POST-HARVEST HANDLING AND VALUE ADDITION OF AFRICAN INDIGENOUS VEGETABLES IN WESTERN KENYA

AYUA EMMANUEL OWINO

THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN COMMUNITY NUTRITION IN THE SCHOOL OF AGRICULTURE AND BIOTECHNOLOGY DEPARTMENT OF FAMILY AND CONSUMER SCIENCES

UNIVERSITY OF ELDORET, KENYA

OCTOBER, 2015

DECLARATION

This thesis is my original work and has not been presented in any other university. No part of this thesis may be reproduced without prior consent of the author and/or the University of Eldoret.

Student	Signature	Date
Emmanuel Owino Ayua	………………	…………….
AGR/PGF/003/12		

SUPERVISORS' APPROVAL

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

	Signature	Date
Prof. Violet Mugalavai	………………	………………

Department of Family and Consumer Sciences

School of Agriculture and Biotechnology

University of Eldoret

	Signature	Date
Dr. Florence Wamunga	..……………	……………. ..

Department of Family and Consumer Sciences

School of Agriculture and Biotechnology

University of Eldoret

	Signature	Date
Prof. James Simon	....	....

Department of Plant Biology and Plant Pathology

School of Environmental and Biological Sciences

Rutgers University

DEDICATION

This work is dedicated to my mother, Rosah Ayuma and my late father for their encouragement throughout my life. May God bless you all.

ABSTRACT

African Indigenous Vegetables (AIVs) are the major source of micronutrients in western Kenya and in Africa at large. However, AIVs utilization is not fully exploited because they are perishable. As a result, the vegetables are not available throughout the year. The study involved three AIVs Amaranthus (Amaranthus ssp), spider plant (*Cleome gynandra)* and nightshade (*Solanum spp)*. The objectives of the study were to determine AIVs processing methods in western Kenya; to determine the effects of some post-harvest handling techniques on nutritional composition; to assess consumer acceptability of both developed and local AIVs and to test the efficiency of mixed modes solar dryer over direct solar drying. A survey was done in Busia, Uasin Gishu and Trans Nzoia counties to determine the AIVs processing methods in western Kenya. To determine the effects of processing techniques on the nutritional composition, minerals analysis was done using Atomic Absorption Spectrophotometer (ASS) and flame photometer. The leaves were subjected to different treatments; exposed to direct sun, others were preserved under the shade. Recipes for the three varieties were developed and a panel of 51 consumers invited to participate in acceptability tests. The vegetables were ranked on taste, color, aroma, texture and overall acceptability. The performance of mixed mode solar dryer was compared to Mace Foods dryer (direct mode). Data analysis was done using SAS version 9.3. Means were separated by least significant difference at $P \leq 0.05$. T-test was used to compare vegetable preferences in western Kenya. AIVs (72%) were mostly grown after maize (92%). Boiling (22%) was the most common processing technique used by the farmers. There was no significant difference on preservation techniques on the elements at $P\leq 0.05$. However, vitamin C loss was greater during sun drying than shade preservation. From solar drying, the lowest and highest ambient temperatures recorded were 21.3^0C and 41.1^0C respectively. The mixed modes solar dryer recorded temperatures ranged between 23.0^0C to 72.1^0C. Mace Foods dryer temperatures ranged from 22.0^0C to 59.0^0C. The moisture content of the solar dried AIV ranged from 4.5% to 8.2 % while that from Mace Foods dryer ranged from 9.2% to 12.8 %. Findings of acceptability studies revealed that a combination of spider plant, nightshade and amaranthus prepared using cream was ranked highly (8.16± 1.07) followed closely by EX-ZIM amaranthus variety (7.29± 1.03) at $P\leq 0.05$. Bitter local nightshade (7.04±1.04) was preferred to the developed SS-49 variety (6.33±1.14) at $P\leq 0.05$. From the study findings consumers should be both enlightened on sound preservation techniques and be availed with seeds of the improved AIVs varieties for planting. Finally, the mixed modes solar drying technology should be adopted by farmers for AIVs preservation.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS AND ACRONYMS

AAS	Atomic Absorption Spectrophotometer
AIDs	Acquired Immunodeficiency Disease
AIVs	African Indigenous Vegetables
AMPATH	Academic Model Providing Access to Healthcare
AVRDC	Asian Vegetable Research and Development Center
AIVs	African Indigenous Vegetables
CDC	Center for Disease Control
FAO	Food and Agriculture Organization
HIV	Human Immunodeficiency Virus
Hort CRSP	Horticultural Crops Support Programme
IPGRI	International Plant Genetic Resource Institute
KARI	Kenya Agricultural Research Institute
KNBS	Kenya National Bureau of Statistics
PPM	Parts per million
SAS	Statistical Analysis System
SCN	Standing Committee on Nutrition
SSA	Sub-Saharan Africa
UK	United Kingdom
UNICEF	United Nations Children Educational Fund
USAID	United States Agency for International Development
WHO	World Health Organization

ACKNOWLEDGEMENT

I wish to convey my gratitude to United States Agency for International Development (USAID) through Horticultural Crops Support Program (Hort CRSP) for funding the study. I would like to appreciate Prof. Stephen Weller (Purdue University) for facilitating research funds to carrying out the study. Special thanks go to Prof. Violet Mugalavai and Dr. Florence Wamunga all from the University of Eldoret and Prof. James Simon of Rutgers University for their inputs during project proposal formulation and the directions and guidance they have gave during the entire period of the development of this research.

Additionally, I would like to appreciate the department of Biochemistry and Chemistry at the University of Eldoret for allowing me to carry out vitamin and elemental analysis in their laboratory, the enumerators who assisted in the survey and Mace Foods Company in Eldoret for giving me an opportunity to conduct a study in their industry. Sincere appreciation goes to Mr. Elijah Kamau and Miss. Catherine Mutinda who assisted me during sensory evaluation. Sensory evaluation panelists are also highly appreciated.

I wish to extend my gratitude to the entire Hort CRSP project Kenyan team for the team work and motivation they accorded to me during the study. The efforts of the farmers who assisted in during the survey are also appreciated. Finally, I wish to thank the almighty God for the strength and sound health during the project period. Thank you all.

CHAPTER ONE

INTRODUCTION

1.1 Background Information

The number of food insecure persons have reduced from 870 million (Food and Agriculture Organization, 2012) to 842 million (FAO, 2013). This is a good indicator that some gains are being made towards eradication of extreme hunger and poverty. Micronutrient deficiencies, especially vitamin A and iron, are major impediments to social and economic development, and impair learning ability, growth, productivity and development (World Health Organization, 2002). Child malnutrition is a significant problem in developing countries and notably in Africa. It is estimated that 60% of the children in the African continent suffer from iron deficiency anemia (Standing Committee on Nutrition (SCN), 2010). An additional 146 million children who are underweight are at high risk of dying from malnutrition because mortality rate increases exponentially with declining weight (FAO, 2007). Malnutrition is rampant in the tropics where per capita vegetable supply in most countries falls far short of the minimum recommended 73 kg/person/year. In Sub-Saharan Africa (SSA), per capita vegetable supply is only 43% of the required leading to widespread malnutrition. According to the World Health Organization (2005), consumption of fruits and vegetables in Sub-Saharan Africa (SSA) is less than the recommended 400g per capita daily. Subsequently, the region is prone to micronutrient deficiency diseases. Luchuo et al. (2013) stated that the major causes of malnutrition in Sub Saharan Africa include rampant poverty, climate change, corruption, lack of knowledge/education and poor ways of distributing food.

With such food and nutrition problems, the World Bank (2011) reported that dedication of more efforts in post-harvest technology is crucial in the attainment of food and nutrition security in Africa particularly Sub-Saharan Africa (SSA). Kader (2005) reported that cutting down on post-harvest losses for freshly harvested produce like leafy vegetables is vital for enhancing food availability. According to Kader and Rolle (2004), less than five percent of funding has been devoted to projects geared towards reducing food losses with more funds being geared to boost food production.

Loewenberg (2014) reported that nearly 1.3 million Kenyans are food insecure with up to 80% of pastoralists living below the poverty line. In Kenya and Tanzania, 40%-45% of pregnant and nursing women suffer from anaemia while 25%-30% of children under five are stunted and highly susceptible to infectious diseases. Micronutrient deficiency is a major cause of morbidity, disease and mortality among resource-poor women and children (WHO, 2000). According to UNICEF (2013), 46% of Kenyans live in less than a dollar daily with national AIDs/HIV prevalence being 7.8% in people of ages 15-49 years. The Kenya demographic and health survey (2008) reveals that 7%, 16% and 35% of children with less than five years are wasted, underweight and stunted respectively (KNBS, 2008-09). In western Kenya, poverty levels stands at 57.9% in the grassroots and 37.9% among the urban populace (KNBS, 2008-09).

African indigenous vegetables (AIV's), like African nightshades, Amaranths and spider plant contain vitamins, micronutrients, antioxidants (Keding et al., 2009; IPGRI, 2006), anticancer and other health-promoting phyto chemicals with antibiotic, probiotic and prebiotic properties (Abukutsa, 2010). Thus, they offer excellent health benefits to consumers and are a cheap, practical and sustainable intervention tool to address malnutrition-related problems especially in women and children. The vegetables play an important role in crop and nutrition diversity, food security of populations in both rural and urban settings, have high market potential and can help in poverty alleviation (Gockowski et al., 2003; Abukutsa, 2010). However, these plants are under threat from neglect by development agencies, government-sectors, agriculture and conservation groups and lack of interest by stakeholders. Nnanna et al. (2012) revealed that minerals like zinc, selenium and iron are helpful in slowing down the onset of opportunistic infections among HIV patients as they boost the immunity. Additionally, the same report revealed that the minerals levels are low among patients with HIV virus than healthy persons. Consequently, AIVs that are rich in minerals can be used to meet the micronutrient demand in HIV patients. Kimiywe (2007) found out that AIVs like black nightshade are used to manage HIV, cancers and heart diseases. According to Irungu (2007), Black nightshade and Crotalaria are used to manage HIV disease. Spider plant also referred to as spider flower plant is high in lipids, phenolic compounds and crude protein (Silue, 2009). Stems, tender leaves, flowers and pods comprise the consumed parts of the plant. Spider plant alleviates migraine, vertigo, septic ears and pneumonia (Silue, 2009). Feeding spider plant to women after birth increases lactation and formation of blood. Therefore, AIVs influences bulk consumption of staples even if the AIVs are consumed in smaller amounts compared to the staples. According to Adewale and Alani (2013), amaranthus *spp* and spider plant have minerals and phytochemicals that both boost and protect consumers from chronic diseases like cancers, diabetes and HIV.

African indigenous vegetables are often cultivated in small patches in home gardens, fitting well in resource-poor farmers’ agricultural systems. The perception of African indigenous vegetables as low-status foods has hampered their utilization which can be addressed by awareness creation supported by well-coordinated scientific research and development.

1.2 Statement of the Problem

About 50% of vegetable loss in developing countries is because of poor infrastructure and excess supply of perishable produce that are realized when there is limited access to markets (Brown et al., 2005; Acedo, 2010). Further, Acedo (2010) revealed that few attempts and interventions have been put in place to tackle these problems of post-harvest losses. In western Kenya, perishability is a great challenge that hampers efficient utilization of African Indigenous Vegetables (AIVs) (Abukutsa, 2010). As a result, vegetable surplus that is realized during the rainy seasons becomes scarce during the dry seasons. Consequently, the vegetables are not available throughout the year. During peak production of the vegetables, the farmers sell their produce at low prices because of poor preservation technologies (Abukutsa, 2003; 2010). Abukutsa (2010) reported that AIVs are perishable and spoil easily within 24 hours when kept at room temperatures. In that regard, post-harvest handling techniques used by farmers like putting under the sun and shade as well as sprinkling water on top of the AIVs cannot prolong the shelf life of AIVs. As a result, the AIVs cannot access the external markets. Rickman (2007) concluded that if changes in nutritional composition of the vegetables during postharvest handling were to be factored in, losses could be much higher as is reported.

Perishability has become a challenge to vulnerable persons such as the elderly, children below five years, the poor and HIV infected persons that have been encouraged to grow improved indigenous vegetable that are drought resistant for food and nutrition security (Mamlin et al., 2009). Apart from traditional sun drying, these vulnerable farmers also access the Mace Foods direct mode solar dryer for processing the vegetables that is not as efficient. As an alternative, a mixed modes solar dryer is being tested in performance in comparison to Mace Foods direct modes solar dryer.

Therefore, there is need to investigate the performance of mixed modes solar dryer for AIVs processing, acceptability of improved AIVs, the effect of farmer postharvest handling practices on the nutrient composition of vegetables in the value chain and also curb the post-harvest losses. Based upon this realization, this study sought to explore post-harvest handling of AIVs in western Kenya for food and nutritional security.

1.3 Purpose of the Study

The overall aim of the study was to assess post-harvest handling practices of AIVs smaller holder farmers in western Kenya for food and nutritional security.

1.4 Objectives

1.4.1 General Objective

To assess the existing post-harvest handling practices and value addition of AIV among small holder farmers in western Kenya

1.4.2 Specific Objectives

1. To determine the post-harvest handling practices of African Indigenous Vegetables used by small holder farmers in western Kenya.

2. To evaluate the effect of farmers postharvest handling practices (preservation under the sun and shade) on the nutrient composition of African indigenous vegetables.
3. To determine the drying efficiency of modified mixed modes solar dryer over direct mode solar dryer
4. To assess the acceptability of local and improved varieties of AIVs using conventional cooking methods.

1.6 Hypotheses

H_{o1}: Farmers do not have effective postharvest handling practices.

H_{o2}: Farmers practised post-harvest handling practices do not alter the nutrient composition of AIVs.

H_{o3}: Mixed mode solar dryer has a higher drying efficiency than direct solar drying technology.

H_{o4}: There are no differences in acceptability between local and improved AIVs varieties among small holder farmers.

1.7 Justification of the Study

The study findings will be useful in many ways. The study will provide sound optimal post-harvest handling techniques that can be used by farmers to reduce post-harvest losses. The study will also inform the farmers the improved drought tolerant AIVs that are recommended and can be cultivated under limited moisture conditions. Kimiywe et al. (2007) suggests that AIVs can be used to manage HIV, cancers, stomachache and diabetes. Therefore, campaigns will be devoted to promote AIVs consumption as a remedy to the above mentioned ailments. This study therefore seeks to determine proper post-harvest handling practices that will minimize loss of vitamins, minerals and phytochemicals that boost the immunity of farmers. The improved solar dryer will be up scaled for processing other horticultural produce by Mace Foods Company besides AIVs as an attempt to curb the losses. Finally, the study will form a basis upon which policies on sound post-harvest technologies can be implemented in the grassroots of western Kenya.

1.8 Limitations of the Study

The study was restricted to Uasin Gishu, Trans Nzoia and Busia counties of western Kenya although western Kenya covers a vast region. This is because these huge AIVs loss is witnessed in the three counties. Major emphasis focused only on three AIVs: Amaranths, spider plant and African nightshade because of their higher market value in the region.

1.9 Assumptions

It was assumed that farmers used the same postharvest handling practices such as boiling, drying, cooling and sorting.

1.10 Theoretical Framework

This research utilized the social ecological model (CDC, 2002) to better understand the aspects of post-harvest handling, value addition and consumption of AIV. The socio-ecological model is used in understanding the link that exists between the numerous personal and ecological factors. The theory focuses on the role played by the environment and individual in preventing and containing phenomena. This model has four components; the societal, community, individual and the relationship factors which interplay in handling a particular issue. Adedze et al. (2011) used the model to provide a context to be used to prevent obesity within a framework that consisted of social context, environmental factors in addition to inter and intra-personal level. This study used the four elements of the theory as follows;

Individual factors of the model included the factors within an individual. These included factors such as income level, taste and preferences, knowledge about the nutritional components of the vegetables and methods of preparation/ preservation. The relationship aspect focused on whether or not an individual had prior experience with the vegetables. In addition, relationship with people who consume the vegetables can influence value addition of the African indigenous vegetables.

The community component lay emphasis on the role played by various institutions to promote value addition and utilization of the AIVs. Among them included universities, schools, research institutes, ministry of health and nongovernmental organizations. The society part of the model concentrated on the cultures that either promote or hinder value addition hence consumption of the AIVs. For instance, the social class with the society plays a key role. Some of these vegetables such pumpkin leaves are associated with people of the lower social class while African nightshade is associated with higher social class.

CHAPTER TWO

LITERATURE REVIEW

2.1 African Indigenous Vegetables

Indigenous foods like AIVS are attracting the interests of many people in Africa especially how they can be used to eradicate hunger besides enhancing food and nutrition security. Consumption of AIV and diet diversification is seen to be useful in eradicating malnutrition (Abukutsa, 2010; Keding, 2009). AIVs cultivated in Eastern, Western and Southern Africa include Amaranths, cowpea leaves, spider plant, African nightshade, slender leaves and pumpkin leaves (Abukutsa Onyango, 2010). African indigenous vegetables are still on stage in enhancing food security and nutrition to both the rural and urban populaces. These vegetables have not been fully utilized in western Kenya as an enterprise for income generation instead they are mostly produced for consumption at home (Abukutsa-Onyango, 2010). There is need to create awareness on the AIVs and explore their potential for achieving food and nutrition security in western Kenya

2.2 African Indigenous Vegetables in Western Kenya

2.2.1 Spider plant (*Cleome gynandra*)

Spider plant belongs to the family *Capparaceae*. Spider plants are used as vegetables in western Kenya to accompany *Ugali*, the staple food in the region. The major micronutrients in spider plant include vitamins A, C, calcium and phosphorous (Abukutsa-Onyango, 2010; Silue, 2009). Spider plant is useful in treating diseases like stomach ailments and it also reduces the severity of labor period during delivery (Kimiywe et al., 2007). Masayi and Netondo (2014) indicated that spider plant requires unique preparation processes which when not followed leads to the retention of bitter taste which is less preferred by consumers.

2.2.2 Amaranth (*Amaranthus spp*.)

Amaranth is an indigenous vegetable whose seeds have high protein content. The leaves of Amaranth are rich in calcium, iron, protein and antioxidant properties due to the presence of polyphenols and lecithines (Mibei et al., 2012). Amaranthus species are useful in labour induction in women, treatment of burns, Stomach ache, diabetes, malaria and weight boosting among children and infants (Kimiywe et al., 2007). Nonetheless, Masayi and Netondo (2014) attributes amaranthus to short life span in the field making the vegetable less suitable in alleviating food insecurity.

2.2.3 African Nightshade (*Solanum spp.)*

This vegetable comes second after amaranth in terms of its use to alleviate food insecurity in western Kenya. The vegetable is used to manage HIV and AIDs (Kimiywe et al. 2007). African nightshade has several medicinal values. For instance, it can be used to treat malaria, diabetes, stomach ache, diabetes and hypertension (Mibei et al., 2012). According to Masayi and Netondo (2014), cooked nightshade can stay longer without spoilage.

2.3 Nutritional and Medicinal Importance of African Indigenous Vegetables

The nutritional benefits derived from AIVs are enormous. According to Heever (2007), consumption of Spider plant and Amaranths can help in relieving constipation and help mothers to ease child birth. African nightshade and Amaranth can be used in curing stomach pain, colds, diabetes and pain in the chest (Kimiywe et al., 2007).

Nutritionally, AIVs have calcium, iron, vitamins A and C, Zinc, Magnesium, Manganese and Copper (Mibei et al., 2012). They contain a good amount of antioxidants that can bind and remove harmful radicals that have some linkages to heart diseases, cancers and diabetes (Kimiywe et al., 2007). In addition, they are excellent sources of both micro and macro nutrients and can be used to alleviate malnutrition and food insecurity during emergency situations (Abukutsa-Onyango, 2010). The traditional leafy vegetables cooked by addition of traditional additive (lye) results into higher iron content than raw ones (Abukutsa-Onyango, 2010b). African indigenous vegetables are not only rich in micro nutrients but also have medicinal importance (IPGRI, 2006). Some of the medicinal values of AIVs are outlined in Table 2.1 below

Table 2.1 Medicinal Values of African Indigenous Vegetables

AIVs name	Medicinal Value
Jute mallow	Anemia and stomach ache
Pumpkin leaves	Treatment of diabetes, hypertension, and back ache
Black night shade	Hypertension, diabetes, AIDs stomach ache, malaria, coughs.
Stinging nettles	Anemia, fainting, coughs, colds, backache
Crotalaria	Stomachache
Amaranth	Malaria, coughs, HIV, stomachache, diabetes, colds, skin rashes, diarrhea
Spider plant	Stomach ache, ease child birth.

Adopted from Kimiywe et al. (2007), Mibie et al. (2012)

2.4 Consumption of African Indigenous Vegetables

Many organizations are working to create awareness on consumption of AIVs. Bioversity International is one of the organizations championing for cultivation and consumption of AIVs in Sub Saharan Africa (IPGRI, 2006). The western culture is negatively influencing the consumption of indigenous leafy vegetables by introduction of convenient foods that are rich in calories (Mavengahama, 2013). Western culture has led to the introduction of convenient foods in the market. The convenient foods have a lot of calories and fats which predispose individuals to chronic degenerative diseases. Keding et al. (2009) reported that wild indigenous vegetables are underutilized yet they are rich sources of proteins and minerals such as iron, potassium, calcium and sodium. However, nutrition information on some wild indigenous vegetables has not been documented. Kimiywe et al. (2007) and Charles Ogoye-Ndegwa (2003) found out that some of the African indigenous vegetables that are consumed on regular basis are *Amaranthus*, *Crotalaria*, spider plant, nightshade and *Bacella alba* (Nderema) (Table 2.1). Among the factors that influence consumption of AIVs include ethnicity, preparation skills and price (Kimiywe et al., 2007).

Table 2.2: Some of the indigenous vegetables consumed in Kenya

Scientific name	Local name	Common name
Amaranthus sp.	Mchicha	Amaranth
Amaranthus sp.	Kunde	Amaranth
Solanum sp.	Osuga, Managu	African nightshade
Crotalaria	Mitoo	Crotalaria
Corchorus sp.	Mrenda	Jute
Cleome gynandra	Saga	spider plant
Brassica carinata	Kanzira	Water spinach, Ethiopian Kale

Source: Charles Ogoye-Ndegwa (2003); Kimiywe et al. (2007)

2.5 Knowledge and attitude towards African Indigenous Vegetables

Findings by Voster et al. (2008) revealed that women remain the core custodians of knowledge regarding AIVs because they are involved in their production, preservation, gathering and cooking. Moreover, Voster et al. (2008) found out that the loss of indigenous knowledge regarding AIVs is because people have become unwilling to acquire knowledge about them. Some reasons that make people unwilling to gain information about AIVs is because the vegetables are ascribed to low status and due to people tending to depend more on exotic vegetables (Mavengahama, 2013). According to Flyman and Afolayan (2006), many studies on indigenous vegetables have focused on already domesticated species. This means that more knowledge can be generated on underutilized species that have more nutritional potential. Mavengahama (2013) reported that researchers investigate information regarding AIVS based on their interests rather than on a basis that aims to commercialize and domesticate wild AIVs. Consequently, there is a dearth of knowledge regarding wild AIVs. Modi et al. (2006) concluded that young family members are less familiar or have limited knowledge regarding AIVs. This is because older people remain the custodians of knowledge concerning AIVs. Similarly, knowledge about AIVs increases with increase in the education level of an individual.

2.6 AIVs role in enhancing food security

Mavengahama (2013) found out that some AIVs are hardy and hence capable of thriving during floods and dry conditions. As a result, they are present when environmental conditions are harsh to the cultivated crops. As such, they contribute to food security among subsistence farmers. Moreover, Kepe (2008) discovered that AIVs offer substitutes for food crops among the rural poor thereby broadening the food base. Mavengahama (2013) discovered that in some instances, AIVs are not consumed when food is adequate but in difficult circumstances such as famines and droughts. This is because AIVs survive during floods and droughts times when food crops do not thrive. Van der Walt et al. (2009) reported that AIVs like amaranth are drought tolerant and mature faster to provide food for hungry households after dry spells. Since AIVs are rich in micronutrients (Abukutsa-Onyango, 2010), they can be used to fight hidden hunger. Finally, Mavengahama et al. (2013) established that AIVs can acts as substitutes for food crops for rural populace trapped in perpetual poverty during food scarcity.

2.9 Post-harvest Handling practices for Leafy Vegetables

Post-harvest operations influence post-harvest losses in several ways. Some of the post-harvest operations include packaging, transportation, washing, sorting and grading (Acedo, 2010). Acedo (2010) reported that packaging could prevent physical injury during transport and minimize loss of water from vegetables. According to Muhammad et al. (2012), use of local baskets in vegetable packaging may trigger vegetable loss. This is because the baskets are characterized by poor ventilation and rough baskets can cause bruises to the vegetables. Therefore, it is advisable that plastic or wooden crates that are well ventilated be used during storage, marketing, transportation and harvesting of fruits and vegetables (Workneh et al., 2012). Rough handling of fruits and vegetables prior to marketing can increase the chances of bruising. Roads between the packing house and fields should be free from holes and bumps. Arrangement of vegetables sacks on top of the other also causes vegetable damage. In addition, sacks that are not arranged properly may cause heat buildup from metabolic reactions and this hastens mechanical damage (Kereth et al., 2013).

Kereth et al. (2013) explains that some of the packaging containers include the use of crates, sacks and baskets. These packaging materials should allow provisions for ventilation.

Ofor et al. (2009) discovered that the quality of water helps to reduce contamination in post-harvest washing and cooling of vegetables. The water used to wash fruits and vegetables should be free from microorganisms that cause postharvest diseases. Findings by Tsado et al. (2013) disclosed that irrigation of vegetables and fruits using waste water and manures can increase bacterial loads in the harvested vegetables. Chapman (2005) adds that pathogens that occur in water or soil can cause contamination during post-harvest operations of fruits and vegetables. According to Dhatt and Mahajan (2007), washing vegetables in chlorinated water of about 100-150 ppm is useful in reducing the buildup of microorganisms. For good results, the PH of the wash solution should range from 6.5 to 7.5. However, Acedo (2010) reported that chlorine concentration in the wash solution greater than 200ppm can cause damage to the vegetables. Chlorinated wash solution may also be applied in hydro cooling and disinfection of transport facilities, packing house and packaging materials. Kader (2006) acknowledged that as much as cleaning helps in the removal of surface impurities and rubble, it can favor the development of bacterial soft rot in the vegetables if not well dried.

Cooling of fruits and vegetables is helpful in the prolonging their shelf life through reduction in the rates of transpiration and respiration (Acedo, 2010). Further, cooling retards the growth of micro-organisms. Several modes of cooling are available. These include keeping vegetables away from direct sun light, cooling naturally like harvesting during cool times of the day and providing ventilations in vegetable stores.

Evaporative cooling is also practiced by passing dry air on top of moist surfaces (Figure 2.3). During evaporative cooling, the vegetables should be exposed to the sun intermittently to prevent both yellowing and chilling injury.

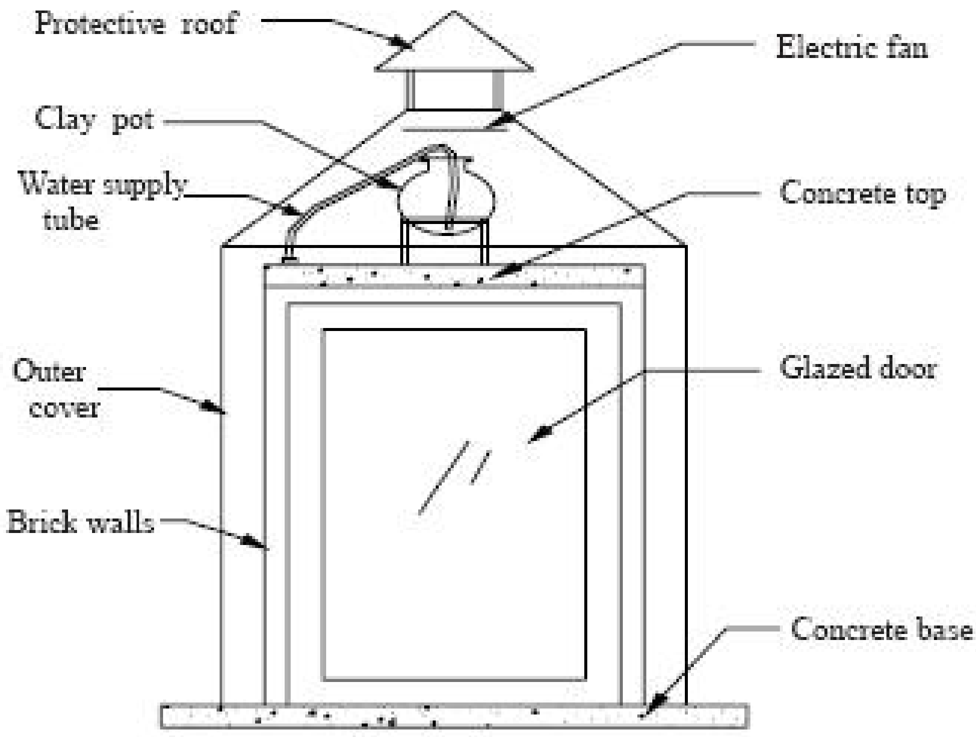


Fig. 2.3: Modest evaporative cooler. Acedo (2010)

Kader and Kitinoja (2002) encourage refrigeration and precooling after harvesting to extend the shelf lives of vegetables. Precooling preserves vegetables by inhibiting the growth of spoilage microorganisms, reduction of both ethylene production
and water loss. In developing countries ice usage to cool vegetables has increased tremendously (Huang, 2006). Acedor (2010) confer that ice is readily available and is

helpful in the preservation of vegetables during storage and in distribution. To prevent chilling injury in vegetables, newspapers layers can be placed between ice and the vegetables (Acedo, 2010).

2.7 Effect of Processing on the Nutritional Composition of African Indigenous Vegetables

The perishability of AIVs necessitates the need to process them so as to avoid post-harvest losses. This can be through traditional sun drying, oven drying, cooling and solar drying. These processing techniques make changes in the nutritional composition of the indigenous vegetables (Akubugwo, 2008). Processing of AIVs reduces the phytochemicals like phenols, flavanoids and pytates (Akubugwo, 2008). Abukugwo (2008) adds that shredding then drying of the vegetables leads to reduction of flavonoids. However sun drying of vegetables leads to a high retention of phytochemicals (Abukugwo, 2008). Steaming of vegetables destroys most of alkaloid, phenols in addition to saponins. Drying the vegetables using both an oven and in the sun is highly encouraged for retention of micronutrients like sodium and potassium (Akubugwo, 2008).

Another processing technique is cooking. Prabhu and Barrett (2009) discovered that as cooking destroys ascorbic acid, more phenols are freed which dominate antioxidant properties. As a result, antioxidant activity is increased upon cooking. Cooking increases bioavailability of iron from about 5% to more than 20% (Yang and Tsou, 2006). Compared to other processing techniques like sun drying or pickling, boiling increases iron content of vegetables (Yang and Tsou, 2006). Cold storage however does not cause any variations in the iron content (AVRDC, 2002). Studies have shown that cooking and processing of vegetables results in reduction in the amount of vitamin C levels (Oboh et al., 2008; Habwe et al., 2010). This is because vitamin C is unstable at high temperatures. Both Sun drying and boiling decreases the amounts of beta carotene (Kiremire et al., 2010). Habwe et al. (2010) found out that cooking vegetables and/ or a combination of vegetables cooked together increases their copper content. According to Kimiywe et al. (2007) preparation techniques such as vegetable chopping then washing, repeated boiling and use of sodium bicarbonate during preparation should be avoided. Washing then cutting leaches water soluble vitamins while repeated boiling denatures the vitamins. Despite sodium bicarbonate helping to tenderize and keep the green colour of vegetables, it leads to loss of niacin and vitamins B_1 and B_2. Findings by Prabhu and Barrett (2009) divulge that calcium, zinc and iron are also leached into the cooking water during vegetable cooking. As a result, Bradbury (1987) advised that the water used for cooking should be retained for making soup and this can help minimize nutrient loss. On the other hand Lewu et al. (2009) found that the anti-nutritional factors like Calcium oxalate leached into the cooking water should be eliminated by discarding the cooking water. Overall, cooking water needs to be retained to prevent nutrient loss as vegetables may not necessarily contain micronutrients.

2.8 Solar Drying of Vegetables

Solar drying though considered an ancient way of processing foods is a feasible method that can be used to process vegetables (Kiremire et al., 2010). Solar drying is an optimal way of reducing the moisture content of fresh vegetables. Limited moisture content in vegetables inhibits microorganism growth (Bates et al., 2001). Nonetheless, Ukegbu and Okereke (2013) stated that solar drying leads to enormous protein loss compared to sun drying. This is because solar drying leads to more moisture loss which in turn affects dry matter. One advantage of solar drying is that nutrients in solar dried products are more bioavailable than sun dried (Ukegbu and Okereke, 2013).For instance, the amount of crude fibre, ash and carbohydrates in solar dried products are higher compared to sun dried. Additionally, solar dried products have lower microbial load compared to sun dried (Ukegbu and Okereke, 2013).

Before solar drying, the vegetables are blanched. This entails heating the vegetables in hot water at temperatures that can destroy all the enzymes available in the leaves for 1-2 minutes. Blanching also increases the rate of drying as it makes the tissues walls to relax making it easy for moisture to escape rapidly. Additionally, blanching aids during rehydration as it makes moisture re-enter quickly into the vegetables. Finally, blanching helps in killing microorganisms present in the vegetables which can reduce the quality of the vegetables (Kader and Kitinoja, 2002).

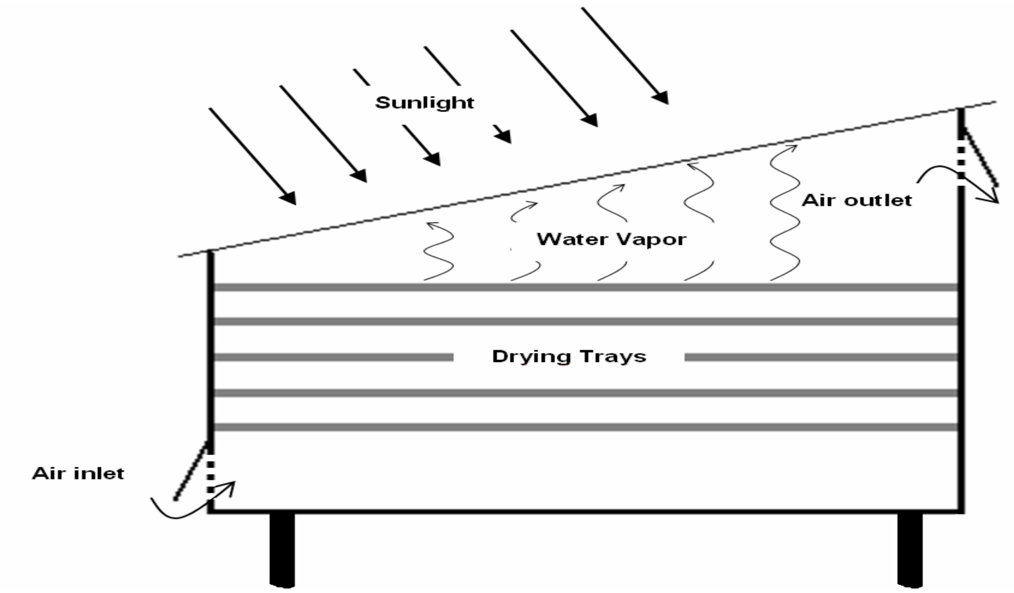


Fig. 2.1: Direct solar drying technique (Vriens, 2007)

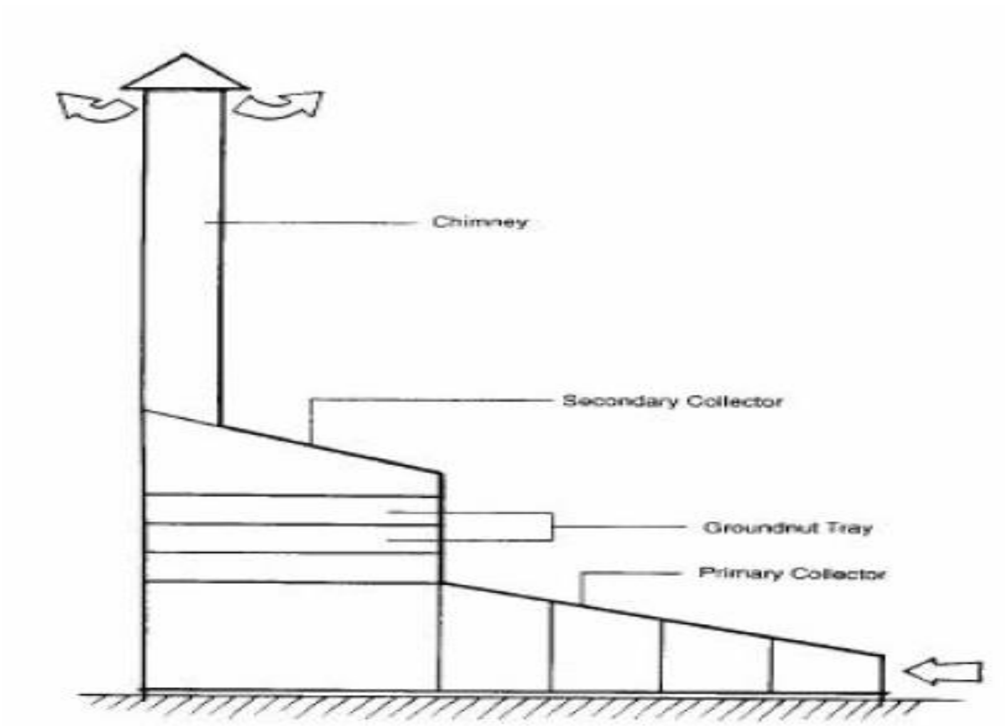


Fig. 2.2: Indirect solar drying technology (Vriens, 2007)

In direct solar drying products absorb energy from the sun via transparent covers. Thus, the produce is dried directly from the sun while the chamber provides protection to the product being dried from the external environment (Fig. 2.1). In indirect solar drying air is first heated before heating products in the drying chamber (Fig. 2.2). Through the hot air, moisture is evaporated from the product. Mixed modes of solar drying combine the indirect and direct solar drying techniques. Mixed mode solar dryers have chimneys designed where moist airs are exhausted through buoyancy effects (Stiling et al. 2012). Simate (2001) proved that the amount of moisture being evaporated from product equals convection currents entering the dryer. Joshi et al. (2004) discovered that rates of drying in mixed mode solar drying technologies depends on the rate or speed at which moisture is eliminated from products being dried and the speed at which moist air is eliminated from the space close to the products being dried.

In most regions of the developing world, traditional solar drying exists because of its simplicity and low cost of installation. However, traditional solar drying has many weaknesses, including uncontrolled drying, insects' infestation, produce exposure directly to the sun and contamination from dust (Olalusi and Bolaji, 2008). Solar drying is attributed to several benefits including volume reduction, product diversity and increased shelf life (Olalusi and Bolaji, 2008). Solar dryers can be designed as mixed modes, indirect and direct modes (Simate, 2001; Olalusi and Bolaji, 2008).

2.10 Sensory Evaluation of Foods

Walker (2004) established that descriptive sensory analysis attempts to describe the sensory attributes of food. Aroma, sound, flavor and texture are some of the qualitative food attributes. Sensory evaluation is very vital in determining whether or not consumers have accepted a food product. Taiga et al. (2008) posit that sensory evaluation should be done using a hedonic scale that is used to measure the level of acceptance of a food product. Waghray et al. (2012) concluded that sensory evaluation helps to determine the acceptability of a product. Hence, the product that is well accepted is then marketed to the consumers for adoption. The findings of his research revealed that consumers have less preference for bitter foods compared to the less bitter ones.

One of the most common ways that can be used to assess the preferences and acceptability of foods in sensory analysis is by use of a 9.0 point hedonic scale (Like extremely=9, Like very much=8, Like moderately=7, Like slightly=6, neither like nor dislike=5, Dislike slightly= 4, Dislike moderately= 3, Dislike very much=2, Dislike extremely=1) (Lawless and Heyman, 2010). The participants of such sensory evaluation are usually untrained hence unaware of the sensory evaluation task.

The conduct of testers prior to sensory evaluation should adhere to the following conditions (Muzzalupo et al., 2012). Smoking and coffee taking should not occur within 30 minutes before they engage themselves in sensory evaluation. Secondly, fragrance use or cosmetics whose smells could linger up to the time sensory evaluation is conducted should be avoided. Likewise, the participants of sensory evaluation need to fast for a minimum of an hour before tasting is done. Furthermore, anyone who is physically unwell or has a condition that interferes with taste, smells and hence unable to concentrate in such an evaluation should refrain from participating in such a study. Each taster each taster should be allocated a booth so as to gain confidence to participate in the study. It is important that each of them remains silent when sensory evaluation is being done. Finally, participants should not talk to another to avoid seeking each other's opinions.

Van der Hoeven et al. (2013) reported that apart from salt, peanuts and oils are also used during vegetables preparation to increase palatability. Umuhozariho et al. (2013) and Kimiywe et al. (2007) acknowledged that some of the ingredients used during vegetable preparation are table salt and sodium bicarbonate. Sodium bicarbonate however is discouraged because it can lead to biotin and niacin loss besides demineralization of bones (Kimiywe et al., 2007). Garcia-Bailo et al. (2009) found out that a products taste influences its overall acceptability. As a result, products with bitter tastes have lower acceptability.

Summary

From the literature reviewed, it is very evident that AIV has a lot of micro nutrients. In addition, western Kenya has abundant AIV. However, the value addition methods used like boiling lead to great nutrient losses and short shelf life of the products. Further, there are large losses attributed to perishability. This affects availability hence consumption of the AIV. Processing through solar drying not only makes nutrients to be more available but is a better option that farmers can use to prolong the shelf lives of the vegetables. The focus therefore would be to adopt an optimal postharvest technology that would prolong the shelf life for a longer time and maintain consumer attributes or both. Finally, each processing technique should maintain product safety.

CHAPTER THREE

RESEARCH METHODOLOGY

3.2 Study Area

The study was conducted in Uasin Gishu, Busia and Trans Nzoia counties of western Kenya (Appendix 2). In Uasin Gishu county field experiments were conducted at the University of Eldoret farm, located 9 km from Eldoret town. The altitude of university of Eldoret is 2120 m above sea level. The latitude is $0^0$34'N while the longitude is $35^0 18^{'}$E. Eldoret receives an annual rainfall of between 900 to 1300 mm. The mean range of temperature is 10^0C to 25^0C in July and January respectively (Jaetzoldt and Schmidt, 1983). Soil fertility is low with a pH below 5.5 (GoK, 1996). The soil class of Eldoret town is rhodic Ferralsols (FAO, 1994).

Busia county is located in western Kenya at a latitude of 0-0^0 25'N and a longitude of $33^0$54'E (Jaetzoldt and Schmidt, 1983). The altitude range is 1130m to 1375 m above sea level. The annual rainfall varies from 1270 mm to1790 mm and the mean annual temperatures range is 140^0C to 18^0C. The soils in Busia County are Orthic Ferralsols soils (FAO, 1994).

Kitale is within Trans Nzoia County and has an altitude of 1890 m above sea level, a mean annual rainfall is 1143 mm and a mean daily temperature in the region is 22.5^0C. Kitale is located at latitude of Kitale town are 35^0 7.5' E and 1^0 01' N (Nyakuri et al., 2014). Peak rainfall is received in April until the beginning of August.

3.2 Research Design

Descriptive survey and experimental designs were used in the study.

3.2.1 Descriptive Survey

A baseline descriptive survey was conducted in Uasin Gishu, Transzoia and Busia Counties among vulnerable farmers and other farmers. The survey included questions pertaining to basic bio data, current knowledge of production practices of AIVs, post-harvest handling practices, household consumption of AIVs and production. Market characteristics of AIVs were also captured in the survey. According to WHO (2001), surveys are good as they help researchers to better understand the situation on the ground.

3.2.2 Survey Sample Size Determination

The subjects of the study were drawn from Kitale, Busia and Eldoret. A sampling frame was obtained from agricultural centers in the three sites indicating a list of the vulnerable farmers. For other farmers, they were identified by local authorities. Then, simple random sampling was used to select 105, 97 and101 from Busia, Eldoret and Kitale respectively. Subjects within the study area were selected as described by Mugenda and Mugenda (2003) below;

$$n = \frac{z^2 . p . q}{d^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{(Eqn 1)}$$

Where:

n = Sample size required

z = Confidence level at 95% (standard value of 1.96)

p = Estimated proportion of those consuming AIVs

q = 1-p, an estimate of those not consuming AIVs (1-0.50 = 0.50)

d = error (0.05)

Hence, the sample size calculated was

$$n = \frac{1.96^2 x 0.50 x 0.50}{0.05^2} = 384 \text{ farmers } \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(Eqn 2)}$$

Allowing for 10% attrition the sample size was set at 423 farmers.

3.2.3 Survey Data Collection

The farmers were interviewed using a questionnaire containing both open and close ended questionnaires (Appendix 1). The questionnaire captured information concerning AIV production, post-harvest handling/processing practices, value addition, AIV consumption and demographic characteristics. Twenty (20) enumerators were trained for a week to assist in data collection. Participant observation was used to complement information gathered through questionnaires. Since questionnaires are developed from the objectives of the study, they provided firsthand information. Either gender of the household was interviewed in the s tudy. In the absence of the house hold head, either eldest child or caretaker available participated in the study.

3.3 Experimental Studies

3.3.1 Micronutrient Analysis

Following the farmers conventional preservation methods of storing the vegetables either in the sun or under the shade, experiments were done to determine the effects of these methods on the nutritional composition. First, the vegetables were harvested at the pre-flowering stage. After harvesting the leaves were divided into two groups. One group was preserved in the sun and the other preserved under the shade for a period of 8 hours from 9.00am to 5.00 p.m. Thereafter, each sample was analyzed for micronutrients (Zn, Cu, Iron and K) as described by Association of Analytical Chemist (AOAC) (1995) and Okalebo et al. (2002).

3.3.2 Vitamin C Analysis

Vitamin C was analyzed as described by College of science (2011) at the University of Canterbury. First, 100g of fresh leaves were manually ground using mortar and pestle. The ground vegetable pulp was then strained in cheese cloth to obtain the vegetable juice. The extracted sample was diluted with distilled water and 0.2 g of potassium iodide was carefully weighed into a beaker of 100ml. Next, 1.3 g of iodine was added into the same beaker and swirled to dissolve the iodine solution where it was then transferred into in to a one litre volumetric flask. This solution was then made to a litre using distilled water. Next, 20 ml of the sample solution was pipetted into a 250 ml conical flask and 150 ml of distilled water was added to the conical flask. Finally, 2 drops of starch solution previously made was added into the flask. Titration was done using 0.005 moles per litre solution of potassium iodine until a dark blue black color of starch-iodine complex was formed. Leaves from each plot were analyzed in triplicates. Vitamin C was expressed in mg/100g.

$I_2 \longrightarrow 2I^- +$dehydro ascorbic acid

Below are vegetables that were used in micronutrient analyses.

Local Nightshade

SS-49

BG-16

Local Amaranth

UG-AM-40

EX-ZIM

UG-SF-17

LOCAL VARIETY

ML-SF-29

Fig 3.1: Vegetables used in the experiment: (Source: Author, 2014)

3.4 Solar Drying African Indigenous Vegetables

3.4.1 Construction of the Mixed Modes Solar Dryer

The solar dryer was modified from Horticultural Innovation Lab design and had three parts namely, the collector, the drying chamber and the chimney. This solar dryer was modified from that designed by Reid and Thompson (2013), from Horticulture Innovation Lab, Davis, CA. The solar dryer was 2.4 m in length with a width of 1.2 m. The dryer height was 0.35 meters above the ground. The collector was a black plastic sheet held in place by pins below the dryer bed. The collector increased incident sun rays intensity and the incoming air getting into the dryer. The collector roof was flat. Therefore, no adjustments were needed on the solar collector for maximum absorption of incident solar energy either in the morning or afternoon sun. On the upper end, four pieces of wood were placed into the soil for stability and to construct a chimney of 1.8 m tall with a square base of 0.25 m. The chimney was wrapped with a black polythene sheet. As a result, the chimney helped provide draft to aid in air movement within the chamber. The drying chamber had three drying trays. The bottom part of the drying trays was made of plastic mesh to permit air circulation through the vegetables during drying. The drying chamber was partitioned into three; front section of air inlet, middle section of the dryer, and far section of the dryer by heated air outlet. A clear polythene paper was put on top of the drying trays to concentrate solar energy. Moreover, the transparent polythene protected the vegetables being dried from rainfall, dust and helped to minimize vegetable discoloration during drying. The mixed modes solar dryer design incorporated both direct and indirect solar drying technologies (Figure 3.1). The direct drying mode helped in moisture removal from the vegetables through incident ray radiation. Hot air entering the dryer carries away moisture from the products being dried in the chamber through indirect drying mode. Moreover, the hot air currents passing through the dryer helped by preventing excessive heat buildup in the drying chamber that could destroy the vitamins. Thus, the vaporization heat that aided in moisture removal from the vegetables was brought about by the combined efforts of both the incident radiation and hot air heated by the black collector. As a result, the amount of hot air entering the dryer equaled the moisture levels leaving the dryer from the vegetables being dried. The mixed modes solar dryer cost approximately $75.00 for all supplies excluding labour. The model described above was constructed by Ayua, Simon, Weller, Pamela and Naman and required 7 hours to construct.

The direct mode solar dryer was a greenhouse solar dryer used by Mace Foods Company to dehydrate vegetables. In the figure below, A= Front section by air inlet, B = middle section of the dryer, C = Far section of the dryer by heated air outlet.

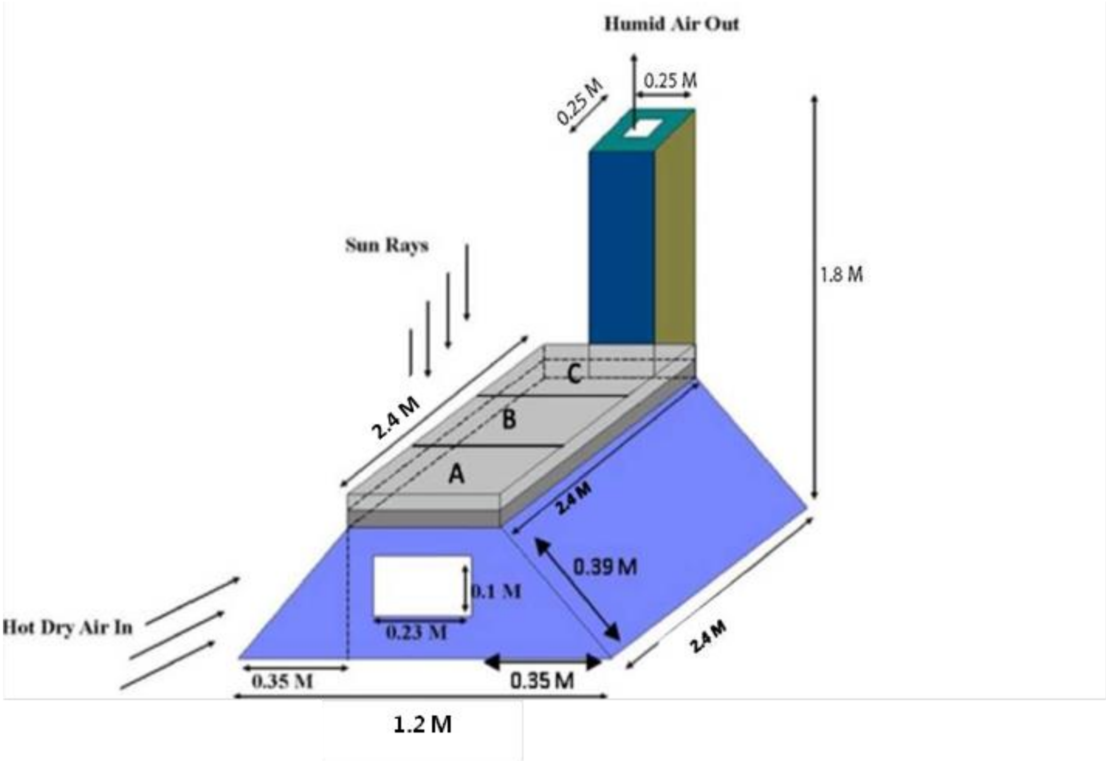


Fig. 3.1 A figure showing 3-dimensional drawing of the modified horticultural Innovation Lab mixed modes solar dryer

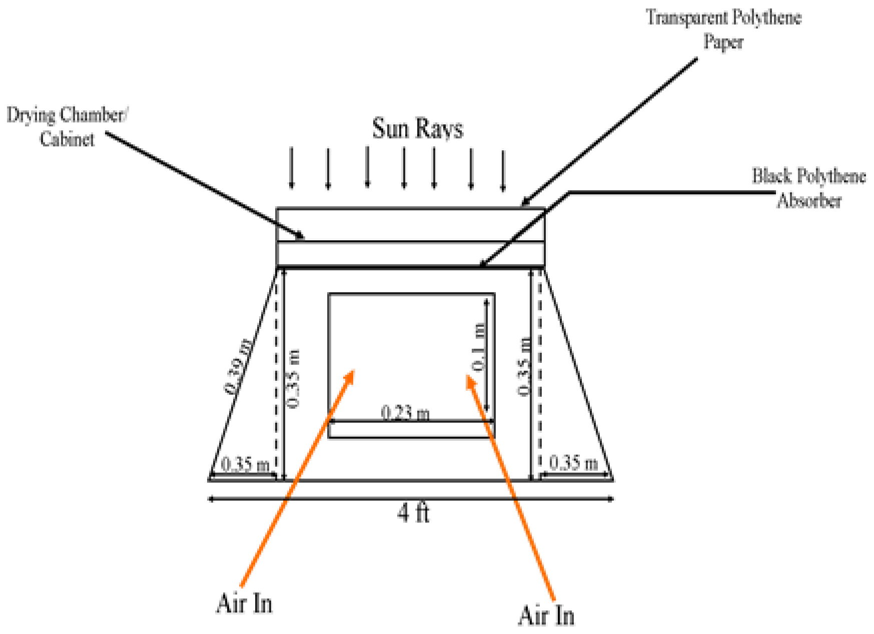


Fig. 3.2: A figure showing the drying cabinet of the modified Horticultural Lab mixed modes solar dryer.

3.4.2 Harvesting and Pretreatment of theVegetables Before Solar drying

The vegetables that were used in this study were field grown, and then manually harvested and brought immediately the same day from the experimental plots at the University of Eldoret, Eldoret, Kenya to Mace Foods, a second site in Eldoret, where the solar dryer was located for these studies. Upon arrival at the site, the fresh vegetables were graded and sorted to ensure all the harvested materials were clean, devoid of any damage; leaves were carefully separated from stems, the stems removed and discarded. Leaves were then washed by dipping them in a bucket of water to remove soil particles and surface debris. Before solar drying, the vegetables were blanched. A sauce pan of water that is 2/3 filled was brought to boiling temperatures. Blanching was done in 6 L of water and yet this quantity of water varied depending on the quantity of vegetables to be blanched. The vegetables in a wire basket were submerged in boiling water for about 1- 2 minutes then removed.

Cooling of the blanched vegetables was done using cold water to prevent excessive blanching for 2 to 5 minutes. After blanching the vegetables were squeezed using hands to remove excess water and spread flat randomly with some leaves facing up and others down in the three chambers of the mixed mode solar dryer and the comparative Mace Foods solar dryer. Fruits of the African Birds Eye Chilies were brought in fresh without any pretreatment, weighed and placed in to the direct and mixed modes solar dryers for drying. Drying was done in triplicates for each product being dried. The vegetables leaves were considered dry when they were brittle and shattered when pressed by hands while African Birds Eye Chilies were considered dry when they were brittle. The experiments were conducted during the sunny and in some instances in cloudy days between March 2014 and June 2014. Actual data collection took 40 days and each product was replicated five times.

Fig. 3.3: A figure showing a prototype of the modified Horticultural Lab mixed modes solar dryer (Source: Author, 2014)

3.4.3 Solar Drying Data Collection

The data was collected on hourly basis using a Hygrometer (SL 500 Germany). The temperatures in the three chambers in the drying tunnel, the ambient temperatures, weight of the vegetables in the mixed mode solar dryer and the Mace Foods Company dryer temperatures were noted down every hour. Besides, sunny and cloudy conditions of the day were recorded. Moisture content of the dried products was determined as per AOAC (1995). The dried vegetables were packaged in air tight containers to keep them off from moisture.

3.5 Consumer Acceptability of African Indigenous Vegetables

The leaves of the three species of AIV namely spider plant, nightshade and amaranth were collected from Eldoret University research farm when tender on February 21st 2014. Harvesting was done at the same age to minimize the effects of leaf age, soil and environmental factors on consumer acceptability. Harvesting of the vegetables was done a day prior to consumer evaluation. The vegetables were then kept in the refrigerator for 12 hours prior to consumer evaluation.

A group of 51 consumers were selected from households in Uasin Gishu County to assess the acceptability of the vegetables. The selected consumers were inducted on how to score the close ended questions. The vegetables were prepared using conventional recipes used the local residents as described below. After harvesting of the AIVs, they were destalked to separate leaves from stalks. The vegetables were weighed using a digital scale. Thereafter, categories of vegetables were made into two; single and combinations of vegetables. This gave four single vegetables of amaranthus and African nightshade where each vegetable consisted of a local variety (*Amaranthus spp.* and *Solanum nigrum*) and a developed variety. The two combinations were prepared out of spider plant, amaranth and nightshade cooked together. One combination was made using cream while the other fresh milk was used. EX ZIM (developed amaranth variety) and SS-49 (developed nightshade) were selected because they stayed vegetative for a long time and ability to withstand drought conditions based on observations made on the farms.

3.5.1 Preparation of African Nightshade, Amaranth and Spider plant combination

A kilogram of each of the vegetables (amaranthus, black nightshade and spider plant) was sorted, washed and finely chopped. The onions were fried lightly in a pan until golden brown after which tomatoes and salt was added (Table 3.1). Stirring was done to soften the tomatoes. Then, chopped amaranth/nightshade leaves were added and cooking continued for further 5 minutes in the covered pan to prevent overcooking. The cooked amaranth was then served in a bowl.

Table 3.1: Ingredients formulation for consumer acceptability*

Main ingredients	Formulation code	Mixing ratio (s) in Kg
LV-NS	LVN1	1 kg + 200g tomatoes + 1 onion
EX-ZIM	EX1	1 kg + 200g tomatoes + 1 onion
SS-49	LAN	1 kg + 200g tomatoes + 1 onion
LV-AM	LA	1kg + 200g tomatoes + 1 onion
Vegetable combinations		
S+A+N	SNS	1 kg/vegetable+ 500ml milk + 200g tomatoes + 1 onion
S+A+N	SNT	1 kg/vegetable +500ml cream+ 200g tomatoes + 1 onion

***LV-NS= Local Variety Nightshade, EX-ZIM= (Developed amaranth variety), SS-49= developed nightshade variety, S+A+N= spider plant, black night shade and amaranth prepared with fresh milk/cream.**

A kilogram of each of the leafy vegetable was sorted, washed and chopped finely. Salted water was then brought to boil, chopped vegetables combination added until soft. The boiled vegetables were then subdivided into two portions. For each of the portions, clean chopped onions were golden fried. Chopped tomatoes were then added while stirring to make a soft paste. The boiled vegetables were then added and simmering continued. In one portion of the vegetable cream was added while in the other fresh boiled milk was added. Stirring was done to ensure that the cream/milk mixed well in the vegetables for 5 minutes. The cooked portions were each served in a bowl and covered ready for consumer evaluation.

Before consumer evaluation, the vegetable samples were warmed in an oven and randomly served in colorless disposable plates. The plates were then coded LVN1 (*Solanum nigrum*), EXI (developed *amaranth ssp*.), LAN (developed *Solanum nigrum*), LA (*Amaranthus ssp*), SNS (vegetable combination made with milk) and SNT (vegetable combination made with cream). The cooked vegetables were then presented randomly to the panelists. A glass of drinking water was availed to help in cleaning the palates after tasting every sample. Aroma, texture, taste, flavour and overall acceptability were the major attributes that were investigated using a 9.0 point hedonic scale. Consumer evaluation was done for single vegetables, then for vegetables prepared using cream and finally for that made using fresh milk. Three graduate students familiar with consumer evaluation from the University of Eldoret assisted the panelists during consumer evaluation. Consumer acceptability data was collected using a consumer acceptability questionnaire (Appendix 2). The major attributes assessed in consumer evaluation included aroma, texture, color, taste and overall acceptability using a 9.0 hedonic scale by Kroll.

3.6 Validity and Reliability

The survey questionnaire was reviewed by experts from Kenya Agricultural Research Institute (KARI) Kakamega and pretested on 20 farmers in Busia County. The farmers did not participate in the study. Content validity was enhanced by including all variables being investigated in the questionnaire. Before data collection, quality control was enhanced through proper definition of questionnaire codes. The enumerators were educated on how to score the questionnaire. Additionally, consistent terminologies were used in the questionnaire to avoid confusion. The data was also summarized into themes to avoid any confusion.

3.7 Data Analysis

Data analyzed using SAS version 9.3 and Microsoft Excel 2010. Demographic information was presented using descriptive statistics (totals, frequencies, means and measures of dispersion). Continuous and categorical variables were presented as means ± standard deviations, respectively. Student T-tests was used to compare production levels of AIV in the three study sites, and consumption patterns of AIVs in between vulnerable farmers and other farmers. Analysis of variance ($P \leq 0.05$) was used to determine differences in the vegetable samples due to preservation techniques. Consumer evaluation attributes means were separated by least significance difference. Non parametric test (Kruskal-Wallis Test) was used to determine significant differences in sensory evaluation variables (aroma, texture, color, taste, overall acceptability). Chi-square test was conducted to determine whether education level and gender influenced the farmer's choice of the vegetables.

3.8 Research Ethics

A research permit was obtained from the National Council for Science and Technology to undertake the study. Confidentiality was maintained and participation was on voluntary basis. Finally, informed written and verbal consent was obtained from the participants to engage in the study.

CHAPTER FOUR

RESULTS

4.1 Demographic Information, Land Ownership and Post-Harvest Handling Practices of AIVs among Vulnerable farmers and other farmers in Western Kenya.

The average age of the household heads was 49 years for vulnerable farmers. The age of vulnerable member households was however, higher by 3 years than those of other farmers. For the entire sampled population, 53% had primary education, 34% secondary education, 5% college education. Only 1% had university education (Table 4.1). A large majority of household heads of the whole group were married and living with their spouses (61%) and 24% were widowed.

Table 4.1: Demographic profile of sampled households

Characteristics	Whole sample	Other household	Vulnerable member
Age of household head (years)	48	46	49
Household size (number)	6.10	6.1	6.1
Marital status (%)			
Married and living with spouse	61.3	82.7	44.9
Married but spouse away	9.9	6.8	10.8
Widowed	24.5	6.8	38.3
Single	2.6	0.8	3.0
Divorced	1.7	3.0	3.0
Highest education (%)			
None	6.7	5.3	7.8
Primary	53.3	48.9	57.2
Secondary	34.4	38.3	31.3
College	4.7	6.0	3.6
University	0.7	1.5	0.0

n= 303

Landholdings for the whole sample averaged 2 acres per household. The vulnerable farmers had larger farms (2.4 acres) than other farmers (2.0 acres) at $P \leq 0.01$ (Table 4.2).

Table 4.2: Mean land size ownership and use

Variable means	Whole sample	Vulnerable farmers	Other farmers
Farm size (acres)	1.9	2.4	2.0
Area rented out (acres)	0.35	0.8	0.1
Area under vegetables 2012 seasons (m^2)	1193	1243	1378.2
Area under other crops (acres)	2.2	1.2	1.2
Fallow area (acres)	0.4	0.5	0.3

Maize is grown by majority of the households (95%) followed by vegetables (72%). Other important crops are beans (69%), sweet potato (35%) and cassava (27%). (Figure 4.1).

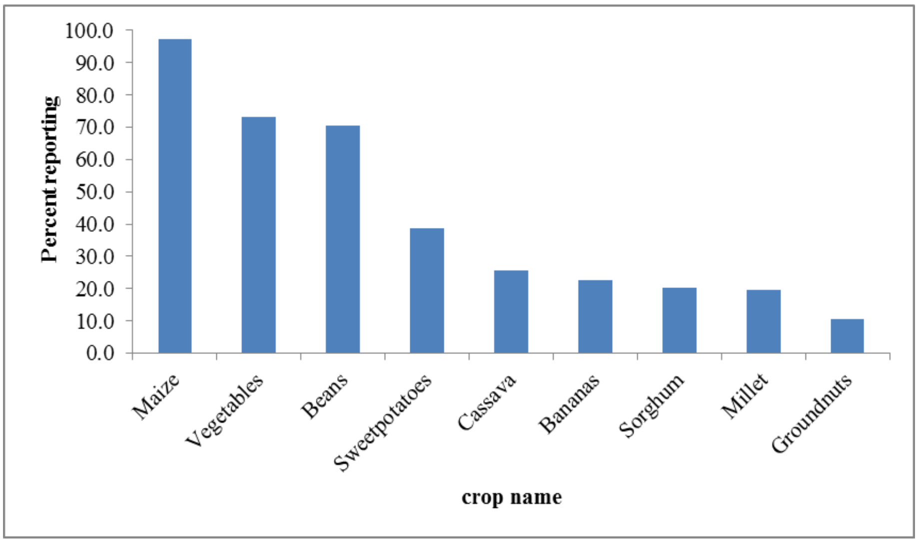


Fig. 4.1: Main crops cultivated by households

African nightshade (38%), cow pea (21%) and amaranth (10%) were the highly ranked AIVs in western Kenya (Figure 4.2).

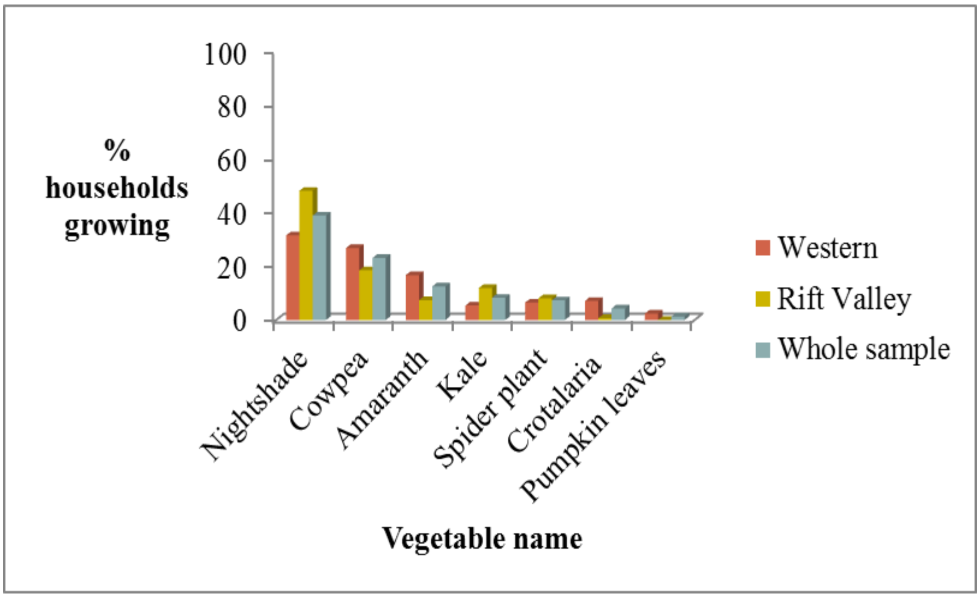


Fig. 4.2: AIVs popularity in western Kenya

African Indigenous Vegetables (AIVs) were consumed by both vulnerable farmers and other farmers in nearly similar frequency. The majority (28%) both vulnerable farmers and other farmers consumed AIVs either every day or once a week (Figure 4.3). This is because the respondents said they used the vegetables as a main dish (58.8%), side dish (31.6%) and as major ingredient of side dish (10%). Most households (92.1%) obtained the AIVs they consumed from their own-farms whilst 7.9% obtained from the market.

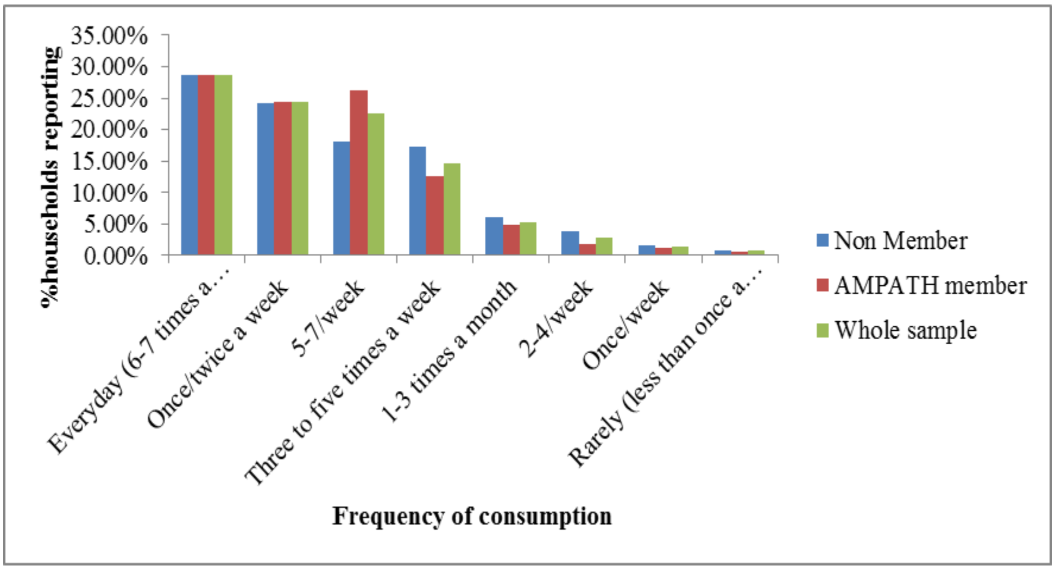


Fig.4.3: Household consumption of AIVs

African Indigenous Vegetables (AIVs) were processed using inefficient techniques both for sale and household use. Boiling was the most processing method (22%) used for processing vegetables followed closely by sorting and grading (21%) for the whole sampled population. Cutting/slicing and sun drying (14%), storage (8%) and bulking with other farmers (3%) were also done to prolong the shelf life of AIVs (Figure 4.4).

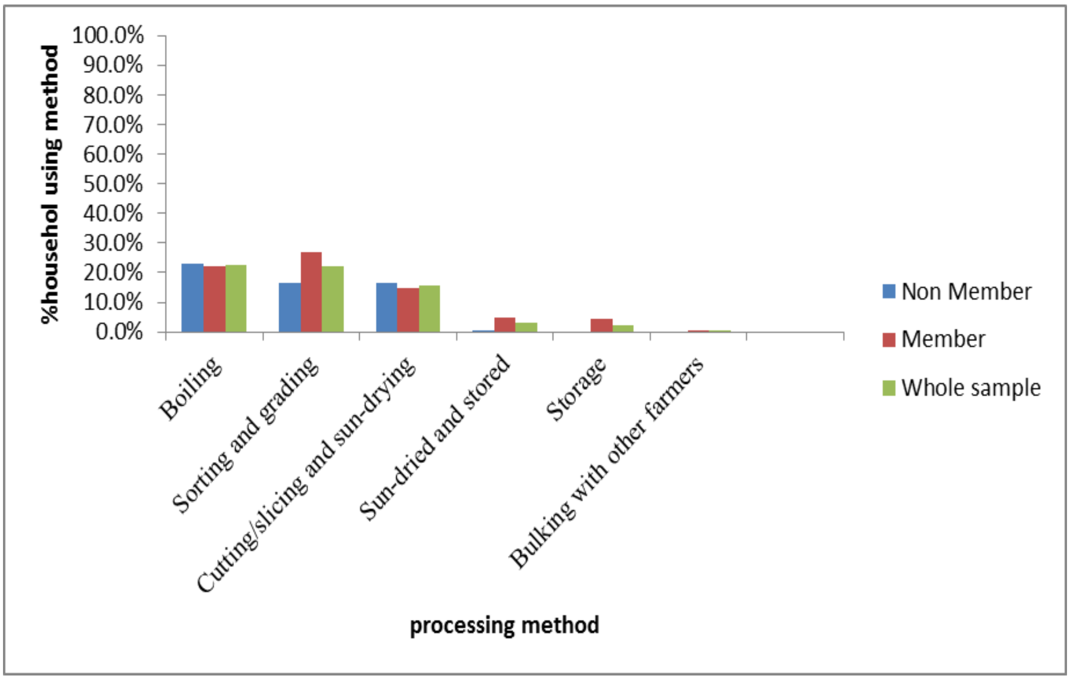


Fig 4.4: Postharvest handling practices used by respondents

4.2 Effects of Farmers Practiced Post-harvest Handling Practices (preserving under the shade and the sun) on the Nutritional Composition of AIVs.

The results below show the effects of shade and sun preservation on the nutritional composition of AIVs. Copper ($p<0.54$), Potassium ($p<0.53$), iron ($p<0.70$) and Zinc ($p<0.47$) were not affected in either preservation method. However, vitamin C ($P <.0001$) was lost when the vegetables were preserved in the sun (Table 4.3). This is because vitamin C is unstable at high temperatures of the sun. All the vegetables sampled were able to meet the Recommended Daily Allowances for vitamin C, Copper, iron and zinc

Table 4.3: Effects of shade and sun preservation on AIV nutrient composition

Variety	PM*	Copper (mg/kg)	Iron(mg/kg)	Zinc (mg/kg)	Potassium (mg/kg)	Vitamin C (mg/100g)
Amaranth						
Local amaranth	1	2.11±0.21[a]	6.59±0.10[a]	5.02±0.16[a]	5.94±0.04[a]	5.19±0.36[a]
Local amaranth	2	2.14±0.27[a]	6.53±0.04[a]	4.91±0.11[a]	5.90±0.53[a]	4.11±0.67[b]
UG-AM-40	1	2.22±0.12[a]	6.56±0.18[a]	4.94±0.08[a]	5.82±0.07[a]	5.06±0.25[a]
UG-AM-40	2	1.88±0.15[b]	6.53±0.14[a]	5.04±0.10[a]	5.88±0.02[a]	4.11±0.03[b]
EX-ZIM	1	2.12±0.39[a]	6.54±0.03[a]	5.20±0.05[a]	5.84±0.08[a]	5.03±0.18[a]
EX-ZIM	2	2.05±0.02[a]	6.51±0.08[a]	5.03±0.10[a]	5.90±0.02[a]	4.11±0.17[b]
Nightshade						
BG-16	1	2.20±0.00[a]	6.89±0.02[a]	4.99±0.02[a]	5.82±0.02[a]	5.31±0.00[a]
BG-16	2	2.35±0.00[a]	6.90±0.00[a]	5.12±0.00[a]	5.97±0.00[a]	4.63±0.06[b]
SS-49	1	2.28±0.00[a]	6.86±0.01[a]	5.13±0.02[a]	5.76±0.02[a]	5.36±0.03[a]
SS-49	2	2.22±0.00[a]	6.87± 0.07[a]	4.88±0.00[a]	5.81±0.00[a]	4.57±0.15[b]
Local night shade	1	2.14±0.03[a]	6.57±0.03[a]	4.92±0.02[a]	5.80±0.02[a]	5.13 ±0.04[a]
Local Night shade	2	2.04±0.17[a]	6.58±0.01[a]	5.21±0.00[a]	5.90±0.00[a]	4.50±0.04[b]
Spider plant						
Local spider plant	1	1.72±0.04[b]	6.39±0.02[a]	5.14±0.00[a]	5.87±0.39[a]	5.08±0.02[a]
Local spider plant	2	2.04±0.06[a]	6.53±0.06[a]	5.15±0.04[a]	5.90±0.05[a]	4.23±0.00[b]
ML-SF-29	1	2.44±0.12[a]	6.58±0.09[a]	4.85±0.11[a]	5.97±0.11[a]	5.14±0.00[a]
ML-SF-29	2	2.55±0.00[a]	6.51±0.03[a]	4.99±0.04[a]	5.92±0.07[a]	4.39±0.14[b]
UG-SP	1	2.01±0.00[a]	6.53±0.01[a]	5.01±0.04[a]	5.91±0.38[a]	5.14±0.00[a]
UG-SP	2	2.05±0.18[a]	6.57±0.19[a]	5.02±0.07[a]	5.91±0.05[a]	4.08±0.00[b]
RDA**		2mg	15mg	15 mg	3500mg	75mg

*1=shade, 2= sun, ** Source: Lennteck (2014), LV-AM=Local variety of amaranth, EX-ZIM=developed amaranth variety, UG-AM= developed variety of amaranth, BG-16= developed nightshade variety, SS-49= developed nightshade variety, UG-SP=developed spider plant, ML-SF-29= developed spider plant variety, PM=Preservation method. Values are presented as log Means ± Standard deviations at $p<0.05$

4.3 Drying efficiency of mixed modes solar dryer over direct mode solar dryer for vegetable processing.

Lower temperatures were recorded between 9 am to 1 p.m. This was a partly cloudy morning. On the other hand, the afternoon was full of average solar radiation. That is why temperatures were lower in the morning but higher in the afternoon during sunshine (Figure 4.5).

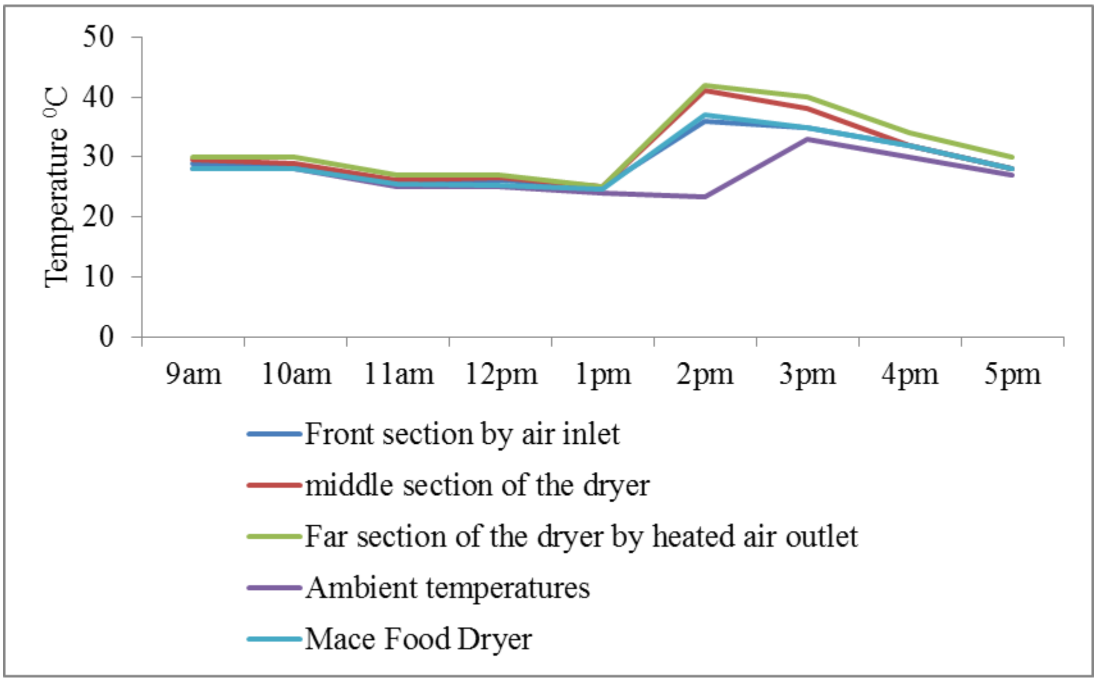


Figure 4.5: Temperatures variations of the modified Horticultural Lab mixed modes and direct modes solar dryer on a cloudy morning and sunny afternoon.

Temperatures in the mixed modes and direct modes are low in the morning but rise as the intensity of sunshine increases. The highest temperature recorded was 68.7^{0}C recorded at 2.00 pm with the lowest being 35^{0}C at 5.00 p.m. Figure 4.6 reveals that peak vegetable drying are attainable between 11 am and 3.00 pm at temperatures of between 40^{0}C to 68.7^0 C (Figure 4.6). There was temperature rise from the first drying chamber to the third. This is because the hot humid air leaving the mixed modes dryer is denser. As a result, the denser air accumulates at the lower end of the chimney and rises slowly due to buoyancy effect leading to heat buildup in chamber three than in chamber one.

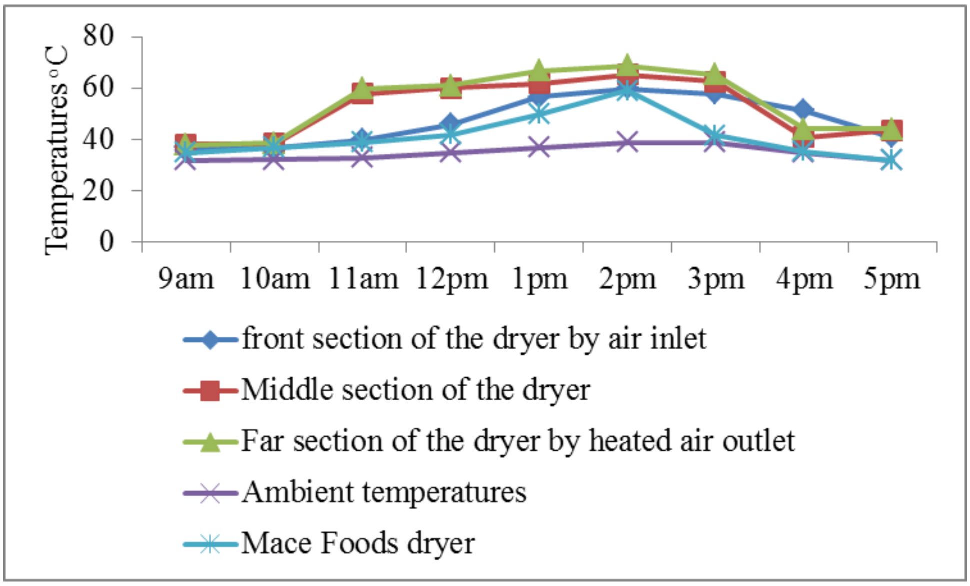


Figure 4.6: Temperature variations of the modified Horticultural Lab mixed mode solar and Mace Food Company dryer in a sunny trial.

Lower temperatures were recorded in a cloudy day with limited sunshine. The temperatures varied from 21^0C to 41.6^0C. The lower temperatures recorded translates to reduced drying rates. Thus, dryer performance on a cloudy day is greatly reduced unlike when there is sufficient sunshine.

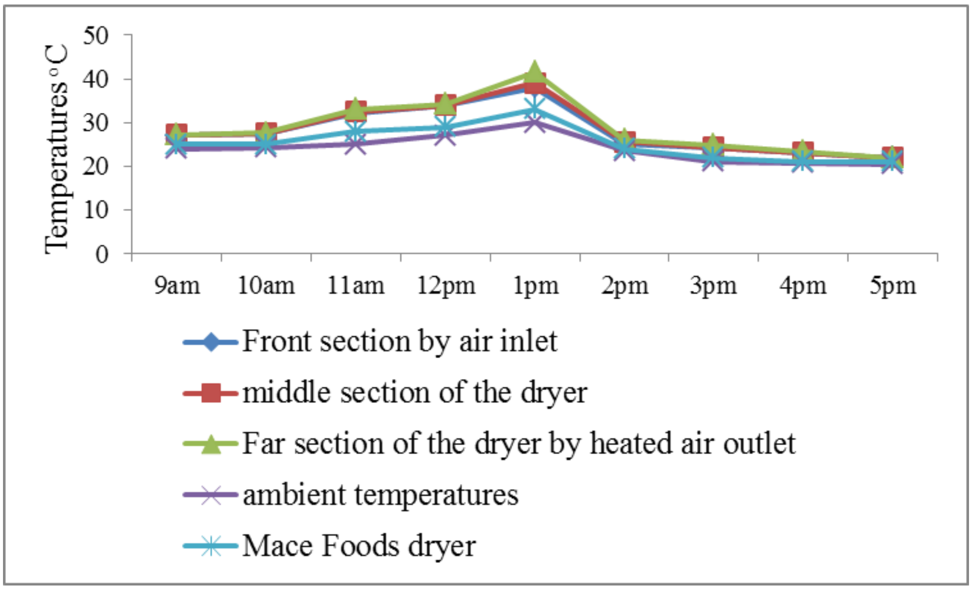


Fig. 4.7: Temperature variations of the modified Horticultural Lab mixed modes and direct mode dryer on a cloudy day with limited sunshine.

From Figure 4.8 above, the highest temperature recorded was 72.1^{0}C while the lowest was 28.2^{0}C. Higher temperatures were recorded on sunny than cloudy days.

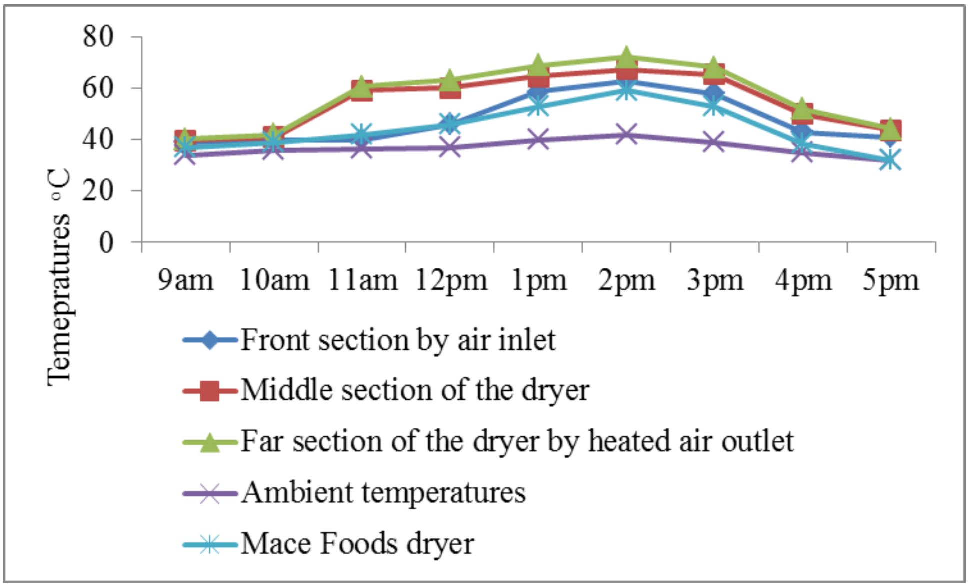


Fig. 4.8: Temperature variations of the modified Horticultural Lab mixed modes and indirect Mace Foods solar dryer on a sunny trial.

Table 4.4: Summary of temperatures (^{0}C) recorded during vegetable dehydration at Mace Foods Company, Eldoret Kenya on tests days.

Temperatures descriptions	**Minimum Temperatures (^{0}C)**	**Maximum temperatures (^{0}C)**
Ambient temperatures	21.3	41.9
Front section of air inlet	23.0	62.7
Middle section of mixed modes dryer	23.4	67.4
Far section of the mixed modes dryer by heated air outlet	24.1	72.1
Direct modes dryer	21.0	59.0

The minimum ambient; chamber one, two and three and Mace Foods dryer temperatures were 21.3^{0}C, 23.0^{0}C, 23.4^{0}C, 24.1^{0}C and 21.0^{0}C respectively. The maximum ambient; chamber one, two and three and Mace Foods dryer temperatures were 41.9^{0}C, 62.7^{0}C, 67.4^{0}C, 72.1^{0}C and 59.0^{0}C respectively (Table 1). The mixed modes solar dryer was able to increase drying rates by up to 30%.

4.5 Moisture content and packaging of dried AIVs

Table 4.5: Moisture content of dried products

Product	Fresh weight (kg)	Final dry weight (kg)	Moisture (%)		Quality
			M	**D**	
Amaranth	0.67±02	0.06±0.01	7.3±0.04	9.4±0.45	Dark brown
Nightshade	2.02±0.18	0.14±0.01	7.5±0.65	9.1±0.39	Dark brown
Spider plant	5.16±0.21	0.85±0.07	5.5±0.92	9.2±0.03	Dark brown
ABEC*	3.04±0.20	0.48±0.33	8.5±0.046	9.5±0.15	Brittle

Values are means ±SD of five replicates, ABEC= African Bird Eyes Chilies, M= mixed modes dryer, D= direct modes solar dryer

The moisture content of the vegetables dried using mixed modes dried vegetables except African birds eye chili were within the Kenya Bureau of Standards (KEBS) (2005) which is 8.4% but still the below 10% which discourages the growth of microorganisms (Bates et al., 2001). Therefore solar drying can transform raw vegetables into processed vegetables with longer shelf life and increased marketability. The dried vegetables were packaged in air tight labeled transparent polythene paper as illustrated in Figure 4.9 below;

Figure 4.9: Value added nightshade
(Source: Author, 2014)

4.5 Moisture content of dried AIVs

Table 4.6: Moisture content of dried products

Product	Fresh weight (kg)	Final dry weight (kg)	Moisture (%)		Visual Quality
			M	**D**	
Amaranth	0.67±02	0.06±0.01	7.3±0.04	9.4±0.45	Dark brown
Nightshade	2.02±0.18	0.14±0.01	7.5±0.65	9.1±0.39	Dark brown
Spider plant	5.16±0.21	0.85±0.07	5.5±0.92	9.2±0.03	Dark brown
ABEC*	3.04±0.20	0.48±0.33	8.5±0.046	9.5±0.15	Brittle

Values are means± standard deviations.

The moisture content of the vegetables dried using mixed modes dried vegetables except African birds eye chili were within the Kenya Bureau of Standards (KEBS) (2005) which is 8.4 % but still the below 10% which discourages the growth of microorganisms (Bates et al., 2001). The dried vegetables were packaged in air tight labeled transparent polythene paper to keep off moisture.

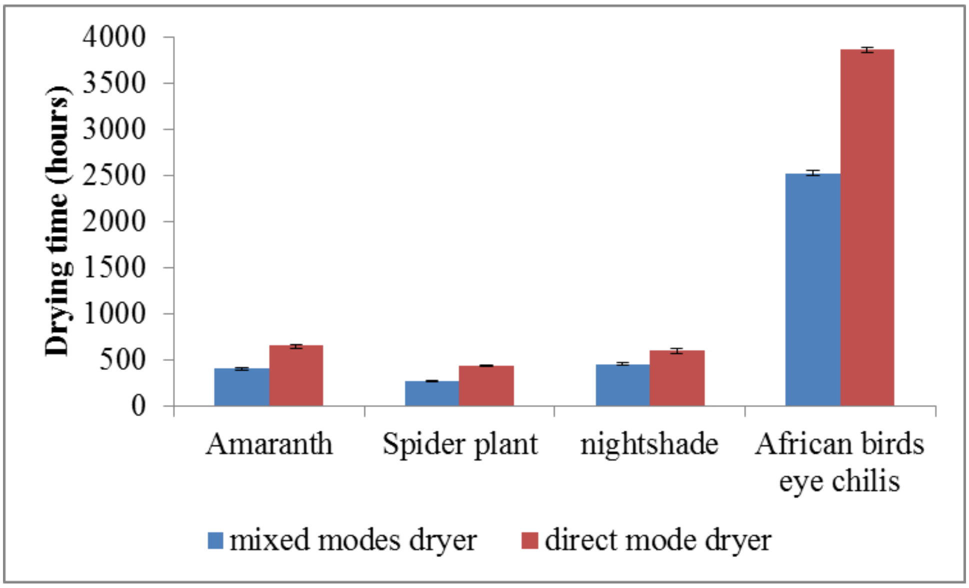


Fig 4.10: Drying times of the modified Horticultural Innovation Lab mixed modes and direct modes solar dryer for Amaranth, Spider plant, Night shade and African Birds eye Chilis. Bars represent standard deviations of the five replicates of each sample.

Tukeys test revealed that both the mixed modes solar dryer and the direct modes dried the vegetables differently with the mixed modes being faster in all the products ($P \leq 0.001$). There were no differences in drying time for both amaranth and nightshade in mixed modes dryer. Spider plant took the shortest time to dry while African bird's eye chili took the longest time (Figure 4.10).

Up scaling of the mixed modes solar dryer

The mixed modes solar dryer use can be extended to other farmers especially those far away from the small scale vegetable processor (Mace Foods Company, Eldoret, Kenya). The dryer can contribute towards reduction of losses that occur between farms and processing points. This is because the farmers can transform the vegetables, chili fruits and mushrooms into stable products that are do not easily spoil. It is important to note that these farmers would need to be trained on the operations of the dryer. Considering that the poverty levels in western Kenya are approximated at 57.9% (KNBS, 2008-09), individual farmers would need financial assistance to invest in the mixed modes solar dryer for horticultural crops dehydration. Another alternative would be to mobilize the farmers into groups. This way they can each group member can contributes towards the installation of a mixed modes solar dryer.

Economics of the modified Horticultural Lab mixed modes solar dryer

Financial feasibility of the mixed modes solar dryer for dehydrating chilies was determined by considerations of the initial dryer construction costs, maintenance costs, and the price of dried and fresh produce. The initial construction of the dryer was approximated at 80 dollars. A bunch of fresh African indigenous leafy vegetables (200g) costs approximately 0.22 dollars. The cost of one packet of dried leafy AIVs (50g) is 1.71 dollars. The estimated volume of dried leafy vegetables is 1000g per month valued at 34.2 dollars. The payback period calculated as initial cost divided by monthly income would 2.34 months. Considering that the same dryer is used to process chilies, tomatoes and other leafy greens the payback period would even be lower. The mixed modes solar dryer is therefore economical as no costs are incurred in heating the air.

4.4 Consumer acceptability of local and improved varieties of AIVs

4.4.1 Demographic information of consumer acceptability participants

There were more females respondents (66%) than men (33%). This indicated that most AIV farmers are female. The level of education for respondents was 31%, 39% and 29% for primary, secondary and post-secondary education respectively.

Table 4.7: Consumer acceptability scores for conventional AIVs recipes*

AIV codes	Aroma	Color	Taste	Texture	Overall acceptability
LV-NS	7.08 ± 2.21^{b}	6.90 ± 1.92^{c}	6.80 ± 1.84^{b}	6.86 ± 1.77^{b}	7.04 ± 1.04^{c}
EX-ZIM	7.12 ± 1.51^{b}	7.04 ± 1.44^{b}	7.18 ± 1.49^{a}	6.90 ± 1.79^{b}	7.29 ± 1.03^{b}
SS-49	6.31 ± 2.09^{c}	6.67 ± 1.77^{c}	6.61 ± 1.76^{c}	6.14 ± 2.30^{c}	6.33 ± 1.14^{d}
LA	5.84 ± 2.23^{d}	6.27 ± 1.81^{c}	6.16 ± 1.94^{c}	5.65 ± 2.11^{d}	5.67 ± 1.33^{f}
SNS	6.82 ± 2.03^{c}	6.88 ± 1.58^{c}	6.18 ± 2.37^{c}	6.22 ± 2.23^{c}	6.78 ± 1.05^{e}
SNT	7.86 ± 1.66^{a}	7.67 ± 1.77^{a}	7.66 ± 1.94^{a}	7.37 ± 1.91^{a}	8.16 ± 1.07^{a}

*LV-NS= Local Variety Nightshade, EX-ZIM= (Developed amaranth variety), SS-49= developed nightshade variety, SNS= spider plant, black night shade and amaranth prepared using fresh milk, SNT= spider plant, black night shade and amaranth prepared using cream, LV-AM= Local amaranth variety

*Attributes in a column with similar letters do not differ at P<0.05. Values are presented as Means± SD

A combination of all the three varieties prepared with cream was ranked highly in terms of overall acceptability (8.16±1.07) followed by the developed amaranth (EX ZIM) variety (7.29±1.03). Local nightshade (LVN1) variety (7.04±1.04) was preferred by the consumers to the developed variety (SS-49) (6.33±1.14). A combination of black night shade, amaranth and spider plant prepared using cream scored highly for all attributes that were evaluated and the local amaranth variety was ranked low for all the sensory attributes (Table 4.5).

Table 4.8: P-values of sensory attributes*

	Aroma	**Color**	**Taste**	**Texture**	**Overall acceptability**
Chi-Square	34.194	21.387	25.955	24.203	103.855
Chi-Square	5.0	5.0	5.0	5.0	5.0
Pr > Chi-Square	<.0001	<.0007	<.0001	<.0007	<.0001

*Kruskal Wallis test

There was a significant difference in the manner in which the panelist rated aroma (χ^2=34.194, P<.0001), color (χ2=21.387, P<.0007), taste (χ^2=25.955 P<.0001), texture (P<.0007 χ^2=24.203), and overall acceptability (P<.0001, χ^2=103.855) (Table 4.6).

CHAPTER FIVE

DISCUSSIONS

5.1 Demographic information from the surveyed households

Majority (53%) of the households had primary education followed by secondary education (34.4%) (Table 4.1). This may affect adoption of sophisticated post-harvest technologies for AIVs. Teaching materials used by extension farmers to enlighten farmers on sound vegetable post-harvest handling practices needs to be simple for farmers to easily understand. Most (59%) households were headed by males. The average farm size of the households was two acres (Table 4.2). Most of the land was used to cultivate food crop (maize) at the expense of AIVs. Consequently, little land is left for AIVs cultivation. Walingo et al. (2001) reported that farmers always allocate more land to food crop production with less being left for AIVs production.

5.2 Post-harvest handling practices of AIVs in western Kenya

The processing technique most utilized was boiling (22%) while sorting and grading was practiced by 21% of the respondents (Figure 4.4). Households represented in the study do not only boil vegetables as a way of making them palatable but also as a way of prolonging shelf lifes too. These findings are similar to those of Olayemi et al. (2011) who showed that farmers preferred to boil perishable items than leaving them to spoil. Thus, farmers would opt to boil most of the available vegetables because of lack of preservation options. The respondents reported that they preferred cooking the vegetables than leaving them to spoil. Adefegha and Oboh (2011) viewed boiling and cooking as a way of increasing the chelating ability of iron (II), flavonoids and total phenols thereby increasing antioxidant property of cooked vegetables. Consequently, boiled vegetables have increased antioxidant capacity. Prabhu and Barrett (2009) also discovered that as cooking destroys ascorbic acid more phenols are freed which dominate antioxidant properties.

During cooking, the farmers said that they added salt, oil, tomatoes and cream during vegetable cooking. Respondents said they boiled the vegetables for almost an hour thereby destroying the vitamins. Some farmers acknowledged that they discarded the water used to boil the vegetables while others retained it so as to minimize losses of nutrients leached into the cooking water. Prabhu and Barrett (2009) showed that minerals and other water soluble nutrients are leached into the cooking water. Consequently, the water used for cooking vegetables should not be discarded as a way of making use of the leached nutrients.

In this study, grading and sorting of vegetables were manually done by the farmers. Grading was done based on leaf size and absence of yellowing, pests and diseases. Grading helps to eliminate vegetables of poor quality and prevent cross contamination between spoilt and good vegetables. After grading, vegetables of superior quality would fetch higher prices in the market. However, Osman et al. (2009) indicated that some farmers do not practice sorting due lack of knowledge, making them to incur a lot of post-harvest losses. Acedo (2010) found out that grading and sorting of vegetables are done based on presence or absence of mechanical damage, shape, size, weight, and produce freedom from diseases and pests. Additionally, trimming was also done to get rid of unwanted parts.

Some farmers processed their vegetables by group bulking followed by vegetable transportation when exposed to sunlight (Figure 4.4). Bulking makes vegetables prone to breakage and bruises and thus damages them. The damaged parts or physical injury in vegetables can act points upon which rotting starts or disease causing microorganisms get into the vegetables. Furthermore, broken points speed up moisture loss from vegetables ultimately propagating post-harvest losses. Farmers also stored their vegetables in the shade or sun awaiting sale or consumption. Sacks and baskets were the most common containers used to store vegetables. The baskets were poorly ventilated leading to heat buildup within the sack and loss of leaf color due to yellowing. The inside of the baskets were rough causing bruises to the leaves. Bruised leaf parts rot easily leading to leaf spoilage. Acedo (2010) recommend soft liners should be placed inside of rough baskets to cushion vegetables. Finally, the farmers practiced sun drying (Figure 4.4). Sun drying takes a longer time to remove moisture. As a result vegetables are exposed to heat for longer time leading to nutrient losses. Moreover, the vegetables are exposed to soil, dust and flies during sun drying. Kiremire et al. (2010) observed that sun drying is done under unhygienic conditions for longer time leading to both nutrient losses and produce contamination from flies and dust.

Most project participants (vulnerable farmers) consumed AIVs than other farmers (Figure 4.3). These can be attributed to their knowledge concerning the nutritional importance and nutrition education/awareness about the vegetables given to them by extension officers. AIVs are popular in Busia, Uasin Gishu and Trans Nzoia counties of western Kenya. Hence, greater consumption of the AIVs can also be attributed to the willingness of the local populations in the regions of study to support interventions that strengthen existing foods habits than introducing new ones. Therefore, interventions should be geared towards promoting existing cultures than introducing new ones. These findings are in line with those of Laurie and Faber (2008) who showed that project participants consumed and grew more pumpkins, orange fleshed sweet potatoes, butter nuts and spinach than non-participants because of receiving nutrition education from health volunteers.

Night shade was the most grown and popular AIV in western Kenya (38%) followed closely by cow pea (21%) and Amaranth (10%). This can be attributed to production experience and familiarity with the vegetables. These findings agree with those of Masayi and Netondo (2014) who also found that the most cultivated and consumed AIVs in western Kenya are African Night shade, cow peas, spider plant and amaranth. Masayi and Netondo (2014) add that reasons for the decrease in the consumption of the vegetable include exotic vegetable preference and pests and diseases.

5.3 Effects of some post-harvest treatments on nutritional composition of vegetables

Preservation of the vegetables in the sun preservation led to higher decrease of the vitamin compared to the vegetables exposed in the shade ($p<0.05$) (Table 4.3). This is because high temperatures denature the vitamin. Moreover, the activities of endogenous enzymes like peroxidase are increased in the sun where the optimal temperatures for enzymatic activities are attained than in the shade. Peroxidase and Ascorbic acid oxidase (AOO) also convert the active form of vitamin C (L-ascorbic acid) to the inactive dehydroascorbic acid (De Tullio et al., 2007). Also, wilting increases the production of Ascorbic acid oxidase which oxidizes the Vitamin C to dehydroascorbic acid. The ultimate result is that there is an increase in the destruction of vitamin C in the sun than in the shade. Ultra violet (from the sun) light converts active form of vitamin C (L-ascorbic acid) to dehydro ascorbic acid which does not exhibit the properties of vitamin C (Kiremire et al., 2010). These conclusions agree with those of Abioye et al. (2014) and Mhina and Lyimo (2013) have demonstrated that high storage temperatures, sunlight and air (oxygen) increase vitamin C loss. According to Lenntech (2014), an adult vitamin C recommended daily allowance (RDA) for zinc, iron, potassium and copper are 75mg, 15mg, 15mg, 3500 mg and 2mg respectively. As a result, consumption of a kilogram of any amaranth variety is able to meet the RDA for zinc, copper, iron and vitamin C for adults. Preservation of vegetables in the sun and shade did not alter potassium, iron, zinc and copper composition. This is because these minerals are stable in both high and low temperatures. Accordingly, such preservation methods can be used to retain minerals in vegetables. The study results disclosed that maximum benefits of vitamin C can be derived by using fresh vegetables. Findings by Kiremire et al. (2010) showed that minerals are less affected by drying heat compared to vitamins. Habwe et al. (2010) proposed that one of the methods that can be used to minimize the loss of vitamin C during vegetable preparation is by adding vegetables into the cooking water rather than boiling them together to avoid lengthened exposure of vitamin C to high temperatures. The preserved minerals play a key role in human nutrition. Potassium is a component of intracellular fluid and plays a vital role in the maintenance of acid-base balance .Copper on the other hand helps in the absorption of iron in the body, bone growth and iron incorporation into hemoglobin (Soetan et al., 2010).

Zinc, iron and copper work collectively act as metalloproteins in metabolic processes like energy production (Soetan et al., 2010). Zinc and iron contributes to immune cell generation and other antigenic responses .Iron is also useful in blood formation.

Vitamin C has antioxidant properties and plays a crucial role in maintenance of the flexibility of blood vessels, blood circulation improvements and facilitation of iron absorption (Shokunbi et al., 2011). Similarly, Zinc and copper are also known to have antioxidant properties. Okoli (2009) adds that potassium may be useful in the management of hypertension to patients sensitive to elevated sodium levels. In a nut shell, the micronutrients work collectively to boost immune systems of patients.

5.4 The drying efficiency of mixed solar drying technology over direct solar drying technology

Drying by solar drying is an affordable and cost effective method that can be used to preserve excess vegetables that cannot be cooked for consumption when vegetables are in excess. From the study, higher drying temperatures were recorded on a sunny day than on a cloudy day (Figs. 4.5, 4.6, 4.8). This is because of more solar radiation experienced on a sunny than cloudy day. Averagely, drying of fruits and vegetables on a cloudy weather can go up to 5 days (Kumar, 2010). The black collector contributed to overall performance of the dryer by absorbing more heat energy from the sun and increasing incident ray absorption. The mixed solar dryers combined the direct and indirect heating systems to dry vegetables. Consequently, the drying time increased by 34% and 12% on sunny and cloudy days respectively. This means that mixed modes solar dryer can be used to preserve nutrients that traditional sun drying that exposes vegetables to heat for prolonged period of time leading to enormous nutrient depletion. Additionally, the mixed modes solar dryer protected the vegetables being dried from flies, dust and direct sun light all which reduce safety and quality of vegetables. Hence, farmer groups can adopt this method as a way of getting rid of the problems associated with traditional sun drying. Vegetables dried through the mixed modes solar dryer were free of any discoloration and were highly marketable.

The temperatures recorded in the mixed modes solar dryer were higher than the ambient temperatures. The highest temperature recorded in the tunnel was 72.1^{0}C while the lowest was 24.1^{0}C. This shows that mixed modes solar dryers can increase the drying temperatures leading to reduced dehydration time and minimal nutrient loss unlike sun drying (Table 4.3). Likewise, the highest and lowest ambient temperatures were 21.3^0 C and 41.1^{0}C respectively. These results concur with those of Umuhozariho et al. (2013) where a mean ambient temperature of 25^{0}C brought about a temperature of about 65^{0}C in a tunnel solar dryer. Solar dryers designed in a mixed modes result into increased temperatures inside the dryer due to combined effects of both incident solar energy and hot air generated by the collectors (Stiling et al., 2012).

The moisture content of the vegetables dried using mixed modes dried vegetables except African birds eye chili were within the Kenya Bureau of Standards (KEBS) (2005) which is 8.4 % but still the below 10% which discourages the growth of microorganisms (Bates et al., 2001). The mixed modes solar dryer was able to heat the air temperature up to 30^{0}C more than the ambient temperatures. This means that the mixed modes solar dryer speeds up drying rates as the heated air moves rapidly in the dryer carrying away moisture from the vegetables. These results coincide with those of Perasiriyan et al. (2013) whose study revealed that a tunnel solar dryer could heat air to temperatures of between 20-30^{0}C above the ambient temperatures.

5.5 Consumer acceptability of local and developed AIVs using conventional recipes

Within the same vegetable categories, local variety of black nightshade was preferred over the developed variety despite the bitterness of the local variety (Table 4.5). The reason for this could be production experience and taste familiarity of the vegetable among the panelists. Sarah et al. (2012) explain that taste difference in samples of food can be due to cultural and personal factors like familiarity with a particular food. There is a possibility that knowledge regarding AIVs may have been passed on by the the older generations had also transmitted knowledge regarding AIVs to the younger generations thus making the latter appreciate the bitter vegetables. Van der Hoeven et al. (2013) reported that the AIVs familiarity can be attributed to transmission of knowledge from the older to the young generations. Nonetheless, Kayode et al. (2008) found out that bitter leaf vegetables are less preferred over non bitter ones. Since the participants were AIVs consumers, they were familiar with the vegetables. In Kenya, bitter vegetables are perceived to be medicinal. There is a possibility that bitter black nightshade was ranked highly because of being perceived to be medicinal. According to Schippers (2002), bitterness in vegetable leaves is because of phenolic compounds and other plant toxins like alkaloids.

High acceptability scores for attributes of vegetable combination prepared with cream and the developed amaranth variety translate to a true reflection of the two products. Cream adds sweet flavor to foods leading to more acceptability. Sarah et al. (2012) concluded that high scores in the characteristics of a product being evaluated reflected the overall acceptability of the product being evaluated. The panelist attributed developed amaranth variety to sweetness. Sweetness in vegetable leaves is because of the presence of simple sugars that are sweet. According to Taiga (2008) sweet carbohydrates in leaves translates to increased acceptability of a vegetable. Preparation of the three varieties together brought all the tastes together, and with the addition of cream the acceptance got enhanced. The acceptance of developed variety of amaranthus over the local one has different interpretation. This reveals that the developed amaranth variety has superior sensory characteristics than the local variety because of the sweetness the developed amaranth variety accords. Similarly, it implies that the absence of the developed amaranths variety has confined farmers to the consumption of the local amaranth variety. This study shows that communities that were represented in the acceptability evaluation are enthusiastic and willing to introduce developed varieties of AIVs into their diets. The color for both the developed and local variety of African nightshade was ranked equally. This reveals that acceptance of a product may not be due to color but the taste.

Educational level (χ^2= 0.9747) and gender (χ^2= 0.81) did not have any influence on how the panelist rated the vegetables. This can be attributed to their earlier known knowledge and experience with the vegetables. These results correspond with Sarah et al. (2012) findings where there no gender differences in the evaluation of samples used in sensory evaluation. Studies have revealed that gender role and education level play a role in sensory evaluation (Sarah et al., 2012; Umuhozariho et al., 2013). The participants below 32 years of age had less preference for bitter preparations of AIVs compared to those above 32 years. This could be because current generations dislike bitter vegetables. Preference of bitter vegetables among respondents above 32 years of age can be linked to their knowledge regarding traditional foods, medicinal values, production experience and the role of tradition. Laureati et al. (2006)

established a strong link between food choice and prevailing traditions. Thus, tradition influences choice of foods such that foods that are part of food habits are well accepted. Voster (2007) discovered that men have preferences for meat leaving indigenous vegetables to children and women.

5.6 General Discussions and Perspectives

The poverty levels in western Kenya are poverty levels stands at 57.9% in the grassroots and 37.9% among the urban populace (KNBS, 2008-09) with the main economic activity being crops cultivation. Cultivation and preservation of African Indigenous Vegetables can prove useful for reducing poverty levels in the region both for food and income generation. Most importantly would be able to preserve the vegetables after production as they are highly perishable. This will help farmers increase their income base because of reduced post-harvest losses. The study results made known that boiling, sun drying, sorting and grading and bulking with other farmers were the most common preservation techniques. Such methods of preservation vegetables are inefficient and can prolong the shelf life of vegetables for a limited period of time. Other studies have had varied conclusions. Prabhu and Barrett (2009) revealed that calcium, zinc and iron are lost in cooking because of being leached into the cooking water. As a result, the cooking water should not be discarded. In contrast, Lewu et al. (2009) indicated that the anti-nutritional factors like Calcium oxalate that leach into the water used for cooking should be eliminated by discarding the water. This is because during boiling, the epidermis ruptures facilitating soluble oxalate leakage into the water used for cooking. Other anti-nutrients destroyed by boiling and cooking are tannins, oxalates and phytates (Lewu et al., 2009). Findings by Gidamis et al. (2003) disclosed that boiling increases protein digestibility. Gidamis et al. (2003) illustrated that protein digestibility in Moringa leaves were increased upon boiling from 55.4% to 65.6%. Nurhuda et al. (2013) proved that boiling can be used to destroy peroxidase and poly phenol oxidase thereby helping in prolonging the shelf life of vegetables. Nonetheless, the food becomes prone to microbiological attack thereafter. According Zu et al. (2014) bruises and broken points increase the speed of water loss from vegetables. The same study also revealed that bruised vegetables have higher incidences of postharvest rots.

Preserving vegetables under the shade/sun and solar drying can preserve nutrients. Kiremire et al. (2010) demonstrated that preserving vegetables in the sun leads to more nutrients than solar drying. This is because the sun takes a longer time to dry vegetables leading to more nutrients losses. Besides, the magnitude of nutrient losses during vegetable processing depends on the duration of preservation and presence of factors that propagate nutrient losses such as oxygen. Kiremire et al. (2010) further showed that during sun drying, products are exposed directly into the sun. According to Prabhu and Barrett (2009), vitamin C loss in vegetables during processing depends on storage temperatures, relative humidity and the activity of oxidase enzymes. A high storage temperature destroys vitamin C than cold temperatures. Additionally, higher temperatures increase the activity of endogenous enzymes that deplete vitamin C.

Developed amaranth variety was preferred to local variety. Adoption of the developed varieties would necessitate farmers to practice better methods of vegetable preservation that are hygienic and leads to less nutrient loss. From the study, mixed modes solar drying would prove useful for vegetable preservation. Ukegbu and Okereke (2013) have acknowledged that removing the moisture content in vegetables by solar drying not only extends the shelf life but also increases nutrient concentration in the final product. Ukegbu and Okereke (2013) reported that solar drying is essential in preservation of minerals than sun drying. In solar drying happens in the shade, at low humidity but high air temperature. On the contrary, sun drying occurs at low temperatures exposing vegetables to heat for prolonged time. As a result more nutrients are leached out in sun drying process.

The cost of mixed modes solar dryer was 60 dollars including labor cost (Table 5.1 below). Also, 50g of valued added dehydrated AIVs processed by mixed modes solar dryer at Mace Foods was priced at Kshs.145 while a bunch of fresh African Indigenous Vegetable (200g) is priced at Kshs.20. This means that processing vegetables adds value to the price. Farmers can therefore form groups and purchase a mixed mode solar to process the vegetable. For Mace Foods, such a dryer will result into increased production because of increased drying rates.

Table 5.1 Construction cost of mixed modes solar dryer.

Item	**Cost**	**Total cost (K.shs)**
Black polythene paper	5meters @ 140/=	700
White polythene paper	2meters@ 160/=	320
Pins	4 packets@ 120/=	480
Screw nails	3 packets@ 150/=	450
Nails	1kg (2'') @ 100/= 1 kg (3'')@ 100/= 1kg (4'')@ 120/=	100 100 120
Timber (soft pine)	38ft (2''x2'')@ 30/= 40 ft (1'' x2'')@ 25/= 12 ft (2'' x 3'')@ 30/=	1140 1000 360
White plastic mesh	2 meters @ 340/=	680
Cardboard	1 meter@ 140/=	140
	Total	**5590**

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

1. The study results revealed cooking/boiling and sorting are the most common options for AIVs processing.
2. From the study, we observe that preserving the vegetables in the shade can preserve vitamins, micro-elements and prevent wilting.
3. Mixed modes solar drying has a higher drying efficiency, protects products from flies, dust, salmonella risks and UV radiation.
4. Since the farmers were willing to adopt developed varieties into their diets.

6.2 Recommendations

I. Extension

The county governments of Uasin Gishu, Trans Nzoia and Busia county should use nutritionist and other extension workers to increase awareness regarding dried AIVs in the communities. Extension work also needs to be conducted to educate farmers on the value of bulking, packaging and storing vegetables.

II. Policy makers

A policy should be drafted to so that governments can develop post-harvest infrastructure in the grassroots. A good way would be to avail a common cold storage room to be shared among the farmers and can also be rented out to generate income for maintenance.

6.3 Suggestions for further research

Further researches need to focus on modeling low costs evaporative cooling for AIVs preservation especially among the vegetable vendors who incur major losses in the value chain. This is because the vendors preserve their vegetables mainly in the sun and shade. Evaporative cooling would avail fresh AIVs. A combination of both evaporative cooling and solar drying would offer variety of products to consumers.

There is need to characterize developed AIVs species based on their phytochemicals. As much the results revealed that vegetables are rich in micronutrients, there are many factors that affect their bioavailability. Among them include phytates, oxalates and other anti-nutritional factors. Therefore, studies should be done to determine the levels of anti-nutritional factors in both the local and developed varieties and relate them to micronutrient utilization and absorption in both fresh and cooked AIVs.

Since micronutrients bioavailability for fresh vegetables have been done, the same needs to be done on cooked vegetables.

Microbial quality if solar dried vegetables should also be looked into. This is because there are a lot of post-harvest operations before drying that can affect microbial load of solar dried vegetables.

The study results revealed that vitamin C was stable in the shade. Studies needs to be done to determine the number of days vitamin C can last during shade preservation.

REFERENCES

Abioye, V.F., Akande, E.A., and Aluko, B.O. (2014). Effects of different local debittering methods on some chemical components and antioxidants in Bitter leaf (*Vernonia amygdalina*), *International Journal of Research in chemistry and environment* 4(1):96-101.

Abukutsa-Onyango**,** M.O. (2003) Unexploited potential of indigenous African Indigenous vegetables in Western Kenya. *Maseno Journal of Education, Arts and Science*; 4**:**103-122.

Abukutsa-Onyango. M.O., A.N. Muriithi, K., Ngamau, V., Anjichi, S.G., Agong, A., Fricke, B. Hau and H Stützel. (2005). Proceedings of the Third Horticulture Workshop on Sustainable Horticultural Production in the Tropics, 26th -29th November 2003.Maseno University, MSU, Maseno, Kenya.

Abukutsa-Onyango. (2007). The Diversity of Cultivated African Leafy Vegetables in Three Communities in Western Kenya. *African Journal for Food Agriculture, Nutrition and Development*, 7 (3):1-16.

Abukutsa, M.O. (2010). African Indigenous Vegetables in Kenya: Strategic Repositioning in the Horticultural Sector. Inaugural Lecture, Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya. Retrieved 30 April 2014 from. http://www.jkuat.ac.ke/article.php?id=177

Abukutsa-Onyango, M.O., Kavagi, P., Amoke, P. and Habwe, F.O. (2010b). Iron and protein content of priority African indigenous vegetables in the Lake Victoria Basin. *Journal of Agricultural Science and Technology* 4(4):67-69.

Acedo , A. L. Jr. (2010). Post-harvest technology for leafy vegetables. AVRDC-ADB Post harvest Projects RETA 6208/6376. AVRDC Publication No. 10-733. AVRDC-The World Vegetable Center, Taiwan.

Adedze, P., Novakofski, K.C., & Orr, R. (2011). Knowledge, Attitudes and Beliefs about Nutrition and Childhood Overweight among Women, Infants and children Participants'. *Journal of Family Community health*, 34 (4): 301-310.

Adefegha, S.A., and Oboh, G. (2011). Cooking enhances the antioxidant properties of some tropical green leafy vegetables. *African Journal of biotechnology*, 10 (4): 632-639.

Adelaja, A.O. and Babatope, B.I. (2013). Analysis and testing of a natural convection solar dryer for the tropics. *Journal of Energy,* Article ID 479894. Hindawi Publishing corporation.

Adewale, A., and Alani, E.A. (2013). The nutrient content and antioxidant property of five traditional west African Dark green leafy vegetables. *International Journal of recent scientific research*, 4(2):143-147.

Akubugwo, I.E., Obasi, N.A., Chinyere, G.C., and Ugbogu, A.E. (2008). Mineral and phytochemical contents in leaves of *Amaranthus hybrid L and Solanum nigrum L.* subjected to different processing methods. *African Journal of Biochemistry Research*, 2 (2):40-44.

AOAC (Association of Official Analytical Chemists). (1995). *Official methods of analysis*. (16th) edition. AOAC Inc. Arlington, Washington, D.C.

Bates, R.P., Morris, J.R., and Crandall, P.G.(2001).Principles and practices of small and medium scale fruit juice processing. FAO Agricultural services bulletin 146. FAO, Rome.

Bradbury, J.H., Bradshaw K, Jealous W, HollowayWD and Phimpisan T,(1987). Effect of cooking on nutrient content of tropical root crops from the South Pacific. *J Sci Food Agric* 43:332–342.

Brown , S., Lumpkin,V., Barber, S., Hardie, E., Kraft, K. H., and Luedeling, E. et al., (2005). Global horticulture assessment. *Scripta Hort* 3:1–134.

CDC (Centers for Disease Control) (2002). The social ecological model: A framework for prevention. Retrieved 2nd August 2013 from http://www.cdc.gov/violenceprevention/overview/social-ecologicalmodel.html

Charles Ogoye-Ndegwa (2003). Traditional gathering of wild vegetables among the Luo of Western Kenya-anutritional anthropology project 1, *Ecology of Food and Nutrition*, 42 (1): 69-89.

College of Science (2011). Determination of Vitamin C Concentration by Titration, University of Canterbury Press. Retrieved 9th August 2013 from http://www.outreach.canterbury.ac.nz/chemistry/documents/vitaminc_iodine.pdf.

De Tullio, M.C., Ciraci, S., Liso, R., and Arrigoni, O. (2007). Ascorbic acid oxidase is dynamically regulated by light and oxygen. A tool for oxygen management in plants. *Journal of Plant Physiology*, **164**, 39-46.

FAO (1994). Soil Map of the world. Rome, Italy: FAO.

FAO.(2002).Agro biodiversity, food security and HIV/AIDS mitigation in Sub-Saharan Africa – Strategic issues for agricultural policy and programme responses.FAO, Rome.

FAO.(2007).Teaching good eating habits to reduce malnutrition and diet-related diseases. Rome, Italy.

FAO. (2011).Climate Change and Food Systems Resilience in Sub-Saharan Africa . Rome.

FAO.(2003). The state of Food insecurity in the World in 20003. FAO, Rome.

Flyman, M.V. and Afolayan, A.J. (2006). A survey of plants used as wild vegetales in four districts of Botswana. *Ecology of Food and Nutrition*, 45:405-415.

Food and Agriculture Organization. (2012)."The State of Food Insecurity in the World 2012". Rome. Retrieved April 2013 from http://www.fao.org/docrep/016/i3027e/i3027e00.htmand

Food and Agriculture Organisaton (2013). State of food insecurity in the world 2013. FAO, Rome.

Gockowski J, Mbazo'o J, Mba G and TF Moulende.(2003) African traditional leafy vegetables and the urban and peri-urban poor. *Food Policy*; 28(3): 221-235.

Gidamis, A.B., Panga, J.T., Sarwatt, S.V., Chove, B.E., and Shayo, N.B. (2003).Nutrient and anti-nutrient contents in raw and cooked young leaves and immature pods of Moringa oleifera, Lam. *Ecology of Food and Nutrition*, 42(3): 99-411

Habwe, F., Walingo, M.K. & Abukutsa-Onyango, M.O. (2010). Copper and Ascorbic Acid Content of Cooked African Indigenous Vegetables. Conference on International Research on Food Security, Natural Resource Management and Rural Development.

Heaton, J.W., Lencki, R.W., and Marangoni , A.G. (1996). Kinetic model for chlorophyll degradation in green tissue. *J Agric Food Chem* 44:399–402.

IPGRI**.** (2006). Reducing hidden hunger and malnutrition through traditional foods. IPGRI newsletter for Sub-Saharan Africa. Nairobi, Kenya; 1-3.

Irungu, C. (2007). Analysis of Markets for African Leafy Vegetables within Nairobi and its environs and implications for on farm conservation of biodiversity. Global Facilitation Unit for Underutilized Species (GFU), Maccaresse, Rome, Italy.

Jaetzold, R. and Schmidt, H. (1983). *Farm management handbook of Kenya Vol. II: Natural conditions and farm management information*. Part B. Bonn, Germany: Ministry of Agriculture.

Kader, A.A. (2005). Increasing food availability by reducing postharvest losses of freshproduce. *Acta Hort*. 682:2169-2176.

Kader, A.A. and Rolle, R.S. (2004). The Role of Post-harvest Management in Assuring the Quality and Safety Horticultural Crops. FAO Agricultural Services Bull. 152.

Kayode, O.F., Okafor, J.N.C., Adeyoju, O.A., Etoamaihe, M.A., and Ozumba, A.U. (2008). Nutrient Composition and sensory Evaluation of selected Nigerian Traditional soups. *Journal of Industrial Research and Technology*, 2(1):37-38.

Keding, G.B., Krawinkel, M.B., Virchow, D., Maass, B.L., and Msuya, J.M. (2009). Consumption of traditional and exotic vegetables and their perceived and real contributions to nutritional health in Tanzania. *Acta Horticulture*. 806: 209-216.

Keller, G. B., H. Mndiga, and B. Maass. (2006). Diversity and genetic erosion of traditional vegetables in Tanzania from the farmer’s point of view. *Plant Genetic Resources* 3:400–413.

Kenya National Bureau of Statistics (KNBS) and ICF Macro.(2010). *Kenya Demographic and Health Survey 2008-09.* Calverton, Maryland: KNBS and ICF Macro.

Kepe, T. (2008). Social dynamics of the value of the wild edible vegetables in a South African rural area. *Ecology of Food and Nutrition*, 4(6):53-538.

Kimiywe J., Waudo, J., and Mbithe, D. (2006). Reducing hidden hunger and malnutrition through traditional foods. Nairobi, IPGRI Newsletter for Sub-Saharan Africa. Issue No. 21.

Kimiywe, J., Waudo, J., Mbithe, D., Maundu, P. (2007) .Utilization and medicinal value of indigenous leafy vegetables consumed in urban and peri-urban Nairobi. *African Journal of Food*, *Agriculture*, *Nutrition and Development*, *7*(4): 1-15.

Kiremire, B; Musinguzi, E & Lukwago, F.(2010). Effects of vegetables drying techniques on nutrient content: A case study of South Western Uganda. *African Journal for Food Agriculture, Nutrition and Development*, 10(5): 2587-2600.

Kumar, R., Jain, S., and Garg, M.K. (2010).Drying behavior of rapeseed under thin layer conditions. *J. Food Sci. Technol*., 47(3): 335-338.

Laureati, M., Pagliarini, E., Calcinoni, O., and Bidoglio, M. (2006).Sensory acceptability of traditional food preparations by elderly people. *Food Quality and Preference*, 17: 43-52.

Laurie, S.M. and Faber, M. (2008).Integrated community- based growth monitoring and vegetable gardens focusing on crops rich in beta carotene: Project evaluation in a rural community in Eastern Cape, South Africa. *J. Sc Food Agriculture* 88:2093-2101.

Lewu, M.N., Adebola, P.O., and Afolayan, A.J. (2009). Effect of cooking on the mineral and antinutrient contents of the leaves of seven accessions of Colocasia esculenta (L.) Schott growing in South Africa. *Journal of Food, Agriculture and Environment*, 7 (3&4):359-363.

Loewenberg, S. (2014). Breaking the cycle: drought and hunger in Kenya. *The lancet, 383* (9922):1025-1028.Retrieved May 20th 2014 from http://www.thelancet.com/journals/lancet/article/PIIS0140-6736%2814%2960492-X/fulltext

Luchuo Engelbert Bain, Paschal Kum Awah, Ngia Geraldine, Njem Peter Kindong, Yelena Sigal, Nsah Bernard, Ajime Tom Tanjeko. (2013) Malnutrition in Sub–Saharan Africa: burden, causes and prospects. *The Pan African Medical Journal*; 15:120. Accessed from http://www.panafrican-med-journal.com/content/article/15/120/full/

Mhina, E.I., and Lyimo, M. (2013). Effects of postharvest handling practices on physic-chemical composition of tomato, *Journal of Agricultural Technology*, 9(6):1655-1664.

Mamlin, J.,Kimaiyo, S.,Lewis, S., Tadayo, H.,Jerop, F.K., et al.(2009).Integrating Nutrition Support for Food Insecure patients and their dependents into an HIV care and treatment program in western Kenya. *American Journal of Public Health*, 99(2):215-221.

Masarirambi, M.T., Mavuso, V., Songwe, V.D., Nkambule, T.P., & Mhazo, N. (2010). Indigenous post-harvest handling and processing of traditional vegetables in Swaziland. *African Journal of Agricultural Research*, 5 (24):3333-3341.

Masayi, N. and Netondo, G.W. (2014). Effects of sugarcane farming on the diversity of vegetable crops in Mumias Division, western Kenya. *International Journal of biodiversity and ecosystems*, 2(1): 1-10.

Martins, R.C., and Silva, C.L.M. (2004). Frozen green beans (*Phaseolus vulgaris*, L.) quality profile evaluation during home storage. *J Food Eng*, 64:481–488.

Mavengahama, S., McLachlan, M., and De Clercq, W. (2013). The role of wild vegetables species in household food security in maize based subsistence cropping. *Food Sec*, 5:227-233.

Mavengahama, S.(2013b).The role of indigenous vegetables to food and nutrition within selected sites in South Africa. A doctor of philosophy dissertation in the Faculty of Agribusiness, Stellenbosch University.

Mibei, E.K.,Ojijo, K.O.,Karanja, S.M.,& Kinyua, J.K. (2012). Phytochemicals and antioxidant analysis of methanolic extracts of four African Indigenous Leafy Vegetables. *Annals. Food Science and Technology*, 13 (1):37-42.

Modi, M., Modi, A.T. and Hendriks, S. (2006). Potential role for wild vegetables in household food security: A preliminary case study in KwaZulu-Natal, South Africa. *African Journal of Food Agriculture Nutrition and Development*, 6(1): 1–7.

Muhammad, R.H., Hionu, G.C., and Olayemi, F.F. (2012).Assessment of the post-harvest knowledge of fruits and vegetable farmers in Garun Mallam L.G.A of Kano Nigeria, *International Journal of Development and Sustainability*, 1(2):510-515.

Mugenda, O. M. and Mugenda, A. G. (2003). *Research methods. Quantitative and qualitative Approaches*. Nairobi: Acts press.

Nurhuda, H.H., Maskat, M.Y., Mamot, S..,Afiq, J., and Aminah, A. (2013). Effect of blanching on enzyme and antioxidant activities of rambutan *(Nephelium lappaceum)* peel. *International Food Research Journal*, 20(4):1725-1730.

Nyakuri, R.W., Wanjala, F.R., Kirui, S.C., and Cheramgoi, E. (2014). Amage of stem borer species to *Zea mays* l., sorghum bicolor l. and three refugia graminae. *Advance in Agriculture and Biology*, 1 (2): 71-78.

Oboh G, Raddatz H, Henle T (2008). Antioxidant properties of polar and non- polar extracts of some tropical green leafy vegetables. *J Sci. Food Agric*. 88: 2486-2492.

Okalebo, R.J.,Gathua, K.W., and Woomer, P.L. (2002). Laboratory methods of soil and plant analysis:A working manual, TSBF-CIAT and SACRED Africa, Nairobi, Kenya.

Olalusi, A.P., and Bolaji, B.O. (2008). Performance evaluation of mixed mode solar dryer. *AU J.T.*, 11(4):225-231.

Olayemi, F.F., Adegbola, J.A., Bamishaiye, E.I.,and Awagu, E.F.(2011). Assessment of post-harvest losses of some selected crops in eight government areas of rivers state, Nigeria. *Asian Journal of Rural development*, 1(4):1-11.

Osman, A., Saari, N., Saleh, R.,Bakar, J.,Zainal, N.D.,and Yacob, M.(2009). Post-harvest handling practices on selected local fruits and vegetables at different levels of the distribution chain. *Journal of agribusiness marketing*, 2: 39-53.

Perasiriyan, V., Karthikadevi, B., and Sivakumar, T.(2013).Optimization of drying process for vegetables and fish by Solar tunnel dryer. *International Journal of Food, Agriculture and veterinary sciences*, 3(2): 51-57**.**

Prabhu, S., and Barrett, D.M. (2009). Effects of storage condition and domestic cooking on the quality and nutrient content of African leafy vegetables *(Cassia tora and Corchorus tridens). J Sci Food Agric* ; **89**: 1709–1721.

Reid, M. and Thompson, J. (2013). Innovative Energy Solutions for Horticulture. Retrieved 7th August 2015 from https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&cad=rja&uact=8&ved=0CCUQFjABahUKEwjV0M7H0aDHAhWEQBoKHVt7A1k&url=http%3A%2F%2Fhorticulture.ucdavis.edu%2F2013%2Fother%2F

Reid%2520Innovative%2520Energy%2520Solutions.pdf&ei=trXJVdWdDYSBadv2jcgF&usg=AFQjCNGFxhJTItXlcjRSSaB3xE2P5n2LFQ&sig2=MKq36NxPKIEQERBi9Z6vew&bvm=bv.99804247,d.d2s

Rickman, J.C., Barrett, D.M., and Bruhn, C.M. (2007) .Nutritional comparison of fresh, frozen and canned fruits and vegetables. Part 1. Vitamins C and B and phenolic compounds. *J Sci Food Agriculture* 87:930–944.

Sarah, T.P., Merwe, D., Beer, H.D.,Magdalena, J.C., and Kruger, A. (2012). Consumers beliefs on indigenous and traditional foods and acceptance of products made with cow pea leaves. *African Journal of agricultural research*, 7(14):2243-2254.

Schippers, R.R. (2002). *African Leafy Vegetables: An overview of cultivated species*. Natural Resources Institute/ACP-EU Technical Center for Agricultural and Rural Co-operation. Catham, UK.

SCN. (2010). Standing Committee on Nutrition. 6th report on the World Nutrition situation, UNSCN Secretariat, Geneva, Switzerland.

Shokunbi, O.S., Anionwu, O.A., Sonuga, O.S., and Tayo, G.O. (2011). Efect of post-harvest processing on the nutrient and antinutrient compositions of *Vernonia amygdalina* leaf. *African Journal of biotechnology*, 10 (53): 10981-10985.

Silue, D. (2009).Spider plant: *An indigenous species with many uses*. AVRDC-The World vegetable Centre, Tanzania.

Simate, I. (2001). Simulation of the mixed-mode natural-convection solar drying of maize. *Drying Technol* ;19 (6):1137–55.

Soetan, K.O., Olaiya, C.O., and Oyewole, O.E. (2010). The importance of minerals and elements for humans, domestic animals and plants: A review. *African Journal of Food science*, 4 (5):200-222.

Stiling, J., Li, S., Stroeve, P., Thompson, J., Mjawa, B., Kornbluth, K., and Barret, D.M. (2012). Performance evaluation of an enhanced fruit solar dryer using concentrated panels. *Journal of energy for sustainable development* 16:224-230.

Sundari, A.U., Neelamegam, P., and Subramanian, C.V.(2013).An experimental Study and analysis on Solar Drying of bitter gourd using evacuated tube air collector in Thanjavur, Tamil Nadu, India. Hindawi Publishing Corporation Conference papers in Energy.

Taiga, A., Suleiman, M.N., Aina, D.O., Sule, W.F., and Alege, G.O. (2008). Proximate analysis of some dry season vegetables in Anyigba, Kogi state, Nigeria. *African Journal of Biotechnology*, 7(10): 1588-1590.

Tilahun, S.W. (2010). Feasibility and economic evaluation of low cost evaporative cooling system in fruit and vegetables storage. *African Journal of Food, Agriculture, Nutrition and Development*, 10(8): 2984-2997.

Ukegbu, P. O. and Okereke, C. J**.** (2013) Effect of solar and sun drying methods on the nutrient composition and microbial load in selected vegetables, African spinach (*Amaranthus hybridus*), fluted pumpkin (*Telferia occidentalis*), and okra (*Hibiscus esculentus*). *Sky Journal of Food science*, 2(5):35-40.

Umuhozariho, M.G., Msuya, J.M., Shayo, N.B., and Sallah, P.Y.K. (2013). Sensory Evaluation of Different Preparations of Cassava leaves from three species as a leafy vegetable. *African Journal of Biotechnology*, 12(46): 6452-6459.

UNICEF (2013). Kenya at a glance. Retrieved 3rd July 2014 from http://www.unicef.org/kenya/overview_4616.html

Van der Hoeven , M., Osei, J., Greeff, M., Kruger, A., Faber, M., and Smuts, C.M. (2013). Indigenous and traditional plants: South African parents' knowledge, perceptions and uses and their children sensory acceptance. *Journal of ethno biology and Ethno medicine*, 9:78.

Van der Walt, A.M., Loots, D.T., Ibrahim, M.I.M., and Bezuidenhout, C.C. (2009). Minerals, trace elements and antioxidants in wild African dark green leafy vegetables (morogo). *South African Journal of science*, 105:444-448.

Vorster, H.J., Stevens, J.B. and Steyn, G.J. (2008). Production systems of traditional leafy vegetables: Challenges for research and extension. *South African Journal of Agricultural Extension*, 37: 85–96

Vorster, H.J. (2007). The role and production of traditional leafy vegetables in three communities in South Africa. M.Sc. dissertation, University of Pretoria, South Africa.

Vriens, E.C.M. (2007). The Implementation of an Innovation for sustainable economic Development in Rural Areas: The case of solar fruits and vegetable drying in rural Tanzania. Published Masters Thesis.

Weinberger and Lumpkin (2007). Diversification into horticulture and poverty reduction: A research agenda. *World Development* 35:1464–1480.

Waghray, K., Gulla, S., Kumar, C.S., Kumar, M.P., and Kumar, A.A. (2012). Sensory Quality and Acceptability of Fresh Juices. *Stud Home Com Scie*, 6(3): 179-181.

Walingo, A., Lungaho, C.,and Shibaro, S. (2001). Market Survey of Indigenous vegetables in western Kenya. In Africa Crop Science Conference Proceedings Vol. 5 Logos 22-26 October 2001: pp. 665-669.

World Bank (2011). Stemming post-harvest waste crucial to African Food security. Retrieved 3rd June 2014 from http://web.worldbank.org/WBSITE/EXTERNAL/COUNTRIES/AFRICAEXT

/0,,contentMDK:22928991~menuPK:2246551~pagePK:2865106~piPK:2865128~theSitePK:258644,00.html

World Health Organization/Food and Agriculture Organization (WHO/FAO). (2005). Patterns and determinants of fruit and Vegetable consumption in sub-Sahara-Africa: A multicountry comparison. FAO/WHO Workshop on fruit and vegetables for Health, Geneva, Switzerland

World Health organization (WHO). (2013). World Hunger and Poverty Facts and statistics. World Hunger Education service. Retrieved 2nd October 2013 from http://www.worldhunger.org/articles/Learn/world%20hunger%20facts%202002.htm

World Health Organization. (2001). *Health Research Methodology*: A Guide to Training in Research Methods, Second Edition. Manila.

World Health Organization. (2002). Nutrition program (Bruno beBenoist, ines Egli), Micronutrient Deficiency information system, Iron Deficiency Anemia. World Health Organization. Geneva.

Yang, R.Y., and Tsou, S.C.S. (2006). Enhancing iron bioavailability of vegetables through proper preparations-principles and applications. *J. International Cooperation* 1 (1): 107-119.

Zu, K.S.A., Wongnaa, C.A., and Appiah, F. (2014). Vegetable handling, distribution and wholesale profitability in Abinchi Night Market, Kumasi Ghana. *Journal of postharvest technology*, 02(01):096-106.

APPENDICES

Appendix I: Questionnaire for the survey

1: IDENTIFYING RESPONDENTS AND THE STUDY AREA

1.1.1 Name of household head ___________________Mobile phone No ___________

1.2. Name of respondent (if not household head) _____________________________

1.3. Relation of respondent to the household head (if not household head) 1.Spouse 2. Son 3. Daughter 4. Others (specify) ________

1.4 Sex of respondent (if not household head) 1. Male 2. Female

1.5. District: ____

1.6. OVC/FPI name___________________________________

1.7. GPS readings: a) Altitude..............................; b) Latitude……………………….;

c) Longitude………………………..….

2: LAND OWNERSHIP AND USE

2.1 What are the sizes of land parcels your household has access to and how did use them in 2010 Short Rains (SR) and 2011 Long Rains (LR) seasons?

Parcel No.	Acres	*Tenure See code below	Area under vegetables in last production cycle (M^2)	Area under other crops (Acre)	Area under fallow (Acre)	Area rented out (Acre)
1.						
2.						
3						
4.						

*Tenure: 1= Freehold with the title 2=Freehold without title 3=Rented -in 4=Communal 5=others (specify) ____________

2.2. Which are the major crops that this household grows and which inputs do you apply? (State area under each crop in 2013 SR and 2014 LR cropping seasons and rank the 5 most important crops).

Crop name	*Rank	Why the crop is preferred See code**			Area 2010SR (Acres)	2011LR (Acre)	Did you apply the following in any season of 2010SR/2011LR?						Total harvest/yield 2010LR (state units)	Total harvest 2010SR (state units)
		1st	2nd				Manure 1=Yes 0=No	Fertilizer 1=Yes 0=No	Pesticide 1=Yes 0=No	Irrigation 1=Yes 0=No	hired labor 1=Yes 0=No	Family labor 1=Yes 0=No		

* Rank: 1=most important…5=least important

** 1= Food security 2= income generation 3=Multiple uses for household 3=nutritious 4=medicinal 5=Good yield in bad weather 6=others (specify)…………………

Indicate multiple responses allowed for **

3: OWNERSHIP OF LIVESTOCK AND OTHER ASSETS

3.1. Please indicate the type and numbers of livestock and other assets your household owns

Livestock type	**Number**
Cattle	
Oxen	
Sheep	
Goat	
Chicken	
Others (specify)	
Other assets/services	**Ownership (1=Yes 0=No)**
Radio	
Television	
Bicycle	
Motor vehicle	
Landline phone	
Mobile phone	
Ox-plough.	
Hoe	
Wheel barrow	
Electricity in house?	
Others(Specify)	

4: PRODUCTION AND PREFERENCES OF VEGETABLES

4.1 Which vegetables does your household grow? (Rank the 5 most important).

Vegetable name (see code below*)	*Rank	Why the vegetable is grown and preferred **(See codes below**)**		
		1st	2nd	3rd

*1=Amaranth 2=Nightshade 4=Spider plant 5=Ethiopian mustard 6= pumpkin 7= African eggplant **8=** cowpea 9= jute mallow **10=** Okra 11= sweet potato (incl. leaves) (*Matembele-TZ*) 12=Kale 13= Cabbage 14=Others (Specify)______________________________________

****1=** good Prices **2=** contract with partner **3** =production experience **4** =available market **5=** opportunity to earn extra income **6=** cultural reasons to IVs **7=** home consumption **8=**Others (specify)

5: PROCESSING AND VALUE-ADDITION

5.1 List and describe the extent of AIV processing (**any procedure after harvesting, e.g., blending, value-addition, etc.**) by your household

ALV name	Do you process (Yes/No)		Year household first processed		Names of 2 most commonly processing/value added products **(See code**)**		Cost of processing /unit	Price of processed product/unit
	For home eating?	For sale?	For home consumption?	For sale?	First	Second		

****1.**Cutting/slicing and sun-drying; 2=sun-dried and stored; 3=Sorting & grading; 4= Bulking with other farmers; 5= Storage, 6= Any other

5.2. are IVs stored immediately after harvest? 1=**Yes 0=No**

5.3, If Yes, how do you store? **1** on ground under a shade **2** on ground under sun **3** on ground unknown **4** in basket **5** in crate **6** in cart **7** in plastic bag **8** in plastic sack **9** others (specify) ______________________On a rack outside in the night, in a traditional hut, etc

10. HOUSEHOLD DEMOGRAPHICS

12.1, HH characteristics

S/No.	**Household (hh) member name (start with hh head)**	**Relationship to hh head** *1 =Head, 2 =spouse 3= Son/ daughter 4=Parent 5= Brother/sister 6 = Grandchild 7= In law 8 =Employee 9 =Other relatives 10=Others--------*	**Marital status** Never married=1 Married =2 Divorced=3 Separated=4 Widowed=5	**Age**	**Gender:** male=1 female=0	**Highest level of education** *1-None 2-Primary 3-Secondary. 4-College. 5-University*	**Informal education** *1. None 2-Adult Education 3-Training on vegetable 4-Artisan training*	**Most important occupation **(see code)**
1								
2								

Occupation codes: 1= Farming 2= Salary earner 3= Wage earner in agricultural sector 5=.Wage earner in non-agriculture large business (factory operation) 6=petty business (kiosk, trade in farm produce) 7=artisan 6 =none (applicable to 2nd most important occupations and preschool-age children only) 7= Student (children actually going to school) 8= Child (of school going age not in school) 9= others (specify)________________

11. HOUSEHOLD FOOD CONSUMPTION FREQUENCY

12.6 What is the frequency of consumption of the following foods by the members of the household?

Food Item	Frequency of consumption per week		
	Frequency	Source	Adequate 1=Yes 2=No
Maize			
ALVs			
Fruits			
Legumes			
Exotic vegetables			
Meat and meat products			
Milk			

1=6-7 times a week, 2=once/twice a week, 3=5-7/week, 4=Three to five times a week, 5=1-3 times a month, 6=2-4 times/week, 7= once a week, 8=Rarely(less than once a month)

Appendix II: Sensory Evaluation questionnaire

Welcome to this Vegetable testing session

Age:

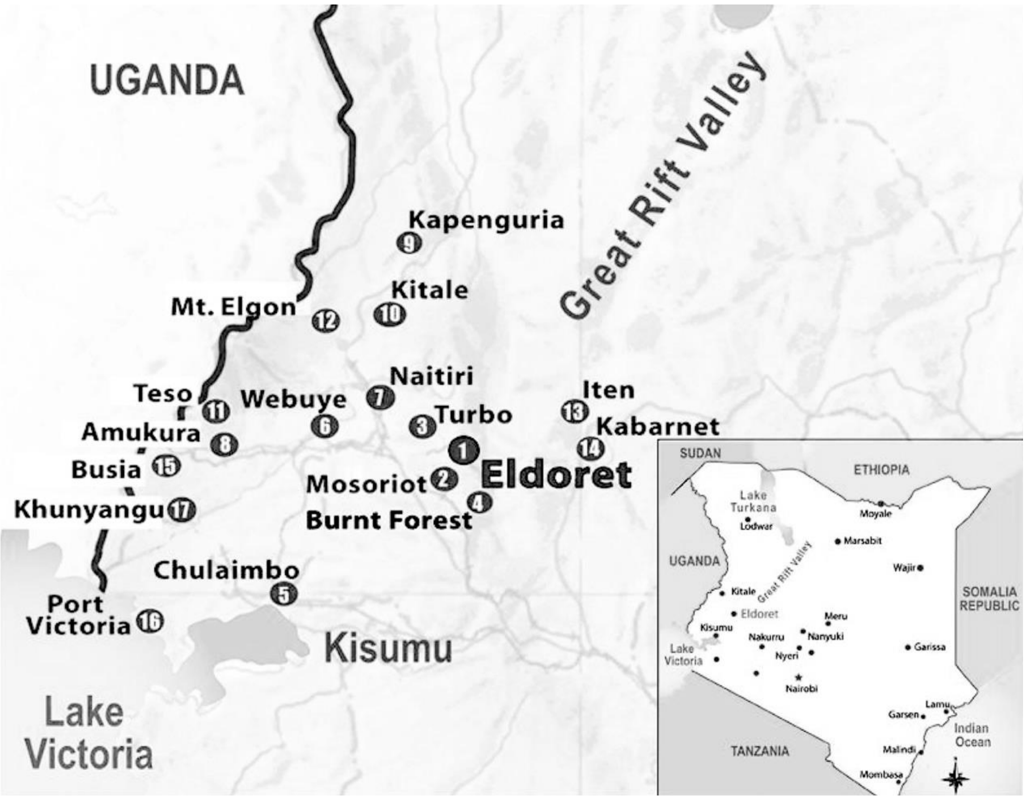
Gender:

SET NUMBER:

You are presented with six (6) samples of vegetables. Please taste the samples in the order provided from left to right. Take a sip of water before you start tasting and in between tasting different samples. Indicate your liking or dislike by placing a check (X) at the appropriate point on the scale.

Sample Code					
	Color	**Aroma**	**Taste**	**Texture**	**Overall acceptability**
Like extremely					
Like very much					
Like moderately					
Like slightly					
Neither like nor dislike					
Dislike slightly					
dislike moderately					
dislike very much					
dislike very much					
Dislike extremely					

Appendix II: Map of study area



Appendix III: Consent Form

I am Emmanuel Ayua, a post-graduate student at the University of Eldoret pursuing a masters degree in Community Nutrition. I am currently undertaking a research project entitled "Postharvest handling and value addition of African Indigenous Vegetables in western Kenya." With reference to this, I am conducting a consumer evaluation for local and developed AIVs varieties. My target population is AIVs consumers.

Carefully read this and sign at the bottom if you agree to participate in the study:

I am well informed of the nature of this study and I understand that participation is on the basis of informed consent. I further agree that I meet the inclusion criterion and I am not allergic to the vegetables used in preparing the samples for this study.

Name: …………………………

Sign …………………………..

Date: …………………………