DEVELOPMENT OF EAST AFRICAN INDIGENOUS VEGETABLE RECIPES AND DETERMINATION OF THEIR IRON, COPPER AND VITAMIN C CONTENTS

BY

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ABSTRACT

Increasing prevalence of chronic diseases and micronutrient deficiency in developing countries is burdening the national and household resources thus interfering with resource distribution. Changes in dietary patterns, attitudes and beliefs about food have resulted in higher prevalence of chronic diseases and micronutrient deficiencies. This is because indigenous foods especially plant foods are being replaced by high-fat, energy-dense diets with increased intake of animal foods and yet plant based foods especially African Indigenous Vegetables (AIVs) are rich in many micronutrients needed for healthy living. These vegetables are seasonal and recipe formulation promises their availability throughout the year and may also reduce wastage. Diversification of diets through increased utilization and consumption of these vegetables would go a long way in alleviating hidden hunger and malnutrition. The main objective of this research was to develop and evaluate high iron recipes of East Africa's indigenous vegetables and this was the first time such research was done in Kenya. The study was carried out at Maseno University where four priority AIVs including: African nightshade (*Solanum scabrum)*, Vegetable Amaranth (*Amaranthus blitum)*, Slenderleaf (*Crotalaria ochroleuca)* and Cowpea (*Vigna unguiculata)* were randomly selected. Together with these four single vegetables, six vegetable combinations were formulated where each vegetable had a probability of being combined with another to form ten vegetable categories. The vegetables were boiled for 10 minutes with or without traditional salt (lye), they were then fried using onions giving rise to twenty vegetable recipes. These vegetables were also blanched and dried under shade then developed into vegetable products using simsim giving rise to ten vegetable product recipes with the aim of increasing their shelf life and marketability. Subjective evaluation using grading charts was used for sensory evaluation to determine acceptability of these recipes. During this evaluation 52 tasters were selected using disproportional stratified random sampling, where four strata were used as follows; age stratum (11-30 years) and (31-50 years), and sex stratum (female) and (male). From each stratum, 13 individuals of good health were randomly selected. AIVs were also evaluated objectively for their iron and copper contents using Atomic Absorption Spectroscopy (AAS) and vitamin C content was determined using titration method. Data obtained were analyzed using ANOVA, descriptive and inferential statistics. A total of thirty high iron AIV recipes were developed out of with twenty were vegetable recipes while ten were vegetable product recipes. Results indicated a significantly higher preference for recipes prepared with traditional salt for both taste and appearance ($P<0.001$) compared to those prepared without traditional salt. Cooking significantly increased iron and copper solubility in AIVs ($P<0.05$), however, fried AIVs had higher content compared to the boiled ones. There were insignificant mean differences between AIVs prepared with and those prepared without traditional salt in terms of their iron and copper availability ($P>0.05$). Fried AIVs recorded higher mean for vitamin C content compared to the boiled ones, while raw AIVs had slightly higher vitamin C content compared to AIVs boiled with traditional salt. Iron, copper and vitamin C levels in the prepared recipes were adequate to supply their respective recommended daily allowances (RDA). The use of lye and frying method in AIV recipe preparation could increase AIV consumption due to the increase in acceptability ($P<0.0001$) and could in the long run reduce iron deficiencies among the vulnerable population. It is possible to develop vegetable products from AIVs that can help increase AIV shelf life, marketability, supply throughout the year, and reduce wastage.

CHAPTER ONE

INTRODUCTION

1.1. Background

Malnutrition is common in East Africa especially among women of childbearing age. It is made worse by micronutrient deficiency, a major cause of weakened immunity to diseases leading to increased mortality in vulnerable groups (Farm Africa, 2006). Nutrition plays a central role in alleviating food insecurity and ill health in developing countries. African Indigenous Vegetables (AIVs) are important for dietary diversification; they are a rich source of many micronutrients needed for good health (Oniang'o *et, al* 2005) and their increased production and consumption can enhance the national and household's economic situation. Studies have also shown the potential synergetic effect of African Indigenous Vegetables neutraceuticals (micronutrient dense and medical) (IPIGRI, 2006). Africa particularly Kenya was in the past experiencing a decline in the consumption of indigenous African Leafy Vegetables, because of lack of knowledge on the correct choice of foods hence reduced dietary diversity (Abukutsa-Onyango, 2003). However activities to scale up production and consumption of AIVs have increased greatly in the recent past. AIVs are fast becoming the vegetable of choice especially in the segments of the society where consumption has been minimal for example in the upper and middle class households, and among the elites in five-star hotels even in parliament (Shiundu and Oniang'o, 2007); therefore AIVs are now a much sought-after item on menus. The increased need to consume AIVs is due to the continued availability of these vegetables to the lower end of the market consumers whose majority are the poor (Shiundu and Oniang'o, 2007). This shows the urgency of the need for information and knowledge on AIV processing and preparation alongside their nutrient contents after cooking.

Although Indigenous vegetables play an important role in food security of most populations in both rural and urban settings, development agencies, formal-sectors, agriculture and conservation institutions have neglected AIVs partly contributed to by lack of interest by Stakeholders themselves and their poor attitude. This has resulted to difficulties in identifying optimal diets yet a diverse and balanced diet including a variety of AIVs provides an intrinsic buffer against the uncertainties of change and remains the preferred choice for human health (Johns, 2004). Diversification of diets through availability and acceptability of recipes of African indigenous vegetables was the main focus of this research and the main objective was to develop high iron recipes of African Indigenous Vegetables from East Africa. Vegetables are a very important dietary component of mankind, they contain micronutrients and phytochemicals, which avail other micronutrients which are present in hidden forms in other foods and contain health-promoting compounds such as vitamins, minerals, anti-oxidants and even anti-cancer factors. The diversity of these African indigenous vegetables forms the basis of food and nutrient diversity (FAO, 2003) hence food and nutritional security.

Iron deficiency is defined as a condition in which there is no mobilizable iron stores and in which signs of a compromised supply of iron to tissues including the erythron are noted, its more severe stages are associated with anaemia (WHO, 2003). This adversely affects; cognitive performance, physical growth of infants, pre-school and school-aged children; the immune status and morbidity from infections of all age groups; the use of energy sources by muscles and thus reduced physical capacity and work performance (FAO, 2003; WHO, 2002 and UNICEF, 2004). This therefore implies a reduction in national and household productivity, increasing malnutrition (anaemia) and food insecurity which if not corrected lead to a vicious cycle of malnutrition.

1.2. Statement of the Problem.

Micronutrient deficiencies are most prevalent in areas where the diet lacks variety as in the case for many individuals in developing countries. Anaemia contributes to 20% of all maternal deaths, an increased incidence of low-birth weight babies, and has serious health consequences (WHO, 2002; UNICEF, 2004). Nutritional iron deficiency or habitual iron intake that is insufficient to cover RDA requirements is the most common cause of iron deficiency that may lead to either death or reduced work capacity thus lead to food insecurity hence the vicious cycle of malnutrition (WHO, 2001, FAO, 2003).

Most researchers have concentrated on the production of AIVs (Maundu, 1997), yet much of the knowledge and practice concerning African indigenous vegetables species, their use and ways of preparation is vanishing without being passed on to the younger generations. Very few studies have been undertaken to improve and tap this information from the elderly, this has led to neglect and disuse of AIVs by the youth and particularly the urban populations. A survey by Waudo *et al*., 2005 and 2007 revealed low AIV consumption among women, children and in the urban and

Peri-urban populations of Lake Victoria region due to lack of knowledge on preparation and cooking of AIVs. Previous neglect and disuse of AIVs has been contributed to by long time taken to prepare these vegetables and lack of knowledge on AIV preparation, processing and nutrient content, which can be made available through recipe formulation. These vegetables are also seasonal and recipe formulation promises AIV marketability, improved shelf life, and availability throughout the year thus reducing wastage. Shiundu and Oniang'o (2007) agreed that availability of AIVs to consumers could positively affect their nutrition and health only if they are provided with recipes and knowledge on their nutrient content, thus the reason for this study.

1.3. General Objective

To develop high iron recipes of African Indigenous Vegetables from East Africa.

1.4. Specific Objectives

1. To develop a variety of AIV recipes from most consumed AIVs from East Africa.
2. To determine acceptability of the developed AIV recipes using organoleptic taste evaluation.
3. To determine the iron, copper and vitamin C contents in raw and cooked AIVs.

1.5. Research Hypothesis

1. A variety of AIV recipes can be developed from commonly consumed East African AIVs
2. African indigenous vegetable recipes are acceptable
3. AIV recipes have high iron, copper and vitamin C contents

1.6. Justification

This research has introduced variety in AIV recipe formulation that could encourage AIV consumption which can lead to the AIVs being used as cash crops in peri-urban and urban systems, source of new crops, source of vegetables for daily sustenance of home gardens, and as source of variation for diversification of production systems and diet. This could in the long run result into nutrient and food security.

1.7. Conceptual Framework

African indigenous vegetables (AIVs) can play a significant role in addressing three major factors of; low income, malnutrition and loss of biodiversity that greatly affect the quality of life of resource-poor households in Africa. However, this has been hindered by lack of variety in AIV recipe formulation, low production, and lack of knowledge on recipe preparation and their nutrient content. These factors result into neglect of AIVs as shown in Figure 1.1, which eventually result into high AIV prices, limited supply and low consumption. Malnutrition and various chronic illnesses come as a result of low food consumption including AIVs, thus leading to nutrient and food insecurity. Malnutrition cycle can be broken through availability of information on AIV production, recipe formulation, and nutrient content, which could lead to AIV recipe availability and acceptability, and eventually increased AIV consumption thus improve food and nutrition security of the population.

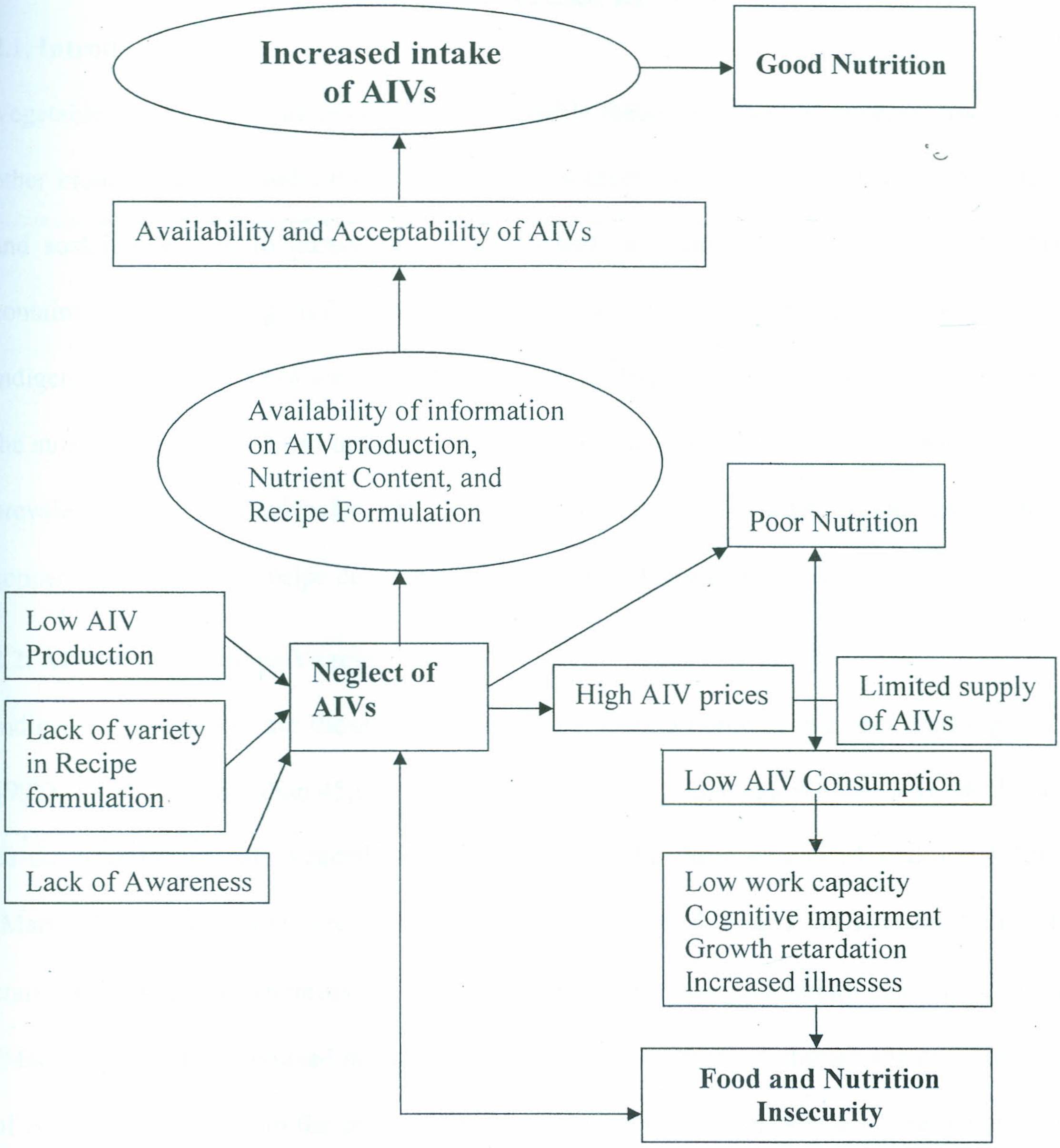

Fig. 1.1: Conceptual framework of the interaction between neglect of AIVs and food insecurity, With the availability and acceptability of high iron AIV recipes with Nutrition status.

Source: Adopted and modified from WHO, (1995). Global Burden of Disease (1990).

CHAPTER TWO
LITERATURE REVIEW

2.1. Introduction

Vegetables are the most affordable and sustainable dietary sources of vitamins, trace elements and other bioactive compounds, they are the major sources of most micronutrients and offer practical and sustainable way to ensure that micronutrients are supplied through the diet. This chapter contains the following information: African indigenous vegetables, advantages of African indigenous vegetables, nutrient composition of raw African indigenous vegetables, factors affecting the nutrient value of African indigenous vegetables, micronutrients, recommended daily iron intake, prevalence of iron deficiencies, effects of iron deficiencies on health, relationship between iron, copper and vitamin C, récipe development, and gaps in knowledge.

2.2. African Indigenous Vegetables (AIVs)

Indigenous vegetables are those vegetables whose natural home is in a specified region (Maundu, 1997). There are more than 45,000 species of plants in Sub-Saharan Africa of which about 1000 can be eaten as green leafy vegetables which happen to be the mainstay of traditional African diets (MacCalla, 1994). They are inexpensive, easily accessible and provide millions of African consumers with the vitamins and minerals needed to maintain health and fight off infections (MacCalla, 1994, Abukutsa-Onyango, 2003 and ICRAF, 2004). Although the consumption and use of AIVs is still rooted in the practices and knowledge systems of Africa's rural people, the current lack of variety in recipe formulation may soon translate into disuse and eventual loss of these vital nutritional and economic resources. Its effect on women, children and the poor in rural and urban areas is likely to be great; therefore families should consume African indigenous vegetables, which are rich in protein, calcium, phosphorus, iron, potassium, carotene and vitamins A, B and C complementing the nutritional value of basic staple foods (FAO. 2003).

African indigenous vegetables contain health-promoting compounds such as vitamins, minerals, anti-oxidants and even anti-cancer factors. Examples of African Indigenous Vegetables found across Eastern Africa include the following: African nightshade (*Solanum scabrum*), Spider plant (*Cleome gynandra*), Vegetable amaranth (Amaranthus *hybridus*), Slenderleaf (*Crotalaria brevidens*), Jute mallow (*Corchorus olitorius*), vegetable cowpea (*Vigna unguiculata*) Pumpkin leaves (*Curcurbita muschata*) and African kale (*Brassica carinata*) among many more (Abukutsa-Onyango *et al* 2006).

2.2.1. Advantages of African Indigenous Vegetables

African indigenous vegetables ((AIVs) play a key role in income generation and subsistence (Adebooye & Opadode, 2004). Studies have also shown that countries that retain Indigenous Vegetable diets and have high consumption of these vegetables are much less likely to be affected by cardiovascular diseases, diabetes and other adverse consequences of the nutrition in transition (Johns and Sthapit, 2004). They are compatible in use with starchy staples and represent a cheap but quality nutrition to the poor both in urban and rural areas where malnutrition is widespread (Maundu, 1997).

African indigenous vegetables could make a positive contribution to world food production because they adapt easily to harsh or difficult environments, input required for growing them is lower compared with other crops, and they are highly resistant to pathogens thus require fewer chemicals and pesticides (Abukutsa-Onyango, 2006). This makes them suitable and advantageous for people living in areas with high population density like Africa. AIVs can act as a substitute for other cultivated crops to alleviate nutrient deficiencies by increasing nutrient supplies (Engle and Altoveras, 2000). Leafy African indigenous vegetables are also rich sources of fiber, minerals and vitamins; they also add diversity to the diet (Midmore *et al*, 1991). AIV production can compensate for low vegetable supply during the off-season, potentially helping to alleviate nutrition deficiency during this period (Engle and Altoveras, 2000). The minerals and vitamins found in African Indigenous Vegetables exceed the levels found in exotic vegetables like cabbage, they are also compatible to use with starchy staples because they contain ascorbic acid, which enhance iron absorption (ICRAF, 2004). The diversity of Indigenous plants in most tropical countries, in addition to providing essential nutrients; presumably offer broad benefits to health (Abukutsa-Onyango, *et al.*, 2006).

2.2.2. Nutrient Composition of Raw African Indigenous Vegetables

African indigenous vegetables are a valuable source of nutrition in rural areas and they contribute substantially to protein, mineral and vitamin intake (Maundu, 1997). Table 1, indicates nutrient content of AIVS.

Table 2.1: Nutrient Content (mg/100g) of Raw AIVs in East Africa

AIV	Ca	P	Fe	Mg	Na	K	Vit C
Amaranth	323.7	89	7.5	122	230	341	50
Nightshade	100.47	62.50	8.63	461	74.22	100	54
Slenderleaf	1,234.4	11.25	28.13	155	22.66	162.50	
Cowpea	428.01	17.23	9.62	46.73	31.25	81.25	8
Pumpkin leaves	231.5	155	1.026	46.45	20.31	125	80
Cassava leaves	300	120	7.7	6	605	-	8
Sweet potato leaves	117.80	30	19.35	61.35	40	620	70
Spider plant leaves	1,484.4	48.95	29.67	47.50	18.75	75	
Tomatoes	14.06	19.04	1.997	11.86	45.193	47.83	10
Onions	39.81	39.54	1.29	18.5	5.32	158.67	11
Simsim	1,429.47	817.5	9.7	459.5	4.21	299	0

Source: National Food Composition Tables and the Planning of Satisfactory Diets in Kenya (Sehmi, 1993).

2.2.3. Factors Affecting the Nutrient Value of African Indigenous Vegetables

Some factors, which affect the nutrient value of AIVs according to Imbamba (1973), are: plant age, storage, processing, cooking and environmental factors e.g. temperature, rainfall and plant mineral nutrition among others. Plant age is inversely proportional to the protein content of vegetables; some leaves of AIV can be stored for up to two years when sun or air-dried but much of the valuable food is lost through damage by insects, rats, mice and other vermin. High humidity encourages growth of fungi and bacteria. The main methods of cooking African vegetables involve boiling in unspecified amounts of water or some form of wet heating, which may contribute, to nutrient loss. Most of the micronutrients especially vitamins, are heat-sensitive and are easily oxidized thus reducing their levels (Abukutsa-Onyango *et al* 2006), equally food additives such as bicarbonate of soda destroys vitamins (Waudo *et al.*, 2007).

Changes in the mineral content as a result of cooking vary with the mineral; cooking does not appear to significantly change iron availability whereas calcium and magnesium leaches into cooking water. An experiment carried out by Imungi and Poter, (1983) as cited by Abukutsa-Onyango, (2003) showed that iron content of raw cowpea was 39 mg/100g while its content in cooked cowpea was 40mg/100g, this showed that cooking increased extractable iron in some AIVs. After cooking the level of total carotene in the drained leaf does not change although carotenes are known to degrade during heat processing; during cooking the leaves loose 87% of the vitamin C through degradation and leaching and only 6% of the vitamin can be recovered in the cooking water. Therefore vegetables should be cooked with little water in order to reduce the losses of minerals and vitamins (Abukutsa-Onyango *et al*, 2006).

2.3. Micronutrients

Micronutrients are those vitamins and minerals needed in very small amounts that must be supplied by a variety of foods in the diet; they are the essential vitamins and minerals required by human beings to stimulate cellular growth and metabolism (FAO, 2003). Micronutrient malnutrition is a term commonly used to refer to vitamin and mineral nutritional deficiency diseases; diets which lack adequate amounts of essential vitamins and minerals lead to such diseases (FAO, 1997). Micronutrient deficiencies can exist in populations even where the food supply is adequate to meet energy requirements, in this case people are not considered hungry in the classical sense but their diets may be grossly deficient in one or more micronutrients (FAO, 2003). Although the major malnutrition problems are found in developing countries, people in developed countries also suffer from various forms of micronutrient malnutrition (FAO, 1997). Blindness and goiter are two of the most visible external manifestation of micronutrient deficiency, and have helped to bring into the limelight the 'hidden hunger' (FAO, 2003).

Micronutrient deficiencies can exist in populations even where the food supply is adequate in terms of meeting energy requirements. In these situations, people are not considered "hungry" in the classical sense, but their diets may be grossly deficient in one or more micronutrients (FAO, 2003). Many nutritionists and social scientists believe that the integration of food rich in micronutrients into the diet is the only sustainable way to improve micronutrient status in the human body (Ali and Tsou, 1997). Undernutrition is high in Africa especially among children being weaned, pregnant and lactating mothers, thus nutrient-deficiency diseases like night blindness, scurvy, rickets and anaemia are common in rural areas (FAO, 2003). To counter these nutritional problems, it's important that most commonly consumed foods be nutritious (Maundu, 1997 and ICRAF, 2004).

Vitamins and minerals are considered essential for physical and mental development, immune system functioning and various metabolic processes while other micronutrients have been shown to play a role in preventing specific disease conditions or in promoting growth (FAO, 2002 and 2003). Micronutrient deficiencies rarely occur in isolation, this is because deficiencies usually occur when the habitual diet lacks diversity or is overly dependent on a single staple food, as in the case with monotonous cereal or tuber-base diets (FAO/WHO, 2002). Situations of food insecurity, where populations do not have enough to eat, will also inevitably result in micronutrient deficiency, however, deficiencies of iron, iodine and vitamin A are the most widespread forms of micronutrient malnutrition with public health consequences (FAO, 2002 and FAO, 2003). Iron deficiency anaemia is considered as a micronutrient deficiency of public health significance not only because it is widespread, but also due to its serious consequences in both adults and children (FAO, 2003).

2.3.1. Recommended Daily Iron Intake

Iron is important in the structure and function of the red blood cells, its lack results in anaemia, which is a common public health problem of significance especially in many developing tropical counties (Abukutsa-Onyango, 2003). According to Latham, 1965 as cited by Abukutsa-Onyango, 2003, recommended daily iron (mg) intakes are as follows: man (16mg), woman (18mg), pregnant woman (20mg), lactating woman (20mg), children one to six years (11mg), children six to eleven years (14mg), and children eleven to eighteen years (19mg).

Dietary sources of iron are present in two forms, haem and non-haem iron. Haem iron, found in animal-source foods such as meat, poultry and fish, has a greater bioavailability than does non-haem iron found in cereals, pulses, fruits and vegetables. Iron absorption is inhibited by phytate, found in whole grains, seeds, nuts and legumes and by the tannins present in tea, coffee and red wine. By contrast, iron absorption is enhanced when consumed with ascorbic acid, present in many fruits and vegetables (FAO, 2003 and ICRAF, 2004). Abukutsa-Onyango, 2003 reported that, in every 100g fresh weight edible portions of raw African indigenous vegetables there is certain amount of iron (mg) present as shown by the following examples: vegetable cowpea (39mg), African night shades (12mg), vegetable amaranth (10mg), jute mallow (7.7mg), slender leaf (4.0mg) and pumpkin leaves (2.1mg).

2.3.2. Prevalence of Iron deficiencies

Iron deficiency anaemia affects more than 3.5 billion people in the developing world out of which 30 to 40 percent live in sub-Saharan Africa (FAO, 2003). While about half of pregnant women in the world are estimated to be anaemic, every second pregnant woman and about 40% of preschool children in developing countries are estimated to be anaemic. Low levels of iron lead to anemia, which is a major health problem in many parts of Eastern Africa (Maundu *et al.*, 1999). Anaemia is defined as a reduction in the oxygen-carrying capacity of red blood cells, which occurs as a result either of decreased hemoglobin or of a reduction in the total number of red blood cells. Iron deficiency is the most common cause of anaemia, although anaemia can also occur as a result of vitamin B12 or folate deficiencies, congenital hereditary defects in red cells, reproductive blood losses, or from infection by malarial parasites or infestations of the gut by parasites (WHO, 2001).

It was estimated that half of all anaemia was caused by dietary iron deficiency (MacPhail and Bothwell, 1992). The groups most affected by anaemia are adolescent girls, women of childbearing age and preschool-age children. In some areas over half of them may be anaemic, but the disorder is also seen in older children and men (ACC/SCN, 1991, WHO, 1992). According to WHO, 2002, the following are the percentages of total iron deficiency anaemia affected population in Non-industrialized countries: Children (0-4years) - 39.0%, children (5-14 years) - 48.1%, pregnant women - 52.0%, all women (15-59 years) - 42.3%, Men (15-59 years) - 30.0%, and the elderly (+60 years) - 45.2%.

2.3.3. Effects of Iron deficiencies on Health

Iron deficiency anaemia during pregnancy can result in serious consequences of both mother and baby. Blood loss in childbirth can be very dangerous for iron-deficient women and is the primary cause of higher mortality risk; maternal anaemia may also lead to foetal growth retardation, low-birth weight infants and increased rates of early neonatal mortality (WHO, 2002). In addition to the effects of anaemia during pregnancy, anaemia affects cognitive performance, behavior and physical growth of infants and children of preschool and school age (WHO, 2001). Iron deficiency anaemia in adults diminishes their stamina and work capacity by as much as 10-15 percent, and it is estimated that this deficiency provokes losses in gross domestic product of up to 4.5% thus exerting a high economic burden on society (FAO, 2003). Increased acceptability and consumption of high iron AIV recipes, which are also rich in copper and vitamin C can enhance the absorption of iron from AIVs thus help anaemia.

2.3.4. Relationships between Iron, Copper and Vitamin C

An intimate relationship exists between minerals; trace elements and vitamins which when combined together in certain specific groupings provide a maximal bioassimilation and functioning process within the body. Vitamin C is known to play an important role in the absorption of dietary iron among other functions (FAO, 2003) it is the most potent enhancer of non-haem iron absorption even in the presence of inhibitors such as phytates, tannates and calcium, Vitamin C can also reduce food ferric iron to the better-absorbed ferrous iron by 75% to 98%. In Indian studies, the addition of ascorbic acid to cereals and pulses enhanced the availability of iron (NIN, 1992 as cited by FAO, 2003). A comprehensive review carried out by Cook and Monsen, 1997 as cited by FAO, 2003 has shown that a food source containing 50mg of ascorbic acid consumed with the main meal provides the most of the daily intake of iron and enhances iron bioavailability significantly. Copper is required for haemoglobin formation; it influences iron absorption and metabolization from the liver and other tissues and for its utilization. It helps oxidize Vitamin C and works with Vitamin C to form Elastin, a chief component of the elastin muscle fiber throughout the body; aids in the formation of red blood cells; helps proper bone formation and maintenance. Nevertheless copper deficiency may result into anaemia, which is the same case as iron deficiency. Two thirds of the body iron is present as haemoglobin (the red oxygen carrying pigment of blood) and it is the same haemoglobin that copper helps in the formation (NIN, 1992).

2.4. Recipe Development

A recipe is a set of written instructions for producing a specific food or beverage; it is a blueprint for food production (www.cooksrecipes.com/cooking-dictionary/R-search.html). A good recipe should; be reproducible in that can be repeated with consistent results; be easily prepared with minimum steps in logical sequence to produce appropriate end results from simple to complex recipes; its ingredients should be listed in the units that are commonly used in order to enhance accuracy; be concise and brief but comprehensive enough to furnish needed information, be appealing in order to furnish variety for the meal; be pleasing to the senses thus stimulate and satisfy flavor and aroma with appropriate texture and mouth feel; be economical with qualities of economy, not always from budget standpoint but also economy of human and material resources; and finally it should require minimum and efficient human energy expenditure, use of dishes, utensils and appliances appropriately.

2.4.1. An Example of a Recipe (standard form)

Slender-leaf and jute with boiled milk

Ingredients

1 kg	slender leaf	½ kg	jute mallow
½ liter	water	1 tsp	ordinary salt
2 tbsp	African salt	½ liter	fresh milk

Preparation

Wash the vegetable leaves, drain and leave them to dry for several minutes. Mix the ½ liter water with 3 tablespoons of African salt. Add 1-tablespoon ordinary salt. Boil the mixture of water and African salt and ordinary salt to boiling point. Add the crotalaria and jute leaves mixed together. Boil the leaves for 20 minutes while turning and stirring occasionally. Add ½ liter milk, stir gently and simmer for 10 minutes. The preparation yields from four to six medium portions and is best served with *ugali* (Woomer, *et al*., 2001).

2.5. Gaps in Knowledge

AIVs are inexpensive, easily accessible and excellent sources of micronutrients yet their use is declining due to the inability of these species to compete with exotic types especially in urban areas by the youth and lack of AIV recipes. Abukutsa-Onyango *et al.*, (2006) and Shitundu and Oniang'o, (2007) reported that high priority should be given to the development of new recipes that will increase market value and competitiveness of AIVs against exotic species. Being a strategy for the promotion of traditional vegetables, very little has been done to develop AIV recipes and this was partly the reason for this study.

Although there are regional leafy vegetable recipes in a cookbook titled "African Leafy Vegetable Cookbook" featuring recipes from several sub-Saharan African countries, these recipes lack regionally appropriate measuring tools, standards needed to ensure specificity in portion sizes and they also lack information on nutritive value of these recipes. This research aimed at analyzing iron, copper and vitamin C contents of selected African indigenous vegetables exposed to ten minutes of boiling and frying with and without traditional salt. Results indicated that cooking significantly increased iron and copper content of AIVs while vitamin C was reduced by cooking, however the reductions in vitamin C was insignificant due to limited cooking time and addition of onions and tomatoes during cooking which are also a source of vitamin C. Vegetable products made of simsim were also developed, this proved that it is possible to develop vegetable products when mixed with simsim and this could enhance their shelf life and marketability. However, there is need to develop a variety of AIV products and identify their shelf life. More research is also required to look into bioavailability of iron in the cooked AIVs.

CHAPTER THREE
METHODOLOGY

3.1. Study Site

The study was carried out at Maseno University, which is located on the equator in Maseno division 30km Northwest of Kisumu city in Nyanza province, at 34°36' East and 0° North at an altitude of about 1503 meters above the sea level. Maseno division covers an area of 168.7cm^2 with a population of 69,336 (GOK, 2002; www.fallingrain.com/world/KE/7/maseno-htms; Otieno et al., 1993 and Oseko, 2007). Long-term average rainfall in Maseno town is 2074mm per annum and its distribution is bimodal with peaks in March/April and September/October (Oseko, 2007). Soils are mainly dominated by vertisols, with a fairly acidic pH in water of 4.5 to 6.5 (Otieno et al., 1993; GOK, 2002; and Oseko, 2007). The soils are also deep, very deficient in P and N, and have a moderate P fixation (FAO, 1990 cited by Oseko, 2007). Mean annual day temperature is 20°C with the average maximum daily temperature not exceeding 31°C and the average minimum night temperature not dropping bellow 15°C (Otieno *et al*., 1993; GOK, 2002; Oseko, 2007).

3.2. Source of African Indigenous Vegetables (AIVs)

African indigenous vegetables commonly found in East Africa, which were used in the experiment were planted at the Maseno University Botanic garden and they included: African nightshade (*Solanum scabrum)*, vegetable amaranth (*Amaranthus blitum)*, slender-leaf (*Crotalaria ochroleuca)*, and Cowpea (*Vigna unguiculata)*. Land was prepared by ploughing and harrowing to a fine tilth. The plots of 5 by 5 meters were demarcated and poultry manure mixed with the soil in the demarcated soil at a rate of 5 tones per hectare. Seeds of each selected AIV were mixed with the soil at a rate of 1:10 and drilled in the respective plots at a spacing of 30 cm. After two weeks, thinning was done to leave an inter-raw spacing of 15 cm for all. All other agronomic practices were done to ensure optimum growing conditions. Harvesting by uprooting of the various AIVs was done at four weeks after seedling emergency for recipe development and evaluation as shown in

Plate 3.1. This was done to enable the researcher to have AIVs with the same harvest age and also in order to avoid other factors that may lead to nutrient loss in the AIVs, and have uniform AIVs with similar environmental exposure in order to avoid bias during nutrient analysis.

3.3. Development of African Indigenous Vegetable Recipes (Vegetable and Product recipes)

Figure 3.1 shows the process of recipe development, after harvesting (Plate 3.1) the AIVs, destalking was done to separate vegetable leaves from the stems as shown in Plate 3.2. Required amounts of AIVs were then weighed and various vegetable categories of single vegetables and vegetable combinations made such that each vegetable had a probability of being combined with another. They were then washed to remove dirt and shredded in preparation for cooking, after shredding, water with lye and without lye was boiled and the vegetables immersed in it to boil for ten minutes. The traditional salt (lye) was prepared by drying the pods of green beans after removing the mature seeds, the dry pods were then burnt over a hot dry pan and the ash collected after complete burning. The ash was put in a container whose bottom had small holes and water poured in it to pass through the ash into another container underneath. The residue is what is known as traditional salt or lye.

3.3.1. Development of Vegetable Recipes

After boiling vegetables were put aside and vegetable oil put on a pan on fire to heat, diced onions immersed in the oil to fry while stirring till golden brown. Tomatoes were then added and cooked till soft while stirring, the already boiled vegetables were then added, stirred and common salt put to taste. The vegetables were then simmered for two minutes, removed from and served (Plate 3.4).

3.3.2. Development of Vegetable Product Recipes

The blanched vegetables were dried under shade. Simsim was washed to remove dirt; salt added to taste and put on a hot pan on fire to dry and fried till golden brown then mixed with the dried AIVs in required proportions. Sugar was then melted on a pan and the mixture of simsim and AIVs put in, after which, various shapes of AIV products made (Plate 3.3), then left to cool under shade.

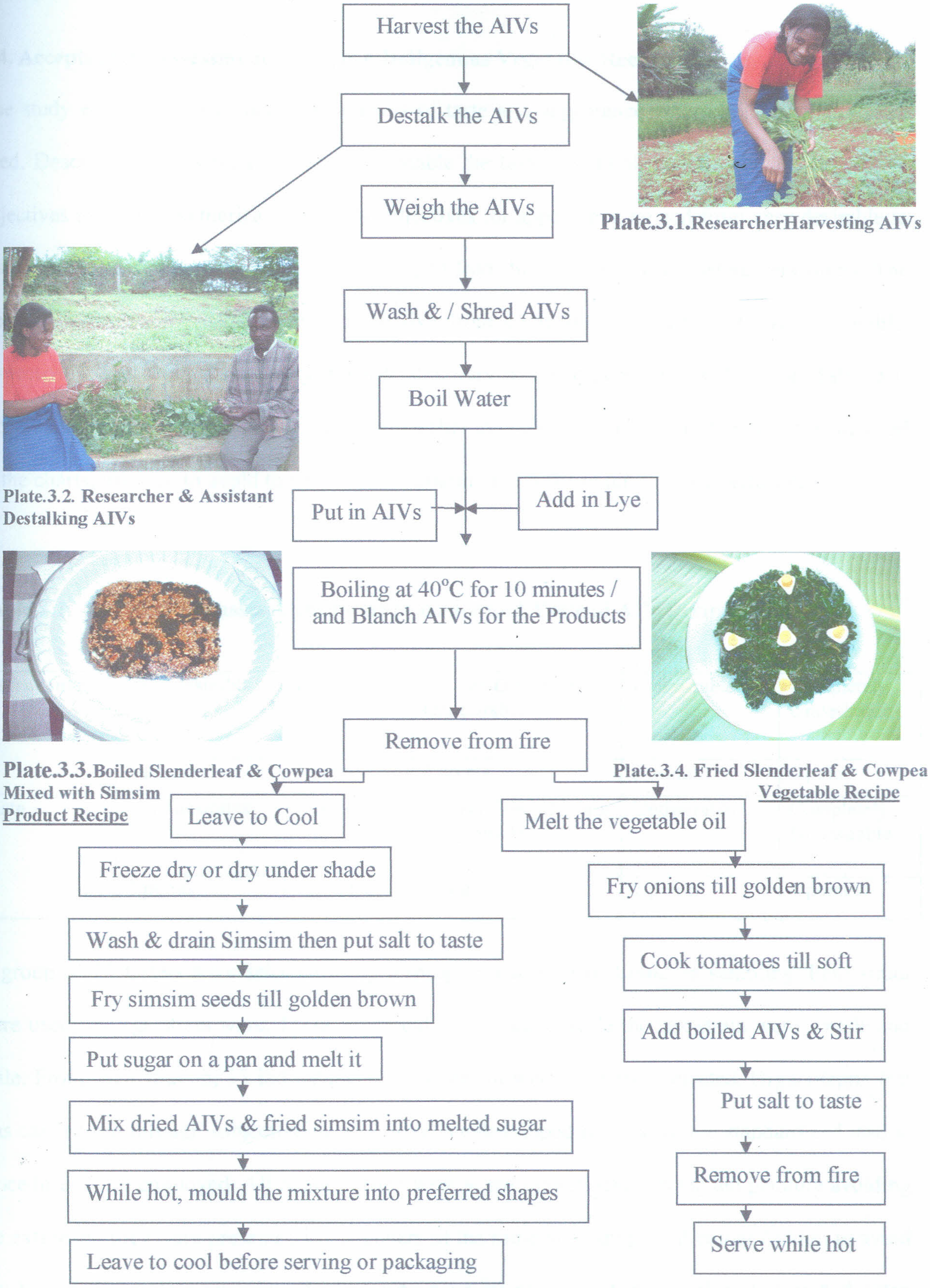

Plate.3.1.ResearcherHarvesting AIVs

Plate.3.2. Researcher & Assistant Destalking AIVs

Plate.3.3.Boiled Slenderleaf & Cowpea Mixed with Simsim <u>Product Recipe</u>

Plate.3.4. Fried Slenderleaf & Cowpea <u>Vegetable Recipe</u>

Fig. 3.1. Simplified Flow sheet for AIV Recipe Development

3.4. Acceptability Assessment of African Indigenous Vegetable Recipes

The study emphasized two major parameters of taste and appearance where grading charts were used. Descriptive terms were employed to enable the tasters to think in terms of the descriptive adjectives instead of numerical scores, the adjectives for appearance ranged from very desirable to completely undesirable while that of taste ranged from like very much to dislike very much. The steps in the series were numbered one to five from completely undesirable to very desirable, respectively; and from dislike very much to like very much respectively as shown in Table 3.1. However the numbers were meant for the researcher to use and not for the testers thus not included in the charts, this was to avoid the testers from grading the AIVs in terms of numerical scores.

Table 3.1. Acceptability assessment by Appearance and Taste of AIV Recipes

Appearance	Very desirable	Desirable	Neither Desirable nor Undesirable	Undesirable	Completely Undesirable
	5 points	4 points	3 points	2 points	1 point
Taste	Very desirable	Desirable	Neither Desirable nor Undesirable	Undesirable	Completely Undesirable
	5 points	4 points	3 points	2 points	1 point

A group of 52 tasters were selected using disproportional stratified random sampling. Four strata were used, the age strata were; 11-30 years and 31-50 years, while the sex strata were female and male. From each stratum, 13 individuals of good health were randomly selected. Organoleptic test was carried out through subjective evaluation of the developed recipes, where standardized tasting procedures were employed. All recipes tasted were at the same warm serving temperature avoiding the extremes; they were presented in containers of the same size, shape and colour (white) to avoid any bias and for clear visibility. Tasting was done 30 minutes after or before tasters had eaten anything in order to avoid flavour confusion. Each taster was provided with at least two to three bites of each recipe and drinking water for rinsing the mouth after tasting each recipe. Numbers and real names of the recipes were deleted and instead contours were used to identify samples; this was meant to avoid suggestions or grading in terms of numbers or usual preferences. Tasting was done in a separate room; far from the cooking room, well lit and ventilated for proper visibility and the environment was without distraction and this enabled the tasters to concentrate. Furthermore tasters were not allowed to see grading charts of others to avoid being influenced in their own grading. Results were analyzed statistically to obtain the mean scores and mean score differences.

3.5. Evaluation of Iron, Copper &Vitamin C Contents of Commonly Consumed AIVs

3.5.1. Sample Preparation for Elemental Analysis

After cooking, samples were cooled and immediately kept in the fridge at 4°C to prevent distortion of the cooking ingredients. Samples were oven-dried at 60°C for 12 hours then crushed into fine powder using a mill (QCG System LLC Model 4E). The powdered samples were sieved through 125 µm apertures BS 410. 0.5g of each sample was weighed and placed in a kjeldahl tube in 20mls of aqua regia acid (5ml HCl + 5ml Nitric acid) (Apha, 1985). The tubes were then heated to boiling for 2hrs at 96°c until the resulting solution was clear and the heating was continued for 30 more minutes. The digested samples were left to cool overnight and the contents were transferred into a 50ml volumetric flask and made up to the mark with distilled water. The samples were then filtered through a Whatman filter paper No.1 and finally transferred to 100ml polypropylene bottles, ready for elemental analysis.

3.5.2. Determination of Iron and Copper in Commonly Consumed AIVs

Elemental analysis was done in three states: on raw AIVs, after boiling, and after frying the AIVs all the material were taken for analysis as there was no liquid left behind after cooking. AAS was used to determine iron and copper contents of selected AIV samples, standards of each element

(1000 parts per million) were diluted with 10% HCl to cover the linear range of each element. Sample solutions were diluted with 10% HCl solution and the aspirated directly using a Narian AAS Model at Mines and Geology department, Ministry of Natural Resources, Nairobi. The spectrophotometer was operated under standard conditions using wavelengths specified for each element 248.3nm for iron and 324.2nm for copper. Each standard solution was fed into the AAS machine after placing the element light in place to generate light specific to that element. The machine then drew a standard curve of absorption against concentration. Each element and sample was analyzed independently where the sample filtrate was then fed into the machine and the machine gave the sample's (solution) absorption. The already drawn standard curve was used to obtain the sample's concentration by dropping a line to the x-axis (concentration) from the y-axis (absorption data). The concentration was then identified in ppm which is equivalent to mg. the known mg were equated to 0.5g the original sample weight, this was then multiplied by two to get the concentration in a gramm (Gerge, 1984).

3.5.3. Determination of Vitamin C Content in Selected AIVs

Nutrient analysis was done in three states: on raw AIVs, after boiling, and after frying the AIVs. Five grams of each sample was weighed and suspended in 60ml of 0.3M Sulphuric Acid. The suspended samples were left to stand for 30 minutes at room temperature and then filtered through Whatman filter paper number one. Five milimeters of the sample filtrate was taken and 2g of solid KI and 5ml of standard KIO_3 was added. This was done to generate a known excess of I_2 by the reaction of iodate with iodine with ascorbic acid; excess I_2 was then back titrated with thiosulphate. The Initial and final readings were recorded then subtracted to obtain the volume used. This was used to calculate Vitamin C quantity in the used solution; this was the actual quantity of Vit C in that particular sample (Gerge, 1984). Pure vitamin C crystal weighing 100mg (0.1g) was backtitrated and it consumed 14 mils, this was therefore used to calculate vitamin C content in the used mils. The initial and final readings were recorded and subtracted, the result was multiplied by

100mg per 5g and divided by 14 milimeters and this resulted in the actual quantity of vitamin C in mg/g.

3.6. Data Analysis

Data obtained were analyzed using ANOVA, descriptive and inferential statistics. Means were used to determine the acceptability of AIV recipes in terms of taste and appearance according to the already filled grading charts. Scores entered in the charts were computed into mean scores for various AIVs and various treatments. Data on the iron and copper content of selected AIVs were subjected to independent and paired sample t-test to determine whether the treatments' effects were significant at 5% level of significance.

CHAPTER FOUR: RESULTS AND DISCUSSIONS

4.1. The Developed African Indigenous Vegetable Recipes

Thirty AIV recipes were developed in the study; out of which twenty were vegetable recipes while ten were vegetable product recipes. The first objective of this study was to develop a variety of AIV recipes from selected African indigenous vegetables, this was because lack or variety in recipe formulation has in the past been an obstacle towards AIV consumption and marketability according to Abukutsa-Onyango *et al.*, (2006) and Shiundu and Oniang'o, (2007). Therefore availability of AIV recipes could pave way for increased AIV consumption, ensure availability throughout the year and improve marketability. The following are the various AIV developed in the study.

4.1.1. The Developed Vegetable Recipes

Table 4.1shows a summary of the twenty different original AIV recipes developed in the study.

Table 4.1 Summary of the Developed Vegetable Recipes

Recipe	**Quantity of Ingredients for Each Recipe**
1. Nightshade fried with lye 2. Nightshade fried without lye 3. Cowpea fried with lye 4. Cowpea fried without lye 5. Slenderleaf fried with lye 6. Slenderleaf fried without lye 7. Amaranth fried with lye 8. Amaranth fried without lye 9. Nightshade & Amaranth fried with lye 10. Nightshade & Amaranth fried without lye 11. Nightshade & Slenderleaf fried with lye 12. Nightshade & Slenderleaf fried without lye 13. Nightshade & Cowpea fried with lye 14. Nightshade & Cowpea fried without lye 15. Amaranth & Slenderleaf fried with lye 16. Amaranth & Slenderleaf fried without lye 17. Amaranth & Cowpea fried with lye 18. Amaranth & Cowpea fried without lye 19. Slenderleaf & Cowpea fried with lye 20. Slenderleaf & Cowpea fried without lye	• ½ kg AIVs for single vegetable recipes • ¼ kg AIVs for vegetable combination recipes • ¼ liter of water • 1 medium diced onion • 1 tbsp vegetable oil • 2 medium tomatoes • 2 tbsp table salt • 3 tbsp traditional salt (lye)

All the twenty vegetable recipes were prepared using the same methodology, illustrated bellow is the procedure used in all the twenty vegetable recipe preparation. Actual recipes are described in appendix I.

1. Wash vegetable leaves let them to drain for 2 minutes then shred.
2. Boil water; add in traditional salt (optional).
3. Add in the shredded vegetables.
4. Boil for 10 minutes over moderate heat (40°C) while tightly covered.
5. Remove from fire and put aside for immediate frying.
6. Put the vegetable oil in a pot (sufuria) over medium heat and add diced onions.
7. Fry onions till golden brown and add the chopped tomatoes.
8. Cook till soft while stirring then add the boiled vegetables and stir.
9. Add salt to taste and cover to simmer for a minute.
10. Remove from fire and serve.

4.1.2. The Developed Vegetable Product Recipes

Ten vegetable product recipes were developed that could help address the fluctuating supply of AIVs on the market though value adding processing as agreed by (Shiundu & Oniang'o, 2007 and Waudo *et al.*, 2007). Development and promotion of locally appropriate processing techniques could help minimize post harvest losses and ensure regular supplies of AIVs from the production areas to consumers in peri-urban and urban centers. Although drying has been an African way of processing leafy vegetables to make them available during periods of shortages, it does not satisfy the needs of a large population of consumers particularly urban dwellers (FAO/WHO, 2004). This study therefore sought to develop vegetable product recipes as listed bellow, which could also help in AIV marketability. Table 4.2, bellow shows a summary of all the ten vegetable product recipes developed during the study.

Table 4.2: **Summary of the Developed Vegetable Product Recipes**

Recipe	Quantity of Ingredients
1. Nightshade blanched with lye 2. Cowpea blanched with lye 3. Slenderleaf blanched with lye 4. Amaranth blanched with lye 5. Nightshade & Amaranth blanched with lye 6. Nightshade & Slenderleaf blanched with lye 7. Nightshade & Cowpea blanched with lye 8. Amaranth & Slenderleaf blanched with lye 9. Amaranth & Cowpea blanched with lye 10. Slenderleaf & Cowpea blanched with lye	• ½ kg AIVs for single vegetable recipes • ¼ kg AIVs for vegetable combination • ¼ liter water • 2 tbsp traditional salt (lye) • 2 tbsp table salt • ¼ kg simsim • ¼ kg brown sugar

All the ten vegetable product recipes were prepared using the same methodology, illustrated bellow is the procedure used in all the ten vegetable product recipe preparation. Actual recipes are described in Appendix II.

1. Wash vegetable leaves, shred and let them drain for 2 minutes.
2. Boil water with traditional salt.
3. Blanch the vegetables.
4. Leave to cool and freeze dry or dry the blanched vegetables under shade.
5. Melt sugar over fire on a pan.
6. Wash simsim seeds, drain, and fry them on a pan till golden brown.
7. While hot, mix the simsim with dried vegetables.
8. Add the mixture of simsim with vegetable into the melted sugar.
9. Mould the mixture into preferred shapes and leave them to cool.
10. Serve while cold or keep for later consumption.

4.2. Assessment of AIV Recipes Acceptability by Appearance and Taste

Determination of AIV recipe acceptability was the second objective of this study using sensory evaluation. Consumers that are dissatisfied with the internal quality of the product will be reluctant to buy that product again, they buy because of good appearance but they will only return to buy again if the product tastes good too. This was the main reason for acceptability assessment of the developed AIV recipes.

4.2.1. Assessment of AIV Recipes Acceptability by Appearance

Appearance of all recipes cooked with traditional salt was significantly preferred compared to those cooked without traditional salt (Fig. 4.1). This means that, besides being a preservative and helping in reducing animal fat from food (Waudo, *et al.,* 2007), lye also improves the appearance of AIVs after cooking. Although bicarbonate of soda can be used for the same purpose, it is feared due to its tendency to destroy vitamins and its effect on bones (Waudo, *et al.,* 2007). A recipe of Slenderleaf cooked with traditional salt had a mean of 4.4 and was the most accepted in terms of appearance while the recipe of a combination of Nightshade and Amaranth cooked without traditional salt had a mean of 1.8 and was the least accepted in terms of appearance (Figure 4.1). Whether the vegetables were prepared singly or as combinations did not have an influence on vegetable appearance acceptability. Generally recipes prepared with lye recorded higher means for appearance acceptability (4.133 ± 0.208) compared to those prepared without lye (2.056 ± 0.199). Independent sample t-test indicated that appearance acceptability of recipes prepared with lye was significant ($P<0.0001$) compared to appearance of those prepared without lye, this therefore indicates that lye improves the appearance of AIVs.

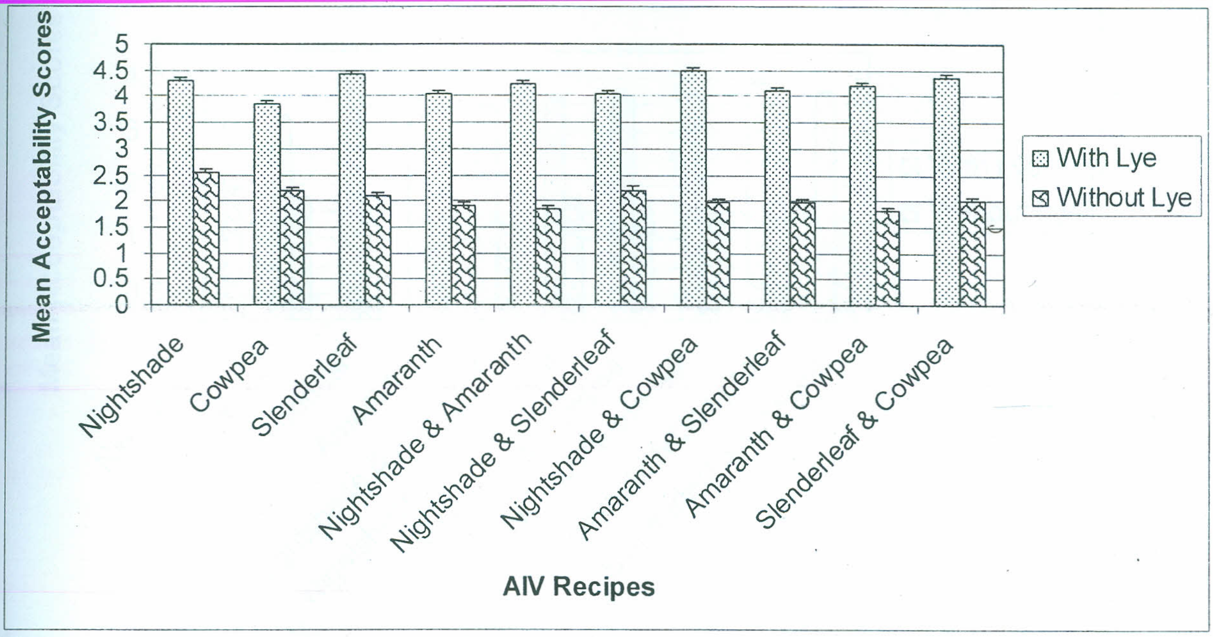

Fig. 4.1. Mean Appearance Scores for AIV Recipe Acceptability

4.2.2. Assessment of AIV Recipe Acceptability by Taste

Recipe's taste acceptability was similar to that of appearance acceptability where, all recipes cooked with lye had their taste significantly accepted (Figure 4.2). Means indicated that the recipe made out of a combination of Nightshade and Cowpea cooked with traditional salt had a mean of 4.5 and was the most accepted in terms of taste while the recipe of a combination of Amaranth and Cowpea cooked without traditional salt had a mean of 1.8 and was the least accepted in terms of taste. Just like appearance acceptability, taste acceptability was not influenced by whether the AIVs were prepared as single vegetables or as vegetable combinations (Figure 4.2). Recipes prepared with lye recorded higher means for taste acceptability (4.206 $\pm$ 0.193) compared to the taste of those recipes prepared without traditional salt (2.052 $\pm$ 0.218). Independent sample t-test was applied and results indicated that the taste acceptability of recipes prepared with lye were highly significant ($P<0.0001$) compared to the acceptability of those prepared without lye, therefore lye improves test of AIVs.

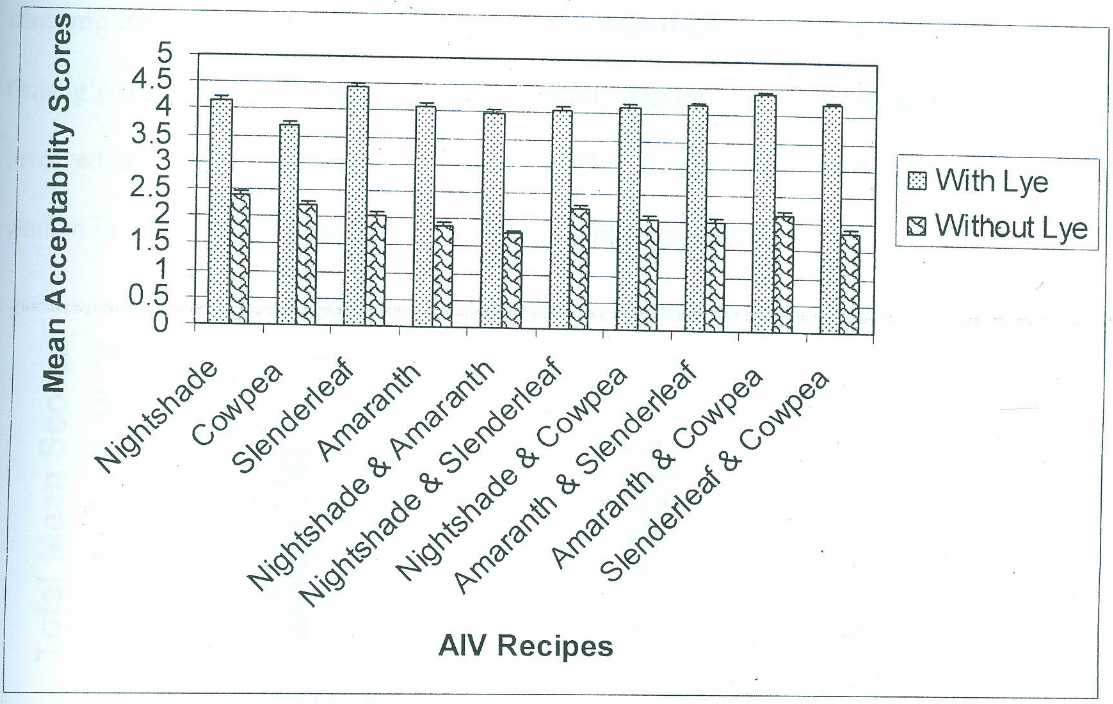

Fig.4.2. Mean Taste Scores for AIV Recipe Acceptability

Increase in AIV acceptability could translate into increase in AIV consumption therefore help in bringing back the neglected crop on the menu, which is important as agreed by Padma, (2005) because according to Okeno & Mathenge (2003); Orech *et, al* (2005); and a report by Community Technology Development Trust, (2000), a significant number of AIVs are not consumed particularly by the younger generation of Africans because of their unfamiliar tastes or ignorance on how to prepare them.

Figure 4.3, compares recipe acceptability between male and female tasters, which indicates that sex did not have influence on AIV recipe acceptability both in terms of appearance and taste. There was no significant difference on AIV récipe acceptability between male and female for both taste and appearance. These findings differs with those of Waudo *et, al* (2007), which indicated a significant difference (P<0.05) between men and women with regard to perceptions on consumption of indigenous vegetables; the findings revealed that men had less preference for vegetable consumption compared to women. However, according to Rubaihayo (2002), and Shiundu & Oniang'o (2007), AIVs have assumed a more commercial outlook and men increasingly get involved in AIV production and marketing. This therefore shows the interest of both men and women in AIVs, which could go hand in hand with acceptability.

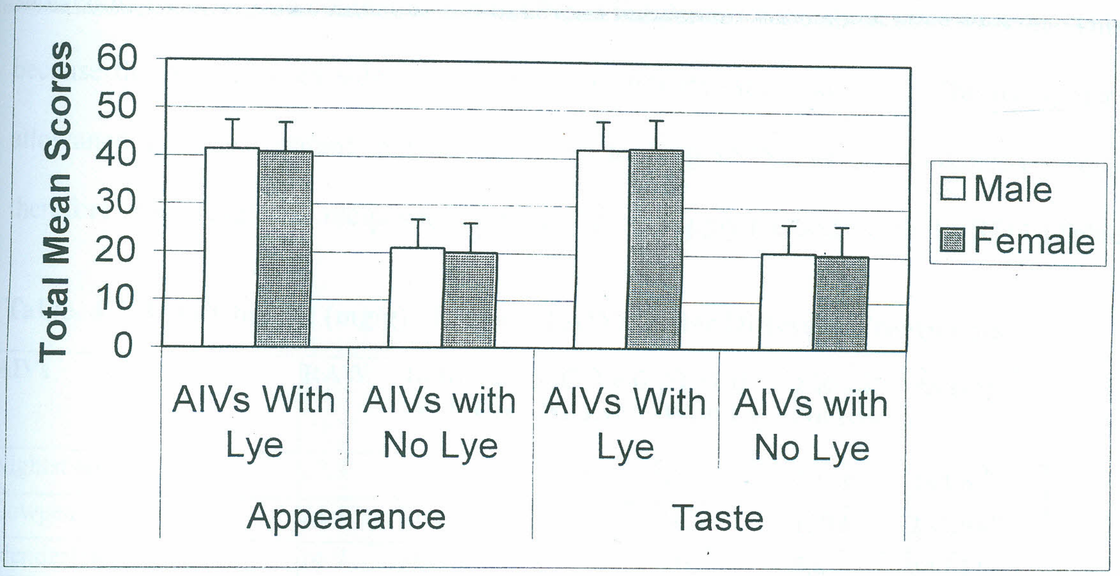

Fig. 4.3. Comparison of AIV Acceptability by Male and Female Tasters

4.3. Nutrient Levels of Iron, Copper and Vitamin C Content of Commonly Consumed AIVs

Objective three of this study was to determine iron, copper and vitamin C contents of the raw and cooked AIVs. According to Padma, (2005) it is not enough just to develop recipes, but their nutrient content is important in the effort of improving nutrition security. AIVs have long been and continue to significantly contribute to the dietary vitamin and mineral intakes of local populations (FAO/WHO, 2004). This is evident from the experimental results of this study, which indicate that AIVs are rich in iron, copper and vitamin C, and if well cooked nutrient loss could be minimized as indicated in the study results herein.

4.3.1. Iron Content of Commonly Consumed African Indigenous Vegetables

Table 4.1, indicates iron content of selected AIVs and AIV combinations, from the table, it was observed that cooking released more extractable iron in AIVs. These results concur with the experimental findings of Imungi and Poter, 1983 as cited by Abukutsa-Onyango, 2003 which showed increase in iron content of some African indigenous vegetables after cooking. This could be because the heat exposes solubility of iron thus aids its bioavailability. The recommended daily allowance for iron content is between 10mg to 8mg (NIN, 1992; Abukutsa-Onyango, 2003); therefore most developed recipes from this study can supply the body with the RDA (Table 4.3).

Table. 4.3. Iron Content (mg/g) of Selected AIVs under Different Treatments

AIVs	RAW	BOILED With Lye	BOILED No Lye	FRIED With Lye	FRIED No Lye	Average
Nightshade	17.3	12.4	11.5	281.2	401.6	**144.8^{ab}**
Cowpea	24.1	20.6	15.3	16.7	1208	**256.94^{ab}**
Slenderleaf	14.7	10.7	6.4	110	5.8	**29.52^{b}**
Amaranth	19.4	95.2	12.4	108	5.3	**48.06^{b}**
Nightshade&Amaranth	20.5	11.5	11.5	9.1	42.3	**18.98^{b}**
Nightshade&Slenderleaf	13.2	12.2	13.9	5.1	8.2	**10.52^{b}**
Nightshade & Cowpea	23.3	69.2	200.4	381.4	6.6	**136.18^{ab}**
Amaranth & Slenderleaf	12.5	23.6	557.5	859.2	859.2	**469.6^{a}**
Amaranth & Cowpea	20.1	69.2	16.6	7.2	303	**83.22^{b}**
Slenderleaf & Cowpea	14.7	26.9	9.1	10.1	8.1	**13.78^{b}**
Average	**17.98**	**35.15**	**85.46**	**178.8**	**284.81**	120.44
Significance Level						**0.05**
LSD						**348.28**
Interaction	**Cooking Method*Lye**					**ns**
	Cooking Method*AIV					**ns**

NB. Traditional Salt (Lye) = **7.2mg/g**

There were no significant interactions between cooking method with AIVs (Table 4.3); however a combination of amaranth and slenderleaf had significantly higher iron solubility. Apart from nightshade with amaranth, nightshade with slenderleaf and amaranth with cowpea, all other AIVs had their iron solubility enhanced after frying (Table 4.3) and this could be due to availability of vitamin A in the cooking oil which increase iron solubility. A study carried out by Weinberger and Msuya, 2004 indicated that raw amaranth and nightshade contain iron content of 37.05mg/g and 8.90mg/g respectively; this slightly varies with the results of this study, which indicate iron contents of 19.4mg/g and 17.3mg/g respectively. The possible explanation for the slight differences in iron contents could be due to the differences in type of vegetable and place (plots) where they were obtained (Weinberger and Msuya, 2004). Whether the vegetables were cooked as single vegetables or as a combination of two vegetables did not have an effect on their iron solubility (Table 4.3), some vegetables had higher iron content as single vegetables while others had higher content when combined with others. For example, a combination of amaranth and slenderleaf boiled without lye, fried with lye and fried without lye had the highest extractable iron of 557mg/g, 859.2mg/g, and 859.2mg/g respectively compared to amaranth alone and slenderleaf alone (Table 4.3). Therefore combining vegetables during preparation have different effects on different vegetables in terms of their iron solubility and this could be attributed to different nutrient-nutrient interactions between different vegetables (Figure 4.4).

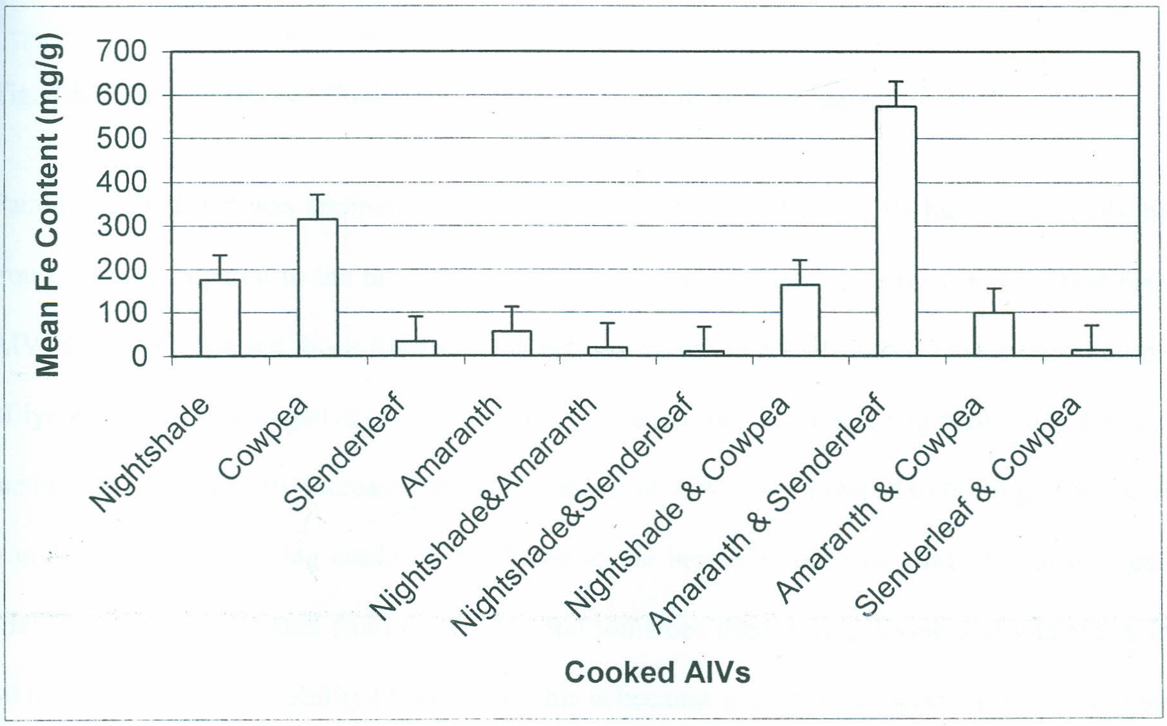

Fig. 4.4. Mean Iron Content (mg/g) in different Cooked AIVs and AIV combinations

Raw African indigenous vegetables had the least mean iron content compared to the boiled and the fried AIVs. Recipes prepared without traditional salt, recorded higher mean iron content for fried (without lye 284.8 $\pm$ 427, with traditional salt 272.7 $\pm$ 382.6) compared to mean iron content for boiled (without traditional salt 85 $\pm$ 176, with traditional salt 30.7 $\pm$ 28.4). Fried AIVs had higher mean iron content compared to the boiled (Figure 4.5), frying therefore increased iron content of African indigenous vegetables recipes (Figure 4.5).

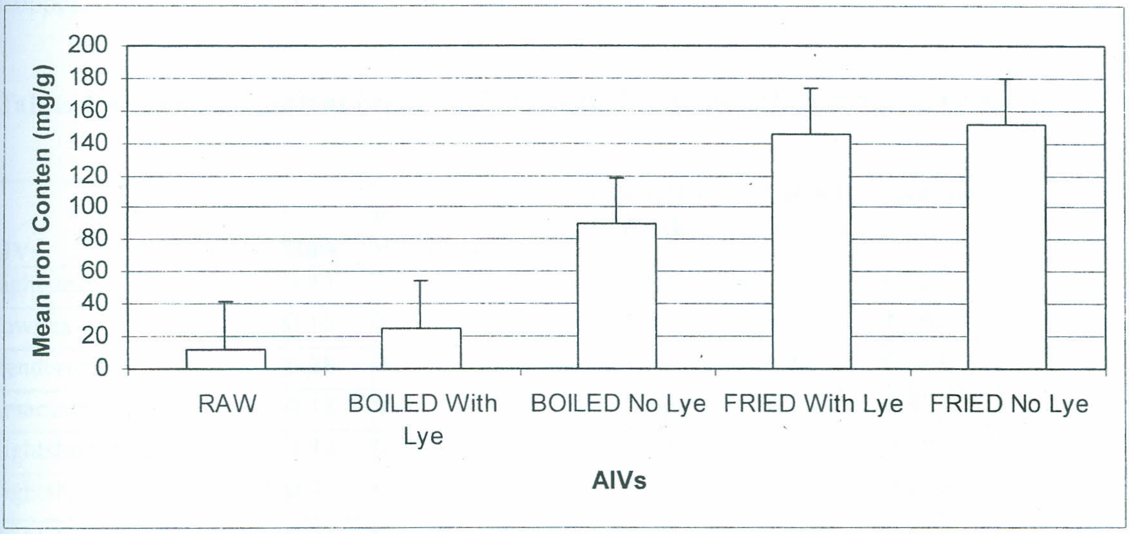

Fig. 4.5. General Effect of Cooking and Cooking method on Iron Content of AIVs

Paired sample t-test was applied and the results indicated that fried AIVs had significantly higher iron content compared to the boiled AIVs ($P<0.05$). The difference in mean iron content between AIVs fried with lye and those fried without lye was insignificant ($P>0.05$). This means that the use of lye had very little negative impact on the iron content of the cooked vegetables but the cooking method of frying greatly increased the iron content of AIVs as compared to boiling. The increased iron solubility after frying could be attributed to the increased cooking time, and also more iron could have been generated from the onions and tomatoes used during frying and vitamin A in the oil that increase iron solubility (Table 4.3). This is because according to Sehmi, (1993); both onions and tomatoes contain iron of 1.48mg/100g and 1.997mg/100g respectively.

4.3.2. Copper Content of Commonly Consumed African Indigenous Vegetables

Copper is among other nutrients that work together with iron in the body therefore the need for copper content analysis. Copper is required for haemoglobin formation; it influences iron absorption and metabolization from the liver and other tissues and for its utilization. Nevertheless copper deficiency may result into anaemia, which is the same case as iron deficiency. Two thirds of the body iron is present as haemoglobin and it is the same haemoglobin that copper helps in the formation (NIN, 1992), it also helps oxidize vitamin C and works with vitamin C to form elastin. Copper, iron and vitamin C therefore work together.

Table. 4.4. Copper Content (mg/g) of Selected AIVs under Different Treatments

AIVs	Raw	Boiled With Lye	BOILED No Lye	FRIED With Lye	FRIED No Lye	Average
Nightshade	0.44	0.52	0.34	0.98	**1.52**	**0.76^{ab}**
Cowpea	0.16	0.16	0.6	0.1	**6.32**	**1.468^{ab}**
Slenderleaf	0.28	0.32	0.12	0.42	0.1	**0.248^{b}**
Amaranth	0.18	0.46	0.18	**3.48**	0.06	**0.872^{ab}**
Nightshade&Amaranth	0.42	0.24	0.4	0.74	0.18	**0.396^{b}**
Nightshade&Slenderleaf	0.3	0.2	0.34	0.08	0.36	**0.256^{b}**
Nightshade & Cowpea	0.26	0.46	1.36	1.18	0.08	**0.668^{ab}**
Amaranth & Slenderleaf	0.34	0.36	1.66	**4.56**	**4.56**	**2.296^{a}**
Amaranth & Cowpea	0.16	0.46	0.2	0.7	0.6	**0.424^{b}**
Slenderleaf & Cowpea	0.28	0.28	0.18	0.14	0.1	**0.196^{b}**
Average	**0.282**	**0.346**	**0.538**	**1.238**	**1.388**	
Significance Level						**0.05**
LSD						**1.68**
Interaction	**Cooking Method*Lye**					**ns**
	Cooking Method*AIV					**ns**

NB. Traditional Salt (Lye) = **1.6mg/g**

Study results indicated no significant interactions between cooking method and AIV, a combination of amaranth and slenderleaf recorded significantly higher copper solubility (Table 4.4). Cooking increased copper content of African indigenous vegetables but whether the vegetables are cooked as single vegetables or as a combination of two vegetables, did not have an effect on their copper content, some vegetables recorded higher copper content as single vegetables while others recorded higher copper content when they are combined with others. For example, a combination of amaranth and slenderleaf boiled without lye, fried with lye and fried without lye had the highest copper contents of 1.66mg/g, 4.56mg/g, and 4.56mg/g respectively compared to amaranth alone (3.48mg/g) and slenderleaf alone (0.42mg/g) (Table 4.4 and Figure 4.6). Therefore combining vegetables during preparation have different effects on different vegetables in terms of their copper content and this could be attributed to different nutrient-nutrient interactions between different vegetables (Figure 4.6).

The recommended daily allowance (RDA) for copper is 2-3mg (FAO, 2003). However results in Table 4.4, indicate that all other fried recipes can only supply the RDA if more than a gram is consumed, apart from nightshade fried without lye (1.52mg/g), cowpea fried without lye (6.23mg/g), amaranth fried with lye (3.48mg/g), and amaranth with slenderleaf fried with and without lye (4.56mg/g each) which can supply the RDA when only one gram is consumed.

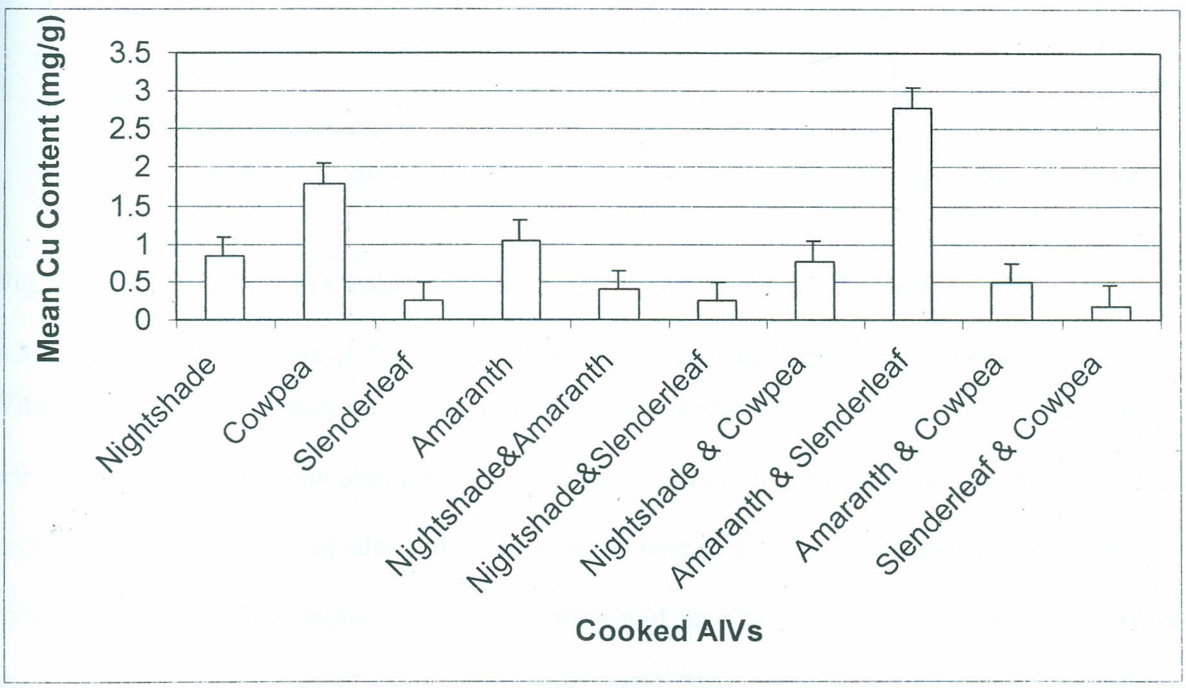

Fig.4.6. Mean Copper Content (mg/g) in different Cooked AIVs and AIV combinations

Recipes prepared without traditional salt had higher mean copper content for fried compared to boiled ones, which means that frying increased copper content of AIVs. Paired sample t-test was applied and results indicated that fried AIVs had significantly higher mean copper content compared to boiled ones ($P<0.05$). However, there were insignificant differences in the mean copper content between recipes fried with traditional salt and those fried without traditional salt ($P>0.05$). Therefore the use of traditional salt had insignificant negative effect on copper content of vegetables (Figure 4.7). Raw African indigenous vegetables had the least copper content compared to the boiled and the fried AIVs; however, fried AIVs had higher copper content compared to the boiled ones.

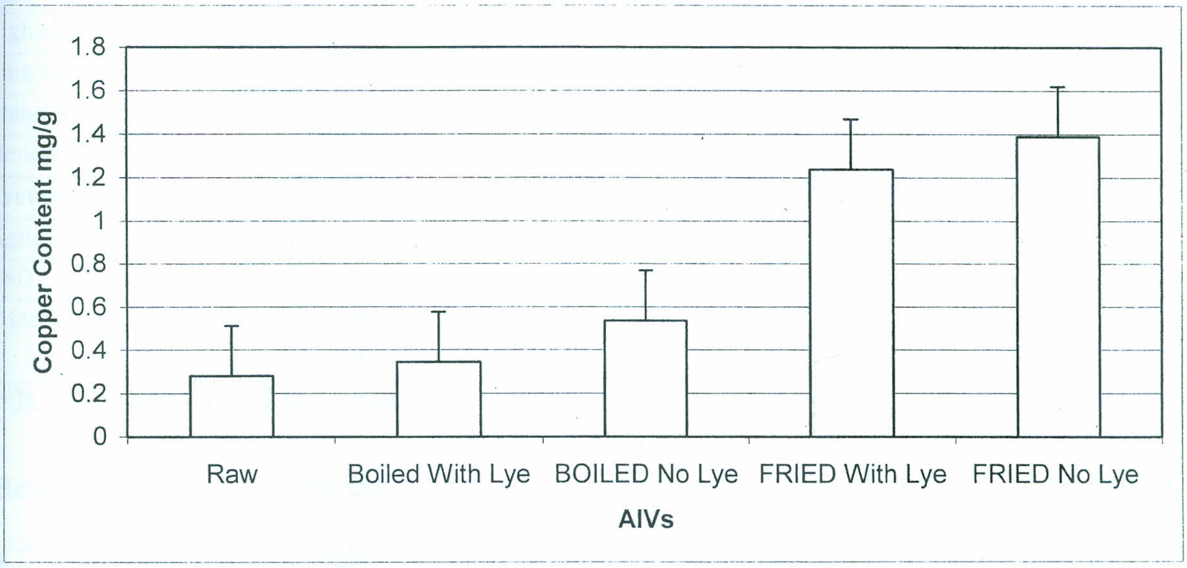

Fig. 4.7. General Effect of Cooking and cooking method on Copper Content of AIVs

4.3.3. Vitamin C Content of Commonly Consumed African Indigenous Vegetables

Vitamin C is known to play an important role in the absorption of dietary iron; it is the most potent enhancer of non-haem iron absorption even in the presence of inhibitors such as phytates, tannates and calcium. Vitamin C can also reduce food ferric iron to the better-absorbed ferrous iron by 75% to 98% (FAO, 2003). In Indian studies, the addition of ascorbic acid to cereals and pulses enhanced the available iron (NIN, 1992 as cited by FAO, 2003). This therefore led to the analysis of vitamin

C content of AIVs. The raw, boiled and fried vegetables were determined for Vitamin C content using the vitamin C screening method as described in the methodology above and expressed in mg/g. Table 4.5, show the effect of different cooking methods and the use of lye on Vitamin C content of AIVs.

Table. 4.5. Vitamin C Content (mg/g) of Selected AIVs under Different Treatments

AIVs	Raw	Boiled With Lye	BOILED No Lye	FRIED With Lye	FRIED No Lye	Average All
Nightshade	5.7	5.7	6	6.1	6.9	**6.08[a]**
Cowpea	5.7	4.3	3.6	5.7	7.1	**5.28[a]**
Slenderleaf	6.4	5.7	6.4	5	6.2	**5.94[a]**
Amaranth	6	5.7	6.4	5.7	5	**5.76[a]**
Nightshade & amaranth	6	5	5.7	5	6.4	**5.62[a]**
Nightshade&Slenderleaf	3.6	6.4	6.8	7.9	5.7	**6.08[a]**
Nightshade &Cowpea	6.7	6	5.7	5.7	5.7	**5.96[a]**
Amaranth & Slenderleaf	5.7	5.7	7.1	5.7	5.7	**5.98[a]**
Amaranth & Cowpea	5.7	5	5.6	6.4	6.3	**5.8[a]**
Slenderleaf & Cowpea	5.3	5	4.3	6.4	5.7	**5.34[a]**
Average	**5.68**	**5.45**	**5.76**	**5.96**	**6.07**	
Significance Level						**0.05**
LSD						**0.96**
Interaction	**Cooking Method*Lye**					**ns**
	Cooking Method*AIV					**ns**

NB. Traditional Salt (Lye) = **0mg/g**

Results in table 4.5 indicate that there were no significant interactions between cooking method and AIVs, there were also no significant differences between all the AIVs. A combination of nightshade and slenderleaf fried with traditional salt had the highest Vitamin C content (7.9mg/g), which was higher than its quantity in the single vegetables of nightshade (5.7mg/g - 6.9mg/g) and slenderleaf (5mg/g – 6.4mg/g) whether raw or cooked. A combination of raw nightshade and slenderleaf had the least quantity of Vitamin C content (3.6mg/g); it remained the least even compared to nightshade alone (5.7mg/g – 6.9mg/g) and slenderleaf alone (5mg/g – 6.4mg/g) whether raw or cooked (Table 4.5). Nutrient-nutrient interaction might have occurred between raw nightshade and slenderleaf, which resulted, to reduction in vitamin C content of this combination. Apart from nightshade, nightshade with slenderleaf, and amaranth with slenderleaf; boiling with traditional salt reduced vitamin C content of other AIVs. Combining vegetables during preparation had different effects on different vegetables in terms of their vitamin C content and this could be attributed to different nutrient-nutrient interactions between different vegetables; some AIVs had higher content as combinations than as single vegetables and vice versa (Figure 4.8).

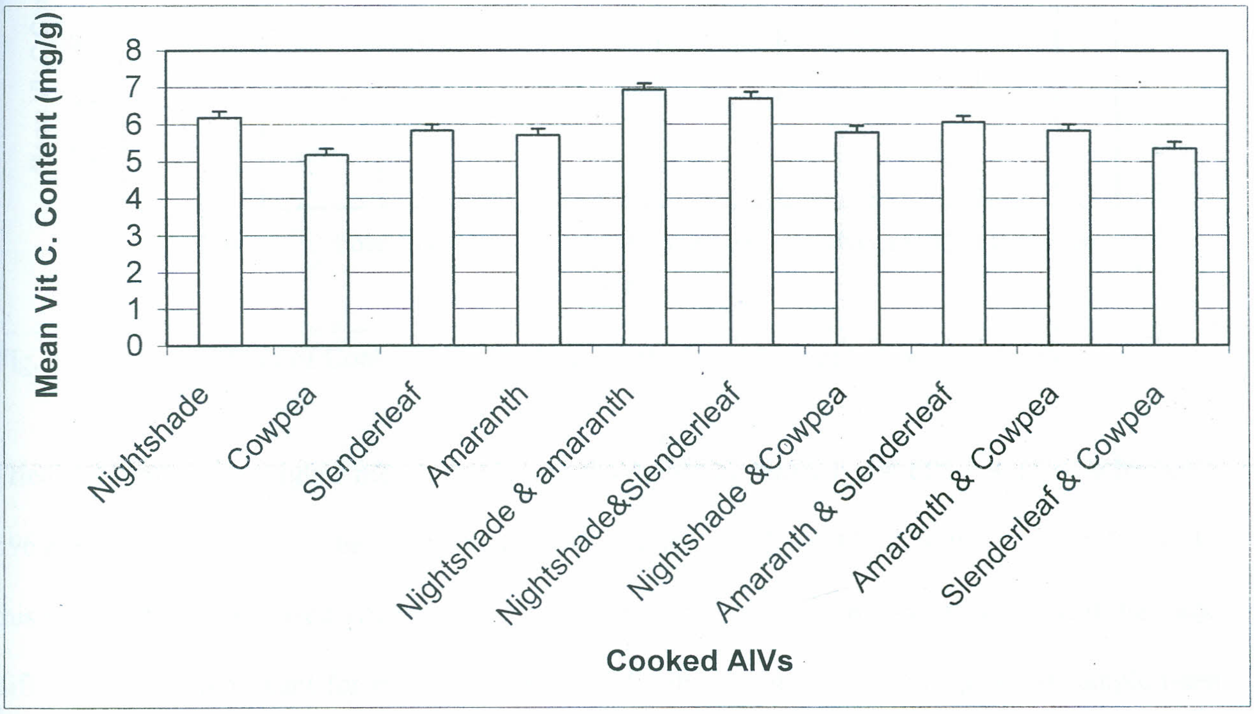

Fig. 4.8. Mean Vitamin C Content (mg/g) in different Cooked AIVs and AIV combinations

Generally fried AIVs had higher vitamin C content compared to the raw and boiled ones. Figure 4.9 clearly shows the general effect of cooking and use of lye on vitamin C content of AIVs. Results indicate that the use of lye slightly reduced vitamin C content of AIVs compared to the raw ones. The reductions in vitamin C content after boiling were minimal and this is due to the less boiling time of only 10 minutes, moderate cooking temperature and putting of vegetables in already boiling water rather than boiling water together with the vegetables. Although the use of traditional salt is seen to reduce vitamin C content of vegetables, frying on the other hand increased vitamin C content of the same vegetables (Figure 4.9).

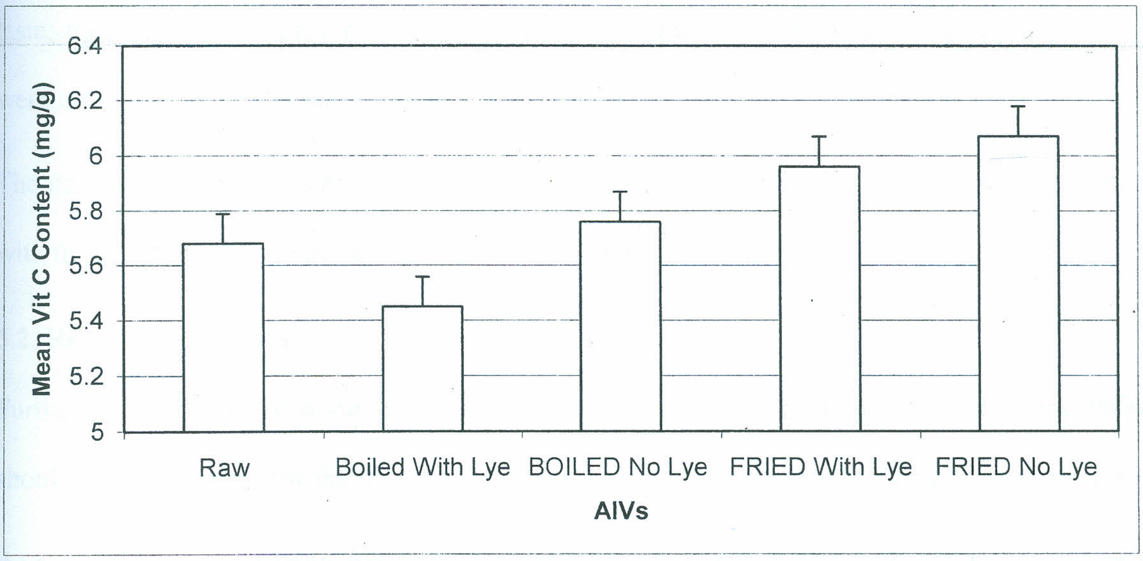

Fig. 4.9. General Effect of Cooking and Cooking method on Vitamin C Content of AIVs

Fried AIVs recorded higher mean for vitamin C content (without lye = 608.1 $\pm$ 63.6, with lye = 596.8 $\pm$ 82.4) compared to the boiled recipes (without lye = 577.1 $\pm$ 110.8, with lye = 545.7 $\pm$ 62.4), this means frying increased vitamin C content of recipes. However, in order to find out if the mean difference was significant for both fried and boiled with or without lye, independent sample t-test was applied and the results indicated insignificant mean difference between boiled and fried AIVs ($P>0.05$). This means that although there was some increase in Vitamin C content of the fried AIVs, these increases were very minimal. The minimal increase in vitamin C content of fried AIVs could be attributed to the use of onions and tomatoes, which contain (11mg/100g and 10 mg/100g) of vitamin C respectively (Sehmi, 1993); and the minimum cooking time and temperature. According to Gahler *et, al.*, (2003), the best way of deriving benefits of vitamin C is eating fresh vegetables or with a minimum of cooking. This is true in relation to the study results which indicate minimum loss of Vitamin C content of AIVs after ten minutes of cooking under low temperature.

5.1. Conclusions

Thirty AIV recipes were developed out of which twenty were vegetable recipes while ten were vegetable product recipes. It is therefore possible to have more varied recipes from AIVs.

Recipes prepared with lye were significantly accepted by all testers both in terms of appearance and taste; through in this study nutrient content of lye, onions and tomatoes was not analyzed. There were no significant differences in recipes acceptability by gender for all the vegetables.

The developed recipes were high in iron, copper and vitamin C adequate to supply the consumers with the recommended daily allowances especially for iron.

5.2. Recommendations

Further development of a variety of AIV recipes by industries, companies, hotels and individuals should be encouraged for the consumer to have a variety to choose from during on and off season.

Lye should be used during AIV recipe preparation in order to ensure AIV recipe acceptability that could lead to increased consumption.

The cooking method of frying should be used during AIV preparation in order to increase acceptability and help minimize nutrient loss during AIV preperation.

5.3. Suggestions for Further Studies

More varieties of AIV recipes should be developed form other AIVs to ensure variety in diets using varied methods of preparation.

Other vital vitamins and minerals should be analyzed as well to provide more information on the nutrient content of AIV recipes, which is paramount to improving community's nutrition status. However iron and copper bioavailability in the developed recipes should be determined if improving the nutrition status of the community is to be realized.

More and varied preservation and processing research should be carried out to increase AIVs' shelf life, which has proved workable through this study. Their shelf life should also be determined.

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