EFFECT OF PRETREATMENTS AND DRYING ON NUTRIENT CONTENT OF ORANGE FLESHED SWEET POTATO TUBERS AND COWPEA LEAVES USED IN MASWA DISTRICT, TANZANIA.

CHRISTERBEL NICANURU

MASTER OF SCIENCE

(Food Science and Technology)

JOMO KENYATTA UNIVERSITY OF AGRICULTURE AND TECHNOLOGY

2016

Effect of Pretreatments and Drying on Nutrient Content of Orange Fleshed Sweet Potato Tubers and Cowpea leaves used in Maswa District, Tanzania

Christerbel Nicanuru

A thesis submitted in partial fulfillment for the degree of Master of Science in Food Science and Technology in the Jomo Kenyatta University of Agriculture and Technology

2016

DECLARATION

This thesis is my original work and has not been presented for a degree in any other University.

Signature…… Date ……

Christerbel Nicanuru

This thesis has been submitted for examination with our approval as University supervisors

Signature..... Date ……

Dr. Daniel Ndaka Sila

JKUAT, Kenya

Signature…… Date……..

Prof. Henry S. Laswai

SUA, Tanzania

DEDICATION

I affectionately dedicate this thesis work to my beloved daughter Careen Leonard and my husband Leonard Ephata, for their patience and tolerance of my absence. A special feeling of gratitude to my loving parent's Nicanuru M. Swai and Sarah H. Swai whose words of encouragements ring in my ears whenever I feel upset. My one and only brother, Christian, and my beloved sisters; Julieth, Jescar, Valentiner and Clementiner have never left my side and they are very special. The undivided support from my family members, they accorded me during the study period in both morally and financially showing how caring they are to me.

ACKNOWLEDGEMENT

I would like to take this opportunity to thank iAGRI for funding my studies at Jomo Kenyatta University of Agriculture and Technology for the whole two years.

I would also like to express my greatest gratitude to the people who have helped and supported me throughout my project. Foremost, I would like to express my sincerely gratitude to my advisors Prof Henry Laswai and Dr. Daniel Sila for their continuous support on my Msc. Study, for their patience, motivation, enthusiasm, and immense knowledge, their guidance and the insightful advice helped me in all the time of research and writing of the thesis.

I am thankful to the Department of Food Science and Technology in Sokoine University of Agriculture (SUA) for allowing me to use their facilities during my research year. My laboratory assistants who have been a precious help were Mr. G. Muffui (Animal Science lab), Mr. S. Mwanyika (Food Science lab) and Mr. Mohammed (Soil Science lab).

I express my appreciation to my fellow Agricultural Officers (AOs) in Maswa District for their support during my baseline survey, all my friends who motivated and appreciated me for my work and all those who participated in this work in whichever capacity.

I am greatly thankful to my beloved husband Mr. Leonard Mwanga and my only one daughter Careen for allowing me to go for study in all two years. Thanks to Almighty God for opening doors and for guiding me throughout my journey of study.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ACRONYMS

AOAC……Association of Official Analytical Chemists

CYMV……...Cowpea Yellow Mosaic Virus

FAO……...Food and Agriculture Organization

FAOSTAT….Food and Agriculture Organization Statistic

HPLC……. High Performance Liquid Chromatography

IDA…… Iron Deficiency Anaemia

JKUAT…… Jomo Kenyatta University of Agriculture and Technology

MAFC ……...Ministry of Agriculture Food Security and Cooperatives

OFSP …….Orange Fleshed Sweet Potatoes

ProNIVA……Promotion of Neglected Indigenous Vegetables for Nutritional Health in Eastern and Southern Africa

RDAs…… Recommended Daily Allowances

RE ……Retinol Equivalent

SUA……..… Sokoine University of Agriculture

VAD……...Vitamin A Deficiency

ABSTRACT

Rural communities in Tanzania are increasing suffering from food shortage and malnutrition (Vitamin A deficiency, Protein energy malnutrition and Iron deficiency Anaemia). A household survey was conducted to determine the baseline situation in Maswa district, regarding production, processing and storage of orange fleshed sweet potato tubers and cowpea leaves. Chemical analysis was carried out on four sweet potato varieties (*Jewel*, *Karoti dar*, *Kabode* and *Ejumula*) possessing different intensities of orange-flesh colour and cowpea leaves to establish levels of nutrients in fresh and processed products using standard methods of analysis. Beta carotene was determined by spectrophotometric method while mineral content was determined using Atomic Absorption Spectrophotometric method. Both cowpea leaves and sweet potatoes were subjected to pretreatments including blanching and boiling. The baseline survey indicated that, respondents have limited knowledge regarding nutritional excellence and blanching of orange fleshed sweet potato tubers and cowpea leaves. *Michembe* is more preferred than *matobolwa* dried sweet potato. Fresh samples of sweet potatoes and cowpea leaves had significantly low proximate composition results (protein, fat, fiber and carbohydrate) and mineral content compared to dried samples due to the fact that during drying food loses a significant amount of moisture resulting into concentrating other nutrients. Moisture content of fresh cowpea leaves was 89.54g/100g and dried cowpea leaves were below 11% moisture. Solar dried samples indicated higher fat content compared to sun dried. Fibre and protein contents of blanched samples were significantly higher than that of cooked samples. Ash content of cooked samples was significantly higher than the blanched samples, regardless of the drying method used. There was a three-fold reduction in β-carotene content when fresh samples were dried. Boiling have a different effect on sweet potatoes compared to cowpea leaves, boiling results into more retention of beta carotene than blanching in sweet potatoes while in cowpea leaves blanching results into more retention than boiling. Results further showed that fresh dried had significantly low β-carotene content and low retention on storage compared to boiled and blanched chips and blanched cowpea leaves retained more beta carotene after six months storage at room temperature. Therefore, blanching

should be introduced to rural communities during processing of green vegetables and orange fleshed sweet potato tubers to protect nutrients loss. Education on processing and nutritional excellence of orange fleshed sweet potato tubers and cowpea leaves should also be provided to assist reduction of incidences of community malnutrition in Maswa district and Tanzania in general.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Food preservation has been practiced in many parts of the world for thousands of years. Methods of preservation include: canning, freezing, pickling, curing (smoking or salting), and drying. Food spoilage can either be microbial, chemical or enzymatic origin and in some case some physical contaminants such as insects, stones, and chaff among others can be a deterrent. Preservation by drying is based on moisture removal to inhibit microbial, chemical and enzymatic activity. It is a process of moisture removal due to simultaneous heat and mass transfer (Babagana *et al.*, 2012). Drying of agricultural products is an essential process in their preservation, which normally provides longer shelf-lighter weight for easy transportation and small space for storage. Drying as a food preservation technique can reduce wastage of a harvest surplus, allow storage to combat food shortages and in some cases, facilitate export to high-value markets (Matthew & Schwarz, 2001).

Direct sun drying method has been practiced since ancient times and it is still being widely used in developing countries (Dhote & Thombre, 2012). Although this method of drying is cheap, it is associated with problems like contamination by foreign materials, dirt, dust and wind blown debris and insect infestation as well as uneven drying. During rainy season, the material cannot be dried to desired safe storage moisture and also may get wet. The poor quality of the dried product cannot be accepted in the world market (Nahar, 2009).

Solar drying results into decreased drying time because the hot air is trapped inside the cabinet. The possibility to preheat air before it enters the cabinet, allows better circulation of dry, hot air around the products. Efficiency is increased due to decreased drying time and higher capacity (Strøm, 2011; Sharma *et al.*, 2009).

This leads to less spoilage of the raw material, caused by shorter post harvest storage. The hygienic conditions are much better, since the system is closed. The fast drying time decreases microbial growth and production of toxic compounds from bacteria and fungi. Degradation of nutrients sensitive to light and high temperature is lower, because of shorter time of heat and light exposure, and no direct sunlight. The look and taste of the products will also be better after a shorter drying time (Strøm, 2011; Sharma *et al.,* 2009).

Mechanical dryers run by fossil fuel or electricity can also be used for drying food products. However, in many rural areas, electricity is either not available or too expensive for drying of vegetables (Nahar, 2009). Mechanical dryers exist in three types namely natural, forced convection and mixed mode types (Nahar, 2009).

Therefore solar drying, which taps on the freely available sun energy, can be utilized while ensuring good product quality via judicious control of the radiative heat (Akarslan, 2012). Therefore, solar dryers can become good substitutes for direct sun drying and mechanical dryers.

Sweet potato (*Ipomoea batatas* (L.) Lam.) is a very important crop in developing world and a traditional, but less important crop in some parts of the developed world. Sweet potato roots are bulky and perishable unless cured. This limits the distance over which sweet potato can be transported economically (FAO, 1990). Moreover, production is highly seasonal in most countries, leading to marked variation in the quantity and quality of tubers in markets and associated price swings (Oke & Workneh, 2013).

Sweet potato is a major staple food and income source in several regions of Tanzania and elsewhere in East Africa and is among under-exploited food crops (Ndunguru, 2003). It is one of the most important food security crops, especially in those regions prone to drought and with poor soils, like Shinyanga and Kagera in Tanzania (FAO, 2004). Sweet potatoes are mainly boiled or roasted and very little attempt has been done to make flour or crisps (Ndunguru, 2003).

Cowpea (*Vigna unguiculata* L. Walp), an annual legume, is one of the most ancient crops known to man (Singh *et al.,* 2003) widely grown and consumed as a basic diet in African region (Oomen & Grubben, 1978). Worldwide, area of production of cowpeas is approximately 10.1 million hectares. Annual global cowpea grain production is approximately 4.99 million tonnes (FAO, 2008). Cowpea is an important food legume and its use as a leafy vegetable is essential in many African countries. The young and tender cowpea leaves are picked and eaten as relish along with the main staples (Mamiro *et al.,* 2011). Cowpea leaves are good source of some amino acids, vitamins, minerals, proteins with higher nitrogen content in the younger leaves. Total dietary fibre content increases with leaf age, but fat and ash contents are less affected (Ahenkora *et al.,* 1998).

1.2 Problem Statement

Malnutrition results directly from inadequate dietary intake and infectious diseases caused by food insecurity at the household, village, community and national levels. Food insecurity is linked to dietary intake, nutritional status, and ultimately to physical health outcomes like child growth morbidity and mortality. In Tanzania, food insecurity is mainly caused by problems related to food production, harvesting, preservation, processing, distribution, preparation and use.

Food losses in the developing world are thought to be 50% for fruits and vegetables and 25% for harvested food grains (Burden, 1989). Losses of vegetables can be caused by several factors, ranging from growing conditions to handling by retailers and consumers (Adeoye *et al.,* 2009). The factors include inadequate harvesting, packaging and handling skills, poor storage facilities and poor transportation to move the food to the market before it spoils (Adeoye *et al.,* 2009). Other factors are refrigerated storage, drying equipment or poor drying season and traditional processing and marketing systems can be responsible for high losses (Adeoye *et al.,* 2009). The losses may either be physiological (wilting, shriveling, chilling injury), pathological (decay due to fungi and bacteria) or physical (mechanical injury), leading to postharvest decay (Atanda *et al.,* 2011).

Post-harvest losses in fresh root/tuber crops have their origin in mechanical damage, physiological processes and infection by decay organisms and occasionally pest infestation (Agriculture and Consumer Protection, 1983). The nutrient content of food, type and level of losses due to processing will be determined by several factors, which include the genetic make-up of the plant or animal, the soil in which it is grown, use of fertilizer, prevailing weather, maturity at harvest, packaging, storage conditions and method of preparation for processing. The storage conditions and handling after processing are also important to the nutritive value of the food. The effect of food processing on nutrient content will depend on the sensitivity of the nutrient to the various conditions prevailing during the process, such as heat, oxygen, pH and light. The nutrient retention may vary with a combination of conditions, such as the characteristics of the food being processed and concentration of the nutrient in the food. For example, vitamin contents of foods are more likely to be affected by processing than the mineral content. During processing and storage of the dried vegetables, beta-carotene is degraded through oxidation reactions (Nyambaka *et al.,* 2012). Storage of the dried vegetables under normal atmospheric conditions results in nutritive degradation, especially of beta-carotene.

Vitamin A deficiency is of public health significance in the developing world. Globally, 140 million children aged <5 years, of whom nearly 100 million live in South Asia or sub-Saharan Africa, have low serum retinol concentrations (<0.7 μmol/L). Countries of eastern and southern Africa have the highest prevalence (37%) of preschool children with low serum retinol concentrations, followed by South Asia (35%) and Western and Central Africa (33%) (Jaarsvel *et al.,* 2005).

In Tanzania, one-third of children aged 6-59 months are vitamin A deficient (after adjusting for infection) (33%). Vitamin A Deficiency (VAD) varies dramatically by region, ranging from 15% of children in Unguja North to 51% of children in Pemba North. The TDHS (2010) found that 37% of women aged 15-49 years are vitamin A deficient (after adjusting for infection).

Women living in urban areas are slightly more likely to be vitamin A deficient than women living in rural areas (40% and 36%, respectively). Small quantity of orange-fleshed sweet potatoes may contain from 300 to over 3,000 μg RE per 100g fresh weight, which can provide the RDAs while also serving as a rich source of other vitamins and nutrients (Woolfe, 1992).

1.3 Justification

Sweet potato is an important staple food crop in Africa. It contains Vitamin A with sufficient quantities of a precursor beta-carotene (Odebode *et al.,* 2008). The three most common strategies for addressing VAD in Tanzania are large scale vitamin A supplementation programmes, food fortification with vitamin A, and food-based approaches that encourage diet diversification and promote consumption of vitamin A rich foods, including bio-fortified foods. Using orange fleshed sweet potato to address VAD is a food-based intervention (Helen Keller International Tanzania, 2012). Vitamin A supplementation to children below 5 years of age started in 1981 in drought stricken regions of Tanzania, done routinely as it is integrated in the government health delivery system and through campaigns twice a year in June and December and to lactating mothers (Mulokozi *et al.,* 2006).

Dark green leafy vegetables such as cowpea leaves (*Vigna unguiculata*), amaranthus (*Amaranthus hybridus (ll)*) and black nightshade (*Solanum nigrum*) are important sources of micronutrients (pro-vitamin A, vitamin C, vitamin E, zinc, iron) and dietary fibre (Nyambaka *et al.,* 2012). Intervention measures used to alleviate vitamin A and iron deficiencies include supplementation and food fortification. However, the best long-term approach is through production and consumption of locally available Vitamin A and iron rich foods. Cowpea leaves have considerable potential to contribute to this food based approach to tackle the problem of vitamin A and iron deficiency, major public health concerns of the poorer sections (Nyambaka *et al.,* 2012; Hagenimana, 2000).

Sweet potato tubers and cowpea leaves have got an important place in fighting VAD, iron deficiency and protein-energy malnutrition. This is because if eaten together in a meal, they supply protein, energy, iron, vitamin A and other needed nutrients on a sustainable basis. Their low price and reliable availability make them an important intervention in tackling rural under-nutrition.

The information and knowledge generated from this study will serve as guide for promoting the consumption and market opportunities for dried orange fleshed sweet potatoes OFSP and cowpea leaves. These in turn will enhance food security and ensure better returns to the farmers upon sale of these dried products.

1.4 Objectives

1.4.1 General objective

To assess the nutrient content of dried orange fleshed sweet potato tubers and cowpea leaves used in Maswa District, Tanzania.

1.4.2 Specific objectives

i. To carry out a baseline study on the current production, processing and consumption practices of orange fleshed sweet potato tubers and cowpea leaves in Maswa district.
ii. To determine the proximate composition of fresh and dried orange fleshed sweet potato tubers and cowpea leaves
iii. To determine beta carotene and mineral content of fresh and dried orange fleshed sweet potato tubers and cowpea leaves.
iv. To determine the effect of storage on beta carotene of dried orange fleshed sweet potato tubers and cowpea leaves (6months).

1.5 Hypothesis

i. Baseline information on orange fleshed sweet potato and cowpea production, processing and utilization varies regionally in Tanzania.

ii. The proximate composition result of fresh and dried orange fleshed sweet potato tubers and cowpea leaves is not similar.

iii. The β- carotene and mineral contents of fresh and dried orange fleshed sweet potato tubers and cowpea leaves is not similar.

iv. The beta carotene of dried orange fleshed sweet potato tubers and cowpea leaves after six months storage is not similar.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Sweet Potato

Sweet potato is a plant that probably originated in or near northwestern South America. This species was first described in 1753 by Linnaeus as *Convolvulus batatas*. However, in 1791 Lamarck classified this species within the genus *Ipomoea* on the basis of the stigma shape and the surface of the pollen grains. Therefore, the name was changed to *Ipomoea batatas* (L) Lam (Huaman, 1992).

Sweet potato (*Ipomoea batatas*) is a perennial tuber. It is a member of the Convolulaceae family, which also contains the morning glory. Flowers can be white or purple, and leaves can be green or purple. Flesh can be white, cream, yellow, orange, or purple (Woolfe, 1992: Bovell- Benjamin, 2007), With orange, white, and cream the most commonly grown and eaten. Both leaves and the tuberous roots are more commonly eaten (Woolfe, 1992: Bovell- Benjamin, 2007). It is extensively grown in the tropical zone, accounting for about 81% of total world production. Sweet potato has the following advantages over other root and tuber crops: low demand on soil nutrient, tolerance of drought and capability of providing reasonable yields in agro-ecological zones where other crops would fail, low requirements for external inputs such as fertilizer and flexibility in planting and harvesting period (Odebode *et al.*, 2008). Due to its versatility and adaptability, sweet potato ranks as the world's seventh most important food crop after wheat, rice, maize, potato, barley, and cassava, as it constitutes a substantial source of carbohydrate and carotene (Classification of Instructional Programs, 2000).

Sweet potato is an important subsistence crop grown in almost all agro-ecological zones of Tanzania (Masumba *et al.*, 2004). It is produced mainly in Shinyanga, Mara, Mwanza, Kagera, Kigoma, Tabora, Morogoro and Mbeya and is the third most important root and tuber crop in the country, after cassava and irish potato (Kapinga *et al.*, 1995). The average yield of sweet potatoes is approximately 5-6 metric tonnes per hectare on dry weight basis. However, the low yield in Tanzania is caused by many factors including susceptibility to pests and diseases, declining soil fertility, moisture stress, and low level of crop husbandry and management and poor accessibility to markets (Ndunguru, 2003). In other parts of the world yields are much higher than this country statistic.

2.1.1 Varieties of sweet potato grown in Tanzania

Due to the differences in agro-ecologies, breeding of sweet potato has been decentralized in major zones. Different institutions, particularly the International Potato Centre (CIP) in collaboration with the National Agricultural Research System have supported research on sweet potatoes in Tanzania (Helen Keller International Tanzania, 2012). This has resulted in the development of genotypes, which are currently at clonal, preliminary and advanced breeding stages and some released. The sweet potato trials are limited to few agro-ecologies in the country such as Lake Zone, Eastern Zone and Zanzibar. However, eight sweet potato varieties (Simama, Juhudi, Sinia, Mavuno, Vumilia, Ukerewe, Kiegea and Mataya), have been released through participatory variety selection between 2002 and 2010 (Helen Keller International,Tanzania, 2012). Many varieties are high yielding with high dry matter but have low beta-carotene levels and have low resistance to pests, and diseases. In response to low beta-carotene, some varieties namely, Zapallo, Japon Tres, Carrot Dar, Resisto, SPK004 (Kakamega), Tainung 65 and *Jewel*1 were introduced by CIP in late 1990 and early 2000. In addition, from 2000 the National Programme embarked on breeding and selection for OFSP, which resulted in the release of Mataya and Kiegea varieties in 2010 (Helen Keller International Tanzania, 2012; MAFC,2010). The OFSP landraces include Carrot C and Mayai (Helen Keller International Tanzania, 2012).

2.1.2 Nutrient content of Orange Fleshed Sweet Potato

Sweet potato tubers are rich in starch, sugars, minerals and vitamins (Table 2.1). Being rich in β-carotene, the orange-fleshed sweet potato is gaining importance as the cheapest source of antioxidant having several physiological attributes like antioxidation, anti-cancer and protection against liver injury and is most suiting as biofortified crop to combat malnutrition in small and marginal farming community (Mitra, 2012). According to Lund and Smooth (1982), tropical fruits and vegetables contribute to dietary fibre and contain 1.4% cellulose, 0.4% lignin and 0.9% hemicellulose of the peel of sweet potatoes. Sweet potato tuber and leaf also contain antinutrients, such as phytates, oxalates and tannins. These antinutrients could affect the digestion and availability of nutrients in the body. However, if exposed to processing and boiling, the levels are reduced and it is rendered to be of no nutritional consequence to the body system.

Table 2.1: Nutritional content of raw sweet potato per 100g

Nutrient (Yellow Variety)	**Amount per 100g**
Energy (Kcal)	110
Moisture (g)	69
Protein (g)	1.6
Fat (g)	0.2
Carbohydrate (g)	28
Fibre (g)	1.2
Calcium (mg)	33
Iron (mg)	2
Folate (mg)	52
Niacin (mg)	0.7
Vitamin C (mg)	37
Beta carotene (µg)	1800

Source, FAO (2001)

2.1.3 Processing of sweet potato into different products

In USA, Japan and India sweet potato is made into bread pudding, casserole, tart, muffins, scalloped sweet potato and refrigerated sweet potato pieces, which are sold in the supermarkets (FAO statistics, 2004). Methods of traditional preparation of sweet potato in sub-Saharan Africa (SSA) are limited to boiling, steaming, roasting and drying (Hall *et al.,* 1998). In Uganda, sweetpotato fresh roots are mainly consumed boiled or steamed (Owori *et al.*, 2007). In the dry season, sweetpotato is stored as *amukeke* (dried sliced storage roots) and *inginyo* (dried crushed storage roots) more so in Northern and Eastern Uganda (Bashaasha & Scott, 2001).

Traditional Tanzanian methods of processing sweet potato are often limited to washing, peeling and boiling. Sweet potato can also be processed by grating, drying and then milling (Schmidt, 2013). In Tanzania, sweet potato is processed into two main products namely, "*michembe*", where the roots are withered, then cut into slices and dried and "*matobolwa*", where the roots are boiled, sliced and dried; both of these products lasting for 5 up to 10 months. Other products that can be prepared from sweet potatoes in Tanzania include cake, chapattis, doughnut, *kalimati*, meal flour, porridge and crisps (Githuki *et al.,* 2005).

2.2 Cowpea Leaves

Cowpea is a *Dycotyledonea* belonging to the order *Fabales,* family *Fabaceae*, subfamily *Faboideae*, tribe *Phaseoleae*, subtribe *Phaseolinae*, genus *Vigna* and section *Catiang* (Verdcourt 1970; Padulosi & Ng 1997). Cowpeas (*Vigna unguiculata* [L.] Walp) are grown most commonly for the edible seeds in Africa and the USA. However, vegetative harvest of cowpeas provides an alternative to conventional cowpea seed harvest (Ahenkora *et al.,* 1998).

Its origin and subsequent domestication is associated with pearl millet and sorghum in Africa. Cowpea is also commonly referred to as southern pea, blackeye pea, crowder pea, *lubia, niébé, coupie or frile*. However, they are all of the species *Vigna unguiculata* (L.) Walp. which in older references may be identified as *Vigna sinensis* (L.).

The largest production is in Africa, largest areas under cultivation being Central and West Africa with Nigeria predominating (Quin, 1997). Other African countries have significant production including, Ghana, Niger, Senegal and Cameroon (Quin, 1997). Outside Africa, the major production areas are South East Asia and Central and South America (Singh & Rachie, 1985; Fery, 2002).

Among African leafy vegetables, cowpea (*Vigna unguiculata*) is one of the highly appreciated species according to a comprehensive survey from four African countries, namely Malawi, Uganda, Rwanda and Tanzania (Weinberger & Msuya, 2004; Keller, 2004) conducted within the collaborative project 'Promotion of Neglected Indigenous Vegetables for Nutritional Health in Eastern and Southern Africa' (ProNIVA). Cowpea leaves are among the top three or four leafy vegetables marketed and consumed in Africa (Mamiro *et al.,* 2011). Cowpea is an important food legume, and its use as a leafy vegetable is essential in many African countries. In eastern Africa, most of the farmers prefer to grow a dual purpose cowpea, whereby both leaves and grains are the final important products. In addition, it is common that many growers who are actually engaged in production prefer the dual purpose cowpea variety: sequentially harvesting leaves along the growing period followed by seed harvest at the end of the season (Saidi *et al.,* 2007).

Its drought tolerance, short growing period and its multi-purpose use make cowpea a very attractive alternative for farmers who cultivate in marginal, drought-prone areas with low rainfall and less developed irrigation systems, where infrastructure, food security and malnutrition are major challenges (Hallensleben *et al.,* 2009). However, despite its regional importance, cowpea's use as leafy vegetable in many African countries has been widely neglected in research and improvement programmes (Schippers, 2000; Barrett, 1990). It can therefore, be considered as underutilized crop. Although lately, some research has been carried out on African indigenous vegetables, especially leafy ones, cowpea research continued to focus on improvements of the grain and/or the entire herbage for animal feed (Singh *et al.,* 2003).

Cowpea is an important grain legume in Tanzania, where its tolerance to moisture stress makes it suitable for cultivation in semiarid areas. Its leaves and seeds are consumed as an important supplement to a staple cereal diet. In Tanzania, cowpea is grown in almost all the areas below 1500 m above sea level (Price *et al.*, 1982).

2.2.1 Cowpea varieties

Domesticated cowpeas are of two types: those from seasonally arid zones, which are short day plants and those from humid tropical regions, which are day neutral and tend to flower later than the short–day types (Quin, 1997). In cowpea production, two main groups of growing habits exists, prostrate or indeterminate type and erect or determinate type and they can be distinguished from one another by different factors such as seed size and colour, taste, yield and time to maturity (Yost & Evans, 1988). In Tanzania, the prostrate types mature in a period of 140 days allowing repeated leaf picking without compromising seed yield, while the erect types take about 80 days to mature, and leaf picking clearly affect seed yield (Keding *et al.*, 2007).

Table 2.2: Examples of cowpea varieties grown in Tanzania

Variety	Altitude recommended (m)	Days to flowering	Grain colour	Grain yield t/ha	Remarks
Fahari	0-1500	50	yellowish brown	2.4	resistant to CYMV
Tumaini	0-1500	48	Cream	2.4	resistant to CYMV and moderately resist to bacterial blight
Vuli 1	0-1500		Red	1.8-2.0	resistant to CYMV and moderately resist to bacterial blight
Vuli 2	below 1500		creamish white	2.0-2.5	resistant to CYMV and bacterial blight; moderately susceptible to pests
Local varieties (landraces)				0.3-0.5	

Source: Kisetu and Assenga (2013).

Cowpea is grown on a wide range of soil as long as the soil is well drained and the plant is acid tolerant to soils with pH 5.5-6.0. Most cowpea cultivars in the tropics and subtropic regions of Africa are grown in humid regions with an annual rainfall varying from 1500-2000mm (Tindal, 1983). In Tanzania, cowpea is grown in almost all the areas below 1500 m above sea level (Price *et al*., 1982). It is usually found intercropped with cereals or other crops, although it is sometimes grown as a monocrop. However, its productivity is limited by high infestation with insect pests, therefore spraying against such pests is important for good yield. Table 2.2 shows the varieties of cowpeas cultivated in Tanzania**.**

2.2.2 Nutrient content of cowpea leaves

Vegetables contain many bioactive compounds and thus serve as an important source of minerals, vitamins and certain hormone precursors, in addition to protein and energy sources (Chote *et al.* (2004) cited by Ilelaboye, 2013). Traditional leafy vegetables are rich in proteins, vitamins A, B and C, as well as minerals like iron and calcium **(**Smith & Eyzaguirre 2007). These make them an indispensable tool when it comes to reducing the prevalence of malnutrition, especially among resource-constrained rural and urban households (Nielson *et al.*, 1997). However, the presence of inherent toxic factors or antinutritional components in plants has been one major obstacle in harnessing the full benefits of nutritional value of plant foods, vegetable inclusive (Liener, 1969). However, boiling and blanching have been highlighted as possible means of reducing the antinutrient levels in plant food sources to innocuous level that can be tolerated by monogastric animal including man (Fasuyi, 2006).

Leaves of cowpea are the source of carbohydrates, proteins, fats, minerals, ß-carotene, and vitamins B and C, which are necessary for maintaining good health (Table 2.3). Cowpea leaves are among the top three or four leafy vegetables marketed and consumed in Africa (Mamiro *et al.,* 2011). A study showed that the levels of tannin and catechin in leaves of cowpea varieties varied from 0.31 to 1.63% and 143.6mg/100ml of leaf sample, respectively (Gatehouse & Bouter, 1983).

Sun drying of cowpea leaves results in reduction of phytate (5.99 to 2.90 mg) and oxalate (4.59 to 1.42mg) (Chikwendu *et al.,* 2014).

Table 2.3: Nutrient content of raw cowpea leaves

Yellow variety	Amount per 100g
Energy (Kcal)	45
Moisture (g)	85
Protein (g)	4.7
Fat (g)	0.3
Carbohydrate (g)	6
Fibre (g)	4
Calcium (mg)	255
Iron (mg)	5.7
Folate (mg)	135
Niacin (mg)	2.1
Vitamin B1 (mg)	0.2
Vitamin B2 (mg)	0.37
Vitamin C (mg)	56
Beta carotene (µg)	700

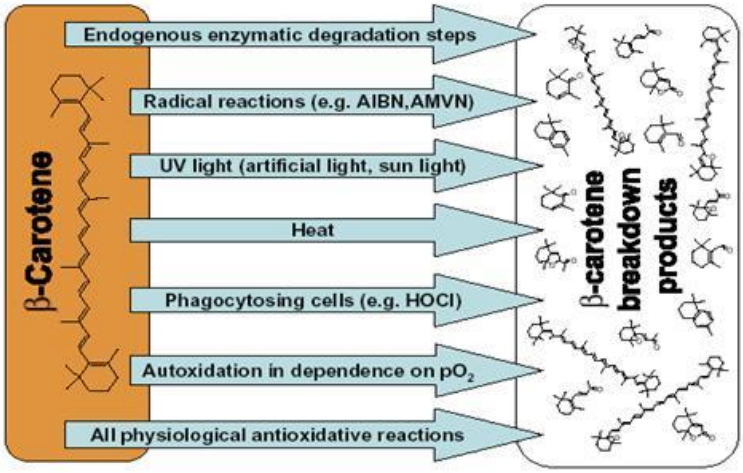
Source: FAO (2001)

2.3 Factors Affecting Degradation of β-carotene

Vitamin A is available in two types in foods, preformed retinol (vitamin A itself) found in animal foods such as eggs, liver, and milk (McLaren & Frigg, 2001) and provitamin A carotenoids found in plant foods such as dark green leafy vegetables, yellow and orange fruits and vegetables, and orange fleshed sweet potato (Mangels *et al.*, 1993). Carrots, sweet potatoes and leafy vegetables contain high levels of β-carotene, usually exceeding 8000 I.U. per 100g and can therefore cover the recommended daily intakes of 5,000 to 25,000 I. U. (Fesco & Boudion, 2002). The carotenoid composition varies with variety, culture, cultivation conditions, state of maturity, post-harvest and storage handling, climate and geographical localization, type of sample and part of plant (Yamini *et al.,* 2001).

The essential role of β-carotene as a dietary source of vitamin A has been known for many years (Britton, 1995). Carotenoids play an important potential role in human health by acting as biological antioxidants (Khalil & Saleemullah, 2004), prevent cancer (Andlauer & Furst, 1999), eye health (Moeller *et al.*, 2000), and atherosclerosis (Dwyer *et al.*, 2001). Some of carotenoids are precursors of the vitamin A synthesis (Humphries *et al.*, 2004). Beta-carotene is the major provitamin A carotenoid and is efficiently converted to retinol. Beta-carotene similarly enhanced both humeral and cell-mediated immune responses (Chew *et al.*, 1991; Britton, 1995; Hinds *et al.*, 1997).

Loss of carotenoids during processing and storage of food has been reported in numerous papers (Amaya, 1997; Rajyalakshmi *et al.*, 2001; Mercela *et al.*, 2003). The main natural causes of losses are oxygen, heat and light. These could play role in breakdown of carotenoids in food products such as sweet potato during drying. Factors leading to the degradation of β-carotene are as illustrated in Fig 2.1**.**



.

Figure 2.1: Factors leading to beta carotene degradation

(Free radical initiators: 2, 2'-azo-bis-isobutyronitril (AIBN); 2, 2'-azo-bis(2,4-dimetylvaleronitril) (AMVN). HOCl: Hypochlorous acid; pO_2: partial pressure in oxygen) (Source: Siems *et al.*, 2005).

Oxidation (enzymatic or non-enzymatic (autoxidation) is considered to be the major cause of loss of provitamin A activity during processing and storage and occurs through a free radical process (Chandler *et al.*, 1988). Free radical reactions are induced by single unpaired electrons that are highly unstable and therefore tend to lead to the destruction of the molecule by a chain reaction. Loss of water during drying has proved to be a risk factor in a free radical process (Chandler *et al.*, 1988). The bleaching process that follows exposure of carotenoids to free-radical species results from the interruption of the conjugated bonds (Krinsky & Yeum, 2003). Enzymatic oxidation easily happens during food preparation, such as cutting, peeling or low temperature heating, because tissue disruption frees enzymes that isomerize and oxidize carotenoids (Bechoff, 2010).

Carotenoids are found in nature as trans-carotenoids. Under stressful conditions such as heating and UV-light exposure, trans-carotenoids are isomerized into cis-carotenoids (9-cis; 13-cis and 15-cis for β-carotene (Figure 2.2) (Bechoff, 2010). Isomerization could be considered as a negative effect of processing since cis-isomers have less provitamin A activity than trans β-carotene (Chandler *et al.*, 1988). In the OFSP variety (*Jewel*), 13-cis was found to be predominant following various processes: blanching, canning, lye peeling, pureeing, dehydrating, microwaving, and baking. The quantity of isomer formed in processed products is related to the heat and length of treatment (Chandler *et al.*, 1988). Isomerization can occur in provitamin A carotenoids at temperatures above 35ºC, 9-cis is predominantly formed above 100ºC whereas 13-cis and 15-cis are formed below 100ºC (Doering *et al.*, 1995). Processes that most induce cis-isomerization in OFSP were: steaming, blanching, pureeing, microwaving, canning, baking and drum drying (Chandler *et al.*,1988). Shade and sun drying did not initiate cis-isomerization on OFSP or leafy vegetables (Bechoff, 2010).

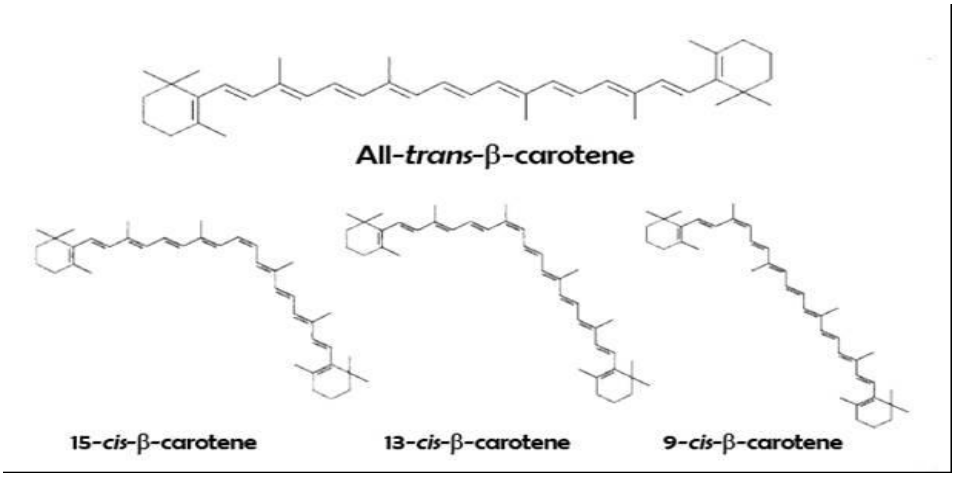


Figure 2.2: Isomers of beta carotene

2.4 Pre-treatments to Limit Provitamin A Degradation

Blanching and the use of additives such as sulphites have the potential to limit provitamin A degradation during drying and storage (Bechoff, 2010). Blanching is a widely used pre-treatment to inhibit or inactivate enzymes that degrade provitamin A. These enzymes include lipoxygenases and peroxidases (Baloch *et al.,* 1997). Other pretreatments include removal of air, hydrolysis and solubilization of pectin (Pradeep & Susanta, 2001). However, blanching has been known to cause an undesirable change in texture and loss of nutrients on account of leaching, especially minerals and the water-soluble vitamins and heat-induced losses (Pradeep & Susanta, 2001).

The efficiency of additives in retaining provitamin A has been reported in various publications. Sulphite acts as an antimicrobial agent and inhibitor of enzymes and nitrosamine formation (Thane & Reddy, 1997). The gas sulphur dioxide (SO_2) or sodium metabisulphite on sun-dried tomatoes results in significantly better colour and carotenoid content (Latapi *et al.,* 2006). The combination of blanching and sulphiting was found to be the most efficient method in terms of the stability of carotenoids in dehydrated carrots (Baloch *et al.,* 1987). However, the use of additives implies extra cost of production of dried products that can make them unsuitable for use at the village level.

Low-Temperature Blanching (LTB), in the temperature range of 55–75°C, has been shown to improve the firmness of cooked vegetables and fruits, reducing physical breakdown and sloughing during further processing and providing an excellent and safe way of texture preservation (Jiwen *et al.,* 2013) . Pectin methylesterase (PME), naturally present in many fruits and vegetables and some tubers including sweet potato, has the potential to play a major role in cell wall strengthening at low blanching temperatures (Helen Keller International Tanzania, 2012; Ni *et al.,* 2005). PME could catalyze the hydrolysis of unesterified carboxyl groups in pectin molecules and induce cross-linking between carboxyl groups and calcium ions (Jiwen *et al.,* 2013).

β-amylase, a heat-activated enzyme contained in sweet potato tissue, can break down starch molecules to maltose and maltodextrins under suitable boiling conditions (Binner *et al.,* 2000). This will lead to a distinctive firm and brittle texture and does not cause cell separation, which goes against the reduction of free starch rate (Binner *et al.,* 2000). In the meantime, polygalacturonase (PG) in sweet potato could catalyze the degrading reaction of pectin, which could weaken the strength and toughness of cell walls, making cell walls easily destroyed during processing. PME, PG and β-amylase are important enzymes in sweet potato tissue concerning cell wall chemistry and tissue texture (Jiwen *et al.,* 2013).

2.5 Drying of Fruits and Vegetables

Preservation methods such as dehydration and fermentation have been utilized for centuries, whereas thermal processing and freezing technologies have developed more recently in the 20th century. Thermal processing is one of the most common current forms of food preservation because it efficiently reduces microbial population, destroys natural enzymes and renders horticultural products more palatable. Most canned and bottled fruits and vegetables are produced under conditions of commercial sterility, and have a shelf life of 2 years or longer.

Thermal processing essentially involves either heating unsterile foods in their final containers (canning), or heating foods prior to packaging and then packaging under sterile conditions (aseptic processing) (Barretta & Lloyd, 2012).

Pre-treatments, together with the drying method and the storage condition influence the quality of dehydrated foods. Among the pre-treatments used in dehydrated vegetables are the addition of chemical compounds, osmotic pre-treatments and blanching (Kasangi, 2010). Drying removes the moisture from the food. Consequently, bacteria, yeast and mould cannot grow and spoil the food. Drying also slows down the action of enzymes (naturally occurring substances, which cause foods to ripen), but does not inactivate them. Food can be dried in the sun, in an oven or in a food dehydrator by using the right combination of warm temperatures, low humidity and air current. In drying, warm temperature cause the moisture to evaporate. Low humidity allows moisture to move quickly from the food to the air. Air current speeds up drying by moving the surrounding moist air away from the food (Mixon, 2009).

2.5.1 Sun drying

Direct sun drying method has been practiced since ancient times and it is still being widely used in developing countries (Nahar, 2009). Sun drying is the most common, economical and environmentally friendly method of preservation of agricultural produces in the tropical and sub-Saharan African regions. However, it has some disadvantages, of which are, undue exposure of produce to weather elements such as rain, ultraviolet rays of the sun and contamination by wind-borne dirt and dust. Others include infestation by pests and other animals as well as degradation by fungi and bacteria. During rainy season, the material cannot be dried to desired safe storage moisture and the material also may get wetted (Adelaja & Babatope, 2013). Very slow drying rates have danger of mould growth and difficulty to dry to a sufficiently low level of moisture to prevent mould growth (Aware & Thorat, 2012).

2.5.2 Solar drying

Solar drying is a continuous process where moisture content, air and product temperature change simultaneously along with the two basic inputs to the systems: the solar insolation and inlet air at ambient temperature (Dulawat & Rathore, 2012).

2.5.2.1 Direct solar drying

The working principle of direct solar crop drying is also known as a solar cabinet dryer. Here the moisture is taken away by the air entering into the cabinet from below and escaping through at the top exit (Visavale, 2012). Direct solar dryers use only the natural movement of heated air (Akarslan, 2012). A part of incidence solar radiation on the glass cover is reflected back to atmosphere and remaining is transmitted inside cabin dryer. Further, a part of transmitted radiation is reflected back from the surface of the product. The remaining part is absorbed by the surface of the material. Due to the absorption of solar radiation, product temperature increases and the material starts emitting long wavelength radiation, which is not allowed to escape to atmosphere due to presence of glass cover unlike open sun drying (Sharma *et al.,* 2009). The direct solar drying is least expensive and simple design although UV radiation can damage food and affect its quality (Mattew & Schwarz, 2001).

2.5.2.2 Indirect solar drying

These differ from direct dryers with respect to heat transfer and vapour removal. The materials in these indirect solar dryers are located in trays or shelves inside an opaque drying cabinet and a separate unit termed solar collector is used for heating of the entering air into the cabinet (Visavale, 2012). The heated air is allowed to flow through/over the wet crop that provides the heat for moisture evaporation by convective heat transfer between the hot air and the wet crop. Drying takes place due to the difference in moisture concentration between the drying air and the air in the vicinity of crop surface (Visavale, 2012). The product is less damaged by extreme temperature and the quality of the product is improved although the process is more complex and expensive (Mwattew & Schwarz, 2001).

2.5.2.3 Hybrid Solar Drying (HBD)

The hybrid solar dryers combine the features of the direct and indirect type solar energy dryers. Here the combined action of incident direct solar radiation and air pre-heated in a solar collector heater produces the necessary heat required for the drying process (Visavale, 2012). Food products are less damaged by temperature although UV radiation can damage food product (Mettew & Schwarz, 2001).

2.5.2.4 Forced convection and natural convection solar dryer

These came under sub-classification in the sense that any of the above mentioned class could be of either forced convection or natural convection design. The forced convection dryer, is designed in such a way that air is forced through a solar collector and the product bed by a fan or a blower, normally referred to as active dryer. In the natural convection solar dryer design, the heated air flow is induced by thermal gradient. It is sometimes called passive dryer because of the natural movement of heated air. Effect of solar dryer may be enhanced by the addition of chimney in which exiting air is heated even more (Babagana *et al.,* 2012).

2.5.3 Freeze drying of food products

Freeze drying is considered to be the best method of food drying from the point of view of product quality. It preserves a very good quality of thermo labile biological products, pharmaceuticals and food products subjected to drying (Stawczyk *et al.,* 2004). When dried by convection at higher temperatures, these products are degraded, change colour and appearance and are characterized by a lower content of vitamins and other nutrients. However, due to deep freezing and low pressures applied the freeze drying is very expensive. So, there is a large class of products for which the application of freeze drying is not economically justified (Stawczyk *et al.,* 2004).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Location of the Study

Maswa District is one of the five districts in Simiyu region in Tanzania. The altitude of the district lies between 1200 and 1300 m above sea level. Maswa has a total of 3,398 square km of which 2,475 square km are suitable for agriculture and livestock keeping. Main food crops are maize, paddy**,** sweet potatoes, cowpeas and millet and the main cash crops are cotton and paddy. The main livestock kept are cattle, goats, sheep and donkey.

3.2 Materials

Four varieties of orange fleshed sweet potatoes (*Kabode*, *Jewel*, *Ejumula* and *Karoti dar*) which are mostly used in Maswa were used in this research. The samples were collected from Ukiliguru Research Centre in Mwanza. The drying process was done to prepare blanched chips, *Matobolwa* and *michembe* of sweet potatoes. Fresh cowpea leaves were purchased at Mawenzi market, sorted and washed. Both dried and fresh samples were analyzed at Sokoine University of Agriculture (SUA) laboratory in Tanzania.

3.3 Methods

3.3.1 Baseline survey

The baseline survey was conducted using questionnaire as in appendix 1. The questionnaire was aiming at collecting information on practices in production, processing and consumption of orange fleshed sweet potato tubers and cowpea leaves in Maswa District. The questionnaire was administered to all members who were provided with orange fleshed sweet potato stem and all members were able to provide the information as indicated in appendix 2.

3.3.2 Research design

Fresh roots were arranged in a line and after five roots the root was picked. The picked roots were peeled, quartered and two opposite sections were combined, fresh cowpea leaves were spread on a table and sampled randomly. The opposite section and picked cowpea leaves were both replicated three times for analysis. The dried samples (cowpea leaves and orange fleshed sweet potato) were grounded and sieved into 1mm sieves and sample was replicated three times during analysis.

In this study Completely Randomized Design (CRD) was used. Maswa district has a total of 26 wards. Baseline survey was conducted within seven wards Nyalikungu, Zanzui, Sukuma, Buchambi, Malampaka, Kadoto and Badi, with a total number of one hundred (100) respondents selected randomly.

3.3.3 Preparation and processing of cowpea leaves

The cowpea leaves were picked randomly to obtain the sample for analysis of beta carotene, proximate and mineral content as shown in appendix 3. The remaining cowpea leaves were divided into two portions. One portion was blanched with boiling water at 90^0C for 5 minutes and another portion was boiled at 90^0c with table salt (2%) for 30 minutes. The blanched and boiled cowpea leaves were each subjected to solar (tunnel dryer maximum temperature 54^0c) drying and open sun drying, respectively. The preparation and nutrient analysis for cowpea leaves were as indicated in Fig 3.1.

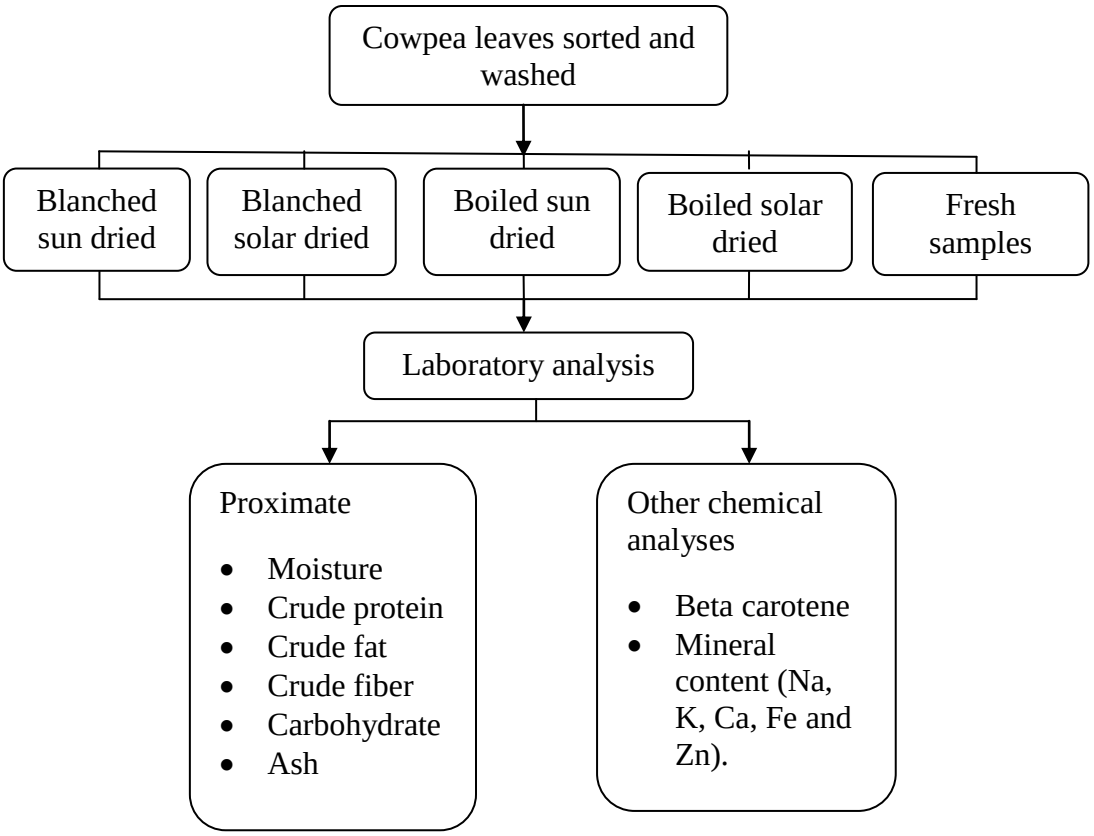


Figure 3.1: Cowpea leaves flow chart

3.3.4 Preparation and processing of Orange Fleshed Sweet Potatoes

Fresh samples of Orange fleshed sweet potatoes (OFSP) were prepared according to the procedure explained by Rodriguez Amaya and Kimura (2004). The fresh roots were arranged in a line and after five roots the root was picked. The picked roots were peeled, quartered and two opposite sections were combined and blended to a fine pulp using a Thermomix multi-purpose household food processor (Vorwerk, Germany). The pulp obtained was used for analysis of beta carotene, proximate and mineral content.

The raw orange fleshed sweet potato varieties remained after picking the samples for fresh sample analysis were washed peeled then sliced into dices (1.5mm). Some sliced pieces were blanched with boiling water at 90^0C for 2 minutes and then solar dried to prepare blanched solar dried chips.

Some of the sliced pieces were sun dried to prepare *michembe* and some roots were boiled at 90^0C for 45 minutes, cooled then sliced to prepare *matobolwa* sun- and solar drying chips. The preparation and nutrient analysed for sweet potatoes are as indicated in Fig 3.2.

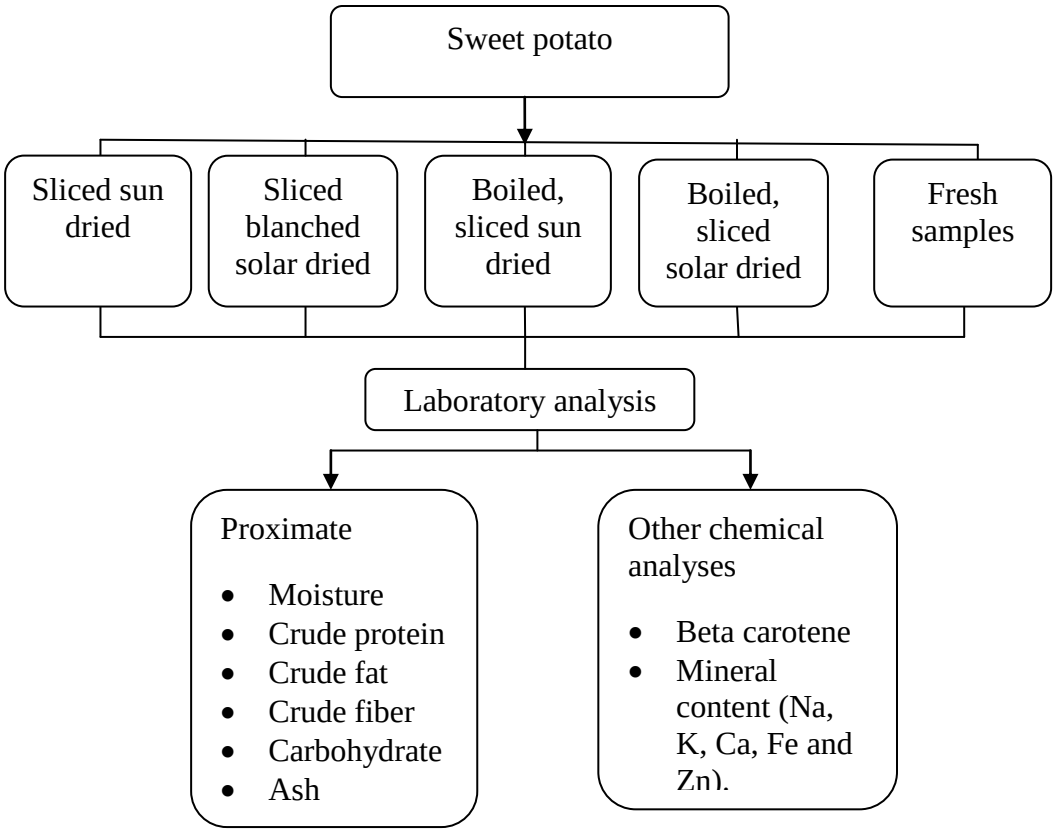


Figure 3.2: Orange fleshed sweet potato flow chart

3.3.5 Shelf life stability

After drying, the samples were divided into three portions. The first portion was analyzed at zero storage for proximate composition, beta carotene and mineral content. The two portions were packed in airtight plastic bags and stored in a box at room temperature. The stored samples were analyzed for beta carotene and moisture content after three and six months.

3.4 Chemical Analysis

3.4.1 Proximate analysis

The proximate content (moisture, carbohydrate, crude fat, ash and crude protein) of fresh and dried sweet potato tubers and cowpea leaves were determined according to Official Methods of Analysis of Association of Official Analytical Chemists (AOAC, 1995).

3.4.2 Determination of beta carotene

About 0.5g of sweet potato was weighed, transferred into a motor. The sample was grounded with 50 ml of acetone (acetone refrigerated at 4^0 C for 2 hours prior to use) being added slowly then filtered using cotton wool plugged into the fume. The extraction was repeated until the sample from the mortar was devoid of colour. About 40 ml of petroleum ether was put in a separating funnel (250 – 500 ml capacity) and acetone was added. Distilled water was added slowly along the neck without shaking to avoid emulsion formation. The two phases were then left to separate and the lower aqueous layer discarded, the sample was washed 3-4 times with distilled water (approx 200 ml) each time to remove residual acetone, in the last phase washing was done ensuring no any amount of the upper phase was discarded. Then the upper layer was collected into 50 ml flask using anhydrous sodium sulphate filter arrangement to remove residual water and the absorbance was determined by using a spectrophotometer (Rodriguez-Amaya, 2001).The absorbance was determined at a wavelength of 450 nm and beta carotene was calculated using the equation of the standard curve.

3.4.3 Determination of mineral content

The analysis of minerals was done according to the AOAC (1995) procedures. The mineral content was determined by the use of Unicam 919 Atomic Absorption Spectrophotometer (AAS). Test portions were dried and then ashed at 450^0C under a gradual increase (about 50^0C/hr) in temperature.

The residue was dissolved in 0.1 N HNO_3 left to dissolve then filtered using a whatman filter paper. The analytes were analysed by flame procedures. The set of instrument was as per the previously established optimum condition / as per the guidelines given in the instruction manual. The absorbance of sample and standard solutions was determined. The standard conditions for Atomic Absorption Spectrophotometer (Element wavelength flame-gases) were: zinc (Zn) 319.9nm, iron (Fe) 248.8nm, potassium (K) 766.5nm and calcium (Ca) 422.7nm. The Standard curve plot of absorbance against the known concentration of standard solutions (0.5, 1, 1.5 and 2.5ppm) was used to determine the concentration of minerals in samples and expressed as in the following formula.

$$\text{Mineral content}\left(\frac{\text{mg}}{100\text{g}}\right) = \frac{\text{Reading value in ppm} \times \text{dilution factor} \times 100}{\text{Sample weight (g)}}$$

3.5 Data analysis

The results of questionnaire were analyzed using SPSS version 16 and Statistical tool R version 3.1.2 was used for the analysis of proximate analysis results, minerals and beta carotene content. One-way ANOVA was used to compare the means and separation of the means was done using Turkey's multiple range tests and the significance was established at $p \leq 0.05$.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Results of Survey Work

4.1.1 Sweet potato

The survey data showed that all of the respondent farmers cultivated and dried local and improved sweet potatoes for future use as food. Other results are as indicated in table 4.1.

Table 4.1: Information collected on sweet potato and percentage respondents during baseline survey

Information collected	Percentage respondents (%)
Drying process	
Boiling then drying	7
Fresh drying	47
Both boiling and fresh drying	46
Preparation of *michembe*	
Wash, peel and wash	2
Wash and peel	25
Peel	73
Drying material	
Mat	17
Sack	4
On bare ground	49
Others e.g. top of the building, iron sheet	30
Storage facilities	
Hessian bags	64
On a bare floor	4
Sack	32
Preference of dried chips form	
matobolwa	6
michembe	20
Both *matobolwa* and *michembe*	74
Use of orange fleshed sweet potato flour to make baked product and porridge	
Yes	5
No	95

According to famers, *michembe* will be shelf stable for 3-5 months while *matobolwa* will be shelf stable for more than a year .Therefore, insecticides used to preserve other crops like maize are also used in *michembe* to prolong shelf life. Processing of *michembe* involved drying of sweet potato roots for about two hours, peeling, slicing and finally drying.

Pre drying facilitate peeling, reduce thickness of peels and breakages during slicing of tubers. *Matobolwa* involved boiling of tubers with or without peels, cooling, peeling, slicing then drying.

Generally, the orange fleshed sweet potatoes have been positively accepted by a large percentage of the population in Maswa district. However, some of the farmers pointed out that OFSP have an unpleasant smell, which results into poor acceptability by adults. The respondents were not aware of the nutritional benefits of orange fleshed sweet potatoes. Being a community where many forms of malnutrition exist, information on the nutritional benefits of OFSP could form the basis for intelligent interventions towards mitigating the problems.

4.1.2 Cowpea leaves

Of the 100 famers interviewed all dried and cultivated local varieties of cowpeas. Other results are as indicated in table 4.2.

Generally, respondents concluded that the processing of dried cowpea leaves (*shiiri* or *mkalango*) have the following common procedures. The cowpea leaves were picked, sorted, dried for about half an hour to wilt and then moulded into small balls. After moulding the leaves were boiled with salt or sodium bicarbonate. When leaves are ready they are removed from the water, left to cool (mostly overnight) and during the morning the cooked leaves are dried on the drying surface mostly rocks (*matale*).

Table 4.2: Information collected on cowpea leaves and percentage respondents during baseline survey

Information collected	Percentage respondents (%)
Which part of cowpea do you consume	
Leaves	4
Tender peas	1
Leaves and grains	41
Leaves, grains and tender pods	20
Leaves, grains and tender peas	34
Preference of cowpea leaves	
Dried form	3
Fresh and dried form	97
Pre treatment of cowpea leaves	
Sorting, washing then drying	17
Sorting then drying	83
Drying material	
On bare ground	14
On the ground on a mat	18
On a raised platform	1
On rocks	59
Others	8
Storage facilities	
Plastic bags	64
Sack	32
On the floor	4

4.2 Experimental Results

4.2.1 Orange Fleshed Sweet Potato

4.2.1.1 Moisture content of orange fleshed sweet potatoes

In this study, the results showed that there were significant differences ($p<0.05$) in moisture content between fresh and dried orange fleshed sweet potato samples (Table 4.3). The moisture content of fresh orange fleshed sweet potatoes were *Jewel*, 70.37 ± 0.17, *Kabode* 65.39 ± 0.1, *Karoti dar* 65.06 ± 0.15 and *Ejumula* 64.53 ± 0.32. The differences in moisture content observed are due to the amount of dry matter content contained in varieties studied. The moisture content of all dried chips of OFSP varieties were below 13%, implying that they could be stored safely for some period.

Wenkam (1983) indicated that fresh sweet potato had a moisture content of 87.8% while Ingabire and Vasanthakaalam (2011) reported the moisture content of studied sweet potato varieties ranging between 62.58 ± 0.42% and 64.34 ± 0.42%. Vimala *et al.* (2011) reported the moisture content of the studied varieties ranged from 75 to 80%. The moisture content of the varieties studied showed positive relationship with the flesh colour. This is in agreement with the study of Vimala *et al.* (2011) and Jones (1977). The differences in the moisture content among the sweet potato varieties can be attributed to the difference in the genetic composition, stage of maturity and also the agricultural practices gaps between harvesting time and analysis.

Table 4.3: Results of proximate analysis of orange fleshed sweet potatoes in fresh weight basis

Variety/Treatment	Moisture (%)	Fat (%)	Fibre (%)	Protein (%)	Ash (%)	CHO (%)
Jewel						
Fresh	70.37±0.17^{d}	1.67± 0.08^{d}	3.6±0.08^{a}	1.87 ±0.08^{a}	4.18±0.07^{d}	18.31±0.07^{a}
Blanched solar dried	12.1±0.45^{c}	0.98±0.08^{ab}	4.65±0.05^{c}	6.78±0.52^{b}	2.56±0.05^{b}	72.93±0.58^{b}
Matobolwa solar dried	11.32±0.16^{b}	1.004±0.12^{bc}	5.53±0.19^{d}	6.96±0.73^{b}	2.12±0.19^{a}	73.07±0.44^{b}
Matobolwa sun dried	10.70±0.21^{b}	0.82±0.001^{a}	6.07±0.20^{e}	5.76±0.84^{b}	1.95±0.07^{a}	74.69±0.58^{c}
Michembe	9.29±0.33^{a}	1.18±0.02^{c}	4.01±0.01^{b}	5.88±0.26^{b}	3.26±0.22^{c}	76.39±0.38^{d}
Karoti dar						
Fresh	65.06±0.15^{d}	1.6±0.07^{c}	3.25±0.01^{a}	2.7±0.41^{a}	3.54±0.12^{c}	23.81±0.37^{a}
Blanched solar dried	11.78±0.20^{c}	0.56±0.01^{a}	3.22±0.02^{a}	5.08±0.69^{b}	2.52±0.11^{ab}	76.84±0.61^{b}
Matobolwa solar dried	10.90±0.38^{b}	0.78±0.06^{ab}	4.27±0.24^{c}	5.65±0.16^{bc}	2.53±0.13^{ab}	75.86±0.3^{b}
Matobolwa sun dried	10.40±0.16^{b}	1.05±0.16^{b}	3.74±0.11^{b}	6.24± 0.33^{b}	2.29±0.03^{a}	76.27±0.36^{b}
Michembe	6.23±0.09^{a}	1.83±0.18^{c}	3.33±0.13^{a}	6.88±0.44^{cd}	2.58±0.08^{b}	79.15±0.42^{c}
Kabode						
Fresh	65.39±0.10^{d}	1.14±0.02^{a}	2.98±0.05^{a}	2.2± 0.05^{a}	3.54± 0.11^{c}	24.80±0.11^{a}
Blanched solar dried	9.64± 0.23^{c}	1.92± 0.02^{b}	4.66±0.09^{c}	9.29± 0.88^{d}	2.13±0.07^{a}	72.36±0.85^{b}
Matobolwa solar dried	8.33 ±0.04^{ab}	1.93± 0.07^{b}	4.76±0.04^{c}	8.01±0.31^{c}	2.02± 0.09^{a}	74.94±0.33^{c}
Matobolwa sun dried	8.84± 0.24^{b}	1.73±0.03^{b}	4.12±0.18^{b}	7.58±0.47^{c}	2.10±0.10^{a}	75.62±0.29^{c}
Michembe	8.10± 0.32^{a}	1.61± 0.28^{b}	3.19±0.18^{a}	5.48± 0.06^{b}	3.23± 0.02^{b}	78.39±0.50^{d}
Ejumula						
Fresh	64.53±0.32^{c}	1.11±0.06^{a}	3.41±0.02^{a}	2.09±0.05^{a}	2.77±0.01^{d}	26.08±0.04^{a}
Blanched solar dried	10.73±1.38^{ab}	1.48±0.31^{a}	4.39±0.13^{c}	5.37±0.22^{b}	2.42±0.03^{b}	75.61±0.34^{c}
Matobolwa solar dried	12.01±2.17^{b}	1.40± 0.28^{a}	4.74±0.25^{d}	6.94±0.27^{c}	2.13± 0.04^{a}	72.79±0.65^{b}
Matobolwa sun dried	10.37±1.49^{ab}	1.82± 0.47^{a}	4.82±0.04^{d}	5.96±1.02^{bc}	2.20±0.03^{a}	74.84±1.47^{bc}
Michembe	6.99±1.97^{a}	1.26± 0.03^{a}	3.77±0.03^{b}	4.89±0.49^{b}	2.69±0.02^{c}	80.33±0.53^{d}

Values are means ± SD. Means in the same column bearing different superscripts are significantly different ($p<0.05$). (Blanched solar dried = blanched then solar dried, *Matobolwa* solar dried =boiled then solar dried and *Matobolwa* sun dried= boiled then sundried and *Michembe* = fresh dried chips).

4.2.1.2 Protein content of orange fleshed sweet potatoes

The results of protein content of all varieties of orange fleshed sweet potato studied (Table 4.3) shows that there were significant differences between fresh and dried samples ($p<0.05$). The orange fleshed sweet potato varieties studied behaved differently on treatment subjected as indicated on Table 5. For *Jewel* variety, the treatments subjected to the samples before drying indicate no significant effect on the protein content, although solar dried samples showed higher values (6.78±0.52 and 6.96±0.73g/100g blanched and *matobolwa* respectively) compared to sun dried samples (5.76±0.84 and 5.88±0.26g/100g *matobolwa* and *michembe* respectively). For *Kabode* variety, solar dried samples had significantly higher values (8.01±0.31and 9.29± 0.8816g/100g blanched and *matobolwa,* respectively) than sun dried samples (5.48± 0.06 and 7.58± 0.47g/100g *matobolwa* and *michembe* respectively).

In *Karoti dar*, it was observed that sundried samples had highest protein content (6.88±0.44 and 6.24±0.33g/100g for *matobolwa* and *michembe*, respectively) compared to solar dried samples 5.08±0.69 and 5.65±0.16g/100g for blanched and *matobolwa*, respectively). For *Ejumula*, *matobolwa* samples showed significantly higher value of protein content (6.94±0.27 and 5.96±1.02 g/100g for solar and sun dried samples, respectively) than blanched samples (5.37±0.22) and *michembe* (4.89±.49 g/100g).

The results showed that the protein content of fresh samples in all varieties studied ranged between 1.87 ± 0.08 and 2.7±0.41g/100g fwb. The results obtained were consistent with previous studies (Villareall *et al.* (1979), Senanayake *et al.* (2013)). Some studies report sweet potato to have low value of protein content (FAO, 2001) and Tumuimbise *et al.*, 2013). Deviation with some of the literature results may be due to varieties or clones used in the specific study. The significant amount observed in dried samples (4.89±0.49 to 9.29± 0.88) could be explained by the fact that during drying, food loses a significant amount of moisture, which results in increasing the nutrients content in the remaining mass.

Idowu *et al.* (2012) reported the protein content of OFSP flour was 5.5±0.01 which was almost the same as the value obtained on dried chips. Sun dried samples was observed to have reduced crude protein content due to protein denaturation and prolonged drying whereby the same reason was reported by different researchers (Seidu, *et al.*, 2012: Eric, 2013: Olapade & Ogunade, 2014).

4.2.1.3 Fat content of orange fleshed sweet potatoes

The results showed that among the varieties studied, three of them (*Jewel*, *Kabode* and *Karoti dar*) showed significant difference in fat content between fresh and dried samples (Table 4.3) ($p<0.05$). For *Jewel* variety, *michembe* showed highest value (1.18±0.02g/100g, fwb). In *Kabode* variety, it was observed that there was no significant difference in all dried samples although solar dried samples had higher value than sundried sample. In *Ejumula* variety there was also no significant difference between fresh and dried samples, the fresh samples having the lowest value when compared with the dried samples.

In this study the fat content of sweet potato varieties ranged between 1.11±0.06 and 1.67±0.08g/100g for fresh samples and 0.56±0.01 to 1.93± 0.07g/100g for dried samples. According to Paul and Southgate (1979) fat content of fresh sweet potato was 0.6 g/100g, Tumuimbise *et al.* (2013) reports 0.17g/100g and FAO (2001) reports 0.2 g/100g. The fat contents of fresh samples were generally higher than literature values and this will be due to varieties differences.

4.2.1.4 Fibre content of orange fleshed sweet potatoes

The varieties studied shows that there was significant difference between fresh and dried samples in crude fibre content ($p<0.05$) table 4.3. Three varieties *Jewel*, *Karoti dar* and *Ejumula* indicated that *matobolwa* have significant highest value compared to *michembe*. For *Kabode*, solar dried samples showed significantly higher value compared to sun dried samples.

In this study the fibre content of sweet potato varieties ranged between 2.98±0.05 to 3.6±0.08g/100g of fresh samples and dried samples ranged between 3.19±0.18 to 6.07±0.20g/100g.

Pectin, cellulose, hemicelluloses together with lignin are classified as dietary fibre (Robinson & Lawler, 1980). Dietary fibre has recently gained much importance as it is said to reduce the incidences of colon cancer, diabetes, heart disease and certain digestive diseases (Ingabire & Vasanthakaalam, 2011). The results obtained from this study are comparable to those of the study of Senanayake *et al.* (2013) reported the crude fiber was 2.1±0.2 g/100g, Oomen and Gruber (1978) reported 3.9g/100g, Huang *et al.* **(**1999) reported 2.01–3.87 g/100 g, FAO (2001) reported 1.2 g/100g and Ingabire and Vasanthakaalam (2011) reported 0.11-0.14 g/100g for the varieties studied. The dried samples indicated higher values compared to fresh samples due to the fact that during drying, food loses a significant amount of moisture, which results in increasing the nutrients content in the remaining mass.

4.2.1.5 Total ash content of orange fleshed sweet potatoes

For all varieties studied, the ash content was significant different between fresh and dried samples ($p<0.05$) as presented in Table 4.3. All varieties studied show that for dried samples *michembe* had highest significant value compared to *matobolwa*.

Goodbody (1984) reported the total ash content in fresh sweet potato as 1.7%. Ingabire and Vasanthakaalam (2011) in their study obtained the ash content ranging between 0.40 ± 0.02 to 0.44 ± 0.07%. Idowu *et al.* (2012) they reported the ash content of OFSP flour was 1.67±0.2%. According to literature, the values obtained in this study are high and could be accounted for by varietal differences. The lowest value was observed in boiled and blanched solar dried samples believed to be caused by leaching during blanching and boiling.

4.2.1.6 Carbohydrates content of orange fleshed sweet potatoes

Among the sweet potato varieties studied, the carbohydrates content shows significant difference between fresh and dried samples ($p<0.05$) (Table 4.3). Fresh dried showed high significant values compared with other dried samples in all varieties studied. The carbohydrate content of fresh samples ranged between 18.31±0.07 and 26.81±0.34g/100g and for dried samples it was 72.36±0.85 to 80.33±0.53 g/100g.

Wenkam, (1983) reported that fresh sweet potato contained 27 g/100g carbohydrates. FAO (2001) reported 28 g/100g for fresh samples. The results of this study were low compared to literature values. This could have been caused by factors like variety, and stage of maturity of the root.

4.2.1.7 Beta carotene content of orange fleshed sweet potatoes

This study revealed that β-carotene contents of Orange fleshed sweet potato (OFSP) varieties were significantly higher ($p<0.05$) for fresh than for the dried samples (Table 4.4). Fresh samples had 24.21±1.52 to 73.92±5.84mg/100g, while dried samples had 8.21±0.52 to 59.77±0.04mg/100g fwb. Pretreatment conditions resulted in reduction in beta carotene content in all cases. Considering fresh samples, *Jewel* had the highest β- carotene content, 2-3 fold higher than any of the other varieties. Of all the samples, *michembe* showed the lowest β- carotene content. For *Jewel* and *Karoti dar* varieties, *matobolwa* results showed that there was no significant difference between solar and sun dried samples although solar dried samples showed relatively higher values than sun dried. *Kabode* and *Ejumula* indicated that solar dried *matobolwa* had significantly higher values compared to sun dried *matobolwa*.

Table 4.4: Beta carotene content of orange fleshed sweet potato varieties in mg/100g in fwb

Variety/ Treatment	Jewel	Karoti Dar	Kabode	Ejumula
Fresh	73.92±5.84^{d} (100)	32.11±0.52^{c} (100)	24.21±1.52^{b}(100)	31.35±0.07^{d} (100)
Blanched solar dried	52.38±0.51^{b} (71)	19.77±0.06^{b} (62)	22.37± 0.01^{b} (92	21.02 ±0.08^{b} (67)
Matobolwa solar dried	59.77±0.04^{c} (81)	19.20±0.04^{b} (60)	28.03±0.68^{c} (116)	31.51±0.47^{d} (101)
Matobolwa sun dried	59.60±0.05^{c} (81)	18.42± 0.55^{b} (57)	23.09± 0.64^{b} (95)	28.69±0.69^{c} (92)
Michembe	39.88±0.99^{a} (54)	14.78± 1.58^{a} (46)	8.21 ±0.52^{a} (34)	18.07±0.75^{a} (58)

Values are means ± SD. Means in the same column bearing different superscripts are significantly different ($p<0.05$). Values in brackets are percentage retentions.

The results of all varieties obtained in this study compare well with findings reported by other researchers. Takahata *et al.* (1993) reported that β-carotene content of sweet potato ranged between 0.01 and 26.6 mg/100g (fwb). Hagenimana *et al.* (1999) reported β-carotene level of 11.8 mg/100 g in the variety Xushu 18.

Burgos *et al.* (2001) indicated percentage β-carotene content ranged between 4.29 and 18.55 mg/100g in deep orange coloured sweet potatoes. Teow *et al.* (2007) reported a value of 9.230 mg/100g for the main USA variety Beauregard, Sunette (2010) found values of beta carotene ranged between 0.009 mg to 20.525 mg in orange variety in South Africa. The study conducted by Mitra (2012) in India indicated that the beta carotene content of orange fleshed sweet potato varieties studied ranged between 2.58 to 9.74 mg/100 g. These sources clearly show the wide variation existing between different types of OFSP.

Other researchers reported lower values as compared to this study: Tumuimbise *et al.* (2013) reported β- carotene content of their study to range between 0.254 ± 3.84 and 0.181± 2.64mg/100g for *Ejumula* and Kakamega, respectively. Leighton (2007) reported OFSP can provide up to 6.528 mg percent of this provitamin. The study conducted by Ingabire and Vasanthakaalam (2011) reported percentage β-carotene of sweet potato varieties ranging between 1.68 and 1.85 mg/100g. These points to varietal differences in the β- carotene content of OFSP.

The β-carotene content may be affected by many factors; among them including, variety, growing conditions, stage of maturity, harvesting and post-harvest handling, processing and storage of OFSP (Mbwaga *et al.,* 2007; Rodriguez-Amaya, 2000), air and soil temperature, radiation, location, soil moisture and fertilization (K'Osambo *et al.,* 1998). Ukom *et al.* (2009) reported nitrogen fertilizer improved beta carotene content of sweet potato. Environmental conditions, genetic factors, crop age and cultivation management strategies can significantly influence the beta-carotene content of varieties (K'Osambo *et al.,* 1998). High irrigation levels were found to decrease beta-carotene content of sweet potatoes (K'Osambo *et al.,* 1998).

The retention of beta carotene of sweet potato varieties studied was to a large extent dependent on variety. Blanching resulted in more retention in *Kabode* (92%), *Jewel* (71%), *Ejumula* (67%) and *Karoti dar* (62%). Retention of beta carotene in *michembe* was *Ejumula* (58%), *Jewel* (54%), *Karoti dar* (46) and *Kabode* (34%) and beta carotene retention in *matobolwa* depended on the drying method used.

According to Vimala *et al.* (2011), sun drying was observed to retain 63-73% beta carotene content in OFSP. Sun drying also caused pro-vitamin A reduction of 16 - 34 % (Bechoff *et al.,* 2009; Hagenimana *et al.,* 1999). Bengsston *et al.* (2008) reported loss of all trans-beta carotene by oven drying at 57°C for 10 hours was 12%, solar drying was 9% and sun drying loss was 16%.

Boiling and processing have a degrading effect on beta-carotene content. In general, retention of beta-carotene content decreases with longer processing time, higher processing temperatures, cutting and maceration of foods (Rodriguez-Amaya, 1997; Sunette, 2010). The influence of different processing procedures on the carotene content of orange-fleshed roots has been reported in sweet potato (Huang *et al.,* 1999), carrots (Debjani *et al.,* 2005), and cassava (Chave`z *et al.,* 2007). Some of varieties indicate that boiling has an effect on the beta carotene content. According to Rodriguez-Amaya (2001), carotenoids cannot be biosynthesized during boiling. Heat treatment inactivates enzymes responsible for carotenoid biosynthesis and stimulates isomerization and oxidative degradation of carotenoids.

The increases may be due to appreciable leaching of soluble solids resulting in concentrating the carotenoids per unit weight of food (Rodriguez-Amaya, 2001).

Analysis of fresh and processed samples may introduce further variability of the results due to difficulties in achieving a complete extraction of carotenoids and during transferring of extract from the mortar to the separating funnel. Others may be due to difference in experimental condition and extraction procedures. Moreover, enzymatic oxidation of carotenoids can substantially lower their concentrations in raw samples, especially when these samples are left standing for some time after being cut or grated.

The study revealed that, among the two dried products studied, *matobolwa* behaved significantly different on sun and solar drying. For *Jewel* and *Karoti dar* variety, it was observed that there was no significant difference in beta carotene content between *matobolwa* solar dried and sun dried samples although *matobolwa* solar dried indicated relatively higher values.

Kabode and *Ejumula* revealed that there was a significant difference in beta carotene content between *matobolwa* solar dried and sun dried chips. The observed characteristics could be a result of size of the chips and the time dried chips awaited before analysis. Also, *michembe* samples had poor retention of beta carotene both on drying and storage in comparison with *matobolwa*.

4.2.1.8 Effect of storage on beta carotene content of sweet potato varieties

Results indicated that orange fleshed sweet potato varieties varied significantly in their beta carotene content and retention capabilities as indicated in table 4.5. Generally, all varieties studied indicate that there was a significant difference in β-carotene content with progression in storage times. Fresh dried started to be infested by insect pests after four months of storage. Although infested, the beta carotene content after six months was in the range between 1.02±0.08 (*Ejumula*) to 5.44±0.24mg/100g (*Jewel*). By looking, the strength of orange colour of dried chips had been reduced.

Beta carotene is lost not only during processing but also during the storage of processed chips. According to Hagenimana *et al.* (1999) storage of sweet potato chips for 11 months in opaque bags under ambient air conditions reduced total carotenoids content between 59 and 70 %. The study on storage of other products also indicated loss on beta carotene, Cha'vez *et al.* (2007) found that sun-dried chips of cassava stored for 4 weeks results into beta carotene content reduction from 37.9 to 18.4%.

Table 4.5: Beta carotene retention after six months storage

Variety/treatment	0 months	3months	6months
Jewel			
Blanched solar dried	52.38±0.51^{b}	42.24±2.24^{a}	40.21 ±1.00^{a}
Matobolwa solar dried	59.77± 0.04^{c}	49.22±0.07^{b}	37.32±0.47^{a}
Matobolwa sun dried	59.60± 0.05^{c}	46.91±0.05^{b}	31.75±0.26^{a}
Michembe	39.88±0.99^{c}	14.43± 0.74^{b}	5.44 ±0.24^{a}
Karoti dar			
Blanched solar dried	19.77±0.06^{c}	7.53 ±0.53^{b}	5.83± 0.19^{a}
Matobolwa solar dried	19.20±0.04^{c}	7.14±0.29^{b}	5.76±0.09^{a}
Matobolwa sun dried	18.42± 0.55^{c}	14.29± 0.01^{b}	10.56± 0.16^{a}
Michembe	14.78± 1.58^{c}	8.23±0.55^{b}	2.25± 0.04^{a}
Kabode			
Blanched solar dried	22.37± 0.01^{c}	15.80± 0.37^{b}	12.94±0.05^{a}
Matobolwa solar dried	28.03±0.68^{c}	21.68±0.30^{b}	9.98±0.41^{a}
Matobolwa sun dried	23.09± 0.64^{c}	20.72± 0.26^{b}	7.59± 0.20^{a}
Michembe	8.21 ±0.52^{c}	4.19± 0.27^{b}	2.18 ±0.04^{a}
Ejumula			
Blanched solar dried	21.02±0.08^{c}	16.41±0.06^{b}	10.50±0.41^{a}
Matobolwa solar dried	31.51±0.47^{c}	25.32±0.49^{b}	18.65±0.09^{a}
Matobolwa sun dried	28.69±0.69^{c}	21.69±0.30^{b}	18.09±1.08^{a}
Michembe	18.07±0.75^{c}	3.13±0.18^{b}	1.02±0.08^{a}

The values are means ± SD. Means in the same rows bearing different superscripts are significantly different ($p<0.05$). (Blanched solar dried = blanched then solar dried, *Matobolwa* solar dried =boiled then solar dried and *Matobolwa* sun dried= boiled then sundried and *Michembe* = fresh dried chips).

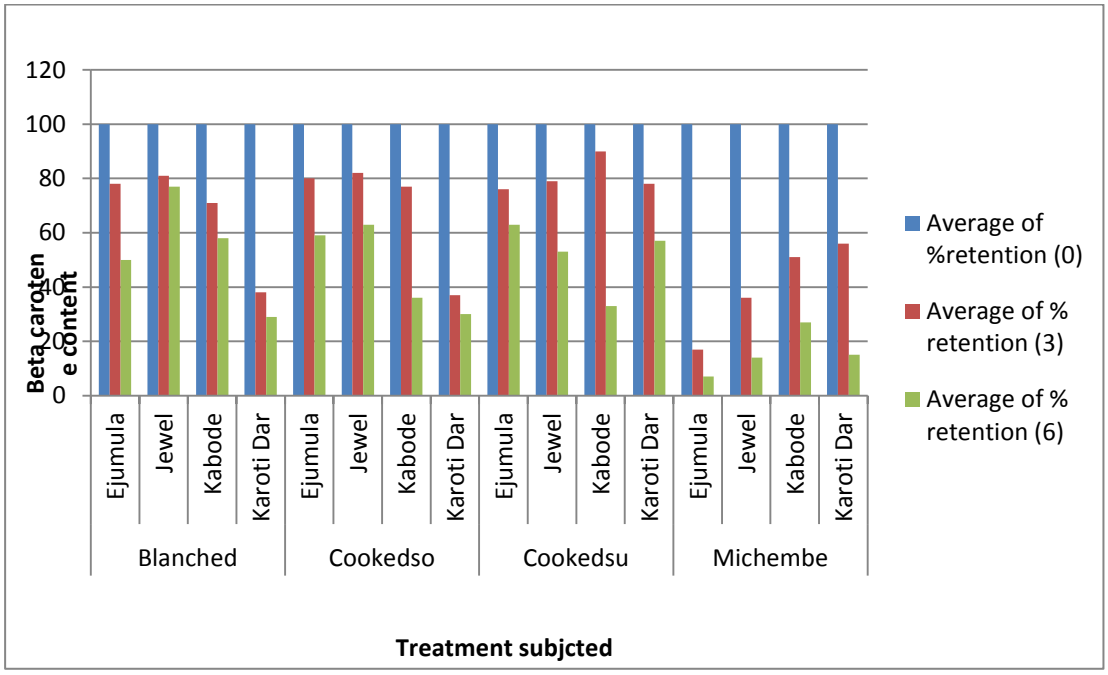


Figure 4.1: Percentage beta carotene retention after six month storage

The effect of storage on beta carotene of the three products (blanched solar dried, *matobolwa* (solar and sun dried) and *michembe)* for the four varieties studied was as seen in Fig 4.1. The loss of beta carotene content was dependent on the variety and treatments. For Blanched solar dried chips *Jewel* had more retention, followed by *Kabode*, *Ejumula* and *Karoti dar*. *Michembe* of *Kabode* had higher retention than *Jewel*, *Karoti dar* and *Ejumula*. *Ejumula* and *Jewel matobolwa* solar dried had higher value than *Kabode* and *Karoti dar*. For sundried *matobolwa*, *Ejumula* and *Karoti dar* had higher value than *Jewel* and *Kabode*. Blanched solar dried and *matobolwa* (solar and sun dried) chips had higher retention than *michembe*, for both varieties. Blanched solar dried for *Ejumula*, *Jewel* and *Kabode* were the best treatment for beta carotene retention on storage while *Karoti dar* had the poorest retention.

4.2.1.9 Mineral content of sweet potatoes in mg/100g DM

Results indicated that there was a significant difference in mineral content analyzed, between fresh and dried OFSP varieties ($p<0.05$) (Table 4.6). Fresh samples had significantly low values of sodium, calcium, potassium, iron and zinc compared to dried samples.

Calcium content ranged between 122.72- and 283.48, Potassium 152.73 and 413.61, Sodium 100.35 and 179.63, Zinc 0.09 and 0.29 and Iron 0.02mg/100g in fwb for varieties of sweet potato studied.

Different studies reported that Calcium (Ca) in sweet potatoes ranged between 7-85 mg/100g and level of Iron (Fe) was 0.16-2.11mg/100g (Woolfe, 1992; Abubakar *et al.*, 2010; Sunette, 2010). Calcium content ranged between 18.50-27.35mg/100g, iron content ranged between 1.03-1.4 mg/100g and Potassium content ranged between 10.4-168.38 mg/100g of varieties of sweet potatoes studied in Vihiga County Kenya (Aywa, *et al.*, 2013).

The variation of mineral content in this study could be a consequence of level of minerals in the soil, variety used and effect of processing. Boiling and washing is known to result in leaching of minerals although in this study the effect was not experienced. The reason could be the use of tap water and table salt during boiling.

Table 4.6: Results of mineral content of OFSP in fwb

Variety/ treatment	Calcium (mg/100g)	Potassium (mg/100g)	Sodium (mg/100g)	Iron (mg/100g)	Zinc (mg/100g)
Jewel					
Fresh	188.18± 29.06^{a}	413.61± 9.70^{a}	179.62±3.73^{a}	0.02±0.00^{a}	0.18± 0.01^{a}
Blanched	266.84±2.46^{c}	830.33±49.26^{b}	266.75±14.60^{b}	2.14 ±0.18^{b}	0.598± 0.06^{c}
Matobolwa solar dried	254.43± 10.42^{c}	1150.25±24.88^{c}	211.16± 2.54^{a}	2.55± 0.21^{b}	0.33±0.03^{b}
Matobolwa sun dried	199.07± 9.96^{b}	825.99±26.37^{b}	315.59±18.82^{c}	2.51 ±0.29^{b}	0.38±0.02^{b}
Michembe	296.24±13.07^{d}	790.03±24.28^{b}	339.12±17.02^{c}	5.10±0.23^{c}	0.64± 0.03^{c}
Karoti dar					
Fresh	175.61 ±3.2^{a}	223.68 ± 3.39^{a}	100.35±1.78^{a}	0.02±0.00^{a}	0.29±0.01^{a}
Blanched	197.67±7.37^{a}	368.87±14.92^{b}	180.26±4.64^{bc}	1.74±0.22b^{bc}	0.62±0.03^{b}
Matobolwa solar dried	321.09 ±2.89^{b}	415.85 ±16.59^{c}	173.11±7.38^{b}	1.19±0.07^{b}	0.59±0.05^{b}
Matobolwa sun dried	365.33±16.92^{c}	421.14±6.67^{c}	193.41±3.92^{c}	2.28±0.39^{cd}	0.78 ±0.01^{c}
Michembe	324.93±14.09^{b}	397.78±26.74^{bc}	244.74±7.86^{d}	2.50±0.30^{d}	0.67±0.04^{b}
Kabode					
Fresh	122.72±2.54^{a}	285.37±5.11^{a}	102.33± 0.98^{a}	0.02±0.00^{a}	0.28 ±0.01^{a}
Blanched	220.32±7.17^{d}	463.13 ±12.63^{c}	133.52±5.05^{bc}	1.40 ±0.14^{b}	0.59±0.02^{cd}
Matobolwa solar dried	181.78±4.17^{c}	471.46± 10.57^{c}	148.16± 4.88^{c}	2.72± 0.21^{d}	0.54± 0.03^{c}
Matobolwa sun dried	136.45±2.07^{b}	485.67±20.19^{c}	122.88±8.86^{ab}	0.20±0.02^{a}	0.43±0.01^{b}
Michembe	132.25± 1.65^{ab}	374.56±28.16^{b}	133.87±5.91^{bc}	1.85± 0.04^{c}	0.61±0.03^{d}
Ejumula					
Fresh	283.48±5.16^{a}	152.73±1.34^{a}	128.13±1.3b^{a}	0.02±0.0^{a}	0.09± 0.01^{a}
Blanched	347.30±17.35^{b}	309.97±35.77^{b}	210.70±5.63^{d}	2.17±0.05^{c}	0.42±0.04^{d}
Matobolwa solar dried	353.47±9.74^{ab}	399.64±29.61^{c}	178.77±3.25^{c}	1.51±0.21^{b}	0.172± 0.01^{b}
Matobolwa sun dried	336.46±30.47^{ab}	401.06±11.85^{c}	157.19±5.26^{b}	2.65±0.27^{c}	0.17± 0.01^{b}
Michembe	352.75±27.24^{b}	333.36±15.19^{b}	215.64±10.32^{d}	1.33±0.24^{b}	0.29±0.02^{c}

The values are means ± SD. Means in the same column bearing different superscripts are significantly different ($p<0.05$).

4.2.2 Cowpea Leaves

4.2.2.1 Proximate analysis

Proximate analysis results (Table 4.7) indicated that there was a significant difference in moisture content between fresh and dried cowpea leaves ($p<0.05$). Moisture content of fresh cowpea leaves was 89.54% and that of dried cowpea leaves was 9.74 and 7.43% for the blanched and boiled leaves, respectively for solar dried leaves. The moisture content was 10.2 and 8.54% for blanched and boiled leaves, respectively for sun dried samples.

There was no significant difference ($p>0.05$) between solar and sun dried samples, regarding the fat content. Fibre content of blanched samples (13.20±0.04 and13.37±0.24g/100g) was significantly higher compared to boiled samples (11.75±0.15 and11.12±0.32g/100g). The protein content of dried cowpea leaves indicated that blanched samples had significantly higher protein content than boiled regardless of the drying method used. Boiled samples showed significantly higher total ash content compared to blanched samples and this could be contributed by water and salt used for boiling. Carbohydrate content depends on the quantity of other nutrients of a food product. Among the dried vegetables, blanched solar dried (20.46±0.11g/100g) and boiled sun dried (18.48±0.58g/100g) samples had higher carbohydrate content than blanched sun dried (16.18±0.72g/100g) and boiled solar dried (16.19±0.28g/100g) samples.

Proximate composition of any food is a reflection of its nutritive value. The higher the value of protein, total carbohydrates, ash and vitamins, the higher the nutritive value of that particular food. The proximate composition of cowpea leaves is known to change with leaf development (Bubenheim *et al.,* 1990). As cowpea leaves aged content of carbohydrate and fibre increased, protein decreased, and fat and ash remained constant (Nielson *et al.,* 1994; Ohler *et al.,* 1996).

Moisture content of cowpea leaves depended on maturity. As reported by Wawire (2013), moisture contents at 4 weeks and 8weeks of harvest were 84.75 ± 1.27% and 81.81 ± 0.80%, respectively.

The fat content obtained in this study was in the same range as that reported by Oguntona (1998) who observed that fat content for green leafy vegetables exceeded 1.0%. Mamiro *et al.* (2011) reported that the leaves of improved varieties of cowpea had high fat content ranging from 8 to 11.2% as compared to local varieties (5.4%) which was higher compared to the results of this study.

The increase in ash content of cooked dried samples could have resulted from some inorganic salt being trapped in the vegetable during processing. Oboh *et al.* (2005) reported the same reason when they were studying the eggplant leaves.

Results of protein content of cowpea leaves obtained in this study corresponded well with the results obtained by other researchers. Ahenkora *et al.* (1998) highlighted that the protein content of cowpea leaves, on dry weight basis, ranged from 27.1 to 34.7%. Bubenheim *et al.* (1990) noted that the mean protein content of cowpea leaves harvested at 5–7 weeks was 37.9 to 40.2% dwb. Angessa (2006) found that 23 cowpea varieties studied in Tanzania have a protein content ranging from 29.4 to 33.1%. Malidadi (2006) reported cowpea leaf protein content (dry weight basis) ranging from 35.0 to 43.1% for 13 varieties studied in Malawi, Kabululu *et al.* (2013) reported values ranging from 25.0 to 34.4% for five varieties. Also, 21.5 to 40.3% of protein content was reported by the study of Towett *et al.* (2013) in 561 cowpea leaf samples collected from ten accessions and about ten landraces in Uganda and Tanzania. Maundu *et al.* (1999) reported the protein content for fresh and dried cowpea leaves as 4.5 and 22.6 g/100g, respectively. Protein content by Bubenheim *et al.* (1990) was 4.2g/100g. Muchoki (2007) reported protein, total ash, crude fibre and lipid/fat content were 31.8±1.5, 12.1 ±1.5, 18.2±2.3 and 3±1.5, respectively per 100g on dry matter basis.

The leaf protein content, though influenced by environmental factors like soil fertility, is highly dependent on age of leaves, the amount of available assimilates and the ability of the individual variety to develop a symbiotic relationship with the nitrogen-fixing bacteria in the root nodules (Ono *et al.,* 1996). Lodhi *et al.* (1990) and Adeyanyu (2009) found that protein content of cowpea leaves varied with age and varieties. Bubenheim *et al.* (1990) and Nielsen *et al.* (1994) found that protein content of young leaves was greater than that of older leaves. Oboh *et al.* (2005) found that high nitrogen levels in the soil, due to cattle and chicken manure, could also result in plants with higher protein content.

Table 4.7: Results of proximate and beta carotene content of cowpea leaves in fwb

Sample	Moist (%)	Fat (%)	Fibre (%)	Protein (%)	Ash (%)	CHO (%)	Beta carotene (%)
CWBSO	9.74^{c}	2.67±0.3^{a}	13.37±0.2^{c}	32.08±0.4^{b}	21.68±0.0^{a}	20.46±0.1^{c}	139.98±7.9^{cd}
CWBSU	10.2^{d}	2.39±0.1^{a}	13.20±0.0^{c}	34.24±0. 9^{c}	23.78±0.3^{b}	16.18±0.7^{a}	129.30±4.7^{bc}
CWCSO	7.43^{a}	2.73±0.3^{a}	11.12±0.3^{a}	27.09±0.3^{a}	35.44±0.6^{d}	16.19±0.3^{a}	117.75±0.0^{b}
CWCSU	8.54^{b}	2.55±0.1^{a}	11.75±0.2^{b}	26.82±0.3^{a}	31.85±0.4^{c}	18.48±0.6^{b}	94.04±1. 7^{a}
FRESH	89.54^{e}						147.68±6.9^{d}

Values are means ± SD. Means in the same column bearing different superscripts are significantly different ($p<0.05$). **(**CWBSO= Cowpea blanched then solar dried, CWBSU= Cowpea blanched then sun dried, CWCSO= Cowpea boiled then solar dried, CWCSU= Cowpea boiled then sun dried) and FRESH = Fresh cowpea leaves.

4.2.2.2 Beta carotene content of cowpea leaves

The results of cowpea leaves analysis (Table 4.7) showed that there was a significant difference in beta carotene content between fresh and dried samples ($p<0.05$). Fresh cowpea leaves were highest in β-carotene content (147.68±6.98 mg/100g), followed by blanched (139.98±7.90 mg/100g and 129.30±4.72 mg/100g) and lastly boiled samples (117.75±0.03and 94.04±1.67 mg/100g), respectively. The effect of driers used was observed as solar dried samples (tunnel) showed significantly higher values than sun dried samples.

Negi and Roy (2000) reported different β-carotene losses for three drying methods used; sun (70%), solar (68%), shade drying (65%) and oven drying (45%). The study by Ndawula *et al.* (2004) in Uganda found that the beta carotene content of fresh cowpea leaves was 140.9±4.5 mg/100g on dry matter basis and Nawiri *et al.* (2013) reported 4.1 to 30.5 mg/100g beta carotene of cowpea leaves, which was almost the same as the results obtained in this study. Agte *et al.* (2000) reported that beta carotene content of 24 green vegetables studied ranged from 0.08 to 9.2 mg /100g. Angessa (2006) reported 4.45 mg of beta carotene per 100 g of edible portion of freeze-dried raw cowpea leaves. Leung (1968) reported the beta carotene content of fresh and dried cowpea leaves was 2.4 and 27mg per 100 g of edible portion, respectively.

Maundu *et al.* (1999) reported the value of beta carotene of cowpea leaves as 5.19 mg/100g. From these literature data it is evident that there is a wide range of these carotenes in cowpea leaves.

The different values obtained in this study compared to literature could be contributed by variety, season, stage of vegetable maturity, environmental aspects and losses between harvesting and analysis. Storage time of vegetable and extraction process of the samples must be kept in control because all these have a tremendous effect on the results (Marcela & Amaya, 2003).

Boiled samples had low values compared to blanched samples and this is in agreement with the study conducted by Gayathri *et al.* (2004) that boiling results in the greatest loss of beta-carotene in *Amaranthus* (misbredie) specie. Some researchers reported that cooked leaves have higher beta carotene content than raw leaves (Faber *et al.,* 2010). Processing reduces the carotenoid content, although it enhances the bioavailability of these carotenoids in cooked vegetables vegetables (van het Hof *et al.,* 1998) which may compensate for the loss.

4.2.2.3 Effect of storage on beta carotene content of dried cowpea leaves

The effect of storage for six months on dried cowpea leaves are as indicated in Table 4.8. The blanched samples were observed to retain more beta carotene compared to cooked samples.

Table 4.8: Beta carotene retention of cowpea leaves after six months storage in mg/100g

Treatment	0 month		3 months	% Retention	6 months	% Retention
Fresh	147.7	100				
CWBSO	139.98±7.90^{b}	94.8	116.19±9.71^{a}	78.7	99.04±1.05^{a}	67.1
CWBSU	129.30±4.72^{b}	87.5	118.81±6.44^{b}	80.4	76.61±3.05^{a}	51.9
CWCSO	117.75±0.03^{b}	79.7	108.81±6.19^{b}	73.7	78.40±1.48^{a}	53.1
CWCSU	94.04±1.67^{b}	63.7	93.12±2.091^{b}	63.0	80.16±3.76^{a}	54.3

Values are means ± SD. Means in the same row bearing different superscripts are significantly different ($p<0.05$). (CWBSO= Cowpea blanched then solar dried, CWBSU= Cowpea blanched then sun dried, CWCSO= Cowpea boiled then solar dried and CWCSU= Cowpea boiled then sun dried).

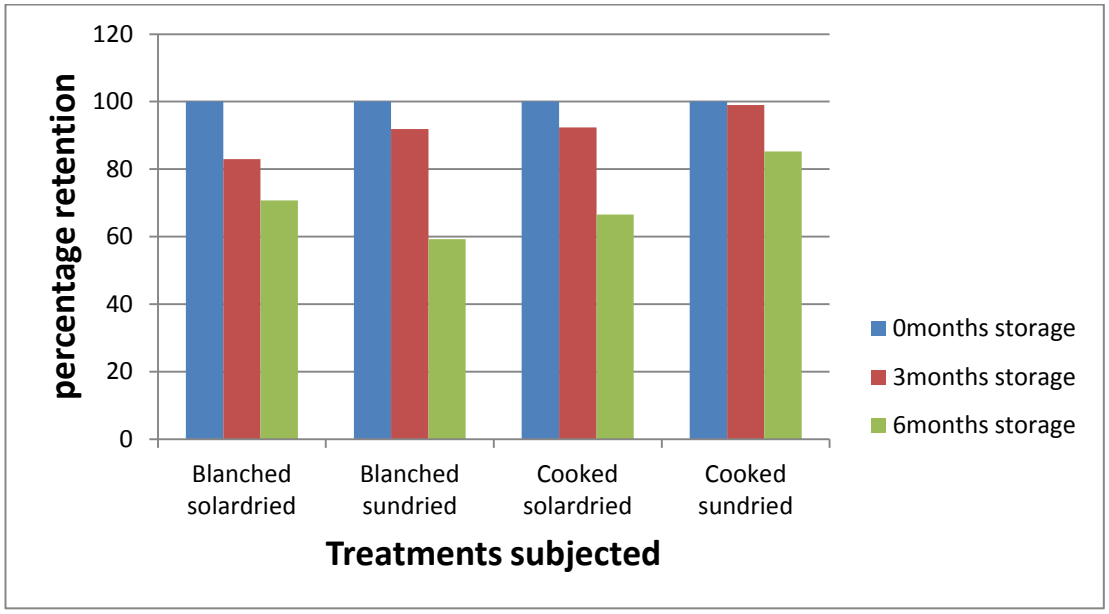


Figure 4.2: Percentage beta carotene retention of cowpea leaves after six months storage

4.2.2.4 Mineral content of cowpea leaves

The mineral results of cowpea leaves were as indicated in Table 4.9. Calcium level ranged between 214.62 and 620.53 mg/100g, Potassium level ranged between 732.57 and 1153.33 mg/100g, Sodium content ranged between 898.66 and 4826.96 mg/100g, Iron content was between 5.46 and 16.66 mg/100g and zinc was between 0.23 and 0.55 mg/100g.

Green leafy vegetables are normally considered to be a very good source of minerals (Torres *et al.*, 2005). The mineral content of many African traditional vegetables changes at different stages of maturity (Ibrikci *et al.*, 2003; Makobo *et al.*, 2010). Wawire (2013) reported mineral content studied have the highest decrease (up to 97%) during maturation; Zn, Fe and Mn recording the highest decrease (88, 85, 81%, respectively) followed by Ca, Mg, K and P (70, 66, 69, 70% decrease, respectively) while Na showed a moderate decrease of 36% and no changes were observed in Se content.

The loss of nutrient (vitamins, minerals) can be brought about by processes including thermal processes and leaching during washing/boiling (Aked, 2002). The higher mineral content in the leaves could be caused by the use of chicken and cattle manure as fertilizers in the soil as reported by Eneji *et al.* (2001). They found that animal manure contains significant amounts of nutrients (nitrogen, phosphorus, potassium, magnesium, copper and zinc), which are easily absorbed by plants.

Table 4.9: Mineral content of fresh and dried cowpea leaves in mg/100g

Treatment	Calcium	Potassium	Sodium	Iron	Zinc
FCW	214.62±3.51^{a}	732.57±26.81^{a}	898.66±11.24^{a}	5.46±0.32^{a}	0.23±0.01^{a}
CWBSO	352.19±68.13^{b}	1153.33±55.98^{c}	1937.04±29.15^{b}	10.40±0.10^{b}	0.55±0.005^{b}
CWBSU	287.99±31.32^{ab}	1031.14±33.82^{bc}	1939.04±18.88^{b}	11.06±0.82^{b}	0.3±0.001^{a}
CWCSO	507.28±83.44^{c}	1118.40±71.74^{c}	4826.96±38.44^{c}	15.78±0.22^{c}	0.55±0.02^{b}
CWCSU	620.53±53.40^{c}	875.01±93.56^{ab}	4690.27±110.0^{c}	16.66±1.47^{c}	0.49±0.09^{b}

Values are means ± SD. Means in the same column bearing different superscripts are significantly different ($p<0.05$). **(**CWBSO= Cowpea blanched then solar dried, CWBSU= Cowpea blanched then sun dried, CWCSO= Cowpea boiled then solar dried, CWCSU= Cowpea boiled then sun dried and FCW= Fresh cowpea leaves).

4.2.3 Importance of consuming both orange fleshed sweet potato tubers and cowpea leaves

Mostly sweet potato tubers and cowpea leaves are consumed in a combined form. Therefore, when these two food products are consumed together they provide the body with important required nutrients. Orange fleshed sweet potatoes are low in protein and mineral (calcium and iron) contents while cowpea leaves have high content. Therefore, when orange fleshed sweet potato tubers and cowpea leaves consumed together, the incidence of Vitamin A deficiency (VAD), Iron Deficiency Anemia (IDA) and protein energy malnutrition (PEM) will be reduced.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Sweet potato tubers and cowpea leaves have got an important place in fighting IDA, VAD, and protein - energy malnutrition. Both fresh and dried sweet potato tubers and cowpea leaves are consumed in Maswa district. Cowpea leaves are boiled first then sundried to make *shiiri* and blanching was not known to many respondents. Sweet potatoes are processed into *michembe* and *matobolwa. Michembe* and *matobolwa* are mixed during storage and after cooking are consumed together with cowpea leaves. The health benefits and multipurpose use of orange fleshed sweet potato were not known and the preference of *michembe* was high compared to *matobolwa*.

Dried samples have high level of proximate composition values (protein, fat, fibre and carbohydrate) and mineral content compared to fresh samples. Beta carotene content of dried samples was low compared to fresh samples of sweet potato and cowpea leaves. After drying boiling retained more beta carotene content in sweet potato varieties and blanching retained beta carotene in both sweet potatoes and cowpea leaves. On storage, after four months *michembe* started to be infested by storage pests and percentage loss of beta carotene was high on storage while *matobolwa*, blanched solar dried chips and dried cowpea leaves were with good quality after six months storage. Solar dried samples were observed to retained more nutrients than sun dried samples.

5.2 Recommendations

Education should be provided to famers to make them knowledgeable on nutritional benefits of consumption of cowpea leaves and orange fleshed sweet potato tubers. Awareness on how to store the dried products safely should be created. Multipurpose use of dried chips should be introduced to famers involving making different value added products, including baked products and porridge as a means of diversifying uses of these potential food commodities.

Solar drying and blanching technique should be taught and encouraged so that they will be used during drying of cowpea leaves and sweet potato for better nutrient retention. This technique results in retaining more beta carotene, long shelf life and the technology is simple and cheap to be implemented by famers. Therefore, resource-poor farmers can readily supplement the more expensive animal products with better and easily grown cowpea leaves and sweet potato as plant protein, iron and vitamin A source for improved nutrition. This will also create an additional market and income for cowpea and sweet potato producers.

More studies should be conducted to determine microbial level of the dried chips and cowpea leaves and how they are influenced by storage. Optimum blanching time and temperature for more nutrient retention and identification of best packaging material need to be established.

REFERENCES

Abubakar, H. N., Olayiwola, I. O., Sanni. S. A. & Idowu, M. A. (2010). Chemical composition of sweet potato (Ipomea batatas Lam) dishes as consumed in Kwara state, Nigeria, *International Food Research Journal 17*, 411-416.

Adelaja, A. O. &Babatope, B. I. (2013). Analysis and testing of a natural convection solar dryer for the tropics. *Journal of Energy, 2013*,1-8.

Adeoye, I. B., Odeleye, O. M. O., Babalola, S. O. & Afolayan, S. O. (2009),Economic analysis of tomato losses in Ibadan Metropolis, Oyo State, Nigeria.*African Journal of Basic & Applied Sciences*, *1*, 87-92.

Adeyanyu, A. O. (2009). Genetics of harvest index and leaf-yield indices in cowpea. *J. Crop Improv., 23*(3), 266-274.

Agriculture and consumer protection (1983), Food loss prevention in perishable crops, Rome: FAO.

Agte, V. V., Tarwadi, K. V., Mengale, S. & Chiplonkar. S. A. (2000), Potential of traditional green leafy vegetables as natural sources for supplementation of eight micronutrients in vegetarian diets. *J. Chro. Bio. Med. 6*(13), 885- 891.

Ahenkora, K., Adu Dapaah, H. K. & Agyemang, A. (1998), Selected nutritional components and sensory attributes of cowpea (*Vigna unguiculata* [L.]Walp) leaves. *Plant Foods for Human Nutrition, 52*, 221-229.

Akarslan, F. (2012), Solar-Energy Drying Systems, Modeling and Optimization of Renewable Energy (ed) Arzu Şenca, INTECH, Open Access Publisher.

Aked, J. (2002). Maintaining the post-harvest quality of fruit and vegetables. Fruit and vegetable processing. Improving quality. *Woodhead Publishing Ltd, 7*, 119-146.

Andlauer, W. & Furst, P. (1999). Does cereal reduce the risk of cancer? *Cereal Foods World 44*(*2*), 76-78.

Angessa**,** T. T. (2006). Towards improved vegetable use and conservation of cowpea and lablab: Agronomic and participatory evaluation in Northern Tanzania and genetic diversity study. Unpublished PhD thesis, Germany: Cuvillier Verlag, Göttingen.

AOAC, (1995). Official Methods of Analysis, (16th ed.), Washington D.C.: Association of Official Analytical Chemists.

Atanda, A. S., Pessu, O. P., Agoda, S., Isong, I. U. & Ikotun, I. (2011).The concepts and problems of postharvest food losses in perishable crops. *Review, African Journal of Food Science 5,* 603-613.

Aware, R. & Thorat, N. B. (2012). Solar Drying of Fruits and Vegetables: Solar Drying Fundamentals, Applications and Innovations. Ed. Hii, C L; Jangam, S V; Ong, S P; Mujumdar, A S. Singapore.

Aywa, A. K., Nawiri, M. P. & Nyambaka, H. N. (2013) Nutrient variation in colored varieties of *Ipomea batatas* grown in Vihiga County, Western Kenya, *International Food Research Journal 20*(2), 819-825.

Babagana, G.,Silas, K. & Ahmed, M. M. (2012), Solar dryer - an effective tool for agricultural products preservation, *Journal of Applied Technology in Environmental Sanitation. 2,* 31-38.

Baloch, A .W., Khan, S. & Baloch, K. A. (1997). Influence of chemical additives on the stability of dried tomato powder, *International Journal of Food Science and Technology 32,* 117-120.

Baloch, K. A., Buckle, A. K. & Edwards, A. R. (1987). Effect of sulphur dioxide and blanching on the stability of carotenoids of dehydrated carrot. *Journal of Food Science and Agriculture 40*,179-187.

Barrett, R. P. (1990), Legume Species as Leaf Vegetable: advances in New Crops, Janick, J. and Simon, J. E. (eds) Portland, Timber Press, 391-396.

Barretta, D. M. & Lloydb, B. (2012). Advanced preservation methods and nutrient retention in fruits and vegetables, *Review, J Sci Food Agric*. *92*,7–22.

Bashaasha, B. & Scott, G. (2001). Processed Sweet potato in the Household Economy of North-East Uganda. *Eastern Africa Journal of Rural Development, 17*(1), 35-50.

Bechoff, A. (2010). Investigating Carotenoid Loss After Drying and Storage of Orange-fleshed Sweet Potato, Unpublished Thesis. Greenwich: University of Greenwich.

Bechoff, A., Dufour, D., Dhuique-Mayer, C., Marouze` C., Reynes, M. & Westby, A. (2009). Effect of hot air, Solar and sun drying treatments on provitamin A retention of Orange-fleshed Sweet Potato. *Journal of Food Enginneering 92*, 164-171.

Bengtsson, A., Namutebi, A., Alminger, M. L. & Svanberg, U. (2008), Effects of various traditional processing methods on the all-*trans*-*β*-carotene content of orange-fleshed sweet potato. *Journal of Food Composition and Analysis.21*(2), 134-143.

Binner, S., Jardine, W. G., Renard, C. M. C. G & Jarvis, M. C. (2000). Cell wall modifications during boiling of potatoes and sweet potatoes, *Journal of the Science of Food and Agriculture, 80,* 216–218.

Bovell-Benjamin, A. C. (2007). Sweet potato: a review of its past, present, and future role in human nutrition, *Adv Food Nutr. Res. 52*, 1-59

Britton, G. (1995). Carotenoids, Vol. 1B, Spectroscopy, edited by G. Britton, S. Liaaen-Jensen & H. Pfander, ch. 2.

Bubenheim, D. L., Mitchell, C. A. & Nielsen, S. S. (1990). Utility of cowpea foliage in a crop production system for space. Janick J. and Simon J. E. (eds.). *Advances in New Crops*, Portland, Ore :Timber Press.

Burden, J. W. (1989). Prevention of Post-Harvest Food Losses: Fruits, Vegetables and Root Crops-A Training manual. Rome:FAO.

Burgos, G., Rossemary, C., Cynthia, S., Sosa, P., Porras, E., Jorge, E. & Wolfagang, G. (2001**)** A color chart to screen for high beta-carotene in Orange fleshed sweet potato breeding. Cairo: International Potato Center.

Cha´vez, A., Sanchez, T., Ceballos, H., Rodriguez-Amaya, D. B., Nestel, P., Tohme, J. & Ishitani, M. (2007). Retention of carotenoids in cassava roots submitted to different processing methods, *J Sci Food Agric.87*, 388–393.

Chandler, L A. & Schwartz, S. J. (1988). Isomerization and losses of trans beta-carotene in sweet potatoes as affected by processing treatments, *Journal of Agricultural and Food Chemistry 36,* 29-133.

Chew, B. P., Wong, T. S., Michal, J. J.,Standaert, F. E. & Heirman, L. R. (1991). Subcellular distribution of β-carotene, retinol and α-tocopherol in porcine lymphocytes after a single injection of β-carotene, *J. Animal Science 69,* 4892-4897.

Chikwendu, J. N., Igbatim, A. C. & Obizoba, I. C. (2014).Chemical composition of processed cowpea tender leaves and husks, *International Journal of Scientific and Research Publications, 4*(5), 1-5.

Cho, E., Seddom, J., Ronser, B., Willet, W. & Hankison, S. (2004). Prospective study of intake of fruits, vegetables, vitamins and carotenoids and related musculopathy, *Arch. Ophthalmology*. *122*, 883-892.

CIP (2006).International Potato Center (CIP) Report. McKnight Foundation CCRP East African Regional Sweetpotato Project Annual Report (April 2005–March 2006). Nairobi: International Potato Center.

Classification of Instructional Programs (CIP) (2000). Effect of Women Farmers Adoption of Orange Fleshed Sweet Potatoes: Stories From Fields: International Potatoes Center Annual report.Dar Es salaam: International Potatoes Center.

Debjani, D., Utpal, R., & Runu, C. (2005). Retention of β-carotene in frozen carrots under varying conditions of storage.*Afr J.Biotechnol. 4* (1), 102–103.

Dhote, C. Y. & Thombre, S. B. (2012). Parametric study on the thermal performance of the solar air heater with energy storage, *International Journal of Mechanical Engineering and Technology 3*, 90-99.

Doering von, E. W., Sotiriou-Leventis, C. & Ro,W. R. (1995). Thermal interconversions among 15-cis, 13-cis, and all-trans-β-carotene: kinetics, Arrhenius parameters, thermochemistry, and potential relevance to anticarcinogenicity of all trans Beta- carotene, *Journal of American Chemical Society 177*, 2747-2757.

Dulawat, M. S. & Rathore, N. S. (2012). Forced convection type solar tunnel dryer for industrial applications, *CIGR Journal 14*, 75-79.

Dwyer, J. H., Navab, M., Dwyer, K. M., Hassan, K., Sun, P., Shircore, A., … & Fogelman, A. M. (2001). Oxygenated carotenoid lutein and progression of early atherosclerosis: the Los Angeles atherosclerosis study. *Circulation Journal of the American Heart Association 103*, 2922–2927.

Eneji, A. E., Honna, T. &Yamamoto, S. (2001). Manuring effect of rice grain yield and extractable trace elements in soils, *Journal of Plant Nutrition*, *24*(7), 967-977.

Eric, D. (2013). Effect of drying methods on nutrient quality of Basil (*Ocimumviride*) leaves cultivated in Ghana.*International Food Research Journal 20(4),* 1569-1573.

Faber, M., Oelofse, A., Van Jaarsveld, P. J., Wenhold, F. A. M. & Jansen Van Rensburg, W. S. (2010). African leafy vegetables consumed by households in the Limpopo and KwaZulu-Natal provinces in South Africa, *South African Journal of Clinical Nutrition*, *23* (1), 30-38.

FAO (1983). Food loss prevention in perishable crops, Rome: FAO.

FAO (1990). Roots Tubers, Plantains and Bananas in Human Nutrition. Rome: FAO.

FAO (2001). Improving nutrition through home gardening: Nutrition Programmes Service Food and Nutrition Division. Rome: FAO.

FAO (2004). Food and Agriculture Organization statistics. Rome: FAO.

FAO (2008). Food and Agriculture Organization statistics, Rome: FAO.

FAO (2015). Food and Agriculture Organization statistics, Rome: FAO.

Fasuyi, A. O. (2006). Nutritional potentials of some tropical vegetables of leaf meals: chemical characterization and functional properties. *African Journal of Biotechnology*, *5*(1), 049-053.

Fery, R. L., Janick, J., & Whipkey, A. (2002). New opportunities in Vigna. In *Trends in new crops and new uses. Proceedings of the Fifth National Symposium, Atlanta, Georgia, USA, 10-13 November, 2001.* ASHS Press.

Fresco, O. L. & Boudion, O. W. (2002). Food and nutrition security towards human security. Proceedings of the International Conference on Vegetables, June 11-13, Rome.

Gatehouse, A. M. R. & Boutler, D. (1983). Assessment of the antimetabolic effects of trypsin inhibitors from cowpea (*Vigna unguiculata*) and other legumes on the development of bruchid beetle *Callosobruchusmaculatus, J. of Science of Food and Agriculture 34*, 345-350.

Gayathri, G. N., Platel, K., Prakash, J. & Srinivasan, K. (2004). Influence of antioxidants spices on the retention of β-carotene in vegetables during domestic boiling processes, *Food Chemistry, 84, 35-43.*

Gichuki, S. T., La Bonte, D., Burg, K., Kapinga, R., & Simon, J. C. (2005). Assessment of genetic diversity, farmer participatory breeding, and sustainable conservation of Eastern African sweetpotato germplasm (Grant No. 02-476). In *Annual Report April 2004–March 2005*.

Goodbody, S. (1984).Nutritional characteristics of a sweet potato collection in the Papua New Guinea highlands.*Trop. Agric.* (Trin.) *61*, 20-24.

Hagenimana, L. J. V. (2000), Potential of orange-fleshed sweet potatoes for raising vitamin A intake in Africa. *Food Nutrition Bull, 21,* 414-418.

Hagenimana, V., Carey, E. E., Gichuki, S. T., Oyunga, M. A. & Imungi, J. K. (1999). Carotenoid contents in fresh, dried and processed sweetpotato products. *Ecology of Food and Nutrition 37,* 455–473.

Hallensleben, M., Polreich, S., Heller, J., & Maass, B. L. (2009, October). Assessment of the importance and utilization of cowpea (Vigna unguiculata L. Walp.) as leafy vegetable in small-scale farm households in Tanzania–East Africa. In *Conference on International Research on Food Security, Natural Resource Management and Rural Development in University of Hamburg, Tropentag*.

Helen Keller International Tanzania (2012). Orange-Fleshed Sweet Potato Situation Analysis And Needs Assessment, Tanzania Report. Tanzania: Helen Keller International.

Hinds, T. S., West, W. L. & Knight, E. M. (1997). Carotenoids and retinoids - a review of research, clinical, and public health applications. *The Journal of Clinical Pharmacology 37*(7), 551–558.

Huaman, Z. (1992). Systematic Botany and Morphology of the Sweet Potato Plant, International Potato Cente, Lima Peru, *Technical information Bulletin 25*, 1-22.

Huang, A. S., Tanudjaja, L. & Lum, D. (1999). Content of alpha-, beta-carotene, and dietary fibre in 18 sweet potato varieties grown in Hawaii. *Journal of Food Composition and Analysis*; *12* (2), 147-151.

Humphries, J. M., Graham, R. D. & Mares-Julia, D. J. (2004). Application of reflectance colour measurement to the estimation of carotene and lutein content in wheat and triticale. *Journal of Cereal Science 40* (2), 151–159.

Ibrikci, H., Knewtson, S. J. & Grusak, M. A. (2003). Chickpea leaves as a vegetable green for humans: evaluation of mineral composition. *Journal of the Science of Food and Agriculture, 83,* 945–950.

Idowu, O. A., Olaoye, O. A., Sogotemi, C. M., & Ajay, B. (2012). Quality assessment of flours and *amala* produced from three varieties of sweet potato *Ipomea batatas,* Research Paper. *International Journal of Food and Nutritional Sciences 2(4),* 1-9.

Ilelaboye, N. O. A., Amoo, I. A. & Pikunda, O. O. (2013).Effect of boiling methods on mineral and antinutrient composition of some green leafy vegetables, *Archives of Applied Science Research 5*(3), 254-260.

Ingabire, M. R.& Vasanthakaalam, H. (2011).Comparison of the nutrient composition of four sweet potato varieties cultivated in Rwanda *American Journal of Food and Nutrition 1*(1), 34-38.

Jaarsveld, J. Van Paul, F. M., Tanumihardjo, S. A., Nestel, P., Lombard, C. J. & Benade, A. J. S. (2005). β-Carotene–rich orange-fleshed sweet potato improves the vitamin A status of primary school children assessed with the modified-relative-dose response test. *The American Journal of Clinical Nutrition*. *81*(5), 1080-1087.

Jiwen, H., Chen, L., Gu Z., Hong, Y. & Li, Z. (2013). Effects of low-temperature blanching on tissue firmness and cell wall strengthening during sweet potato flour processing, *International Journal of Food Science and Technology 49* (5), 1360–1366.

Jones, A. (1977). Heritability of seven sweet potato root traits. *J Am. Soc Hortic Sci. 102*, 440–442.

Kabululu, M. S., Ojiewo, C., Oluoch, M. & Maass, B. L. (2013). Cowpea cultivar mixtures for stable and optimal leaf and seed yields in a maize intercropping system, *International Journal of Vegetable Science. 20*(3).

Kapinga, R. E., Ewell, P. T, Jeremiah, S. C. & Kileo, R.. (1995), Sweet potato in Tanzania farming and food systems: implications for research,Ministry of Agriculture Tanzania, Dar es salaam: Internatinal Potato Center (CIP).

Kasangi, D. M, Shitandi, A. A., Shalo, P. L. & Mbugua, S. K. (2010). Effect of spontaneous fermentation of cowpea leaves (*Vigna unguiculata*) on proximate composition, mineral content, chlorophyll content and beta-carotene content, *International Food Research Journal 17*, 721-732.

Keding, G., Weinberger, K., Swai, I. & Mndiga, H. (2007). Diversity, traits and use of traditional vegetables in Tanzania. Technical Bulletin No. 40. AVRDC - The World Vegetable Center, Shanhua, Taiwan.

Keller, G. B. (2004).African Nightshade, eggplant, spiderflower etc. production and consumption aspects of traditional vegetables in Tanzania from the farmers point of view. Unpublished MSc Thesis, Germany: Georg-August Universität.

Khalil, I. A. & Saleemullah, Iqbal. A. (2004) Book of Bio Analytical Chemistry (2nd Eds) . Islamabad: National Book Foundation.

Kisetu, E. & Assenga, S. P. (2013). Effects of poultry and goat manures to cowpea variety Vuli-1 grown on a highly weathered soil in Morogoro, Tanzania, *Unique Res. J. Agric. Sci*. *1*(3), 028-034.

Ko`sambo, L., Carey, E. E., Mistra, A. K., Wilkes, J. & Hagenimana, V. (1998), Influence of age, farming site and boiling on pro-vitamin A content in sweet potato (*Ipomea batatas* (L) Lam.). *Journal of food analysis 11*, 305-321.

Krinsky, I. N. & Yeum, J. K. (2003). Carotenoid-radical interactions, *Biochemical and Biophysical Research Communications 305*, 754-760.

Latapi, G. & Barrett, M. D. (2006). Influence of pre-drying treatments on quality and safety of sun-dried tomatoes; Part II. Effect of storage on nutritional and sensory quality of sun-dried tomatoes pretreated with sulphur, sodium metabisulfite or salt, *Journal of Food Science*. *71*, S32-S37.

Leighton, C. S. (2007). Nutrient and Sensory Quality of Orange Fleshed Sweet Potatoes. Unpublished Msc. Thesis. South Africa, Pretoria: University of Pretoria.

Leung, W. T. W. (1968.). Food Composition Table for Use in Africa. Rome, FAO.

Liener, I. E. (1969). Toxic Constituents of Plants Foodstuffs, (ed). New York: Academy Press.

Lodhi, G. P., Boora, K. S., Jain, S. & Balchand (1990). Heterosis for fodder yield and quality characters in cowpea (Vigna unguiculata (L.) Walp). *Crop Research 3*, 66-73.

Lund, D. E. & Smoot, J. M. (1982). Dietary fibre content of some tropical fruits and vegetables .*J. Agric. Food Chem. 30,* 1123-1127.

Makobo, N. D., Shoko, M. D., & Mtaita, T. A. (2010).Nutrient content of vegetable amaranth (*Amaranths cruentus* L.) at different harvesting stages. *World Journal of Agricultural Sciences 6,* 285-289.

Malidadi, C. (2006). Cowpea (*Vigna unguiculata*) for leafy vegetable use in Malawi: Agronomic evaluation on station and on farm. Unpublished MSc. Thesis. Germany: Georg-August-Universität.

Mamiro, P. S., Mbwaga, A. M., Mamiro, D. P., Mwanri, A. W. & Kinabo, J. (2011). Nutritional quality and utilization of local and Improved cowpea varieties in some regions in Tanzania, *African Journal Food Agriculture Nutrition and Development, 11*(1), 4490-4506.

Mangels, A. R., Holden, J. M., Beecher, G. R., Forman, M. R. & Lanza, E. (1993). Carotenoid content of fruits and vegetables: an evaluation of analytic data. *J Am Diet Assoc 93*, 28–96.

Masumba, A. E., Kulembeka, H. Tollano, M. S. & Yongolo, M. (2004).Participatory evaluation of improved sweetpotato varieties in Eastern Tanzania, *African Crop Science Journal. 12*, 259-266.

Matthew, G. G. & Schwarz, D. (2001). Solar Drying Technology for Food Preservation. Germany: GTZ-GATE Eschborn.

Maundu, P. M., Ngugi, G. W.& Kabuye, C. H. S. (1999). Traditional Food Plants in Kenya. Nairobi: KENRIK.

Mbwaga, Z., Mataa, M & Msabaha, M. (2007). Quality and yield stability of orange fleshed sweet potato (*Ipomoea batatas*) varieties grown in different Agro-ecologies, *African Crop Science Conference Proceedings*. *8*, 339-345.

McLaren, D. S. & Frigg, M. (2001). Sight and Life guidebook on vitamin A in health and disease. Basel, Switzerland: Task Force Sight and Life.

Mercela, C., Delia, B. & Amaya, R. (2003). Carotenoid composition of cooked green vegetables from restaurants. *Journal of Food Chem. 83*, 595-600.

Ministry of Agriculture Food Security and Cooperatives (MAFC) (2010). Annual Performance Report for 2009/10 Financial Year. Dar Es Salaam, Tanzania: Monitoring and Evaluation and Statistics Section.

Mitra, S. (2012). Nutritional status of orange-fleshed sweet potatoes in alleviating vitamin A Mmalnutrition through a food-based approach, *J Nutr Food Sci 2*, 160.

Mixon, M. (2009). Drying fruits, Retrieved from http://www.msucares.com/pubs/infosheets/is0725.html

Moeller, S. M., Jacques, P. F. & Blumberg, J. B. (2000). The potential of dietary xanthophylls in cataract and age-related macular degeneration. *Journal of the American College of Nutrition 19* (5), 522S–527S.

Mosha, T. C., Pace, R. D., Adeyeye, S., Laswai, H. S. & Mtebe, K. (1997). Effects of traditional processing practices on the content of total carotenoid, β-carotene, α- carotene and vitamin A activity of selected Tanzanian vegetables, *Plant Foods for Human Nutrition, 50,* 189-201.

Muchoki, N. C. C. (2007). Nutritional, sensory and keeping properties of fermented solar-dried cowpea leaf vegetables. Unpublished Msc. Thesis. University of Nairobi.

Mulokozi, G, Meghji, W., Rwiza, E. & Kamala, A. (2006). National coverage of vitamin A supplementation integrated with de-worming. Tanzania Food and Nutrition Centre (TFNC), Report No. 2070.

Nahar, N. M. (2009). Processing of vegetables in a solar dryer in arid areas Central Arid Zone Research Institute, International Solar Food Processing Conference , Jodhpur, India: Central Arid Zone Research Institute

Nawiri, M. P., Nyambaka, H. & Murungi, J. I. (2013). Sun-dried cowpeas and amaranth leaves recipe improves β-carotene and retinol levels in serum and haemoglobin concentration among preschool children. *European Journal of Nutrition*, *52*(2), 583–589.

Ndawula, J., Kabasa, J. D. & Byaruhanga, Y. B. (2004). Alterations in fruit and vegetable b-carotene and vitamin C content caused by open-sun drying, visqueen-covered and polyethylene-covered solar-dryers, *African Health Sciences 4*(2), 125-130.

Ndunguru, G. T. (2003), Handling of Sweet Potato during Marketing. In: Cassava and Sweet Potato after Harvesting. Proceedings of a Workshop held at the

Lake Zone Agricultural Research and Development Institute, Ukiriguru, Mwanza Tanzania, 2002.

Negi, P. S. & Roy, S. K. (2000). Effect of blanching and drying methods on beta carotene, ascorbic acid and chlorophyll retention of leafy vegetables. *Lebensmittel Wissenschaft und Technologie, 33*, 295-298.

Ni, L., Lin, D. & Barrett, M. D. (2005). Pectin methylesterase catalyzed firming effects on low temperature blanched vegetables *Journal of food engineering, 70*(4), 546-556.

Nielsen, S. S., Ohler, T. A. & Mitchell, C. A. (1997). Cowpea leaves for human consumption: production, utilization, and nutrient composition. In: BB Singh, B. B., Dr Mohan R, Dashiell, K. E. and Len, J. (Eds). *Advances in Cowpea Research,* 326-332.

Nielsen, S. S., Osuala, C. I. & Brandt, W. E. (1994).Early leaf harvest reduces yield but not protein concentration of cowpea seeds, *Hort Science 29*(6), 631-632.

Nyambaka, H., Nderitu J., Nawiri, M. & Murungi, J. (2012).Use of kitchen steel wool as oxygen absorber improves storage retention of beta-carotene in solar-dried vegetable, *Mediterranean Journal of Chemistry*.*1*(6), 326-333.

Oboh, G. (2005). Effect of Some Post-Harvest Treatments on the Nutritional Properties, *Pakistan Journal of Nutrition 4(4, 226-230.*

Oboh, G., Ekperigin, M. M. & Kazeem. M. I. (2005). Nutritional and hemolytic property of egg- plant (*Solanum macrocarpon*) leaves. *J. Food compo. Anal. 18*, 153-160.

Odebode, O. S., Egeonu, N. & Akoroda, M. O. (2008). Promotion of sweetpotato for the food industry in Nigeria, *Bulgarian Journal of Agriculture Science 14* (3), 300-308.

Oguntona, T. (1998). Green leafy vegetables. In: Osagie, A. U and Eka, O. U. (eds) *Nutritional Quality of Plant foods, Nigeria*. 120-123.

Ohler, T. A., Nielsen, S. S. & Mitchell, C. A. (1996).Varying plant density and harvest time to optimize cowpea leaf yield and nutrient content. *Hort Science, 31*(2), 193-197.

Oke, M. O. & Workneh, T. S. (2013). A review on sweet potato postharvest processing and preservation technology, *African Journal of Agricultural Research 8* (40), 4990-5003.

Okonya, J. S. & Maass, B. L. (2014) Protein and iron composition of cowpea leaves: an evaluation of six cowpea varieties grown in Eastern Africa. *African Journal of Food, Agriculture, Nutrition and Development*: *15*(5), 2129-2140.

Olapade, A. & Ogunade, O. (2014) Production and evaluation of flours and crunchy snacks from sweet potato (*Ipomea batatas*) and maize flours. *International Food Research Journal; 21*(1), 203-208.

Ono, K., Terashima, I. & Watanabe, A. (1996). Interaction between nitrogen of plant and nitrogen content in the old leaves. *Plant Cell Physiology 37*(8), 1083-1089.

Oomen, H. A. P. C., & Grubben, G. J. H. (1978). Tropical Leaf Vegetables in Human Nutrition. Communication 69, Department.of Agricultural. Research, Royal Tropical Institute, Amsterdam.

Owori, C., Berga, L., Mwanga, R.. O. M., Namutebi, A. & Kapinga, R.. (2007). Sweet Potato Recipe Book*: Sweet potato Processed Products from Eastern and Central Africa*. Kampala, Uganda, 93

Padulosi, S. & Ng, N. Q. (1997). Origin, taxonomy, and morphology of *Vigna unguiculata* (L.)Walp. (eds.) Singh, B. B., Mohan Raj, D. R., Dashiel, K. E. and Jackai, L. E. N. Advances in cowpea research. Co-publication of International Institute of Tropical Agriculture (IITA) and Japan International Research Center for Agricultural Sciences (JIRCAS). IITA, Ibadan, Nigeria.1-12.

Paul, A. A. & Southgate, D. A. T. (1979), McCance and Widdowson's the Composition of Foods, London: Her Majesty's Stationery Office.

Pradeep, S. N. & Susanta, K. R. (2001), The effect of blanching on quality attributes of dehydrated carrots during long-term storage. *European Research Technology 212,* 445-448.

Price, F. M., Machange, F. & Assenga, A. J. (1982), Improved cultivation of cowpea (*Vigna unguiculata*) in Tanzania: Tanzania Ministry of Agriculture.

Quin, M. F. (1997), Introduction: *Advances in Cowpea Research*, (eds). Singh H.H, Mohan Raj D.R, Dashiell I.E and Jackai L.E.N, Ibadan Nigeria: IITA.

Rajyalakshmi, P., K. Venkatalaxmi, K. Venkatalakshmamma, Y. Jyothsna, K. Devi &Suneetha, V. (2001). Total carotenoid and beta-carotene contents of forest green leafy vegetables consumed by tribals of south India. *J. Food Science*, *56*, 225-238.

Robinson, C. H. & Lawler, M. (1980), Normal and Therapeutic Nutrition, New York: Macmillan Co Ltd.

Rodriguez-Amaya, D.B.(1997), The retention of provitamin A carotenoids in prepared, processed, and stored foods, *J. Biol. Science 3*, 345- 444.

Rodriguez-Amaya, D. B. (2001), *A Guide to Carotenoid Analysis in Foods*, Washington D.C, ILSI Press.

Rodriguez-Amaya, D. B., (2000), *A Guide to Carotenoid Analysis in Food*. Washington DC: ILSI Press.

Rodriguez-Amaya, D. B., & Kimura, M. (2004). *HarvestPlus handbook for carotenoid analysis* (Vol. 2). Washington: International Food Policy Research Institute (IFPRI).

Saidi, M., Ngouajio, M., Itulya, F. M. & Ehlers, J. (2007). Leaf harvesting initiation time and frequency affect biomass partitioning and yield of cowpea. *Crop Science 47,* 1159-1116.

Schippers, R.R. (2000). African Indigenous Vegetables; An Overview of the Cultivated Species Natural Resources International Limited. - UK : Aylesford.

Schmidt, V. (2013). Nutrition Security in Tanzania: Orange-fleshed Sweet Potatoes and Their Contribution to Health. Anchor Academic Publishing.

Seidu, J., Bobobee, E., Kwenin, W., Tevor, W., Mahama, A. & Agbeven, J. (2012). Drying of sweet potato (*Ipomoea batatas*) (chipped and grated) for quality flour using locally constructed solar dryers. *Journal of Agricultural and Biological Science*, *7(*6).

Senanayake, S. A., Ranaweera, K .K. D. S., Gunaratne, A. & Bamunuarachchi, A. (2013).Comparative analysis of nutritional quality of five different cultivars

of sweet potatoes (*Ipomea batatas* (L) Lam in Siri Lanka, *Journal of Food Science and Nutrition*.*1*(4), 284-291.

Sharma, A., Chen, C. R. & Vu Lan, N. (2009). Solar-energy drying systems, *Renewable and Sustainable Energy Reviews, 13*(7), 1185-1210.

Siems, W., Wiswedel, I., Salerno, C., Crifo, C., Augustin, W., Schild, L., Langhans, C.D. & Sommerburg, O. (2005), Carotene breakdown products may impair mitochondrial functions potential side effects of high-dose β-carotene supplementation, *Journal of Nutritional Biochemistry 16*, 385–397.

Singh, B. B., Ajeigbe, H. A., Tarawali, S. A, Fernandez-Rivera, S. & Abubakar, M. (2003). Improving the production and utilization of cowpea as food and fodder. [Report] : *Field Crops Research 84*(1-2), 169-177.

Singh, S. R., & Rachie, K. O. (1985). *Cowpea research, production, and utilization*. Wiley.

Singh, S. R. & Rachie, K. O. (1985). Cowpea research, production and utilization. N. Y: John Wiley and Sons.

Smith, F. I. & Eyzaguirre, P. **(**2007) African leafy vegetables: their role in the World Health Organization's global fruit and vegetables initiative. *African Journal of Food Agriculture Nutrition and Development 7*(3), 631-632.

Stawczyk, J., Li, S. & Romuald, Z. (2004), Freeze drying of food products in a closed system, Proceedings of the 14th International Drying Symposium (IDS 2004) - São Paulo, Brazil, vol.B pp. 949-953.

Strøm, K. (2011). Product quality in solar dried carrots, tomatoes and onions, Unpublished Msc. Thesis, Norwegian, University of Life Science.

Sunette, M. L. (2010). Agronomic Performance, Consumer acceptability and nutrient content of new sweet potato varieties in South Africa. PhD Thesis, South Africa, University of Free State.

Takahata, Y., Noda, T.&Nagata, T. (1993). HPLC determination of beta carotene content of sweet potato cultivars and its relationship with colour values. *Japanese Journal of breeding 43*, 421-427.

Tanzania Demographic and Health Survey (TDHS) (2010), Micronutrients: Results of the 2010 Tanzania Demographic and Health Survey, Zanzibar: National Bureau of Statistics and Office of the Chief Government Statistician.

Teow, C. C., Truong, V. D., McFeeters, R. F., Thompson, R. L., Pecosta, K. V. & Yencho, G. C. (2007). Antioxidant activities, phenolic and beta-carotene content of sweet potato genotypes with varying flesh colors. *Food Chemistry*. *103*, 829-838.

Thane, C. & Reddy, S. (1997), Processing of fruit and vegetables effect on carotenoids, *Journal of Nutrition and Food Science 2*, 58-65.

Tindal, H. D. (1983). Vegetables in the tropics. London: Macmillan Press, Ltd.

Torres, A., Frias, J., Guerra, M. & Vidal-Valverde, C. (2005). Influence of fermentation on the nutritional value of two varieties of *Vigna sinensis*. *European Food Research and Technology 220*(2), 31-36.

Towett, E. K., Alex, M., Shepherd, K. D., Polreich, S., Aynekulu, E, & Maass, B. L. (2013).Applicability of near-infrared reflectance spectroscopy (NIRS) for determination of crude protein content in cowpea (*Vigna unguiculata*) leaves. *Food Science & Nutrition, 1*(1), 45-53.

Tumuhimbise, A. G., Orishaba, J., Atukwase, A. & Namutebi, A. (2013). Effect of salt on the sensory and keeping quality of orange fleshed sweet potato crisps, *Food and Nutrition Sciences*, *4*, 454-46

Ukom, A. N., Ojimelukwe, P. C. & Okpara, D. A. (2009). Nutrient composition of selected sweet potato [*Ipomea batatas (L) Lam*] varieties as influenced by different levels of nitrogen fertilizer application, *Pakistan Journal of Nutrition 8*(11), 1791-1795.

Van het Hof, K. H., West, C. E., Weststrate, J. A. & Hautvast, J. G. A. J (2000). Dietary factors that affect the bioavailability of carotenoids, *Journal of nutrition, 130*(3), 503-506.

Venkam, N. S. (1983). Foods of Hawaii and the Pacific Basin Volume I: Composition, Hawaii Institute of Tropical Agriculture and Human Resources, University of Hawaii at Manoa, *Research Extension Series 38*, 1-172.

Verdcourt, B. (1970). Studies in the Leguminosae-Papilionoideae for the flora of tropical East Africa. *Kew Bulletin 24*, 507-569.

Villareal, R. L., Tsou , S. C. S., Lin, S.K. & Chiu. S. C. (1979). Use of sweet potato leaf tips as vegetables. II. Evaluation of yield and nutritive quality. *Exp. Agric*. *15*, 117-122.

Vimala, B., Nambisan, B. & Hariprakash, B. (2011). Retention of carotenoids in orange-fleshed sweet potato during processing *J Food Sci Technol. 48*(4), 520–524.

Visavale, G. L. (2012), Principles, Classification and Selection of Solar Dryers: In *Solar drying Fundamentals, Applications and Innovations* (ed) Hii C. L, Jangam, V. S., Ong, P. S. and Mujumdar S. A., Singapore., 1-50.

Wawire, M. M. (2013).Optimization of nutritional and quality properties of African cowpea (*Vigna unguiculata*) leaves and other selected traditional African vegetables from farm to fork. Unpublished PHD Thesis. Juja: Jomo Kenyatta University of Agriculture and Technology.

Weinberger, K. & Msuya, J. (2004), Indigenous Vegetables in Tanzania – Significance and Prospects,The World Vegetable Centre (AVRDC), Taiwan, Shanhua *Technical Bulletin* No. 31.

Wenkam, N. S. (1983). Foods of Hawaii and the Pacific Basin; vegetables and vegetable products: raw, processed, and prepared; volume 1 composition. Hawaii Institute of Tropical Agriculture and Human Resources, University of Hawaii Manoa, *Research Extension Series 038*, 1-172.

Woolfe, J. A. (1992). Sweetpotato: *An Untapped food Resource*, UK: Cambridge University Press.

Yamini, C. N., Ranjana, Y. C. & R. Nagar (2001). Levels of beta-carotene and effects of processing on selected fruits and vegetables of the arid zone of India. *J. Food Sci*ence *56*, 127-132.

Yost, R., & Evans, D. (1988). Green manure and legume covers in the tropics. *Research series-Hawaii Agricultural Experiment Station, Hitahr College of Tropical Agriculture and Human Resources (USA).*

APPENDICES

Appendix 1: Questionnaire for household survey on production, processing and use of orange - fleshed sweet potato tubers and cowpea leaves in Maswa district

A: General information

i. Date of interview
ii. District
iii. Ward/Division
iv. Location of the market surveyed
v. Respondent name
vi. Respondent age …… Gender ……

B: PRODUCTION, PROCESSING AND USE

1. Do you cultivate sweet potatoes?
    a) Yes (01)
    b) No (02)
2. If yes, which variety do you cultivate?
3. Have you heard of Orange fleshed sweet potato (*viazi lishe*)?
    a) Yes (01)
    b) No (02)
4. Do you dry the orange fleshed sweet potato in the same way you dry local varieties?
    a) Yes (01)
    b) No (02)
5. If no, why? .....

How do you process the orange fleshed sweet potatoes or any sweet potato variety?

a) Boiling, then drying (01)
b) Peeling, slicing then drying (02)
c) Peeling then drying (03)
d) Both a and b (04)

6. Do you cultivate cowpeas?

a) Yes (01)
b) No (02)

7. If yes, which varieties?
   (a) Local (01)
   (b) Improved (02)
   (c) Both (03)
8. Which part do you consume?
   a) Leaves (01)
   b) Grains (dry) (02)
   c) Tender pods (03)
   d) Tender peas (04)
   e) All the above (05)
   f) A and b (06)
   g) A, b and d (07)
9. Do you dry the cowpea leaves
   a) Yes (01)
   b) No (02)
10. In what form do you consume the leaves?
   a) As a fresh vegetable (01)
   b) As dried vegetable (02)
   c) Both forms (03)
11. On which surface do you dry them?
   a) On the ground on a mat (01)
   b) On bare ground (02)
   c) On a raised platform (03)
   d) On rocks (04)
   e) Others (specify) (05)
12. If you don't use them as dry vegetables, what is the reason?
13. Do you dry the leaves for long term storage?
   a) Yes (01) Reason?
   b) No (02) Reason?
14. Before drying, what do you do to your orange fleshed sweet potato

a) Washing, Peeling, washing then drying (01)
b) Washing peeling then drying (02)
c) Peeling then drying (03)

15. Before drying what do you do to your cowpea leaves
    a) Sorting, washing, blanching then drying (01)
    b) Sorting, washing then drying (02)
    c) Sorting then drying (03)
16. What are the materials used by your family member as a surface for drying sweet potatoes.
    a) Mat (01)
    b) Sack (02)
    c) On the ground (03)
    d) Others specify (04)
17. Where do you normally store your dried product
    a) Hesian bags (01)
    b) On the floor (02)
    c) Sack (03)
18. For how long do you consume your dried products
19. Do you use the sweet potato chips as flour for making baked products
    a) Yes (01)
    b) No (02
20. In which products do you use this flour?
    a) *Chapatti* (01)
    b) Buns (02)
    c) B*agia* (03)
21. Which type of dried sweet potato do you prefer most?
    a) *Boiled* (01)
    b) Fresh dried*/mapalage*(02)
    c) Both (03)

Appendix 2: Different people interviewed during baseline survey, rocks used for drying and well water used by some villagers.

Appendix 3: Preparation and drying of cowpea leaves