieties (Kiegea and Mataya) in meeting VA requirements for the different age group.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONs

5.1 Conclusion

This study aimed at evaluating the nutritional, sensory quality and the potential of orange fleshed sweet potato varieties in combating vitamin A deficiency. The proximate compositions results showed significantly difference ($p<0.05$) between varieties in moisture content, fat, protein, crude ash content, dry matter content, and carbohydrates except in fibres.

The β-carotene content were high and varied significantly ($P<0.05$) between OFSP varieties but were below the detection level in WFSP varieties which further confirms the superiority of OFSP varieties in β-carotene contents. Furthermore, it was demonstrated that both boiling and frying of OFSP have a significant adverse effect in beta-carotene concentration. Nevertheless, the findings of this present study has indicated that OFSP sweet potatoes varieties (kiegea and mataya) are richer sources of β-carotene and have the potential of meeting VA requirements for different age groups (7 Month- 13 years) and address the problem of vitamin-A deficiency.

The sensory analysis indicates significant differences ($p< 0.05$) in all attributes between OFSP varieties (Kiegea and Mataya) and WFSP varieties (Vumilia and Sinia) but were insignificant ($P \geq 0.05$) between OFSP varieties. OFSP varieties were superior in both colour and aroma whereas WFSP varieties were superior in texture. In terms of overall acceptability WFSP varieties, Vumilia ranked first and Sinia ranked last. The overall ranking was in the following descending order: Vumilia >

Kiegea >Mataya > Sinia. The differences in the overall acceptability was similarly significant ($P < 0.05$) between Sinia and the other three varieties but was insignificant ($P \geq 0.05$) among the first three leading varieties (Vumilia, Kiegea and Mataya). Nevertheless both OFSP varieties have the potential of addressing VA deficiencies and can play an important role in the alleviation of VAD in the children of developing countries if consumed in the required amount. Therefore, it is necessary to bring the beneficial role of OFSP consumption to the attention of the public, the medical profession, producers and consumers.

5.2 Recommendations

Based on the findings of the present study it is recommended that;

(i) Sweet potatoes stakeholders should concentrate on the promotion of OFSP cultivars in comparison with the local ones due to their nutritional benefits specifically B-carotene.

(ii) OFSP varieties should be advocated to awareness among community members on the richness of beta carotene in OFSP varieties and its potential in alleviating VA deficiencies.

(iii) It is better to consume OFSP in boiled form due to high retention of β-carotene compared to frying method, which degrade the β-carotene.

(iv) WFSP varieties specifically Sinia, were superior in texture compared to OFSP hence are sweet potato breeding team should work on how to improve the texture OFSP cultivars.

(v) More research should be carried out on OFSP value addition methods in order to offer a wide range of value added products at affordable price and good palatability.

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APPENDICES

Appendix I: Sensory Evaluation Sheet

Name:……. Date:……..

Panelist No: …….

Instructions:

Taste the given samples of sweet potatoes, then place an X mark on the point in the scale which best describes your feeling.

Score	**Sample Code**			
	295	918	357	569
(6)Like extremely				
(5)Like very much				
(4)Like much				
(3)Neither like nor dislike				
(2)Dislike much				
(1)Dislike very much				
(0)Dislike extremely				

Appendix II: Sensory Quality Analysis Outputs of WFSP and OFSP Varieties

A. Sensory quality analysis outputs on colour

Color			
Tukey HSD			
Variety	**Subset for alpha = 0.05**		
	1	2	3
Sinia	1.45		
Vumilia		3.30	
Mataya			5.30
Kiegea			5.35

B. Sensory quality analysis outputs on texture

Texture		
Tukey HSD		
Variety	**Subset for alpha = 0.05**	
	1	**2**
Kiegea	2.85	
Mataya	3.25	
Vumilia		4.60
Sinia		4.75

C. Sensory quality analysis outputs on flavour

Flavour			
Tukey HSD			
Variety	**Subset for alpha = 0.05**		
	1	**2**	**3**
Sinia	1.70		
Vumilia	2.40	2.40	
Mataya		2.90	2.90
Kiegea			3.30

D. Sensory quality analysis outputs on overall acceptability

Overall acceptability		
Tukey HSD		
Variety	**Subset for alpha = 0.05**	
	1	**2**
Sinia	2.65	
Mataya		3.65
Kiegea		4.05
Vumilia		4.15

Appendix III: Research Clearance Letter

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15th January 2017

Sub-Center Manager,
TARI Kibaha,
P. O. Box 3003,
KIBAHA.

RE: RESEARCH CLEARANCE

The Open University of Tanzania was established by an Act of Parliament No. 17 of 1992, which became operational on the 1st March 1993 by public notice No.55 in the official Gazette. The Act was however replaced by the Open University of Tanzania Charter of 2005, which became operational on 1st January 2007. In line with the Charter, the Open University mission is to generate and apply knowledge through research.

To facilitate and to simplify research process therefore, the act empowers the Vice Chancellor of the Open University of Tanzania to issue research clearance, on behalf of the Government of Tanzania and Tanzania Commission for Science and Technology, to both its staff and students who are doing research in Tanzania. With this brief background, the purpose of this letter is to introduce to you **Mr. Badi Mwalim Bao, Reg No: PG201608282** pursuing **Master Human Nutrition.** We here by grant this clearance to conduct a research titled ***"The Potential of Fresh Bred Orange Fleshed Sweet Potato Varieties in Combating Vitamin A Deficiency"***. He will collect his data in your institution between 20th January to 31st July 2017.

In case you need any further information, kindly do not hesitate to contact the Deputy Vice Chancellor (Academic) of the Open University of Tanzania, P.O. Box 23409, Dar es Salaam. Tel: 022-2-2668820.We lastly, thank you in advance for your assumed cooperation and facilitation of this research academic activity.

Yours Sincerely,

Prof. Hossea Rwegoshora
For: VICE CHANCELLOR
THE OPEN UNIVERSITY OF TANZANIA

Appendix IV: Published Papers

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Evaluation of the Potential of Freshly Bred Orange-Fleshed Sweet Potato Varieties in Combating Vitamin A Deficiency

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Abstract

Orange-fleshed sweet potato (OFSP) is advocated as a rich and readily accessible source of vitamin A. This study was done to evaluate the potential of the newly bred OFSP varieties in combating vitamin A deficiency. OFSP varieties and white fleshed sweet potato (WFSP) varieties were used for the study. β-carotene was extracted with acetone and its spectrophotometric reading at 450 nm used to calculate its concentration. The optimum amount of OFSP required to meet vitamin A needs for children of different age groups were established. Results indicate that β-carotene was below detection levels in WFSP varieties but was detectable in OFSP varieties regardless of the processing treatment. The concentration varied significantly ($P < 0.05$) between OFSP varieties and between processing treatments. The reduction rate of β-carotene varied with processing treatments and was much higher in fried potatoes (3.2 –37.1%) than boiled potatoes (19.6 – 21%). This implies a higher retention rate of β-carotene (78.97% – 80.44%) in boiled than fried OFSP varieties (62.88% – 67.83%). The optimum amount of OFSP (g/day) required to meet vitamin A requirements for 7–12 months to 10–13 years varied from 98.91 and 144.27 g/day to 148.36 and 216.41 g/day for Kiegea and Mataya cultivars (OFP varieties), respectively. The results provide an insight of the richness of OFSP varieties in β-carotene and its great potential in preventing vitamin A deficiency.

Keywords: Children; Age groups; β-carotene; Vitamin A requirements; Processing treatments

Introduction

Vitamin A deficiency (VAD) is a serious prevalent public health problem in many developing countries (WHO 1995). It mainly affects the poor, young children under five years, pregnant and lactating women (Low et al. 1997). In children, VAD causes millions of deaths, poor growth and development, increased risks of infections and severity of infections, and blindness. About 140 millions children are affected from VAD globally; 100 millions live in sub-Saharan Africa (Mason et al. 2001). More findings (WHO 2009) indicate that low serum retinol concentration (< 0.70 µmol/l) affects an estimated 190 million pre-school age children and 19.1 million pregnant women worldwide. This corresponds to 33.3% of the preschool-age population and 15.3% of pregnant women in populations at risk of VAD, worldwide. VAD also enhances several risks to pregnant women including; death during pregnancy, miscarriage, night blindness, pre-mature baby, giving birth to low weight children and also it may increase the risk of spread of HIV/AIDS virus infections (Tumwegamire et al. 2004). In Tanzania, VAD is categorized as a 'problem of public-health significance'. Likewise, the health agencies worldwide in order to reduce the effects of VAD, they promote the usage of vitamin A capsules, supplements, fortifying processed and packaged foods to children, pregnant and lactating women especially in hospitals and

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health centers. These efforts have proven to reduce cases of the deficiency. For example, the vitamin A supplements delivered twice a year to children less than 5 years have been shown to reduce child mortality by 24% (Imdad et al. 2010). Also, children blindness cases related to VAD have significantly been reduced.

Currently, the cheapest and cost-effective method for combating VAD is through food-based strategies by promoting consumption of locally available vitamin A-rich foods that can be grown in home gardens. Orange-fleshed sweet potatoes (OFSP) can be a very suitable crop for food-based strategy (Low et al. 2007). OFSP are high in carotenoids and β-carotene (Takahata et al. 1993). Consumption of OFSP can provide sustainable vitamin A, which plays crucial role in preventing night blindness (Ndirigue 2004). Research findings (Low et al. 2007) have established that a small amount of 100 –150 grams of OFSP varieties can supply daily recommended allowance for children under 5 years of age. Farmers in Tanzania have been growing white fleshed sweet potatoes (WFSP) varieties for many years due to their high yielding capacity, high dry matter and acceptability by consumers though they have low beta-carotene levels. Two varieties of OFSP (Mataya and Kiegea) were released in 2010 for use by Tanzanian farmers (MAFC 2010). These varieties have moderate yields (12 –15 t/ha), are tolerant to Sweet Potato Virus Disease (SPVD), and have moderate dry matter content. However, limited information is available regarding their nutritional potential in addressing nutritional deficiencies, particularly vitamin A. Therefore, the aim of this study was to evaluate the potential of the released OFSP varieties, in combating vitamin A deficiency.

Materials and Methods

Description of study area

The study was carried out in Kibaha district, one of the six districts of the Coast region, Tanzania. Other districts are Rufiji, Mafia, Mkuranga, Bagamoyo, and Kisarawe. The district is bordered in the North by Bagamoyo district, in the East by Dar es Salaam Region, to the South by the Kisarawe district and to the west by Morogoro region. Kibaha district covers an area of about 1,812 total km^2. According to the 2012 census, the district has a population of 198,697 people. It is located within the latitude -6.7813° S and longitude 38.9929° E. The district experiences a typical tropical climate with an average temperature of 28 °C, with rainfall ranging from 800 mm to 1000 mm per annum. It has a bimodal rainfall pattern, a short rainy season from October to December and long rainy season between March and June. Typical of coastal areas, the district has hot and humid conditions, with an average day temperature of 30 °C.

Experimental design and field layout

This trial study was experimented using a randomized block design at the National Root Crops Research Institute (NRCRI). The vine cuttings of OFSP varieties (Kiegea and Mataya) and WFSP varieties (Sinia and Vumilia) for the trial were propagated in a field multiplication block. Each clone was planted in an experimental plot size of 6.0 × 4.0 m in randomized block design with 3 replications. The distance between and within the ridges were 100 and 30 cm, respectively. No fertilizers were used in any of the trial field and weeding and cultivation were done as per the institute advice. All of the four varieties were harvested from the same experimental field, the usual cultural practices such as early planting and delaying harvest hold were observed.

Pre-preparation of potato root samples

Four sweet potato cultivars, namely Kiegea, Matai (which are OFSP varieties) and Sinia and Vumilia (WFSP varieties) were used in this study. These cultivars were planted in early March 2018 and the consignments of the roots were harvested in Mid-June 2018. Only sound potato roots free of diseases or physical damage were chosen

for data collection. The roots were thoroughly washed with tap water and dried with paper toweling. The roots were then transported immediately to the International Institute of Tropical Agriculture (IITA) for laboratory analysis.

Sample preparation and cooking processes

Two cooking processes were considered, that is, boiling and frying. Raw samples were used as control.

Raw samples: Sampled roots were peeled, cut into equal parts, thoroughly mixed and 3 g of each variety was measured using an analytical balance scale (Mettler, Switzerland) and transferred into a mortar. The samples were ground with 50 ml of cold acetone (acetone refrigerated at 4 °C for 2 h prior to use) being added slowly and then filtered using a glass microbore filter disk (GF/A, What man, England) Filter (porosity 3; pore size 20-30 μm) with suction through a sintered glass funnel in a fume chamber. The mortar, pestle, funnel, and residue were washed with small amounts of acetone (which was used as an extraction medium), receiving the washings in the suction flask through the funnel. The extraction was repeated until the sample from the mortar was devoid of colour. About 40 ml of petroleum ether was put in a 500 ml separating funnel containing the filtrate with teflon stop-cock and 1-2 ml of acetone was added. Distilled water (300 ml) was added slowly along the neck without shaking to avoid emulsion formation. The two phases were then left to separate and the lower aqueous layer discarded. The sample was washed 3–4 times with distilled water (approx. 200 ml) each time to remove residual acetone. In the last phase, washing was done in such a way that the upper phase was not discarded. The upper layer was then collected into a 50 ml flask through a filter containing anhydrous sodium sulphate to remove residual water.

Boiled samples: Raw samples of each variety (300 g) were cleaned using portable water; 500 ml water was added and then boiled unpeeled in stainless steel saucepans with the lid on to boiling point (100 °C). Keeping the skin on helps retain the nutrients and enhances the nutritional quality (Rodriguez-Amaya and Kimura 2004). The potatoes were cooked until soft for approximately 40 minutes, when the core temperature reached approximately 100 °C. Samples were then cooled to room temperature and peeled (skin was easily peeled off from cooked potato samples). The flesh (peeled potato) was mashed with a spoon, thoroughly mixed and weighed to 1 kg sample which was packed in plastic bags and sealed. Samples were coded and stored at –20 °C until analysis. Three grams (3 g) of the sample was used for extraction of beta carotene as was for raw samples.

Fried samples: Peeled and sliced raw samples of each potato variety (300 g) were dried shortly for 5 minutes in open air and then immersed in 300 ml of preheated oil for 10 min at 170 °C. Samples were then cooled to room temperature. The fried samples were then mashed in a clean plastic container with a fork, thoroughly mixed and weighed samples (1 kg) were packed in plastic bags and sealed for analysis of β-carotene. Samples were coded and stored after in the analytical laboratory at –20 °C. Three grams (3 g) of the samples were used for extraction of beta carotene as was for raw samples.

Each individual cooking experiment (boiling and frying) and control experiment (raw samples) was conducted in triplicate.

Determination of β-carotene contents

The absorbance of the extract (1.5 ml) of the four potato cultivars was determined at 450 nm using UV-visible spectrophotometer model BioMate-6 (Sigma Adrich). The concentration of beta carotene was calculated using the equation below as described in Rodriguez-Amaya and Kimura (2004).

$$\text{Carotene content}(\text{mg}/100\text{g}) = \frac{A \times \text{volume}(\text{mL}) \times 10^3}{Ac \times \text{Sample weight}(\text{g})}$$

Where: A = Absorbance; Volume = Total volume of extract = 50 ml; Ac = Absorption

coefficient of carotene in petroleum ether = 2592.

Determination of the optimum amount of OFSP needed to supply recommended vitamin A to a child

The amount in grams/day of OFSP needed to meet the requirements of a child with marginal vitamin A status at different life stages was calculated following the formula deduced by Low et al. (1997).

$$\text{Grams per day OFSP} = \frac{(\mu\text{gRE/day})}{(\mu\text{g bioaccessible beta carotene / gram sweet potato} \times 12)}$$

Where: µgRE represents microgram retinol equivalents and 12 represents a conversion ratio for marginal vitamin A deficiency, i.e., 12-µg beta-carotene: 1-µg retinol for well-nourished individual.

The optimum amount of OFSP was computed based on the concentrations of bio-accessible beta-carotene and the weight of 1 cup of sweet potato (US Department of Agriculture 2015). The saving cup that was used to measure the amount (in grams/day) of OFSP needed to supply VA requirements of a person at different life stages weighed 255 g when full. Therefore, to calculate the number of cups/day of OFSP that would supply 100% of the requirement for VA, the amount of OFSP in gram/day was divided by 255 g/cup. This amount corresponded to the amount of OFSP needed by an individual with marginal VA status. A child who is 5 years-old or younger needs to consume only 100 g OFSP/day (almost half a cup) of OFSP roots in order to receive the recommended daily amount of vitamin A (Tsou and Hong 1992).

Statistical analysis of data

Statistical Analysis of the data was done by using SPSS (version 12.0 SPSS Inc, IL, USA). Descriptive statistics were performed and values expressed as mean, standard deviation and percentage. ANOVA was done at the 5% level of significance to determine differences in the mean values among different sweet potato cultivars and the specific differences between pairs of means were separated by using Duncan's Multiple Range Test.

Results and Discussion

β - carotene content of unprocessed and processed OFSP and WFSP

Table 1 indicates that β-carotene was below detection level in WFSP varieties (Sinia and Vumilia) but was detectable in OFSP varieties (Kiegea and Mataya) regardless of the treatments. The β-carotene contents varied significantly ($P < 0.05$) between the OFSP varieties and between processing treatments. The processing treatments (boiling and frying) had significant ($P < 0.05$) negative effects on β-carotene contents which varied significantly between OFSP varieties. The reduction rate of β-carotene varied with processing treatments. It was much higher in fried potatoes than in boiled potatoes (Table 1). These results generally imply that the retention rate of β-carotene (78.97%–80.44%) was higher in boiled OFSP potatoes than in fried OFSP potatoes (62.88%–67.83%). The variation could be due to heating intensity and shielding effect of the heating media. β-carotene is fat soluble but water insoluble. Furthermore, the variation in β-carotene retention could also be due to the difference in the enzymatic oxidation during processing (Ameny and Wilson 1997). Other researchers (Demasse et al. 2007) indicated that variations during processing could also be attributed to the temperature, duration of frying, and stage of maturity. Previous findings (Mudambi and Rajagopal 1977) also observed a decrease in β-carotene content of palm oil samples heated

between 138 °C and 258 °C with an interval of 12 °C. The amount of β-carotene declined with a rise in temperature. The damage of β-carotene was highest when the oil was heated constantly for 30 min at various selected temperatures. Other researchers (Ishiwu et al. 2014) also recorded a significant decrease in beta-carotene content as boiling or frying period increased between 2 and 30 minutes. In their study, the beta-carotene content decreased by 61.4% while it decreased by 63.6% when the tomato pulp was fried for 30 minutes. In the present study, boiling was done for 40 minutes, whereas frying was for 10 minutes. Another study by Gurmu and Mekonen (2019) also indicated variations in β-carotene retention due to treatment, e.g., sun drying retained 63–73%, oven drying 89–96%, boiling 84–90% and frying 72–86% β-carotene among the OFSP varieties. The results of the present study compare well with the previous findings (Gurmu and Mekonen 2019) in terms of β-carotene retention rate due to heat treatments (frying and boiling) implying a much higher destructive effect of frying. The variations in β-carotene contents between cultivars in the present study could also be attributed to other factors such as genetic variations (Demasse et al. 2007). Nonetheless, the β-carotene contents recorded in the present study fall within the range of earlier reported results (Takahata et al. 1993) which varied between 0.01 and 26.6 mg/100g on fresh weight basis (fwb). A study by Gurmu and Mekonen (2019) quantified β-carotene content of four genotypes which ranged from 2.4 to 12.4 mg/100 g with an average β-carotene content that was greater than 10 mg/100 g. This is lower than the β-carotene content quantified in the present study.

Table 1: β - carotene contents of differently treated OFSP and WFSP varieties

Variety/ Cultivar		Processing Treatments			% reduction	
		Fresh	Boiled	Fried	in boiled samples	in Fried samples
OFSP	Kiegea	21.57 ± 0.45^{a}	17.35 ± 0.20^{a}	14.63 ± 0.30^{a}	19.6%	32.2%
	Mataya	14.79 ± 0.19^{b}	11.68 ± 0.45^{b}	9.30 ± 0.16^{b}	21%	37.1%
WFS	Sinia	ND	ND	ND		
	Vumilia	ND	ND	ND		

Values are means of triplicate experiments and values for the same treatment within the same column with different superscript letters are significantly different at $P < 0.05$. ND = Not Detected.

Optimum amount of OFSP needed to supply the required amount of vitamin A for the different age groups

The availability and amount of β-carotene in OFSP are influenced by several factors including genetic variability and soil composition. In this regard, although dietary reference intakes for VA are available, however owing to inherent variations among cultivars, it was deemed important to establish the optimum amount needed to meet individuals demands based on the richness of vitamin A in OFSP cultivars (Kiegea and Mataya). VA determination was done for the various age groups as presented in Table 2 (from 7–12 months to 10–13 years of age) as age is among the determining factors.

Table 2: Amount of OFSP needed to supply optimum quantity of VA among children of different age groups

OFSP Cultivars	Estimated β-carotene contents *	Recommended VA intake for different age groups		Computed Optimum amount of OFSP (g/day) required to supply the recommended amount of VA	P-value
		Age groups (months/years)**	Recommended VA intake (µg RE/day)**		
Kiegea	17.35	7– 12 Months	400	98.91	0.001
Mataya	11.68			144.27	
Kiegea	17.35	1–3 years	400	98.91	0.001
Mataya	11.68			144.27	
Kiegea	17.35	4–6 years	450	111.27	0.001
Mataya	11.68			162.31	
Kiegea	17.35	7–8 years	500	123.63	0.001
Mataya	11.68			180.34	
Kiegea	17.35	9 years	500	123.63	0.001
Mataya	11.68			180.34	
Kiegea	17.35	10-13 years	600	148.36	0.001
Mataya	11.68			216.41	

**These were obtained from Booth et al. (1992).

The estimated beta carotene contents of Kiegea and Mataya cultivars of OFSP variety were 17.35 and 11.68, respectively. The optimum amount of OFSP (g/day) required to meet VA requirements for different age groups (7–12 months to 10–13 years) varied from 98.91 and 144.27 g/day to 148.36 and 216.41g/day for Kiegea and Mataya cultivars, respectively (Table 2). This implies that Kiegea cultivar is a richer source of β-carotene than Mataya cultivar, suggesting that it has more potential in combating VAD. The variation in the amounts of OFSP (grams/day) needed to meet VA requirements are attributable to both age and concentrations of β-carotene in the OFSP cultivars. The results (Table 2) generally indicate that a much higher amount of Mataya cultivar is needed to supply the required optimum amount of vitamin A among different children age groups compared to Kiegea cultivar. According to earlier findings (Tsou and Hong 1992), a child who is 5 year old or younger needs to consume only 100 g OFSP/day (half-cup) of OFSP roots per day in order to receive the recommended daily amount of vitamin A. This amount corresponds well with the optimum amount established for Kiegea variety that is required to supply the needed VA at 7–12 month, 1–3 years and 4–6 years.

The study by Burri (2011) showed that the amounts of OFSP needed to be consumed ranged from 31 to 176 g/d for a 10–13 year old child with good vitamin A status. The estimated optimum amounts for children aged 10–13 years in the present study are 148.36 and 216.41 g/d for kiegea and mataya cultivars, respectively which compare well with the ranges established earlier (Burri 2011) for the respective ages. Any recorded difference in the estimated amounts of the OFSP needed to meet VA requirements could be due to the concentrations of β-carotene in the current OFSP cultivars. The results generally indicate significant differences between OFSP cultivars (Kiegea and mataya) in meeting VA requirements for the different age groups. Linus (1999) revealed evident effects of boiling, cultivar, farming site and root age on β-carotene contents. He further indicated that the time taken to reach maximum carotenoid content varied with cultivars. Cultivar and root age could also be

the contributing factors to the differences in β-carotene content observed in the present study.

Conclusions

This study aimed at evaluating the potential of orange fleshed sweet potato varieties in combating vitamin A deficiency. The β-carotene contents were high and varied significantly ($P < 0.05$) between OFSP varieties but were below detection levels in WFSP varieties. This further confirms the superiority of OFSP varieties in β-carotene contents. It was demonstrated that both boiling and frying have significant adverse effects on beta-carotene concentrations. The deleterious effects of heat processing (boiling and frying) on β-carotene in OFSP varieties could be attributed to oxidation of the carotenoids by heat, air and light during processing. The findings further indicated that OFSP sweet potatoes varieties (kiegea and mataya) are richer sources of β-carotene and have the potential of meeting VA requirements for different age groups and address the problem of vitamin-A deficiency. The optimum amounts of OFSP (g/day) required to meet VA requirements for different age groups (7–12 months to 10–13 years) varied from 98.91 and 144.27 g/day to 148.36 and 216.41 g/day for kiegea and mataya cultivars, respectively. It is thus important to advocate and capture the attention of the general public on the richness of β-carotene in OFSP varieties and its potential in alleviating VA deficiencies.

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Conflict of Interest

The authors declare that there is no conflict of interest.

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