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Biochemical Compositions, Functional Properties of Orange Fleshed Sweet Potato Varieties and Effect of Treatment on its Beta Carotene Retention

By: Yemesrach Tiruneh

Advisor: Mr. Kelbessa Urga (Assoc. Prof)

A Thesis Submitted to the School of Graduate Studies, Addis Ababa University College of Natural Science in Partial Fulfillment of the Requirement for the Degree of Master of Science in Food Science and Nutrition.

Addis Ababa, Ethiopia

Jan, 2017

ADDIS ABABA UNIVERSITY
GRADUATE STUDIES PROGRAM
CENTER FOR FOOD SCIENCE AND NUTRITION

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LIST OF ABBREVIATIONS

AOAC: Association of Official Analytical Chemists

ANOVA: Analysis of Variance

BHT: Butylated Hydroxytoluene

CIP: International Potato Center

CSA: Ethiopian Central Statistical Agency

DW: Dry weight

EDHS: Ethiopia Demographic Health Survey

EFMHACA: Ethiopian Food, Medicine and Health care Administration and Control Authority

EHNRI: Ethiopian Health and Nutrition Research Institute

FAO: Food and Agriculture Organization

HPLC: High Performance Liquid Chromatography

IP6: Inositol Hexaphosphate

OFSP: Orange-Fleshed Sweetpotato

OAC: Oil Absorption Capacity

PTFE: Polyterrafluoroethylene

RBP: Retinol Binding Protein

RE: Retinol Equivalents

RSD: Relative Standard Deviation

SCN: Standing Committee on Nutrition

SNNPR: Southern Nations Nationalities and Peoples' Region

SPSS: Statistical Package for Social Sciences

UNICEF: United Nations Children's Fund

USDA: United State Agency for International Development

VAD: Vitamin A Deficiency

WAC: Water Absorbance Capacity

WFP: World Food Programme

WHO: World Health Organization

ABSTRACT

Vitamin A deficiency (VAD) is a public health problem in Ethiopia. It affects vision, growth, tissue differentiation and immune system. Orange-fleshed sweet potato varieties are known to contain high amount of β -carotene and other carotenoids. This study was designed to determine β -carotene retention, mineral composition, antinutrient level and functional properties of orange-fleshed sweet potato varieties. In order to compare β -carotene contents of different orange fleshed sweet potato varieties, to investigate the effect of treatment methods on β -carotene retention, orange-fleshed sweet potato varieties were collected from Hawassa Agricultural and Research Institute. The results showed that β -carotene contents were significantly affected by many factors, and this was demonstrated using the varieties of Kulfo and Tulla. β -carotene contents in orange-fleshed sweetpotatos Kulfo and Tulla grown in the same farming sites in the same area ranged from 400-334.05 μ g/g and 335.25-280 μ g/g fresh weight, respectively. Six treatment methods including boiling, steaming, microwave cooking, oven drying, sun drying and post steam-drying were simulated in the study to check their effects on the true retention of β -carotene. Compared to boiling, steaming resulted in much more loss of β -carotene and microwave cooking resulted in the biggest loss of β -carotene among the six treatment methods. The level of retention was significantly different ($P < 0.05$) among treated Orange Fleshed Sweetpotato. The dietary Ca, Fe, Zn, and K contents of Kulfo and Tulla varieties respectively were Ca (22.14mg/100g, 18.78 mg/100g); Fe (20.83 mg/100g, 7.47 mg/100g); Zn (3.63 mg/100g, 1.23 mg/100g) and K (3064.68 mg/100g, 1469.13 mg/100g). Similarly phytate and tannin content of Kulfo and Tulla respectively were (432.10 mg/100g, 89.29 mg/100g) and (89.36 mg/100g, 40.02 mg/100g). The mineral composition and antinutrient content of the two varieties was significantly different ($P < 0.05$). The functional properties were observed to have Bulk density (0.74 and 0.62g/ml); Swelling index (161.1 and 138%); Water absorption capacity (253 and 212%); Oil absorption capacity (1.84 and 1.68ml) in both varieties respectively. Orange-fleshed sweet potato should be prepared for consumption, using methods that protect the loss of β -carotene content which helps orange-fleshed sweet potato as a staple food as well as a snack food for supplying vitamin A for both rural and urban populations.

Key words: - Vitamin A Deficiency, β -carotene, Retention, Orange fleshed sweet potato, boiling

1. INTRODUCTION

Malnutrition, a deviation from the normal growth and development, can be manifested as under or over nutrition and affects physical growth, morbidity, mortality, cognitive development, reproduction, and physical work capacity (Lesiapeto., 2009; Mahgoub., 2006). Micronutrient deficiency is a global problem even much bigger than protein energy malnutrition. More than Two billion people are affected globally by ‘hidden hunger’ particularly due to the deficiency of vitamin A, iodine, iron and zinc. Most of these people live in low income countries and are typically deficient in more than one micronutrient (WHO/WFP/UNICEF; Thompson and Amorson, 2014). In Ethiopia, the most common forms of malnutrition are protein-energy malnutrition (PEM), vitamin A deficiency, Iodine deficiency disorders, and Iron deficiency anemia (EHNRI., 2009/2010; Melkie., 2004). Micronutrient deficiency imposes enormous cost on societies in terms of ill health, lives loss, reduced economic productivity and poor quality of life (Ruel, 2001).

Micronutrients are substances in foods that are essential for human health and are required in small amounts. They include all of the known vitamins and essential trace minerals. Micronutrient malnutrition develops when intakes of bioavailable micronutrients are too low to meet requirements. It affects one third to half of the world population. The three most prevalent forms of micronutrient malnutrition are iron, iodine, and vitamin A deficiencies (Allen et al., 2006). Zinc and vitamin B-12 deficiencies are also widespread. Consequences of micronutrient malnutrition include increased mortality rates, especially in women and children; poor pregnancy outcomes; increased morbidity; impaired mental and physical development in children; and reduced work productivity in adults (Black et al., 2008). Both the density and bioavailability of micronutrients in the diet are important for achieving optimal micronutrient status. Nutrient density is the amount of nutrient in a food per calorie or unit weight. Bioavailability is the proportion of an ingested nutrient that is absorbed and utilized for some essential metabolic function.

Infants are particularly vulnerable to nutritional deficiencies when complementary foods are introduced as documented in Ethiopian (EDHS, 2014). Inadequate dietary intake is primary cause of vitamin A deficiency (VAD) in developing countries (Adem et al., 2012)

Vitamin A deficiency (VAD) predisposes an estimated 100 million Africans to a higher risk of visual impairment and blindness (African Union, 2005). Vitamin A deficiency is a serious public health problem in Ethiopia. National prevalence rates of 1.7 % for Bitot's Spots and 0.8% of night-blindness among children and 1.8% for night-blindness among mothers are reported. Nationally, 37.7% of children had deficient serum retinol levels (Demissie et al., 2010).

Addressing the global challenge of micronutrient deficiency requires the need for many strategies both short and long-term sustainable approaches. In addition to micronutrient fortification and supplementation, promoting food based approaches is important to enable adequate intakes of micronutrients by much of the population. Agricultural biotechnology offers the opportunity of increasing crop yields and improvement of the micronutrient content of staple foods that poor people already eat, and provide a comparatively inexpensive, cost effective, sustainable and long-term means of delivering micronutrients to the poor (Thompson and Amoroso, 2011, 2014).

Sweet potato is a dicotyledonous plant that belongs to the family Convolvulaceae, and a tuberous root crop important for food security. It is cultivated in over 100 developing countries and ranks among the five most important food crops in over 50 of those countries. It is one of the most widely grown root crops in Sub-Saharan Africa. The flour can serve as a source of energy and carbohydrates, β -carotene (pro-vitamin A), minerals (Ca, P, Fe and K) and dietary fiber which can add natural sweetness, colors and flavor to processed food products (Ulm, 1988., Woolf, 1992). In Africa, it is grown predominantly in small plots by poorer farmers, and hence known as the "poor man's food." Ethiopia has about 92 million people and is the second most populous country in Africa. Sweet potato is among well known and established crops in Southern, Eastern and South Western parts of Ethiopia. It is produced annually on over 53,000 hectares of land with total production over 4,240 tons and average productivity of 8.0 tons per hectare. Orange-fleshed sweet potato (OFSP) is among the biofortified staples bred for high provitamin A carotenoid content (CIP, 2006). Sweet potato is a major food root crop in developing countries (Woolfe, 1992), and it is mainly consumed as boiled roots.

Sweet potato varieties, especially orange-fleshed sweet potato (OFSP) varieties, contain significant amounts of β -carotene, starch, dietary fiber, minerals, vitamins (especially vitamins C, B6 and folate), as well as antioxidants, such as phenolic acids, anthocyanins, and tocopherol

(Woolfe, 1992). The composition and contents of nutrients in sweet potato varieties vary greatly; depending on genetic and environmental factors. Foods from plant origin are an important source of pro-vitamin A in developing countries (Tumuhimise et al., 2013). OFSP is naturally a bio-fortified crop and it has great potential to be used in food-based intervention programs to address vitamin A deficiency. The crop is a promising solution to vitamin A deficiency because it is rich in β -carotene and substantially better absorbed than other leaves and vegetables (Jalal, 1998). Among the ways to incorporate OFSP to foods, its flour appears to be the most effective way for increasing the vitamin A content of OFSP enriched food products (Hagenimana and Low., 2000). The efficacy of β -carotene rich OFSP variety in preventing vitamin A deficiency (VAD) has been demonstrated in primary school children from South Africa (van Jaarsveld et al., 2005). It is reported that β -carotene rich OFSP can make a major contribution in alleviating vitamin A malnutrition in Sub-Saharan Africa (Low, Walker and Hijmans, 2001). Also, the incorporation of OFSP in meals eaten by 3- to 6-years old Indonesian children, marginally deficient in vitamin A, increased serum retinol concentrations (Jalal et al., 1998).

It is important to quantify the losses of provitamin A carotenoids during processing of orange fleshed sweet potato. Thus, the present study was designed to determine β -carotene retention of treated food (boiling, steaming, microwave cooking, sun drying, oven drying, and post steam-drying) and nutrient composition from orange fleshed sweet potato varieties (Kulfo and Tulla). In addition, functional property and better retention with time and temperature variation will be determined.

Table 1. Sweet potato production figures for selected countries, 2008

Country	Production (1000 t)	Area (1000 ha)	Average Yield (t/ha)
Asia Total	92 490	4 433	20.9
China	*85 213	*3 685	23.1
Indonesia	1 877	174	10.8
Vietnam	1 324	162	8.2
India	1 146	126	9.1
Japan	*968	*41	23.8
Philippines	572	116	4.9
Korea, DPR	380	*28	13.6
Korea, R.	329	19	16.9
Bangladesh	307	32	9.7
Africa Total	14 013	3 312	4.2
Nigeria	3 318	1 106	3.0
Uganda	2 707	599	4.5
Tanzania	*1 322	*505	2.6
Kenya	895	63	14.3
Madagascar	*890	127	7.0
Burundi	*874	*131	6.7
Rwanda	*800	*140	5.7
Angola	*710	*145	4.9
Ethiopia	526	62	8.4
Americas Total	2 852	301	9.5
United States	837	39	21.2
Brazil	*519	*47	10.9
Cuba	375	59	6.4
Argentina	*340	*24	14.2
Oceania	706	125	5.6
Papua New Guinea	*580	*115	5.0
Europe	67	6	12
World Total	110 128	8 178	13.5

Source: FAOSTAT (2008)

* FAO estimate

1.1. OBJECTIVES

1.1.1. General Objective

To compare the retention of β -carotene in different treatment methods of (Sun drying, Oven drying, Boiling, Steaming, Microwaving cooking and Steam-dried chips) orange fleshed sweet potato roots.

1.1.2 Specific Objectives

- To assess β -carotene retention during treatment of orange fleshed sweet potato
- To determine nutrient composition orange fleshed sweet potato
- To determine functional properties of orange fleshed sweet potato

2. LITERATURE REVIEW

2.1. Micronutrients deficiency: Vitamin A

For a long time, the food security debate had primarily focused on undernutrition in terms of calories. Calorie under nutrition is usually the result of an insufficient intake of macronutrients (carbohydrates, protein, and fat) and is associated with a feeling of hunger. Hunger is still a serious problem in large parts of the developing world. According to the FAO, 852 million people worldwide were undersupplied with calories (FAO, 2004).

Micronutrients are essential nutrients, as trace minerals or vitamins that are required by an organism in minute amounts that enable the body to produce enzymes, hormones and other substances essential for proper growth and development. Even though they are needed in tiny amounts, consequences of their absence are severe and can cause susceptibility to infectious diseases, physical and mental impairments, and increased mortality rates (Micronutrient Initiative, 2004). More than 2 billion people in the world suffer from micronutrient deficiencies caused largely by a dietary deficiency of vitamins and minerals especially iodine, iron, vitamin A and zinc (Thompson and Amorson, 2014). Micronutrient deficiencies account for 7.3% of global burden of disease, with iron and vitamin A deficiency ranking among the 15 leading causes of the global disease burden. Although people in all population groups in all regions of the world may be affected, the most widespread and severe problems are usually found amongst poor, food insecure and vulnerable households in developing countries. The public health importance of these deficiencies lies upon their magnitude and their health consequences as they affect fetal and child growth, cognitive development and resistance to infection. In addition to the obvious and direct health effects, the existence of micronutrient deficiency has profound implication for economic development and productivity, particularly in terms of potentially huge public health costs and the loss of human capital formation (Allen et al., 2006).

The dietary sources of vitamin A are preformed vitamin A which comes from animal origin (such as fish oils, liver, milk, eggs and butter) that contain vitamin A in its true form (also called retinol) which can be used directly and easily by the human body and also provitamin A carotenoids (found in yellow and orange-fleshed fruit and vegetables and in dark-green leafy vegetables) (McLaren and Frigg, 2001). Though food of plant origin do not contain vitamin A as

of animal origin, they still do contain precursors or pro-vitamin A i.e. β -carotene and other carotenoids that the human body can convert to vitamin A (Parker, 1996).

Vitamin A is a fat soluble vitamin which can be found in body in three main active forms that are retinol, retinal and retinoic acid, collectively, these compounds are known as retinoids. The cells in the body can convert retinol and retinal to the other active forms of vitamin A as needed. The conversion of retinol to retinal is reversible; whereas the further conversion of retinal to retinoic acid is irreversible. Foods derived from animals provide compounds retinyl esters that are readily digested and absorbed as retinol in the intestine. Foods derived from plants provide carotenoids, some of which have vitamin A activity. The carotenoids with the greatest vitamin A activity is beta carotene which can be split into forms retinol in the intestine and liver (Whitney and Rady, 2008).

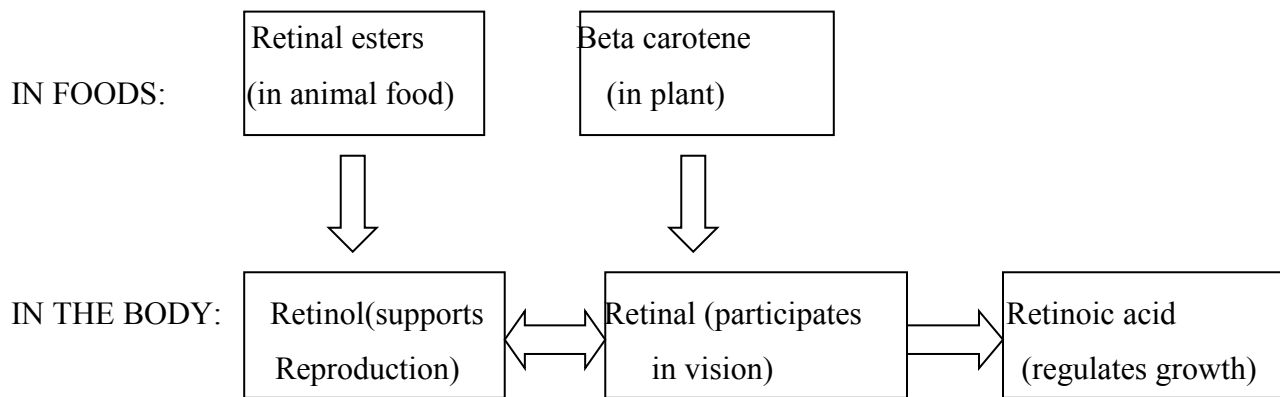


Figure 1. Conversion of vitamin A compounds (Whitney & Rolfes, 2002:356)

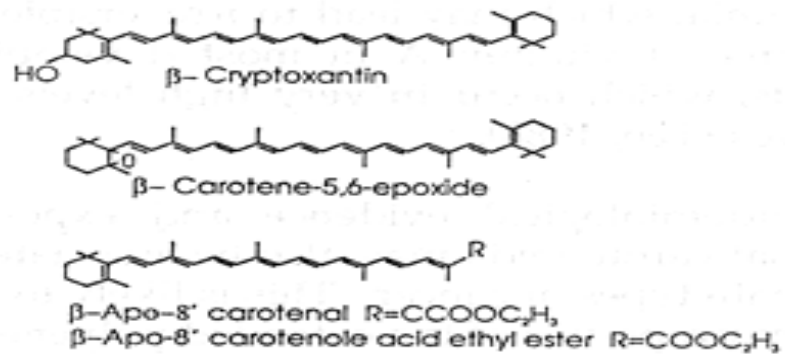
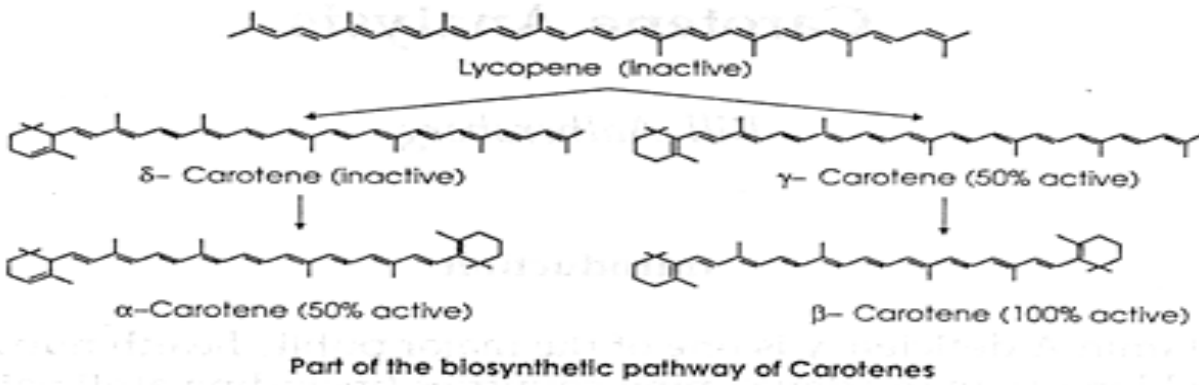


Figure 2. Chemical structures of some provitamin A carotenoids that occur in foods.

Carotenoids are a class of closely related natural pigments synthesized by plants. Their main function is to absorb light during photosynthesis and provide protection against photosynthesis. Over 600 different carotenoids have been identified and approximately 40 of these occur in common food sources. Beta-carotene, alpha-carotene, lutein, beta-cryptoxanthin and lycopene are the most common carotenoids found in plasma. Some of these carotenoids, such as beta-carotene, alpha-carotene and beta-cryptoxanthin, are metabolized beta-cryptoxanthin beta-cryptoxanthin, are metabolized in the small intestine and function as precursors of vitamin A. However, other carotenoids, such as lycopene and lutein, are devoid of provitamin A activity (Yeung and Laquatra, 2003).

Beta-carotene is an intensely colored red-orange pigment abundant in vegetables and fruits, especially in carrots and colorful vegetables. Beta-carotene is only manufactured in plants, not in humans and animals. The color of fruits and vegetables is due to the light that is not absorbed by the pigments and is reflected back to the environment. This is why carrots and other vegetables and fruits look the way they do - because beta-carotene reflects red, orange and yellow light

back into the eyes. There are many vegetables and fruits that contain beta-carotene; some of them are onions, broccoli, spinach, apricots, sweet potatoes, cantaloupes, pumpkins, and various herbs. The beta carotene content of food varies with growing condition and the post-harvest storage of the food. The bioavailability of provitamin A carotenoids can be influenced by various factors such as digestibility of the food, molecular linkage, amount of carotenoids consumed in a meal, matrix in which the carotenoids is incorporated, intake of dietary fat, type and amount of fiber, alcohol, nutritional status of the individual as well as genetic and host-related factors (Berdanier, 1998; Jim and Truswell 2002).

Table 2. Carotenoids with vitamin A activity (Berdanier, 1998)

Compound	Relative Potency
beta-carotene	100
alpha-carotene	53
gama-Carotene	43
crypoxanthin	57
lycopene	0
Zeaxanthin	0
Xanthophyll	0

2.2.1. Metabolism

Dietary sources of vitamin A that are retinyl esters and retinol from certain animal tissue and beta-carotene from certain plants are hydrolyzed in the intestinal mucosa, releasing retinol and free fatty acids. Retinol derived from esters and from the cleavage and reduction of carotenes is re-esterified to long chain fatty acids in the intestinal mucosa and secreted as a component of chylomicrons into the lymphatic system. Retinyl esters contained in chylomicron remnants are taken up by and stored in the liver. Retinol is released from the liver when it is needed and transported extrahepatic tissues by the plasma retinol binding protein (RBP). The RBP complex attaches to specific receptor on the surface of the cells of peripheral tissues (Sommer, 1995).

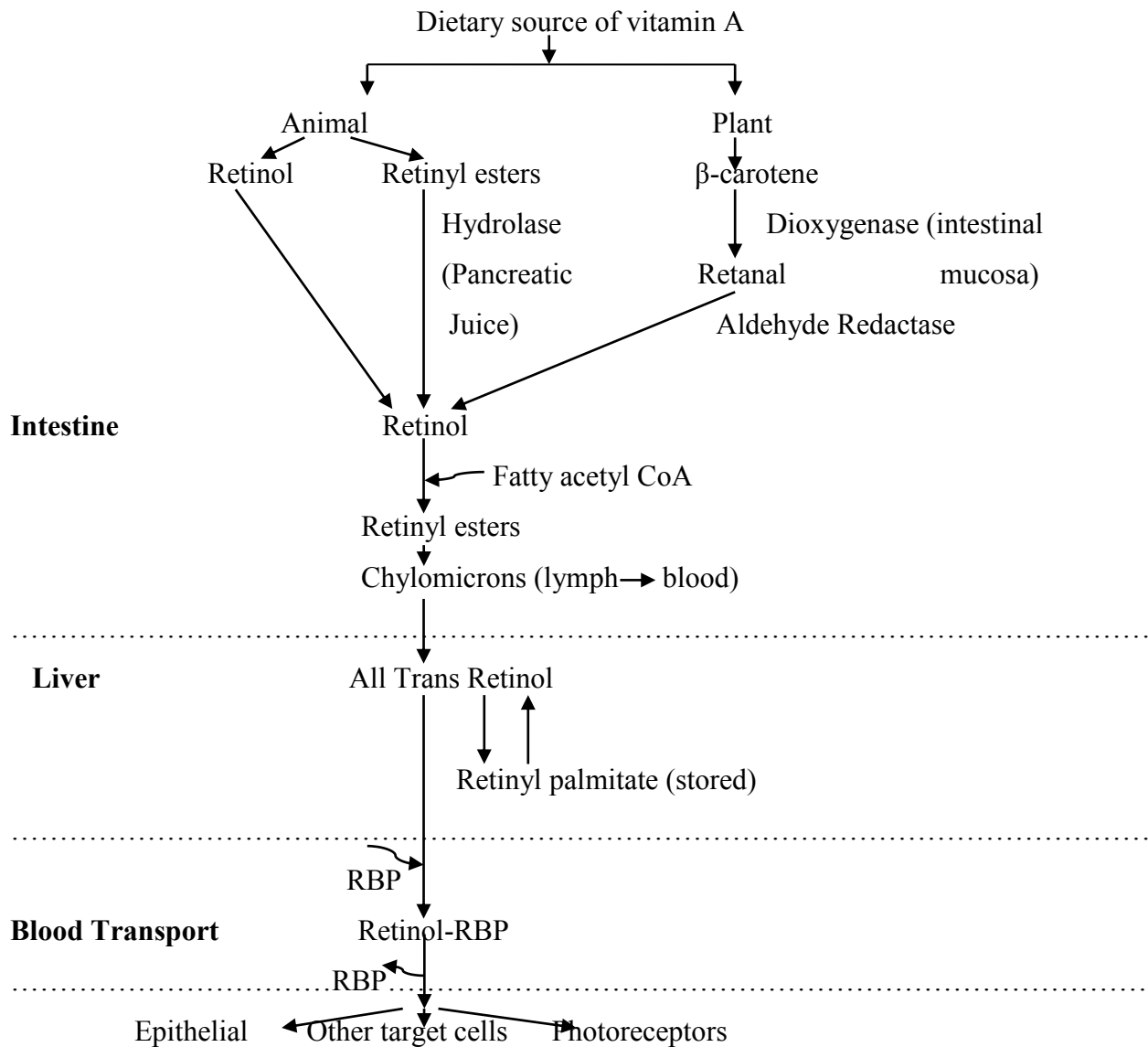


Figure 3. Scheme of Vitamin A Metabolism (Sommer, 1995; Harvey and Ferrier, 2011)

2.2.2. Biological Significant of Vitamin A

Vitamin A and its precursor, provitamin A such as beta-carotene, have diverse role and profound effect on health. Its major roles are promoting vision, participating in protein synthesis and cell differentiation, maintain the health of epithelial tissues and it is known as the anti-infective vitamin, because it is required for normal functioning of the immune system (Whitney and Rady, 2008).

According to Whitney and Rady (2008), the three forms of vitamin A carry out specific functions. Retinal is active in vision and it is also an intermediate in the conversion of retinol to retinoic acid and acts like a hormone, regulating cell differentiation, growth and embryonic development. Retinol supports reproduction and it is a major transport and storage form of vitamin A.

Beta-carotene and other carotenoids are also potent antioxidants and important physiological modulators (Yeung and Laquatra, 2003). Antioxidants have proven effect in fighting free radicals, highly unstable compounds that are formed when oxygen combines with certain substances. Free radicals can damage the basic structure of cells and thus lead to chronic diseases such as cardiovascular disorder and cancer and accelerate the aging process (Sesso et al., 2004).

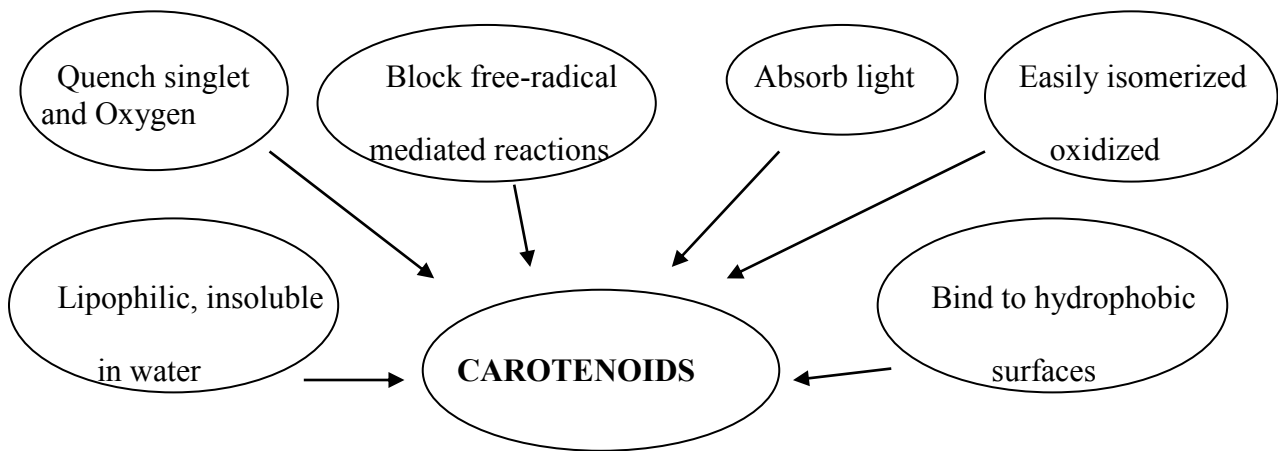


Figure 4. Important Physical and Chemical Properties of Carotenoids

2.2.3. Recommended Intake

Daily nutritional needs of vitamin A in different class-ages were evaluated by FAO/WHO to tackle vitamin A deficiency. The mean requirement intake is the minimum intake to prevent xerophthalmia in the absence of clinical or sub-clinical infection that is expressed as μg retinol equivalents ($\mu\text{g RE}$). whereas the recommended safe level intake is the average continuing intake of vitamin A to permit adequate growth and other vitamin A dependent functions and to maintain an acceptable total body reserve of the vitamin (WHO/FAO, 2004). As the body can derive vitamin A from various retinoids and caroenoids, its contents in foods and its recommendations are expressed in retinol activity equivalents (RAE). Some earlier studies estimated that $6\mu\text{g}$ of β -carotene from plant sources were providing one retinol equivalent (RE). However, Sommer

(1998) suggested that the appropriate conversion factor varies by plant species and might be much lower. The conversion factor published by the Institute of Medicine, (2001) stated that 12µg β-carotene (or 24µg of other carotenoids such as α-carotene and β-cryptoxanthin) found in foods corresponds to one retinol activity equivalent (RAE). A recent study in mashed sweet potato reported a conversion factor of 13:1 (13µg β-carotene in mashed sweet potato equivalent to 1µg retinol equivalent (RE) (Haskell, 2004).

Table 3. Estimated mean requirement and level of intake for vitamin A by age group

Age Group	Mean requirement (µg RE/day)	Recommended intake (µg RE/day)
Infants and Children		
0 – 6 month	180	375
7 – 12 month	190	400
1 – 3 years	200	400
4 – 6 years	200	450
7 – 10 years	250	500
Adolescents 10 – 18 years	330 – 400	600
Adults		
Female: 19 – 65 years	270	500
Male: 19 – 65 years	300	600
65 + years	300	600
Pregnant women	370	800
Lactating women	450	850

Source: (WHO/FAO, 2002)

2.2.4. Prevalence of Vitamin A Deficiency

Vitamin A is essential for good health and eyesight. When the body gets more vitamin A than it needs, the extra/excess vitamin A is stored in the liver. VAD occur due to a diet that provides too little bio-available vitamin A to meet physiologic needs which may be exacerbated by high rates of infection, especially diarrhea and measles (WHO, 2009).

It is a major nutritional concern in poor societies, especially in lower income countries. Vitamin A deficiency is one of the key causes of preventable childhood blindness and is a major contributor to morbidity and mortality from infections. VAD is very common among young

children than adults because children grow more quickly and suffer more from infections and severe malnutrition than adults do and also in pregnant and breastfeeding women (Underwood, 2000; Mbabu, et al, 2012). VAD can limit growth, weaken immunity, cause xerophthalmia leading to blindness, and increase mortality (Sommer and West, 1996). Vitamin A deficiency is defined as liver stores retinol below $20\mu\text{g/g}$ ($0.7\mu\text{mol/g}$). Serum retinal levels may still be within the homostatically regulated normal range. By convention, serum retinal level $< 20\mu\text{g/g}$ ($0.7\mu\text{mol/g}$) are considered deficient (SCN, 2004).

The main cause of vitamin A deficiency in developing countries is inadequate dietary intake of vitamin A and its precursor carotenoids. The secondary cause of vitamin A deficiency include retinol is absorbed from the small intestine dissolved in lipid. In people with a very low fat intake (less than 10% of energy from fat), absorption of both retinol and carotene is impaired, and low fat diets are associated with vitamin A deficiency (Yeung and Laquatra, 2003). Others are unavailability of vitamin A rich foods in the markets, large family size, high maternal parity levels, land size, that are presumed to contribute to inadequate consumption of vitamin A rich foods in developing countries (Demissie et al., 2009).

Vitamin A deficiency is one of the most prevalent forms of micronutrient deficiency in the world. The first symptoms of vitamin A deficiency are night blindness and drying of the conjunctiva of the eye. Bitot's spots may be present in the cornea. With continued vitamin A deficiency, progressive damage to the eye results from drying of the cornea and irreversible corneal damage resulting in xerophthalmia, keratomalacia and blindness (McGuire and Beerman, 2011).

Globally 190 million (33.3%) children under the age of 5 years old are vitamin A deficient, with Africa having one of highest prevalence, at 44.4% (WHO, 2004). Vitamin A deficiency is the cause for 1.2 to 3 million children and significant number of women to die, and 4.4 million children and 6.2 million women suffer from xerophthalmia (SCN, 2004).

Deficiency of vitamin A is a major cause of blindness in developing countries and also contributes to impaired immune function resulting in increased mortality. Africa and Southeast Asia have the highest burden of vitamin A deficiency (WHO, 2009). Estimated 250,000-500,000

vitamin A deficient children become blind every year, approximately half of which die within a year of becoming blind (WHO/FAO, 2006).

Vitamin A Deficiency is a public health problem in Ethiopia pregnant women, infants and young children are most susceptible for VAD and its deficiency affects about 7.7 million children and results in an estimated 50,000 deaths each year. (FMOH 2011 as cited in Owen Fofanh et al., 2011).

2.2.5. Strategies to combat vitamin A deficiency

Globally, there are short and long term strategies to combat micronutrient deficiency including supplementation, and food based approaches such as food diversification, fortification (exogenous fortification and biofortification). Food based approaches promote the consumption of foods that are naturally rich in micronutrient or are enriched foods through fortification (Thompson and Amoroso, 2011).

Supplementation is the provision of micronutrients, usually in the form of pills, capsules or syrups. It has the advantage of being capable of supplying an optimal amount of a specific nutrient or nutrients in a highly absorbable form to control in individuals or population groups that have been identified as being deficient (Allen, 2006). Although supplementation has saved many lives and much suffering has been avoided as a result of these efforts, it is a short term emergency measure. It fails to recognize the root cause of micronutrient deficiency and to assist communities and households to feed and nourish themselves adequately (Ruel, 2011). Supplementation usually requires the procurement and purchase of micronutrients in a relatively expensive pre-packaged form and effective distribution system. It cannot provide the overall long term economic benefits and sustainability that food base approaches can deliver (Allen, 2006).

Dietary diversification this strongly complements supplementation and fortification programs. It refers to a variety of strategy that aim to increase the production, availability and access to foods rich in micronutrient and the bioavailability of micronutrients from the diet. Dietary diversification can be achieved through horticultural approaches such as home gardens, behavioral change and improved methods of food preparation and preservation that minimize the loss of micronutrients (Ruel, 2001).

Exogenous fortification this is adding of essential vitamins and minerals to foods which are regularly consumed such as flour, salt, sugar and cooking oil. In many situations, this strategy can lead to relatively rapid improvements in the micronutrients status of a population, and at a very reasonable cost, especially if advantage can be taken of existing technology and local distribution networks (Allen, 2006).

Biofortification is the process of breeding nutrients into crops through conventional and transgenic methods. It is a promising strategy for combating hidden hunger that provides a sustainable, long term strategy for delivering micronutrient comparatively inexpensive and cost effective way to rural populations in developing countries who may have limited access to diverse diets, supplements and commercially fortified foods. Unlike the continual financial outlays required for supplementation and commercial fortification programs, a onetime investment in plant breeding can yield micronutrient rich planting materials for farmers to grow for years (Bious and Welch, 2010; Thompson and Amoroso, 2014).

Therefore, food-based intervention which improves dietary quality and quantity through diversification of crops (crops rich in β - carotene) is the safest and most sustainable way of combating VAD in areas where chronic deficiencies are common (Tumwegamire et al., 2004). The goal is to achieve and maintain an adequate intake of micronutrient-rich foods in the context of an adequate total diet (WHO, 1996). Thus, food-based intervention is now proposed in the Ethiopia national VAD control framework as the long term option. This is important in order to make the gradual transition from subsidized periodic capsule-distribution effort to a more sustainable agricultural food-based intervention. In this regards orange fleshed sweet potato has the potential to be one of the most important crop used to combat vitamin A deficiency both in children under five years old and lactating women in Ethiopia. Therefore, promoting consumption of locally available vitamin A-rich plant foods that grows in home garden of household is critical since it can reduce the problem of vitamin A deficiency due to its technical feasibility and cost-effectiveness. From the locally available plant foods, orange fleshed sweet potato (OFSP) is a strategic crop to overcome vitamin A deficiency (Tumwegamire et al., 2004). Thus, OFSP is a very good candidate crop for mitigating vitamin A deficiency in Sub-Saharan Africa countries like Ethiopia (Low et al., 1997).

2.3. Orange Fleshed Sweet Potato

2.3.1. Production and Utilization as a source of vitamin A Orange Fleshed Sweet Potato

Sweet potato (*Ipomea batatas*) is a dicotyledons plant from the family Convolvulaceae that grows in tropical and subtropical areas. It occupies an important place in the agricultural production of Sub Saharan Africa countries, covering about 3.2 million hectares with a production estimated at 13.4 million tons of tubers 2005 (FAO, 2005). Sweet potato generates large amounts of food per unit areas per unit time during relatively short rainy periods, tolerates occasional dry spells, and produces greater yields even in less fertile soil than crops such as maize (Woolfe, 1992). In Ethiopia, sweet potato is one of the most important crops for at least 20 million Ethiopians. It is produced in South, South Western and Eastern parts of the country, mainly in Oromia and Southern Nations, Nationalities and People Regional states (SNNPR) (CSA, 2010; MOA, 2012). The total area under sweet potato production in Ethiopia is 75000 ha with an average productivity 8t/ha. White fleshed sweet potato is a staple food for 13 million people in the Southern Regional State (Assefa et al., 2007). In contrast, orange-fleshed sweet potato is a relatively new crop to the country which is known to be a good source of vitamin A. OFSP is also a good source of energy (293 to 460 kJ/100 g) (Hagenimana, V., 2001) easy to cultivate, vegetatively propagated, and fairly drought resistant. These characteristics make OFSP an excellent food security crop. Sweet potato is less labor intensive than most other staple crops and can be planted over a broad range of time without considerable yield loss (Henok, 2015)

In fact before targeting to breed for Vitamin-A rich sweet potato against VAD, Ethiopia released in 2003, Awassa Agricultural Research Center introduced 40 virus indexed OFSP clones from CIP-Kenya (Table 4). Out of these 37 clones established well and are being observed.

Alongside these trials, was the sensitisation of farmers about OFSP and their nutritional advantages. In 1987, AARC released two OFSP from the local collection Koka-12 yielded 25.24 t/ha while AJA-I or Guntute yielded 35.35 t/ha. On the basis of this high yield, these varieties were released. Unfortunately, consumers did not adopt them due to their yellow flesh and moist texture. Recently, however, it was realized that high beta-carotinoid content. Due to the awareness created for their richness in Vitamin-A, a total of 97,000 cuttings of these varieties have been multiplied and distributed on the request of researchers, NGOs and farmers.

In the year 2001 a total of twenty OFSP clones were introduced from CIP-Nairobi and planted for open quarantine inspection and observation at Hawassa Agricultural Research Center (HARC) in non-replicated observation plots. Thereafter, these clones were grouped based on maturity periods and planted in different agro-ecologies to observe them more closely. Out of 20 clones, one clone (440201) was easily maturing (4 months) and had root yields of 10.17t/ha. Nine clones (187017.1, 56638, 440001, 440186, 420009, 440185, 440131, 440163, 440093) were medium maturing (5 months) with total root yield 5.57, 5.39, 4.72, 5.06, 4.56, 4.92, 3.06, 2.44 and 2.24 t/ha, respectively. The remaining 10 clones were late maturing. (Assefa et al., 2007)

The poor households in Sub-Saharan countries like Ethiopia cannot afford to consume highly bioavailable vitamin A from animal food sources on a regular basis. In this regard OFSP is believed to represent the least expensive, year-round source of dietary vitamin A available to poor families (Kapinga et al., 2003) Moreover, unlike many vegetables, the sweet potato has significant amounts of energy as well as vitamin A. Hence, OFSP is considered as an important staple food root crop that can tackle the problem of inadequate caloric intake as well as vitamin A deficiency.

Thus, promotion of food based agricultural interventions is particularly effective in reducing vitamin A deficiency in low income countries. In this regard, the International Potato Centre (CIP) is working on the reduction of food insecurity and malnutrition through the promotion of potato and OFSP in SNNPR and Tigray region, Ethiopia. CIP trained farmers on sweet potato agricultural practices such as vine multiplication, root production and utilization which will increase the productivity of the crop in the target areas (Schulz, 2013). In addition, women development group leaders and farmers received training on different sweet potato food recipe preparation, nutritional value and agro-processing techniques of OFSP which will increase the knowledge level of the target group society on the cultivation and relevance of the root crop in mitigating vitamin A deficiency. In, Ethiopia the root crop is gaining more recognition due to its nutritional potential for combating vitamin A deficiency.

Table 4. List of released sweet potato varieties in Ethiopia

No	Variety	Year of Release	Altitude	Maturity Days	Flesh Color	Yield(t/ha)	Center of release
1	Kulfo (LO-323)	2005	1200-2200	150	Orange	27.0	Hawassa RC
2	Tulla (CIP 420027)	2005	1200-2200	150	Orange	28.5	Hawassa RC
3	Kero (TIS-8250)	2005	1200-2200	150	Orange	35.4	Hawassa RC
4	Kudade (TIS-1499)	1997	1200-2200	90-120	Cream	24.1	Hawassa RC
5	Falaha (TIS-3017(2))	1997	1200-2200	90-120	White	16.7	Hawassa RC
6	Dubo (1-444)	1997	1200-2200	90-120	White	21.7	Hawassa RC
7	Guntute (AJAC-1)	1997	Mid-altitude	120-150	Orange	35.4	Hawassa RC
8	Bareda (375)	1997	1200-2200	120-150	White	29.6	Hawassa RC
9	Damota (Guralowlow)	1997	1200-2200	120-150	Cream	30.7	Hawassa RC
10	Awassa -83	1998	1200-2200	150-180	white	36.6	Hawassa RC
11	Koka-12	1987	1200-2200	120-150	Pale orange	17.7	Hawassa RC
12	Koka-6	1987	1200-2200	120-150	Cream	26.9	Hawassa RC
13	Belella (192040-1)	2002	1200-2200	90-120	Cream	18.3	Hawassa RC
14	Temesgen (192009-VIII)	2002	1200-2200	90-120	White	17.6	Hawassa RC
15	Ordollo (192009-IX)	2005	1200-2200	150	White	17.3	Hawassa RC
16	Jari (CN-2059-1)	2008	1650-1850	133	Yellow	19.2	Sirinka RC
17	Birtukane (saluboro)	2008	1650-1850	150	Orange	19.9	Sirinka RC

18	Berkume (TIS 8250-2)	2007	1650-2000	188-195	White	19.5	Haromaya University
19	Adu (Cuba-2)	2007	1650-2000	150-180	Cream	16.0	Haromaya University
20	Ballo (Koka-18)	2006	1400-1800	120	White	29.4	Bako RC
21	Beletech (192026-II)	2004	1200-2200	150	White	18.4	Hawassa RC
22	Dimtu	2005	1200-2200	120	White	-	Hawassa RC
23	Ogansegan	-	1200-2200	-	White	-	MOA
24	Mae	2010	300-980	-	White	-	Werer RC

Source Hawassa Agricultural Research Center (2010)

2.3.2. Provitamin A Carotenoids in Orange Fleshed Sweet Potato

Orange Fleshed Sweet Potato is known to have an excellent amount of β -carotene which is highly bioavailable and converted into vitamin A (retinol) in human body (Jaarsveld et al., 2005). Just 100-125 g of boiled or steamed OFSP can meet the daily recommended intake levels of vitamin A for children under five years of age (Low, 2009). It is reported that the flesh color and β -carotene content in sweet potato root vary widely because they are affected by variety, maturity, post-harvest storage conditions, season, and the part of the root consumed (Hart and Scott, 1995). The average β -carotene content in raw, peeled sweet potato from the four farming sites ranged from 53.2 to 84.3 mg/kg, indicating that soil type, sunlight and other environmental factors greatly influence β -carotene content in sweet potato root. Small quantities of orange-fleshed sweet potato, which may contain from 300 μ g RE, to over 3,000 μ g RE per 100g fresh weight, can easily provide such RDAs while also serving as a rich source of other vitamins and nutrients (Woolfe, 1992).

Takahata et al. (1993) analyzed 22 cultivars of sweet potato and found that all cultivars contained mostly β -carotene. The β -carotene content varied from 11 to 266 μ g/g, with Resisto having 203 μ g/g. Almeida-Muradian and Penteadó (1992) reported β -carotene content varying from 0.1 to 218 μ g/g in 10 sweet potato cultivars, comprising 10–93% of the total carotenoid content.

K'osambo et al. (1998) observed the β -carotene content of 17 cultivars ranged from <1 to 80 μ g/g, representing 0.1–90.8% of the total carotenoid content. In the latter two studies, the percentage of β -carotene tended to increase with higher total carotenoid content.

Analyzing 32 sweet potato cultivars, Hagenimana et al. (1999) obtained <1 to 63 µg/g β-carotene, its contribution to total carotenoids being 0 to 90%.

Huang et al. (1999) found that β-carotene content varied from 67 to 131 µg/g in seven orange-fleshed, <1 to 6 µg/g in seven yellow/ white-fleshed, and <1 to 5 µg/g in four purple-fleshed sweet potato varieties. Two of the orange-fleshed sweet potato varieties also contained 3 and 15 µg/g α-carotene. Moreover, unlike many vegetables; the sweet potato has significant amounts of energy as well as vitamin A. So, OFSP is considered as an important staple food crop that can tackle the problem of inadequate caloric intake as well as vitamin A deficiency.

2.3.3. Nutrient other than Carotenoid in Orange Fleshed Sweet Potato

The nutritional composition of sweet potato which are important in meeting human nutritional needs including carbohydrates, fibers, carotenes, thiamine, riboflavin, niacin, potassium, zinc, calcium, iron, vitamins A and C and high quality protein (Table 5 and 6). Sweet potato particularly provides energy in the human diet in the form of carbohydrates. orange-fleshed sweet potatoes are a relatively new root crop to the country which is known to be a good source of vitamin A. OFSP is also a good source of energy (293 to 460 kJ/100 g) (Hagenimana et al., 2001) easy to cultivate, vegetatively propagated, and fairly drought resistant once established. These characteristics make OFSP an excellent food security root crop. Sweet potato is less labor intensive than most other staple crops and can be planted over a broad range of time without considerable yield loss.

According to USDA (2009), besides carbohydrates, it is also rich in dietary fiber and have high water content and also provide 359kJ energy with low total lipid content, which is only about 0.05 g per 100 g. In addition, sweet potatoes also are high in minerals such as potassium, calcium, magnesium, sodium, phosphorus, and iron (USDA, 2009). Because of the various roles that sweet potatoes play around the world, the concept of nutritional quality and its contribution must transform to meet specific roles in human diet.

Table 5. Sweet potato chemical composition (per Serving of one medium 5 inch long sweet potato; 130 g).

Nutrient	Unit	Composition
Calories	kJ/s	130

Calories from fat	g	0.39
Protein	g	2.15
Carbohydrate	g	31.56
Dietary Fiber	g	3.9
Sodium	mg	16.9
Potassium	mg	265.2
Calcium	mg	28.6
Folate	mcg	18.2
Vitamin C	mg	3.1 (excellent source)
Vitamin A	IU	18443 (excellent source)

Source: USDA (2009).

Table 6. Nutritional value of raw sweet potato per 100g.

Nutrient	Unit	Value per 100 g
Water	g	77.28
Energy	kJ	359.00
Protein	g	1.57
Total lipid (fat)	g	0.05
Ash	g	0.99
Carbohydrate	g	20.12
Fiber, total dietary	g	3.00
Calcium, Ca	g	30.00
Iron, Fe	mg	0.61
Magnesium, Mg	mg	25.00
Phosphorus, P	mg	47.00
Potassium, K	mg	337.00
Sodium, Na	mg	55.00
Vitamin C	mg	2.40
Pantothenic acid	mg	0.80
Vitamin B-6	mg	0.21
Vitamin A	IU	14187

Source: USDA (2009).

2.3.4. Anti-nutritional Factors in Orange Fleshed Sweetpotato

Orange fleshed sweet potato, possess different anti-nutritional factors such as phytate and tannin. Phytate content was relatively more distributed in orange fleshed sweet potato. The problem with phytic acid in foods is that it can bind some essential mineral nutrients in the digestive tract and can result in mineral deficiencies. Phytic acid also binds to phosphorus and converts it to phytate, while other mineral elements like calcium, zinc, manganese, iron and magnesium are converted to phytic complexes, which are indigestible substance, thereby decreasing the bioavailability of these elements for absorption. Especially the inhibition capacity of phytic acid on the absorption of Ca, Fe and Zn has been reported by Norhaizan and Norfaizadatul (2009). It has also a negative impact on amino acid digestibility, thereby posing problem to non-ruminant animals due to insufficient amount of intrinsic phytase necessary to hydrolyze the phytic acid complex, but its presence is also beneficiary because it may have a positive nutritional role as an anti oxidant and anti cancer agent (Turner et al., 2002).

Tannins are known to inhibit the activities of digestive enzymes and nutritional effects of tannin are mainly related to their interaction with protein. Tannin-protein complexes are insoluble and the protein digestibility is decreased (Carnovale et al., 1991). Different studies also revealed that high tannin in diet adversely affects digestibility of proteins and carbohydrates, thereby reducing growth, feeding efficiency, metabolizable energy and bioavailability of amino acid (Alector, 1993).

2.4. Retention of beta carotene in orange fleshed sweet potato

Orange fleshed sweet potato roots are a rich source of provitamin A and can meet easily the intake needs of young children in their commonly served form, boiled or steamed. True retention (TR) of beta-carotene varies from 70-92%, depending on cooking time (longer cooking periods lowering TR) and whether the pot was covered with a lid (covering increases TR) (Jaarsveld et al., 2006). K'osambo et al. (1998) found that boiling unpeeled medium-sized sweet potato roots for 30 min resulted in a 14–59% reduction of the total carotenoid content of four sweet potato cultivars. However, the formula of Murphy et al. (1975) was not used to calculate retention, thus concentration changes due to loss or gain of water and soluble solids were not compensated for. Hagenimana et al. (1999) reported a 20% loss in total carotenoid content, calculated on a dry

weight basis, after boiling for 30 min and mashing sweet potato cultivar Zapallo. In both studies, the raw and cooked samples were apparently not paired.

The intensity of the orange color reflects the amount of beta-carotene present in the sweet potato. On a fresh weight basis (fwb), light orange varieties contain at least 250 RAE/100gms (30 µg/g), medium-intensity varieties at least 458 RAE/100gms (55 µg/g) and dark-orange -varieties at least 833 RAE/100gms (100 µg/g). To put things into perspective, the recommended daily intake for healthy two and five year old children is 400 RAE and 500 RAE, respectively (Institute of Medicine, 2001). Depending upon the color intensity of the OFSP variety used and taking losses during cooking into account (approximately 20% through boiling), 1/4 to 1 cup of boiled and mashed sweet potato meets the intake requirements of a young child.

2.5. Functional properties of orange fleshed sweet potato flour

Functional properties are basic sources of food attributes an important aspect in determining its competitiveness in the market, as they can impact the sensory, physical and chemical properties of a food, which includes texture and organoleptic characteristics (Saskatchewan, 2015). Plant protein is used in foods as functional ingredient to improve stability and texture as well as nutritional quality of the product. Solubility of protein under varying condition is one of its important functional properties. Because this greatly influences other properties such as foaming and emulsification. Thus, the protein may possess satisfactory properties, example (nutritional value, acceptable flavor, odor and texture (Kinsella, 1982).

Functional properties of food protein are also important in food processing and product formulation. Some of these properties are bulk density, water/oil absorption capacity. Water absorbance capacity (WAC) represented the ability of a substance to associate with water under a limited water condition (Singh, 2001). Oil absorption capacity (OAC) was another important functional property, since it plays an important role in enhancing the mouth feel and retaining the flavor (Kinsella, 1976) and its absorption capacity in orange fleshed sweet potato flour.

There is no research done in Ethiopia on the retention of beta carotene in orange fleshed sweetpotato by preparing different treatment methods that is why this research is conducted.

3. MATERIAL AND METHODS

3.1. Location of the Study and Source of Raw Material

Orange Fleshed Sweetpotato, Samples of two orange fleshed sweet potato varieties used in this study were provided by the Southern Agricultural Research Institute, Hawassa Agricultural Research Center, Ethiopia. Samples were collected from farming at Hawassa site. The varieties, grown for 22 to 24 weeks, were selected based on availability. For each variety, 8kg roots were harvested, placed in a cardboard box and transported to the laboratory of Addis Ababa University (AAU), Centre for Food Science and Nutrition; the roots were stored at temperature of -25°C in refrigerator and β -carotene analyses were carried. Table 4 shows list of released sweet potato varieties in Ethiopia out of which two commercially released orange flesh sweet potato varieties (Kulfo and Tulla) were used for the present study.

Laboratories, The study was conducted at Addis Ababa University (AAU), Centre for Food Science and Nutrition, and Ethiopian Food, Medicine and Healthcare Administration and Control Authority and Ethiopian Public Health Institute, laboratory facilities.

3.2. Chemicals and Standards

All solvents used in the analysis of carotenoid were HPLC grade. The following solvents were used acetone, petroleum ether, acetonitrile, methanol, ethyl acetate, triethylamine, and n-hexane. An analytical grade standard of beta-carotene (Sigma-Aldrich, St. Louis, MO, USA) was used to calibrate and quantify beta-carotene. All chemicals and reagents used for laboratory analysis of other parameters were analytical grade.

3.3. METHOD OF ANALYSIES

3.3.1. Sample preparation of raw roots for β -carotene analysis

3.3.1.1. Roots from different varieties

To measure the content of β -carotene in the two orange fleshed sweetpotatos, two medium-sized sweet potato roots (300–350 g) from each variety were quartered longitudinally from the stem end to the root end, washed with tap water and a brush, and blotted with tissue paper. The two

opposite quarters from each root were selected and the peel removed, cut into cubes of ca 2×2×2 mm and mashed with a porcelain pestle (Xin Wu et al., 2008).



Figure 5. Orange fleshed sweet potato

3.3.2. Preparation of cooked roots for β -carotene analysis

3.3.2.1. Boiling, steaming, microwave oven cooking, steam-dried chips, oven and sun drying

For each (boiling, steaming, microwave oven cooking) method of cooking, two medium-sized roots of two orange fleshed sweet potatoes were washed with tap water and a brush, blotted with tissue paper, peeled, and then cut into 1×1×1 cm cubes and mixed well. Six portions of samples of 25 g were weighed and used for boiling as well as steaming.

Boiling, one sample was untreated, and the other five portions of sample were placed in an electric cooker with enough cold water to submerge the samples and were boiled separately with the cover on for 10, 20, 30, 40 and 50 minutes, respectively (timing started after the water being boiled) (Xin Wu et al., 2008).

Steaming, one portion of sample was untreated and the other five portions of samples were placed in a steamer and steamed one by one for 10, 20, 30, 40 and 50 minutes, respectively (Xin Wu et al., 2008).

Microwave oven cooking, four portions of samples of 25 g were weighed. One portion of sample was untreated, and the other three portions of sample were put in plastic microwave bowls, without covers, and cooked for 10, 15 and 20 min, respectively, in a microwave oven adjusted to medium power (GALANA Industrial Co. Ltd. Tokyo, Japan; Model No: D90N30L; S/N G211030743) (Xin Wu et al., 2008).

Steam-dried chips, two medium-sized roots of orange flesh sweet potato were washed, blotted, peeled and cut into 1×1×5 cm strips 10 g per strip. The strips were divided into three portions and weighed.

One portion was used to determine the β -carotene content immediately, and then steamed for 20 min, removed with chopsticks and cooled for 10 min to room temperature and weighed again. One portion was dried in a drying oven at 50 °C for 5 h, and the other for 11 h (Xin Wu et al., 2008).

Oven and sun drying, two medium-sized 450g from each variety were quartered longitudinally from the stem end to the root end, washed with tap water and brush, and blotted with tissue paper. The two opposite quarters from each root were selected and the peel removed, then sliced to 1–2 mm thickness using a food processor. A portion of approximately 50 g, taken as a reference sample, were placed in an amber polystyrene bottle, screw capped and stored in a freezer (–20 °C) prior to subsequent carotenoid analysis. The remaining slice for each method was used for drying. (Bengtssona et al., 2008).

Oven drying, samples were spread out on aluminum foil lined trays, which were placed in an HT 4 forced- air cabinet oven dryer and dried at 57 °C for 10h to a brittle texture. (Bengtssona et al., 2008).

Open-air sun drying, Samples were spread out on a transparent low-gauge polyethylene sheet placed on a papyrus mat. Sliced sweet potato were dried under direct sunlight and occasionally turned to improve the drying process. Drying temperatures varied between 18 and 25°C (Bengtssona et al., 2008).

3.4. Beta Carotene Analysis

3.4.1. Standard Preparation and Calibration

The standard was prepared by using crystal form of 95% HPLC grade beta carotene type II from Sigma Aldrich. Stock solution was prepared 10mg in 100ml n-hexane.

All calibration points were prepared from stock standard solution through a serial dilution to be 0.25 to 5.0 μ g/ml in n-hexane. A 7 point calibration curve was plotted from 0.25 to 5.0 μ g/ml. The calibration curve was linear ($r^2=0.998$).

3.4.2. Extraction and Partition of Beta Carotene

The analysis was done based on the method described by Rodriguez-Amaya and Kimura (2004) under low light conditions in a hood.

It is relatively easier to determine β -carotene contain from sweet potato. Aside from the advantage that only one carotenoid needs to be determined, the matrix is easy to extract, the lipid content is low, and there are no esterified carotenoids. Acetone is used in this method because it is inexpensive and readily available and it penetrates the food tissue well. 0.1% BHT was added as antioxidant to all solvents. 2g of the representative sample was taken and homogenized with a mortar and pestle, ground with 50mL of cold acetone (acetone refrigerated for about 2 hours) and about 2g of celite was added, and that was grounded again with the pestle to extract the carotenoids. It was filtered with suction through a sintered glass funnel and collected in the same flask. The mortar, pestle and residue were rinsed with small amounts of acetone the rinse was received in the funnel. The extraction and filtration was repeated until the residue is colorless.

The extraction was partitioned among petroleum ether (PE), acetone and water in separatory funnel. 40mL of PE was placed in a 500mL separator funnel and add the acetone extract and 300mL of distilled water was added. The distilled water was added slowly to flow along the walls of the funnel to avoid formation of emulsion, do not shake. The aqueous lower phase was discarded. The partition was repeated for the rest portions of the extract sequentially. After the third portion was portioned, the petroleum ether layer was washed three times with deionized water to remove acetone. In the last washing, it was discarded the lower phase was collected as completely as possible without discarding any of the upper phase.

The upper phase was collected by passing it through a small funnel with anhydrous sodium sulfate (15g) to remove residual water in 50mL round bottom flask for beta carotene analysis. Glass wool was used to plug the funnel to hold the sodium sulfate. The funnel was washed with small amount of petroleum ether collecting the washing into the flasks.

3.4.3. HPLC Analysis of Beta Carotene

The collected extract in 50mL round bottom flask from separatory funnel was concentrated in a rotary evaporator $T \leq 35^{\circ}\text{C}$ and dried under nitrogen gas then it was redissolved by using 4mL of

HPLC grade acetone. Before injection into HPLC, it was filtered through 0.22µg PTFE syringe filter (millipor) directly into sample vial.

Beta carotene analysis was performed using Shimazu (model CTO-20AC S. NO. L20214605018AE 220-240V~ 50-600VA made in Japan) consists of quaternary pump, auto sampler, column thermostat and chemistation software. The carotenoids were separated on a Monomeric C18 column: Waters Spherisorb ODS2 (3µm, 4.6 x 150 mm) operated at a flow rate of 0.7mL/min. The mobile phases used were mixture of acetonitrile, methanol, ethyl acetate and 0.05% triethylamine. The isocratic elution program was set as follows 80:10:10, flow rate of 0.7mL/min. The column temperature was 30⁰C and the wave length of UV/Visible was 450nm. The injection volume was 10µl. The beta carotene content was calculated using the formula:

$$C_x (\mu\text{g/g}) = \frac{A_x \times C_s (\mu\text{g/ml}) \times \text{total volume of extract (ml)}}{A_s \times \text{sample weight (g)}}$$

Where: C_x = concentration of carotenoid of sample

A_x = peak area of carotenoid of sample

C_s = concentration of the standard

A_s = peak area of the standard

3.4.4. Retention of beta carotene

The true retention (TR) of β-carotene refers to the β-carotene content determined in a sweet potato sample after preparation, expressed as the percentage of the β-carotene content in the raw, peeled portion of the sample, before preparation. The calculated value for TR subtracted from 100% thus expresses the loss of β-carotene. All of the samples were weighed before and after preparation, and in calculating TR, the weight loss or gain during preparation is taken into account. The TR of β-carotene was calculated according to the following equation (Murphy, Criner & Gray, 1975):

$$\% \text{ Retention} = \frac{\beta\text{-carotene content in processed SP } (\mu\text{g/g}) \times \text{gram of processed SP} \times 100}{\beta\text{-carotene content in raw SP } (\mu\text{g/g}) \times \text{gram of processed SP}}$$

Where: SP = Sweet Potato

3.4.5. Recovery experiment for beta carotene analysis

The recovery was used to determine the method accuracy. Accuracy is the degree of agreement of a measurement or average of measurements with an accepted reference or 'true value', and is a measure of bias in the system. In this study the accuracy of the technique was evaluated in terms of % recovery. For the analysis of the recovery values between 70% and 120% were considered as acceptable range.

$$\%R = \frac{S - U}{C} \times 100$$

Where: % R is Percentage recovery

S = measured concentration in spiked sample

U = measured concentration in unspiked sample

C = actual concentration added to the sample

The recovery was performed by spiking sample with known amount of beta carotene standard (1µg/ml) and analyzed as per the method and the results were compared to determine the effect of matrix on the accuracy of the analysis. The method recovery was 82.8%.

3.4.6. Analysis of Repeatability

Repeatability expressed as the relative standard deviation (RSD), consists of multiple measurements of a sample by the same analyst under the same analytical conditions. In this study the repeatability of the analytical method was assessed by analyzing six replicate samples within a day. Relative standard deviation of the six analyses of a sample was 3.8%.

Relative standard deviation (RSD) was calculated as follows:

$$RSD = \frac{S}{X} \times 100$$

Where: S = standard deviation of replicate analysis

X = mean of the replicate analysis

3.4.7. Limit of Detection

Detection is the lowest concentration of analyte in sample that can be detected, not necessarily quantitated under stated experimental conditions. The limit of detection was defined as the concentration value of the studied compound for which the signal (S) to noise (N) ratio was higher than 3 ($S/N > 3$) (FDA, 1994). In this study, the instrument detection limit was performed by preparing serial dilution of beta carotene standards for 0.07 $\mu\text{g/mL}$, 0.06 $\mu\text{g/ml}$ and 0.05 $\mu\text{g/ml}$ and run each of them seven times. The signal (S) to noise (N) ratio higher than 3 ($S/N > 3$) was obtained for 0.07 $\mu\text{g/ml}$.

3.4.8. Quality Control

All glasswares and equipments such as analytical balance that were used during beta carotene analysis were calibrated by National Metrology Institute of Ethiopia, and intermediate check was done before use each time. Method blank was run before a batch of analyzed sample and analysis every day; replicate analysis, spiked sample were used in every batch of sample analysis.

3.5. Mineral Analysis

3.5.1. Determination of Calcium, Iron and Zinc

The analysis of Ca, Zn and Fe was done based on the Official Methods of 999.11 of AOAC (2005). The analysis process of these minerals follows two successive steps:-

Step 1 Ashing: At the beginning of this step all crucibles were washed with 6N HCL and glass wares with 10% nitric acid, then the crucibles were placed in an oven for about 30 minutes at 100⁰C. After the crucible thoroughly cooled in a desiccator for 30 minutes, 2.5g of sample was accurately weight. The crucible containing the samples was charred at hot plate starting from low temperature under a hood. Later on, sample were ashed in a muffle furnace at 550⁰C for one hour and the crucibles were take out from the furnace, cooled, and moistened with a few drops of deionized water and evaporated on hot plate. Sample were ashed once again, cooled and some drops of deionized water and 5 drops of concentrated HNO₃, were added then evaporated on hot plate as described above. Samples were finally ashed for 30 minutes at the same temperature as previously described. Crucible was cooled in desiccators for 45-60 minutes and then weighed.

Step 2. Dissolution: At this steps ash was treated with 10 ml of 6N HCL to wet it completely and was carefully taken to dryness on a low temperature hot plate. In addition 15 mL of 3N HCL was added and crucible was heated on the hot plat until the solution just boils. After cooling the crucible, a filtration was carried on through a filter paper into a graduated flask. 10 mL of 3N HCL was again added to the crucible containing the filtrate and heated until the solution just boiled, cooled and continued to filter into the graduated flask. Furthermore, crucibles were washed at least three times with deionized water and washings were filtered into the flask. In the same manner, the filter paper was washed thoroughly and washings were collected in the flask. In this case, 5 ml of lanthanum chloride solution per 100mL of solution was added to determined calcium. The contents of the flask (sample solution) was cooled and diluted to the mark with deionized water. Blank was prepared by taking the same amount of reagents used to prepare the sample. Sample solutions were transferred to polyethylene bottles. AAS was calibrated with standard until the curve is fitted. Hence, a series of standard solutions of the minerals were prepared from stock solution of 20ppm. For Ca (0, 0.5, 2, 4, 6 and 8ppm.), Fe (0, 0.5, 1, 2, 3 and 4ppm.) Zn (0, 0.5, 1, 2, 3 and 4ppm.) and K (2, 4, 6, and 8ppm). The blank, control and samples were run respectively. The content of each mineral was calculated using the formula:-

$$\text{Metal content (mg/100g)} = \frac{[(C_s - C_b) \times V]}{[10 \times W]}$$

Where, C_s = concentration of sample in ppm

C_o = concentration of blank in ppm

V = volume (mL) of extract

W = weight (g) of samples

3.5.2. Determination of Potassium

Analysis of potassium was done using the flame photometer method. Two gram of the sample was weighed on a filter paper and the filter paper was fold up and transferred in to a 250mL conical flask. 20mL of diluted nitric acid was added and boiled gently for about 10 minutes and cooled to room temperature. The digested solution was filtered through a filter paper into a 100 mL volumetric flask, then the conical flask and the filter paper were washed three times each with 10 ml deionized water and the solution was made up to 100mL and mixed properly

(solution A). Blank was prepared in the same way as started above excluding the sample (solution B). 5mL of solution A and B were pipetted into a 100mL graduated flask, make up to the mark, and mixed (solution C and D). The flame photometer calibrated with 3.15ppm. of potassium solution which give 100 absorbance using potassium filter and obtained values was correct for zero concentration standard the solution C and D were finally measured to determine the potassium content and the following formula was primarily used to calculate its value.

$$\text{Potassium content (mg/100g)} = \frac{(C - D) \times 2000}{W}$$

Where, W = Weight (g) of sample

$$C \text{ and } D = [0.033 \times A]/10$$

A = Absorbance

3.6. Anti-nutritional factors

3.6.1. Phytate content

Phytate was determined by following AOAC (2000). About 0.2 g of dried sample was extracted with 10mL of 0.2N HCl for 1 hour at an ambient temperature. The extracted sample was centrifuged for 30 min at 3000 rpm and the clear supernatant was used for phytate determination. Two milliliters of wade reagent was added to 3mL of supernatant sample solution that was homogenized and centrifuged for 10 min at 3000 rpm. Wade reagent was prepared by mixing equal amount volume of 0.03% FeCl₃.6H₂O and 0.3% Sulfosalclic acid. The absorbance of the solution was measured at 500nm using UV-Vis spectrophotometer. The phytate content was calculated from the difference between the absorbance of the blank (3ml of 0.2N HCL +2mL of wade reagent) and that of assayed sample. The amount of phytic acid was calculated using phytic acid standard curve and the result was expressed as phytic acid in mg/100g DW.

Standard solution preparation: A series of standard solution was prepared containing 0, 4, 9, 18, 27, 36µg/g. Phytic acid in 0.2N HCl. Then, 3mL of each standard was pipetted into 15mL centrifuge tubes and 3mL 0.2N HCl (blank). Then, 2ml of wade reagent was added to each tube, and the solution was mixed on a vortex mixer for 5 seconds. The mixture was then centrifuged

for 10min at 3000rpm and the supernatant was read at 500nm. The calibration curves (absorbance vs. concentration) and the slope and intercept were calculated as follows:

$$\text{Phytic acid in } \mu\text{g/g} = \frac{[(\text{Ab}-\text{As}) - \text{Intercept}] \times 10}{\text{Slope} \times \text{w} \times 3}$$

Where: As = Absorbance of the test sample

Ab = Absorbance of the blank

W = Weight of sample (gm)

3.6.2. Tannin content

Tannin content of OFSP flour was analysed using the method of Burns (1971) which is modified by Maxson and Rooney (1972). About one gram of OFSP flour was weighed and 10mL of 1% HCl in methanol was added to each test tube containing the sample. After that, the test tubes were shaken for about 24 hours at room temperature using mechanical shaker. The shaken sample was then centrifuged at 1000 x g for 5 minutes. One milliliter of clear supernatant was diluted with 3mL 1% HCl and 1mL of the diluted solution was mixed with 5mL vanillin-HCl reagent in another test tube. The mixture was then allowed to wait at a dark place for about 20 minutes so as to complete the reaction. Twenty minutes later the absorbance was read at 500nm using UV-VIS spectrophotometer. The concentration of tannin was actually calculated using D-catechin standard curve (0, 12, 0.24, 0.36, 0.48 and 0.6 mg/ml). So that the result was expressed as catechin equivalent of tannin in milligram per 100g in dry weight base. The following formula was used to calculate the tannin content of the sample:-

$$\text{Tannin (mg/100g)} = \frac{[(\text{Absorbance of sample} - \text{Absorbance of blank}) - \text{Intercept}] \times 4}{\text{Slope} \times \text{Density} \times \text{Weight of sample}}$$

3.7. Determination of molar ratio for phytate/minerals

The mole of phytate and minerals was determined by dividing the weight of phytate and minerals with its atomic weight (phytate: 660g/mol; Ca: 40g/mol; Fe: 56g/mol; Zn: 65g/mol). The molar ratio between phytate and mineral was obtained after dividing the mole of phytate with the mole of minerals (Morris and Ellis, 1989).

3.8. Functional Properties of orange fleshed sweet potato flour

3.8.1. Bulk density

Bulk density of orange fleshed sweet potato flour was determined using the method of Okezie and Bellow (1988). A 10gm of sample flour was weighed and continuously tapped in a measuring graduated cylinder until a constant volume is attained. The bulk density of the sample (g/ml) was calculated as weight of the sample per unit volume of sample.

$$\text{Bulk density} = \frac{\text{mass of sample}}{\text{volume of sample}}$$

3.8.2. Water absorption capacity (WAC)

The WAC of orange fleshed sweet potato flour was determined using the method of Onwuka (2005). A measured quantity of 1gm of the sample was dispersed in 10 mL of distilled water in a conical graduated centrifuge tube. The sample was thoroughly mixed for 30 s and allowed to stand at room temperature for 30 min before being centrifuged at 5,000 x g for another 30 min. The volume of the supernatant was measured directly from the graduated centrifuge tube. The amount of the absorbed water was multiplied by the density of water (1 g/mL) and results were expressed as g/100 g.

$$\text{Water absorption capacity (WAC)} = \frac{W_3 - (W_1 + W_2)}{W_1} \times 100$$

Where: W_1 = Weight of a sample

W_2 = Weight of a centrifuge

W_3 = The weight of sample after partially drying

3.8.3. Oil absorption capacity (OAC)

Oil absorption capacity of orange fleshed sweet potato flour was determined using the centrifugal method of Beuchat (1977) as modified by Adepeju et al. (2011). One gram of sample was mixed with 10 mL (V_1) of pure soya bean oil for 60 seconds. The mixture was allowed to stand for 10 min at room temperature, centrifuged at 4000rpm for 30 min and the oil that separated as supernatant was carefully decanted and measured in 10 ml cylinder (V_2). The

difference in volume was taken as the oil absorbed by the sample. Oil absorption was expressed as ml of oil bound by 100g dried sample.

$$\text{Oil (fat) absorption capacity (ml)} = (V_1 - V_2)$$

Where: V_1 = volume of refined oil (ml),

V_2 = volume of supernatant

3.8.4. Swelling Index (SI)

Ten grams of each flour sample were weighed into a calibrated measuring cylinder. Then, 80 mL of water was added and the cylinder was gently tapped to remove air void after which the initial volume was recorded. The cylinder containing the sample in water was allowed to stand for 1 h undisturbed at room temperature (25°C). At the end of 1 h, the swelling capacity of the sample was expressed as an index, that is, the ratio of the final volume (Narayana and Narasinga, 1982).

3.9. Statistical Analysis

Statistical Package for Social Sciences (SPSS) version 16.0 was used to analyze the data. Descriptive statistical mean, standard deviation (SD) and range were calculated from analysis and the data was expressed as mean \pm SD. The mean were statistically compared by using one way ANOVA, student t-test and LSD. Differences in means were considered significant at level of $P < 0.05$.

4. RESULTS

4.1. Beta carotene in orange fleshed sweet potato varieties

In the raw, peeled samples of two orange fleshed sweet potato varieties, β -carotene was the most abundant provitamin A carotenoid. The β -carotene content in the raw, peeled samples Kulfo and Tulla was found 400 μ g/g and 335 μ g/g, respectively.

Beta-carotene in orange fleshed sweet potato varieties is presented in the following Tables all values done in fresh weight and Values are represented as means \pm SD. In duplicate determinations.

Table 7. β -carotene content of fresh orange fleshed sweet potato

OFSP Varieties	β -carotene content (μ g/g fresh peeled weight)
Kulfo	400 \pm 0.42
Tulla	335.25 \pm 0.07

Kulfo and Tulla varieties grown for 20 - 22 weeks

Values within the same column are significantly different (P<0.05).

4.2. Retention of Beta Carotene in Processed orange fleshed sweet potato varieties

Table 8. Effect of boiling time on the β -carotene content of the orange flesh sweet potato

OFSP Varieties	β -carotene content (μ g/g fresh peeled weight)	Boiling time (min)	β -carotene content (μ g/g) boiled, peeled	True retention of β -carotene (%)
Kulfo	381.85 \pm 1.90	10	371.05 \pm 0.63	97.1
		20	368.15 \pm 1.06	96.4
		30	317.45 \pm 0.07	83.1
		40	255.2 \pm 2.68	66.8
		50	217.9 \pm 0.56	57.0
Tulla	303.65 \pm 0.63	10	294.5 \pm 2.40	96.9
		20	279.9 \pm 1.13	92.1
		30	232.65 \pm 0.77	76.6
		40	210.3 \pm 0.42	69.2
		50	181.45 \pm 1.06	59.8

Kulfo and Tulla varieties grown for 20 - 22 weeks

Values within the same column are significantly different (P<0.05).

Table 9. Effect of steaming time on the β -carotene content of the orange fleshed sweet potato

OFSP Varieties	β –carotene content ($\mu\text{g/g}$ fresh peeled weight)	steaming time (min)	β -carotene content ($\mu\text{g/g}$) steamed, peeled	True retention of β -carotene (%)
Kulfo	345.3 \pm 1.13	10	325.85 \pm 0.49	94.3
		20	277.6 \pm 2.12	80.3
		30	260 \pm 1.83	75.2
		40	231.6 \pm 0.28	67.0
		50	187.8 \pm 2.61	54.3
Tulla	288.05 \pm 1.06	10	278.9 \pm 1.27	96.8
		20	264.75 \pm 2.19	91.9
		30	201.65 \pm 2.05	70.0
		40	176.25 \pm 0.21	61.1
		50	156.15 \pm 2.05	54.3

Kulfo and Tulla varieties grown for 20 - 22 weeks

Values within the same column are significantly different ($P < 0.05$).

Table 10. Effect of microwave heating time on the β -carotene content of the orange flesh sweet potato

OFSP Varieties	β –carotene content ($\mu\text{g/g}$ fresh peeled weight)	microwave heating time (min)	β -carotene content ($\mu\text{g/g}$) microwave heated, peeled	True retention of β -carotene (%)
Kulfo	347.95 \pm 1.06	10	292.3 \pm 1.69	84.0
		15	166.95 \pm 0.21	47.9
		20	138.6 \pm 0.14	39.8
Tulla	280 \pm 0.28	10	197.8 \pm 0.42	70.6
		15	149.5 \pm 1.27	53.3
		20	132.1 \pm 0.28	47.1

Kulfo and Tulla varieties grown for 20 - 22 weeks

Values within the same column are significantly different ($P < 0.05$).

Table 11. Effect of oven drying time on the β -carotene content of the orange fleshed sweet potato

OFSP Varieties	β -carotene content ($\mu\text{g/g}$ fresh peeled weight)	Oven drying time (hr)	β -carotene content ($\mu\text{g/g}$) Oven dried, peeled	True retention of β -carotene (%)
Kulfo	385.5 \pm 0.14	Oven dried at 57 $^{\circ}$ C for 10hr	373.2 \pm 0.98	96.8
Tulla	311.95 \pm 0.35		288.85 \pm 0.07	92.6

Kulfo and Tulla varieties grown for 20 - 22 weeks

Values within the same column are significantly different ($P < 0.05$).

Table 12. Effect of sun drying time on the β -carotene content of the orange fleshed sweet potato

OFSP Varieties	β -carotene content ($\mu\text{g/g}$ fresh peeled weight)	Sun drying time (min)	β -carotene content ($\mu\text{g/g}$) Sun dried, peeled	True retention of β -carotene (%)
Kulfo	334.05 \pm 0.35	Sun dried 18-25 $^{\circ}$ C	264.35 \pm 0.35	79.1
Tulla	288.75 \pm 0.63		224.35 \pm 0.07	77.6

Kulfo and Tulla varieties grown for 20 - 22 weeks

Values within the same column are significantly different ($P < 0.05$).

Table 13. Effect of drying on the content of β -carotene in orange fleshed sweet potato chips

OFSP Varieties	Content ($\mu\text{g/g}$) of fresh peeled weight	Steamed for 20 min	Content of β -carotene in chips ($\mu\text{g/g}$)	True retention of β -carotene (%)
Kulfo	367.7 \pm 0.14	Dried at 50 $^{\circ}$ C for 5 h after steaming	345.7 \pm 0.28	94.0
		Dried at 50 $^{\circ}$ C for 11 h after steaming	289.05 \pm 0.21	78.6
Tulla	330.35 \pm 1.20	Dried at 50 $^{\circ}$ C	288.1 \pm 0.14	87.2

		for 5 h after steaming Dried at 50 °C for 11 h after steaming	199.8±0.14	60.4
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Kulfo and Tulla varieties grown for 20 - 22 weeks

Values within the same column are significantly different (P<0.05).

4.3. Mineral analysis

The mineral composition of orange fleshed sweet potato of varieties Kulfo and Tulla flour is given in Table 13

4.4. Anti-nutritional factors

The amount of anti-nutritional factors particularly phytate and tannin in orange fleshed sweet potato Kulfo and Tulla flour is given in Table 13

Table 14. Mineral contents and anti-nutritional factors of orange fleshed sweet potato Kulfo and Tulla flour (mg/100g, dwb)

Components	Values	
	Kulfo	Tulla
Ca	22.14±0.01	18.78±0.01
Fe	20.83±0.00	7.47±0.00
Zn	3.63±0.01	1.23±0.01
K	3064.68±0.02	1469.13±0.02
Phytate	432.10±2.10	89.29±2.00
Tannin	89.36±0.05	40.02±0.05

Values within the same row are significantly different (P<0.05).

Values are represented as means ± SD. In duplicate determinations

4.5. Molar ratio of phytate to minerals (Ca, Fe, and Zn)

Table 15 shows values for the molar ratio between phytate and divalent cations, Ca, Fe and Zn.

Table 15. Molar ratio between phytate and minerals of orange fleshed sweet potato flour

Molar ratio	Contents	
	Kulfo	Tulla
Phytate/Ca	1.18±0.01	1.39±0.01
Phytate/Fe	1.76±0.05	4.99±0.05
Phytate/Zn	11.72±0.22	34.59±0.18

Values within the same row are significantly different ($P < 0.05$).

Values are represented as means \pm SD. In duplicate determinations

4.6. Functional properties of orange fleshed sweet potato flour

Bulk density, water absorption capacity, oil absorption capacity and water solubility index were analyzed in this study do as to evaluate the functional properties of orange fleshed sweet potato flour. Accordingly, high amount of Water absorption capacity (253 and 212%) in Kulfo and Tulla varieties respectively table 15 show the value functional properties of orange fleshed sweet potato flour

Table 16. Functional properties of orange fleshed sweet potato flour

Properties	Values	
	Kulfo	Tulla
Bulk density (g/mL)	0.74±0.01	0.62±0.01
Swelling index (%)	161.1±0.14	138.0±0.11
Water absorption capacity (%)	253.0±0.01	212±0.00
Oil absorption capacity (mL)	1.84±0.05	1.68±0.02

Values are represented as means \pm SD. In duplicate determinations

5. DISCUSSION

Root crops have pro-vitamin A proved to be an effective means to alleviate vitamin A deficiency (Jalal, 1998). The present study revealed difference β -carotene level in OFSP varieties. These beta carotene results are similar to findings reported by other researchers. β -carotene content of sweet potato ranging between 0.01 and 26.6 mg/100g (fwb) have been reported (Takahata et al., 1993). β -carotene level of 11.8 mg/100 g in the variety Xushu 18 have been reported (Hagenimana et al., 1999). In deep orange coloured sweet potatoes, β -carotene content ranged between 4.29 and 18.55 mg/100g (Burgos et al., 2001), 0.009 and 20.525 mg/100g in orange variety in South Africa (Sunette, 2010) and 9.230 mg/100g for the main USA variety Beauregard (Teow et al., 2007) have been reported. Other researchers reported low values as compared to those obtained in this study. β -carotene content of 0.254 ± 3.84 and 0.181 ± 2.64 mg/100g for *Ejumula* and *Kakamega*, respectively have been reported (Tumuhimbise et al., 2013). Leighton (2007) reported that OFSP can provide up to 6.528mg/100g and (Vimala et al., 2011) reported β -carotene of sweet potato varieties ranging between 1.68 and 1.85mg/100g. The literature data led to the conclusion that, in the OFSP, there are high as well as low values of this nutrient, and are all determined by varieties.

Variation in β -carotene content may be due to differences in varieties, growing conditions, stages of maturity, harvesting and post-harvest handling, processing and storage of OFSP, air and soil temperature, radiation, location, soil moisture and fertilization (K'Osambo et al., 1998; Rodriguez-Amaya, 2000; Mbwaga et al., 2007; Ukom et al., 2009). Environmental conditions, genetic factors, crop age and cultivation management strategies can significantly influence the β -carotene content of varieties (K'Osambo et al., 1998). High irrigation levels were found to decrease β -carotene content (K'Osambo et al., 1998).

Results indicated that the orange fleshed varieties varied in their β -carotene content and retention capabilities. In the raw, peeled samples of two orange fleshed sweet potato varieties, β -carotene content was high. However, β -carotene content in the different varieties varied greatly, the highest β -carotene content was found in the variety, Kulfo whereas a lowest amount was found in Kulfo variety (Table 10). This indicates that the β -carotene content in the same variety of sweet potato is influenced by many factors, such as growing conditions, climate, soil type, sunlight, processing and stage of maturity. van Jaarsveld et al. (2006) found that the β -carotene

content of medium-sized OFSP from the same harvest batch ranged from 132 to 194 mg/kg fresh weight. The β -carotene content in the raw, peeled samples Kulfo and Tulla was found to be 400 ± 0.42 - $334.05\pm 0.35\mu\text{g/g}$ and 335.25 ± 0.07 - $280\pm 0.28\mu\text{g/g}$ fresh weight, respectively

Cooking and processing have a degrading effect on β -carotene content. Sun drying was observed to retain 63 - 73%, oven drying 89 – 96%, boiling 84–90% and frying 72– 86% β -carotene in OFSP varieties studied (Vimala et al., 2011) and boiling retained 70-80% of the vitamins (Van Jaarsveld et al., 2006 ; Bengtsson et al., 2008). The influences of different processing procedures on the carotene content of orange-fleshed roots have been reported in sweet potato (Huang et al., 1999), carrots (Debjani et al., 2005), and cassava (Chavez et al., 2007). In general, retention of beta-carotene content decreases with long processing time, high temperatures, cutting and maceration of food (Rodriguez-Amaya, 1997; Sunette, 2010). Some of the sweet potato varieties indicate that cooking has an effect on β - carotene content. According to Rodriguez-Amaya (2002), carotenoids cannot be biosynthesized during cooking. Heat treatment inactivates enzymes responsible for carotenoid biosynthesis and stimulates isomerization and oxidative degradation of carotenoids.

Effect of boiling on β -carotene, for both varieties the results indicated that the decrease in β -carotene content was positively related to the duration of boiling, decreasing by about 2.9%-43.0% and 3.1%-40.2% in Kulfo and Tulla varieties respectively, This also resulted in 40.1% and 37.1% decrease in TR (Table 8). Boiling for 50 min resulted in a decrease of about 50% of the β -carotene content, whereas boiling for 10 min resulted in a highest retention of β -carotene (Table 8). K'osambo et al. (1998) results a 14 – 59% reduction in the content of total carotenoids in unpeeled, whole medium-sized sweet potato roots from four cultivars boiled for 30 min.

Effect of steaming on β -carotene content, of sweet potato can lead to a reduction in the β -carotene content. Results showed that the decrease in β -carotene content was positively related to the duration of steaming, decreasing by about 5.7% - 45.7% and 3.2% - 45.7% when steamed for 10 to 50 min for Kulfo and Tulla varieties (Table 9). The decrease in the content of β -carotene was larger with steaming than boiling.

The results of effect of microwave oven cooking on β -carotene content, this method is fast and the loss of nutrients during microwave cooking is perceived to be minimal showed that the reduction in β -carotene content was positively related to the duration of microwave cooking

(Table 10). When compared with boiling and steaming, microwave cooking resulted in the largest reduction in TR of β -carotene 44.2% and 23.5% in Kulfo and Tulla varieties respectively.

Effect of oven drying on β -carotene content, in this study, resulted the reduction in β - carotene content was 3.2% and 7.4% respectively (Table 11).

Effect of sun drying on β -carotene content, in this study, the reduction in β - carotene content was 20.9% and 22.4%, respectively. (Table 12).

Effect of steaming and drying of chips on β -carotene content in this study, the reduction in β -carotene content was 6% and 12.8% after, drying at 50 °C for 5 h, respectively after drying for an additional period of 6 h (to remove the remnant water), the reduction in β -carotene content was 21.8% and 39.6% the reduction more than tripled (Table 13).

Amount of each mineral was obtained in this study as compared to other literature sources (Table 14). Studies report Ca in sweet potatoes to vary in the range of 7-85 mg/100g while level of Fe varies between 0.16-2.11mg/100 g (Woolfe, 1992; Abubakar et al., 2010; Sunette, 2010).

Calcium content is within the range but iron and potassium content was very high respectively, Kulfo (20.83), Tulla (7.47); Kulfo (3064), Tulla (1469), whereas the zinc content was relatively low Kulfo (3.63), Tulla (1.23) as compared with the other minerals and this is in good agreement with the finding of La Frano et al., (2014). The differences in mineral contents reported by various studies could be attributed to the location of plants, the application of fertilizations and irrigation use, climate; and genetic differences between the varieties (Munoz et al., 1995).

Ant-nutritional factors are generally toxic and negatively affect the nutritional value of orange fleshed sweet potato flour by impairing protein digestibility and mineral availability. Two ant-nutritional factors namely phytate and tannin were examined in this study (Table 14). Phytate content was (432.10mg/100g) and (89.29mg/100g) in Kulfo and Tulla respectively, the value of Tannin was considerably higher; (89.3610mg/100g) and (40.0210mg/100g) for both varieties.

The molar ratio between phytate and minerals indicates the impact on the bioavailability of dietary minerals. The critical molar ratio, above which mineral absorption may be inhibited, has been determined as Pa: Ca > 1.56, Pa: Fe > 14, Pa: Zn > 10 (Saha et al., 1994). In this study these limits were employed to predict the bioavailability of minerals. Accordingly, the values (table 15) revealed that the molar ratio of both Kulfo and Tulla for phytate: Ca (1.18) and phytate: Fe (1.76) and phytate: Ca (1.39) and phytate: Fe (4.99) respectively were found to be

below the critical limit. This implies that the bioavailability of calcium and iron is not inhibited by the concentration of phytate in orange fleshed sweet potato flour. However, the molar ratio of phytate:Zn exhibited a high ratio in both Kulfo and Tulla varieties respectively. The phytate:Zn (11.73), phytate:Zn (34.59) in both varieties were beyond the stated critical limit. Thus, such values indicate that the bioavailability of zinc in the flours is inhibited by phytate. Therefore, the risk of zinc inhibition in this regard requires a preferable mode for minimization of the concentration of phytate in the orange fleshed sweet potato flour.

Functional properties contribute an important role in determining the competitiveness of ingredients or products in the market, as they can impact the sensory, physical and chemical properties of a food. Some representative attributes such as bulk density, water absorption capacity, oil absorption capacity and swelling index were analyzed to evaluate the functional properties of orange fleshed sweet potato flour (Table 16)

Bulk density of the Kulfo and Tulla flours were 0.74 g/mL and 0.62 g/mL respectively. This indicates that the heaviness and its suitability of the flour may be used for production of confectioneries. Increase in bulk density offers a greater advantage for packaging. Hence greater quantity may be packed within a constant volume (Fagbemi, 1999). Water absorption capacity ranging from 149.1 to 471.5% is considered critical in viscous foods such as soups and gravies (Aletor et al., 2002). Judging from the value that was obtained from this orange fleshed sweet potato flour respectively (253%, 212%) (Table 16). The water absorption capacity helps to determine the ability of the flours to absorb water and swell for improved consistency in food. Flours are used as food ingredient because of their interaction with water (Nide et al., 2001). It is found to be useful in soups or gravies. The oil absorption capacity of the flours ranging from 1.84 and 1.68 mL for both varieties respectively. The similarity in water and oil absorption properties may be associated the proportional balance of hydrophobic and hydrophilic nature of the particle of the sample. The swelling indices were 162% and 138%, in both varieties respectively. This is related to associative binding within starch granules, strength and character of the micelle network as related to the amylose content. High amylose content produces low swelling index (Adebowale et al., 2005). The functional attributes of products may vary considerably due to the differences in the raw material, processing and environmental condition during testing.

6. CONCLUSIONS AND RECOMMENDATION

6.1. Conclusion

The present study showed that orange fleshed sweet potato is superior in beta carotene content and had comparable amount of other nutrients. In order to combat vitamin A deficiency by enhancing consumption of orange fleshed sweet potato, evaluation of the processing methods in the retention of beta carotene is an important step to recommend and promoting the food to consumers. This study revealed different preparing methods regulating can affect the retention of beta carotene, mineral composition, antinutritional factors and functional properties

Different preparation methods led to a decrease in true retention of β -carotene in orange fleshed sweet potato roots. Among the six preparation methods used in this study, boiling resulted in the highest true retention, where as microwave cooking for 20min resulted in the lowest true retention. It is notable that in the samples of Kulfo and Tulla from the same growing site and the same batch, β -carotene content varied from 400 ± 0.42 - $334.05\pm 0.35\mu\text{g/g}$ and 335.25 ± 0.07 - $280\pm 0.28\mu\text{g/g}$. In addition, orange fleshed sweet potato has an appreciable content of potassium, calcium, iron and zinc and high level of phytate and tannin. Moderate levels of functional properties were exhibited in the orange fleshed sweet potato.

In order to minimize the reduction in the content of β -carotene due to preparation, In this study, used much longer cooking times than usual; in order to show that the effect of cooking time is on the content of β -carotene in orange flesh sweet potato.

6.2. RECOMENDATION

Orange fleshed sweet potato is a naturally biofortified root crop which can be useful in combating vitamin A deficiency in the country.

It is recommended that sweet potato roots be cooked, as longer duration of cooking leads to greater reduction of beta carotene.

Optimization of cooking temperature and time to find optimum cooking condition needs further study.

Farmers should be motivated to engage in the production of orange fleshed sweet potato.

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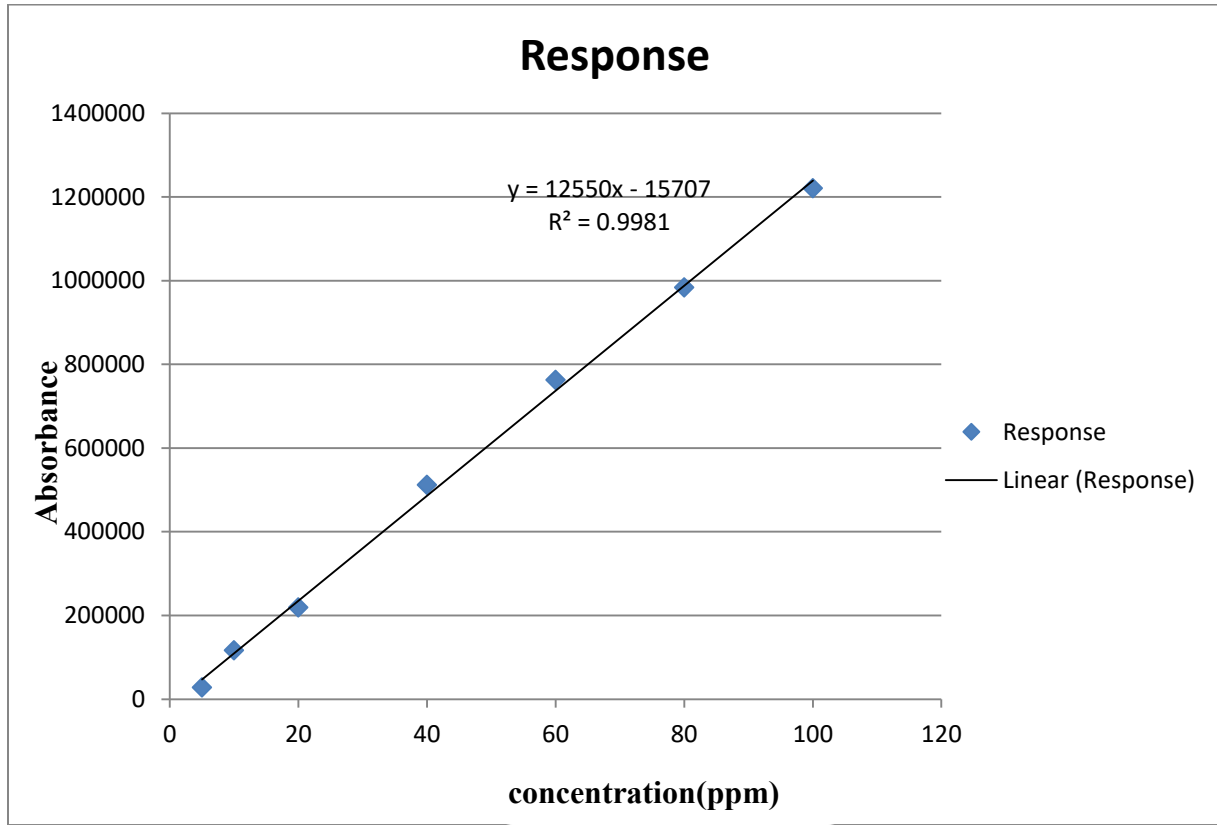
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APPENDICES

Appendix 1: Calibration curve for beta carotene analysis



Appendix 2: Representative chromatogram for method blank, standard and sample

Addis Ababa University
School of Graduated Studies

DECLARATION

This is to certify that the thesis prepared by Yemesrach Tiruneh, entitled “Biochemical Compositions, Functional Properties of Orange Fleshed Sweet Potato Varieties and Effect of Treatment on its Beta Carotene Retention” and submitted in partial Fulfillment of the requirement for the Degree of Master of science in Food Science and Nutrition with the regulation of the university and meets the accepted standards with respect to originality and quality.

Candidate: Yemesrach Tiruneh Signature _____

Advisor: Mr. Kelbessa Urga (Asso. prof) Signature _____

APPROVAL

This thesis has been approved by Examining board.

Name	Signature	Date
1. _____	_____	_____
2. _____	_____	_____
3. _____	_____	_____

Place of submission: Addis Ababa University School of Graduated Studies

Center for Food Science and Nutrition

Addis Ababa, Ethiopia

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