NUTRIENT RETENTION AND SENSORY ACCEPTABILITY OF SOLAR-DRIED AFRICAN LEAFY VEGETABLES AMONG WOMEN OF REPRODUCTIVE AGE, KIAMBU COUNTY, KENYA

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REG NO. H60/CTY/PT/29784/2014

A RESEARCH THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF SCIENCE IN FOOD, NUTRITION AND DIETETICS IN THE SCHOOL OF PUBLIC HEALTH AND APPLIED HUMAN SCIENCES, KENYATTA UNIVERSITY

OCTOBER, 2020
DECLARATION

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

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DEDICATION

This work is dedicated to my wife Margret Njoki, my daughters Faithmary Gladys, Susan as well as my late father Samuel, and my mother Mary for their love and support.
ACKNOWLEDGEMENT

My appreciation goes to Department of Food Nutrition and Dietetics and Kenyatta University for providing enabling environment; study space, materials and equipped laboratories. More appreciation goes to Prof Judith Kimiywe and Dr Ann Munyaka and all staff of Department of Food Nutrition and Dietetics of Kenyatta University for providing guidance during the study and for the inspiration that enabled me to continue with my academic studies; Ann Mwangi and Josephine Ontita for their assistance during sample preparation for sensory evaluation and Mariam Gathee for assisting in sorting and cleaning vegetable samples. Hellen Nyaguthii and Rose Muniu for their continuous assistance in office protocols.

Gratitude goes to my employer Kenyatta University for granting me permission to embark on this study and Jomo Kenyatta University of Science and Technology for providing me with their solar dryer.

Very special gratitude goes to my entire family starting with my wife Margret Njoki, my daughters Faithmary, Gladys and Susan, my mother Mary Wanjiru wa Gachoya and my brothers Reuben and Johnson as well as my sisters Susan, Ann, Peninah, Virginia and Hellen for their undying support all through my study.
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OPERATIONAL DEFINATION OF TERMS

Acceptability: The quality of being tolerated or allowed

Africa Leafy Vegetable: Leafy vegetables that have their natural habitat in Africa

Blanching: Cooking process of immersing fresh vegetables in boiling water for a specified time and finally plunging in ice or cold running water to halt the cooking process.

Cooking: The process of preparing food by combining, mixing and heating ingredients

L- Ascorbic Acid: Term used to refer to vitamin C content in vegetables

Micro Nutrient: Nutrients needed in small amounts in the body but are essential for the overall health of an individual

Nutrient Retention: The action of absorbing and continuing to hold

Selected ALVs: Refers to Pumpkin Leaves, Fig-gourd Leaves and Stinging nettle leaves

Sensory: The physical senses; transmitted or perceived by the senses

Women of Reproductive Age: Women aged between 15 years and 49 years
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>AA</td>
<td>Ascorbic Acid</td>
</tr>
<tr>
<td>Abs</td>
<td>Absorbance</td>
</tr>
<tr>
<td>AOAC</td>
<td>Association of Official Analytical Chemists</td>
</tr>
<tr>
<td>ALVS</td>
<td>Africa Leafy Vegetables</td>
</tr>
<tr>
<td>ANOVA</td>
<td>Analysis of Variance</td>
</tr>
<tr>
<td>BHT</td>
<td>Butylated Hydroxytoluene</td>
</tr>
<tr>
<td>DHAA</td>
<td>Dehydroascorbic Acid</td>
</tr>
<tr>
<td>EDTA</td>
<td>Ethylene Diamine Tetra Acetic Acid</td>
</tr>
<tr>
<td>DW</td>
<td>Dry Weight</td>
</tr>
<tr>
<td>FAAS</td>
<td>Flame Atomic Absorption Spectrophotometer</td>
</tr>
<tr>
<td>FW</td>
<td>Flesh Weight</td>
</tr>
<tr>
<td>GL</td>
<td>Guard Leaves</td>
</tr>
<tr>
<td>KFCT</td>
<td>Kenya Food Composition Table</td>
</tr>
<tr>
<td>LOD</td>
<td>Limit of Detection</td>
</tr>
<tr>
<td>RP-HPLC</td>
<td>Reversed phase Higher Pressure Liquid Chromatography</td>
</tr>
<tr>
<td>RDA</td>
<td>Recommended Daily Allowance</td>
</tr>
<tr>
<td>RSD</td>
<td>Relative Standard Deviation</td>
</tr>
<tr>
<td>MDG</td>
<td>Millennium Development Goals</td>
</tr>
<tr>
<td>MOH</td>
<td>Ministry of Health</td>
</tr>
<tr>
<td>MPA</td>
<td>Metaphosphoric acid</td>
</tr>
<tr>
<td>NGO</td>
<td>Non – Governmental Organization</td>
</tr>
<tr>
<td>NaH$_2$PO$_4$</td>
<td>Sodium Dihydrogen Phosphate</td>
</tr>
<tr>
<td>PL</td>
<td>Pumpkin Leaves</td>
</tr>
<tr>
<td>STL</td>
<td>Stinging Nettle Leaves</td>
</tr>
<tr>
<td>Acronym</td>
<td>Description</td>
</tr>
<tr>
<td>---------</td>
<td>----------------------------------</td>
</tr>
<tr>
<td>SPSS</td>
<td>Statistical Package for Social Science</td>
</tr>
<tr>
<td>TCEP</td>
<td>Tris (2 – Carboxy – Ethyl) Phosphine</td>
</tr>
<tr>
<td>UNICEF</td>
<td>United Nation Children Education</td>
</tr>
<tr>
<td>UV</td>
<td>Ultra Violet</td>
</tr>
<tr>
<td>USDA</td>
<td>United States Department of Agriculture</td>
</tr>
<tr>
<td>VAD</td>
<td>Vitamin A Deficiency</td>
</tr>
</tbody>
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ABSTRACT

Micronutrient deficiencies pose major health challenges in many African countries with certain population groups such as women of reproductive age being at a greater risk. African leafy vegetables form part of local agricultural biodiversity and have been part of the daily livelihoods of the local populations for many years. These vegetables hold promise in addressing micronutrient deficiencies if their supply and consumption are scaled up through the right application of appropriate postharvest technologies. The study adopted an experimental design to determine the retention of iron, zinc, β-carotene and vitamin C as well as sensory acceptability in three African Leafy vegetables; i.e. pumpkin leaves (Curcubita maxima), Fig-leaf gourd (Cucurbita ficifolius), and stinging nettle (Urtica dioica) subjected to various processing treatments including solar drying, blanching and cooking. About 10kg of fresh vegetables randomly sampled were purchased from Kiambu market, transported using cool box at 15°C to Kenyatta University, appropriately packed and stored at 5°C for processing and analysis. Solar drying was carried out using a locally fabricated solar dryer, blanching was done at high temperature (80-100°C) for 5 minutes and cooking was done using ohms model electrical cooker with four plates set at medium temperature 165°C for 15-20 minutes. Iron and zinc were quantified using Atomic Absorption Spectrophotometer while β-Carotene and Vitamin C were quantified using Reverse Phase High Pressure Liquid Chromatography. All determinations were carried out in triplicate and mean values computed. Sensory evaluation was determined using the 9-point hedonic scale questionnaire administered to a sample of 30 women of reproductive age purposively selected from Kiambu County. Pumpkin leaves had the highest iron content amounting to 29.33 ± 0.474 mg/100g dw followed by Fig-leaf gourd at 25.38 ± 0.06 mg/100g dw. Fig-leaf gourd had the highest content of zinc at 5.51 ± 0.08mg/100g dw followed by pumpkin leaves at 3.307 ± 0.055mg/100g dw. Stinging nettle leaves had the highest pro-vitamin A (β-carotene) content of 34.69± 0.14 mg/100g dw followed by pumpkin leaves. Vitamin C concentration was highest in stinging nettle leaves 228.60±1.81mg/100g dw followed by Fig-leaf gourd 122.59 ± 0.09 mg/100g dw while pumpkin leaves had the lowest content 118.73 ± 0.15mg/100g dw of the vitamin. Both blanching and cooking had significant effect on the content of both minerals and vitamins in the leafy vegetables. Solar drying caused significant reductions (p ≤ 0.05) in the levels of vitamins in the vegetables, but it did not significantly change their mineral contents. Solar drying had the best retention of iron, zinc, and vitamin C. Vitamin A was well retained during heat treatments but was sensitive to solar drying. Vitamin C suffered the heaviest losses in all processing treatments. Highest retention of nutrients was achieved in Fig-leaf gourd compared to pumpkin leaves and stinging nettle leaves. Pumpkin leaves were given the best sensory rating among cooked fresh vegetables, while stinging nettle leaves was the most acceptable among solar-dried cooked vegetables. Cooked fresh vegetables were more acceptable than the cooked solar-dried ones except for stinging nettle leaves where the reverse was true. The study reveals that pumpkin leaves, Fig-leaf gourd and stinging nettle leaves are important sources of key nutrients after solar drying, blanching and cooking with a good retention of this nutrients. The study therefore recommends popularization of the solar dried ALVs as key sources of micronutrients.
CHAPTER ONE: INTRODUCTION

1.1 Background of the Study

Micronutrient deficiencies among women of reproductive age remain a major health related challenge to reckon with in many Sub-Saharan Africa countries (Andersen, Thilsted, Nielsen, and Rangasamy 2003; Kamga, Kouamé, Atangana, Chagomoka, & Ndango 2013). Adequate nutrition before the reproductive years, proper adolescent growth, sufficient nutrient stores and specific interventions of folic acid and multivitamins supplements during pregnancy, nutrition education and healthy diet programmes have been emphasized during the different stages of women of reproductive age that is during infancy, adult life, preconception period, pregnancy and during the lactating stage (Islam, 2010).

Adequate micronutrient status of women of reproductive age is critical since it is required during adolescence, pregnancy and in lactation. Micronutrient intake by women of reproductive should be maintained to prevent depletion of body nutrient reserves during stages of vulnerability of pregnancy and lactation (Darnton-Hill & Mkparu, 2015). Micronutrient deficiencies amongst women of reproductive ages can cause major consequences such as reduction in breast milk nutrient concentrations Kamga et al. While many government and non-government agencies are emphasizing on the nutritional status of women of reproductive age (pregnant and non-pregnant) very little is being done to ensure that lactating women achieve optimal nutrition status (World Health Organization & UNICEF 2003).

The consumption of African Leafy vegetables (ALVs) that are accessible to the low-income communities offers opportunity for improving micronutrient status and food
security of many poor families whose health and nutrition are at risk (Raneri et al., 2019)

Three ALVs; Pumpkin, Fig-leaf, and Stinging nettle have been widely used both as dried and fresh vegetables to make mukimo a mixture of boiled potatoes and green maize together with the vegetables in Kenya. This is a common practice among the Kikuyu community who are also the majority in the Kiambu County in Kenya as noted by Chivenge et al. (2015). This study sought to investigate the nutrient retention and sensory evaluation of three (ALVs) i.e. Pumpkin, Fig-leaf, and Stinging nettle after applying different heat treatments of solar drying, blanching, and cooking. The sensory evaluation was assessed among women of reproductive age in Kiambu, County, Kenya. Pumpkin, Fig-leaf, and Stinging nettle were selected in this study due to their local availability and common consumption among residents of the proposed study area. Vitamin C has an important role in collagen synthesis, wound healing, prevention of anaemia and also an oxidant. It is also known to increase bioavailability of dietary non–haem iron which is an important in WRA who are at risk of iron deficiency anaemia (Bries, 2017).

1.2 Problem Statement

Vitamin A, iron and zinc are currently the micronutrients of greatest public health concern among Kenyan vulnerable groups including women of reproductive age (Harika et al., 2017). Although many studies have reported high nutritional value of ALVs, their production and utilization have not been optimized especially in areas where they are not naturally grown (Mavengahama, 2013). The main impediments in the utilization of ALVs appear to be the low availability due to seasonality and post-
harvest wastage occasioned by their high perishability (Negi & Roy, 2001 & Gupta et al., 2013).

A recommendation by Sheetal Gupta et al (2013) emphasizes the need to explore appropriate ways that can be adopted by rural communities to preserve leafy vegetables for use during dry spells when production plummets and popularizing them among women of reproductive age. Another challenge in the consumption of these ALVs has been the limited data on different varieties of ALVs in terms of their nutrient composition, little knowledge being passed from those with more knowledge concerning ALVs to those with less knowledge. Most of the studies on pumpkins are compositional studies conducted both on flesh and pumpkin seeds hence data on nutritional content of the pumpkin leaves is scarce.

Currently, we have limited data on studies conducted on the nutrient content of the fig–leaf gourd. In regard to the stinging nettle several studies have been conducted on the medicinal value of the plant but there is limited data on the nutritional composition of stinging nettles (Dar et al., 2013; Namazi et al., 2003; Kregiel, Pawlikowska, & Antolak 2018). Some of the ALVs species have also disappeared locally while the consumption of others has been despised by the modern people (Abukutsa-Onyango 2003). There is also limited data on the effect of various drying methods on the quality of ALVs in Kenya; information’s which is necessary to establish suitable drying methods for the cultivated leafy vegetables within Kenya (Gockowski, Mbazo’o, Mbah & Moulende, 2003).

This study therefore seeks to investigate the effect of solar drying, blanching and cooking on the content of iron, zinc, and β-carotene (pro–Vitamin A) in Pumpkin
leaves (*Curcubita maxima*), Stinging nettle (*Urtica dioica*), and Fig-leaf gourd (*Cucumis ficifolius*).

### 1.3 Purpose of the Study

The overall aim of this study was to evaluate the effect of solar drying and cooking treatments before and after blanching on the nutrient (vitamin C, β-Carotene, iron, and zinc) retention in three ALVs namely pumpkin leaves (*Curcubita maxima*), stinging nettle (*Urtica dioica*) and fig-leaf gourd (*Cucurbita ficifolia*) and their sensory evaluation among women of reproductive age in Kiambu County.

### 1.4 Objectives of the Study

1. To analyze the nutrient (β-carotene, vitamin C, iron, and zinc) content of fresh and cooked fresh ALVs.
2. To assess the nutrient content of solar dried fresh and solar-dried blanched ALVs.
3. To evaluate the sensory properties of both cooked fresh and cooked solar dried ALVs.
4. To determine the effect of different combinations of blanching, cooking and solar drying treatments on the nutrient retention of the ALVs.

### 1.5 Study Hypotheses

\[ H_{01} \] There is no significant difference between iron and zinc content of the fresh and solar dried of the selected ALVs.

\[ H_{02} \] There is no significant difference between the β-carotene and vitamin C content of the fresh and solar dried of the selected ALVs.
$H_03$ There is no significant effect of cooking and blanching on nutrient content of cooked solar dried of the selected ALVs.

$H_04$ There is no significant difference in the sensory evaluation between the cooked fresh and cooked solar dried of the selected ALVs.

1.6 Significance of the study

The finding from this research may be useful in supporting nutritional education programs at health facility level during nutrition counseling or in community forums that seek to popularize the consumption of ALVs especially to lactating mothers who are usually left out in most programs that address micronutrient deficiencies. The study has generated data, which may be of use to the food industry in making decisions regarding to commercial processing of these vegetables. The study provides information that will be used to update the Kenya food composition table. The result from the study on acceptability of ALVs will be useful for promotional and intervention activities. The finding from this research can be used as a basis for further research.

1.7 Limitations of the Study

The quantity of the nutrient contents in the three selected ALVs may be affected by such factors as the source of the plants, soil conditions, maturity stage at harvest and postharvest handling that were not investigated in this study.

1.8 Delimitations of the Study

The study researched on three African leafy vegetables i.e. (pumpkin leaves ($Curcubita maxima$), stinging nettle ($Urtica dioica$) and fig-leaf gourd ($Cucurbita ficifolia$) with regard to trace minerals iron and zinc and also nutrients vitamin A and
C of greatest concern to public health. This however does not underscore the importance of other micronutrients in the diet.

1.9 Assumption of the Study

The study assumed that all the three purchased African Leafy Vegetables from Kiambu markets were grown from the same area.

1.10 Conceptual Framework

The conceptual framework of this study was based on the fact that the perishable nature of the ALVs makes them susceptible to huge postharvest losses and wastage, which coupled with their seasonality lead to low availability during the off-season (Fasuyi, 2006). This compounds the problem of food shortage. Scarce information on the nutritional value of most of these vegetables may contribute to their low consumption (Chivenge et al., 2015). In addition, low consumption could be an issue related to sensory attributes as affected by various postharvest processing/preparation treatments (Raneri et al., 2019). Figure 1.1 shows the conceptual framework generated by the researcher to illustrate the interrelationships between variables that will lead to higher availability of micronutrients to women of reproductive age.
Figure 1. Conceptual Framework Source: researcher 2016

- Micronutrient intake
- Intake of ALVs by women of reproductive age
  - Supply of ALVs
  - Acceptability of solar dried African Leafy Vegetables by women of reproductive age
  - Preservation and year round availability
  - Solar drying of ALVs (Nutrient retention and appropriate processing)
CHAPTER TWO: LITERATURE REVIEW

2.1 Nutritional Value of African Leafy Vegetables

The fresh leaves of most ALVs have been found to have more than 100% of the Recommended Daily Allowances (RDAs) for vitamins and minerals and 40% proteins for growing children and lactating mothers (Abukutsa-Onyango, 2003). Some of the species lauded for superior nutrient value include spider plant (*Gynandropsis gynandra*), pumpkin leaves (*cucurbita maxima*), vegetable amaranths (*Amarantha spp.*), slender leaf (*Crotalaria brevidens*), vegetable cowpeas (*Vigna ungingulata*) and jute mallow (*Corchorus olitorius*) with dark green pumpkin leaves being an excellent sources of Vitamin A, Calcium, iron and protein.

The pumpkin leaves are also suggested by Gibson and Hotz (2001) to increase the bioavailability of zinc and iron. African leafy vegetables have been found to contain high levels of vitamins and minerals as compared with exotic vegetables such as cabbages. The ALVs are also suitable to consume with legumes because they contain ascorbic acid, which enhance non-heme iron absorption (ICRAF, 2004). Furthermore, ALVs are reported to contain some bioactive compounds (phytochemicals) which are beneficial to health (Chavasit et al. 2002; Kamga et al. 2013 and Oulai et al., 2015). The activity of retinal reductase which is involved in conversion of retinal to retinol while increasing the activity of retinol oxidase that’s is responsible for converting retinol to retinoic acid can be diminished by zinc deficiency (Debier & Larondelle, 2005).

African leafy vegetables should therefore be incorporated in the diet to overcome micronutrient deficiencies(Chivenge et al., 2015; Raneri et al., 2019). Obel-Lawson (2005) stated that consumption of the ALVs by both the rural and urban populations
in high levels can result in positive outcomes in terms of nutrition status and economic status. These crops can be consumed together with starchy staples as part of a balanced diet, and help to mitigate micronutrient deficiencies (Kamga et al. 2013).

Factors that’s affect the contribution of ALVs to human nutrition and food security include low production, low per capita consumption and lack of information on nutrient content and bioavailability (Shackleton et al. 2009). Cultural fusion and the westernization of the current generation have led to adoption of the western perception of ALVs being weeds. In other settings, ALVs are considered as food for the poor. Such misperceptions have resulted in decline in consumption of ALVs (Senyolo et al., 2014). Productions of ALVs have been low due to postcolonial shift of attention from local/indigenous food crops to exotic species and cash crops (Musinguzi et al. 2006). Furthermore, the ALVs have been declared as vegetables associated with poor community hence little has been done to increase awareness in the market as well as in research and development programs with efforts mainly directed to major crops/cash crops (Lyatuu et al. 2009).

2.2 Postharvest Processing Technology of African Leafy Vegetables

ALVs are highly perishable due to the presence of endogenous quality degrading enzymes. There is a need to preserve the nutrients in ALVs through appropriate processing technologies to minimize losses/wastage and ensure their all year round supply (Gupta & Prakash 2011). Large quantities of ALVs spoil due to insufficient processing capacity and growing market difficulties caused by intensifying competition from exotic vegetables (Schippers et al 2002). Developing ALVs products with extended shelf life can help reduce wastage/losses, while also making
an important contribution to improving the population’s income and supply situation (Habwe et al., 2008).

Drying is the deliberate removal of water from food products. The primary objectives of removing water from any food material are to reduce its weight and bulk, leading to economical transportation, handling and distribution; and to improve its keeping quality by reducing the water activity ($a_w$) (Babajide et al., 2008). The water removal should be under controlled conditions causing minimum or no changes in the food properties. A major criterion of quality of dehydrated food is that when they are reconstituted in water they should be very close to, or virtually indistinguishable from the original food material used (Muhanji et al., 2011).

Drying has been used from the early ages as a method of preserving food. Drying using sun is the oldest method with minimum cost as compared with other methods of drying (Eshun et al., 2011). However, sun drying has been associated with many challenges including health, environmental and chemical hazards (Gupta et al. 2013).

In recent years, exhaustive efforts have been made towards improving nutrient retention in dried products by altering processing methods and/or pretreatment (Gupta et al. 2013). Solar drying is a preferred method of preserving vegetables owing to its minimum cost of production, high quality product hence making these ALVs available in the market. (Masarirambi et al. 2010). Though drying leads to loss of a proportion of the water soluble vitamins, fat soluble vitamins such a β-carotene are fairly well-retained (Singh, Sagar, Behera, & Kumar 2006). Solar drying has increased the availability of ALVs products in the market. Solar drying requires minimum cost of production, but the products are of high quality (Muchoki et al, 2007).
In dehydration of vegetables, enzyme systems must be inactivated prior to drying. This is accomplished usually by blanching of vegetables (Eshun et al., 2011). Blanching prevents the formation of off-flavors, odors, and colors. However, blanching may cause partial destruction of some nutrients such as ascorbic acid (Gupta et al., 2013). A study by Schippers (2000) indicated that steam blanching followed by dehydration is more effective in retaining ascorbic acid. The quality of dried product is reflected not only in its texture, flavor, and color, but also in its ability to rehydrate as closely as possible to the original raw material.

During rehydration, dehydrated vegetables should be soaked in water for some time before cooking and the same water should then be used for cooking of the vegetables. Cooking induces significant changes in chemical composition affecting concentration and nutrient bioavailability (Gao-feng et al., 2009). Some cooking methods may oxidize antioxidants and affect the nutrient retention of the vegetable (Tumwet et al., 2013). It is therefore important to choose a cooking method that results into optimal nutrient retention and bioavailability (Funke, 2011).

Fermentation of vegetables has also been known to be effective and less expensive with a lot of nutritionally benefits among household technology in developing countries as reported by Ifesan et al, (2014). A study by Mathara et al (2004) also indicated that fermented foods to be considered to be of health benefit while many regions belief to be able to control different diseases especially intestinal disorder.

2.3 Utilization of African Leafy Vegetables

Indigenous vegetables are part of traditional foods among different cultural groups across the world. This notwithstanding, ALVs have been associated with poor communities across the Sub-Saharan Africa hence their cultivation and consumption
patterns are scarcely documented (Smith & Eyzaguirre, 2007). Many varieties of ALVs are rarely consumed hence their nutritional content has not been fully investigated (Keatinge, 2012). Some species such as the wandering Jew (*Comelina bengalensis*) and black jack (*Bidens Pilosa*) might even be getting gradually phased out as vegetables (Habwe, 2008).

Cultivation of the ALVs for purpose of consumption has not been widely practiced amongst most African cultures due to high availability of the vegetables during the rainy seasons and also probably due to the fact that these (ALVs) are sometimes picked freely from wild. Cultural interaction and inter marriages have been linked to an increase in the growing of the ALVs in home gardens and increasing the diversity of consumed ALVs (Chivenge et al., 2015). Introduction of exotic vegetable breeds from other parts of the world offered much competition to the disadvantage of the indigenous breeds since the former was touted for their superior yields and amenability to commercial cultivation.

A study in Kenya indicates that ALVs are among the vegetables that are not consumed with regard to addressing the food and nutrition security within the affected communities (Ogoye-Ndegwa & Aargard-Hansen, 2003). However, owing to the aggressive popularization campaigns that have kicked off in the recent past, evidence is emerging that ALVs are now gaining much awareness such that it is becoming a common vegetable among the back street joints, big hotels as well as in the supermarkets (K. Shiundu & Oniango, 2007).

The manner of utilization of ALVs varies from region to region and community to community. The vegetables are usually eaten as prepared to stews to accompany the staple starches such as maize meal, matoke (mashed bananas); mashed mixtures of
starches like Irish potatoes or pumpkin fruit and legumes. Some such as ginger and pepper have strong flavor and are used as spices; Some with very high nutrient content or medicinal bioactive compounds have been powdered for blending in enriched weaning porridge flours or herbal health products (Fanzo et al., 2013; Matenge et al., 2015; Shiundu & Oniang’o, 2007). Some of the ALVs such as stinging nettle when soaked or cooked in water or dried have the stinging quality removed. Cooked stinging nettle is a great source of vitamins A as β-carotene, C, Protein, and iron (Moser et al., 2010). Rutto et al 2013 indicated that stinging nettle has a minimum effect on blanching and cooking on the fatty acid composition hence it is a good source of essential fatty acid when eaten as a leafy vegetable.

2.3.1 Fig-leaf gourd (*Cucurbita ficifolia*)

Fig-leaf gourd see figure 2.1 belong to the squash species that are grown for their edible seeds, fruit, and greens (Lema, 2011). It is one of the plants that have so many common names in English such as Fig-leaf gourd, Malabar fig-leave gourd, black seed squash, and cidra. Unlike other curcubita species fig-leaf gourd does not have swollen storage roots, but it contains some tendrils that help it climb to other plants and structures. Its fruit resembles that of watermelon with wide black seeds only that its fruit is highly uniform in size, shape and colour (Sanjur et al., 2002).
Figure 2. 1 Photograph of Fig-leaf gourd (*Cucurbita ficifolia*)

2.3.2 Pumpkin (*Curcubita Maxima*)

Pumpkin is in the family of squash plants with its fruit being round with smooth, slightly ribbed skin and deep yellow to orange coloration. It is a widely grown vegetable which is fast growing vine that creeps along the ground with similar characteristics like other cucubitaceae family. The pumpkins vegetables are rich in dietary fibre, anti-oxidants, minerals, and vitamins. The pumpkins leaves are more recommended for control of cholesterol and weight management Echessa 2011.

Figure 2. 2 Photograph of pumpkin (*Curcubita Maxima*)
https://garden.org/plants/photo/456251/
2.3.3 Stinging nettle (*Urtica dioica*)

Stinging nettle is a small plant that has fine hairs on the leaves and stem. It comes from the genus urtica which is a latin word that means “to burn” due to its stinging hairs (Kavalali, 2003). The species *dioca* means “two houses” that is it contains either the male flower or the female flower. Stinging nettle has stinging hairs called trichomes which are located either on the leaves or the stems which acts like hypodermic needles injecting histamines, serotonin and choline that produce a stinging sensation when they come into contact with human or other animals hence proper protection should be used to protect the hands when harvesting (DiTomaso & Healy, 2007). Stinging nettle has been known to provide iron and other minerals, vitamin C, carotenoids and essential amino and fatty acids Guil-Guerrero, Rebollos-Fuentes, & Isasa, 2003. Although the usage of *U. dioica* as a leafy vegetable is widespread, there is little information on processing potential, and the impact of different processing methods on nutritive and functional value.

![Photograph of Stinging nettle](https://www.ediblewildfood.com/stinging-nettle.aspx)
2.4 Economic Importance of ALVs
Trade in ALVs has been known to improve the economic status of some of the communities (Adebooye & Opadole, 2004). These ALVs have given the poor communities an opportunity to be self-reliant by cultivating the ALVs for commercial purpose (Opiyo et al. 2015). In addition, the ALVs have be known to change the living standards of many communities by offering them source of employment to those who engage themselves in the practice of commercial production of these ALVs within the peri – urban areas and sell them to the urban markets. The ALVs are easy to produce because they are not labour intensive, require less capital compared to the exotic vegetables which requires pesticides (Kwenin et al., 2011). ALVs thus constitute one of the economic pillars that can change the livelihood of communities producing these vegetables by increasing their economic status and also as a means for diet diversification for the low income household in rural setting, through home gardens. Furthermore, they hold more advantages for being introduced in the peri–urban cities as a cash crop (Shackleton et al., 2009).

2.5 Effects of Different Processing Conditions on Micronutrient Retention in ALVs and other Vegetables
Micronutrients are significantly important to our health; The high amounts of micronutrients present in ALVs may not translate to actual intake due to losses that occur during postharvest handling including storage, preparation and processing (Abukutsa-Onyango, 2003). Different methods of processing such as blanching in hot water have an effect on water-soluble vitamins.

Blanching time of vegetables has been shown to significantly reduce the total phenolic content, antioxidant activities and mineral content of all the green leafy
vegetables. Singh & Harshal (2016) recommended blanching time of between 1 to 5 min to prevent the loss of health benefiting compound present in the vegetables.

Sun drying, which is the oldest and the cheapest method causes considerable destruction of nutrients (Amarowicz et al., 2009). Eshun et al., 2011 indicated that when blanched vegetables are cooked they take less time to cook compared with un–blanched vegetables because the blanched vegetables are partially cooked, the research also reported that blanching prior to drying gave the dried vegetables a tender cooking character, better flavor and also better keeping quality compared to un–blanched dried vegetables. A study by Muchoki et al (2007) indicated that blanching has a reduction effects on the number of micro-organisms and also aids in removing the disagreeable odor and flavor while assisting in retention of the green colour of the vegetables although the retention of the green colour depends on the type of the vegetable and the blanching temperature.

The enzymatic oxidation of vitamin C is of more importance than the non–enzymatic oxidation by oxygen which is catalyzed by presence of traces metals such as copper and iron during the blanching of vegetables (Fagbuaro et al., 2006).

Thermal processing has been known to have different effects on bioactive compounds and their activities, the magnitude of these varying effects depends on some of the process parameters i.e. temperature, time and also the food matrix (Munyaka et al., 2010). Irradiation has been known to be one of the food processes that can extend the shelf life of foods in a number of ways by reducing the number of spoilage organisms hence it has been reported by (Moreno et al., 2006) to lengthen the shelf life of fruits and vegetables.
A study by Bamidele, Fasogbon, Adebowale, and Adeyanju (2017) on the cyanide content of the Hibiscus Sabdariffa vegetable indicated that sun drying of the vegetables decreased the amount of cyanide content by about 19.4% compared with the fresh vegetable samples while the β-carotene content in the vegetable leaves when boiled for 5 minutes was more than that in fresh vegetables and other processed vegetable samples, sun drying reduced the concentration of β-carotene to 42.07% but heating for 5-10 minutes did not significantly change the concentration of β-carotene. Vitamin C content decreased by 47.5% and 64.76% when heated for 5 and 10 minutes respectively. Solar drying was noted to reduce the Vitamin C content with a loss of over 66% being reported. Iron content was not affected by solar drying but when the vegetables leaves were heated for 5 to 10 minutes there was a significant reduction on the iron content by 26%.

Steaming has been recommended by (Aworh, 2015) as one of the best methods to retain maximum concentrations of the nutrients such as carotenoids, folate and phytochemicals. Freezing of amaranthus leaves have been reported to reduce the levels of oxalate to 73.5% while minimizing losses of vitamins and minerals (Martínez et al., 2017).

Processing of vegetables using additives such as seasoning salts decreased iron availability by about 40% while 99.9% monosodium glutamate inhibited iron availability from amaranthus leaves by only 10% (Osuntogun et al., 2004). Dehydration methods have little effects on the proximate, mineral, and anti-nutrient content of green leafy vegetables. Dehydration of vegetables was reported to result in nutrient of 1-14%, 20-69% and 22-71% for ascorbic acid, β-carotene, and thiamine respectively. (Singh and Harshal, 2016).
During home processing of ALVs, using methods such as microwave and boiling content of vitamins has been shown to decrease depending on the method of cooking of minerals; such as iron may be increased by cooking (P. Singh et al., 2016). The effect of high pressure processing, a relatively a new technique of food processing technology that enhances food safety and shelf–life without compromising on the organoleptic qualities, on nutrient retention was studied by McInerney et al (2007) who reported that high pressure processing did not affect the concentration of nutrients such as antioxidants and total carotenoids.

Fermentation has been one of the oldest methods that have been used for preparing and preserving vegetables. Fermentation was reported by Kasangi et al (2010) to reduce the concentration of iron, and zinc in cowpeas leaves, while Wakhanu et al 2014 indicated that fermentation positively impacted the retention of minerals and β-carotene, increased the taste, aroma, texture and also improved the palatability of the fermented vegetables. Fermented amaranthus vegetables were shown to preserve more vitamin C compared to amaranth preserved with other methods although there was an increase in thiamine and niacin after fermentation. Fermentation was also found by Ifesan et al., (2014) to be in expensive and effective way of processing vegetable which had nutritional benefit to household technology in the developing world.

2.6 Summary of Literature Review

African Leafy Vegetables have a great potential to improve nutrition status of many vulnerable groups, such as lactating mothers, in the developing countries. However, their potential has not been fully exploited owing to lack of application of technologies and cooking methods that increases the ALVs shelf life, without
compromising their nutritional value. There is need to develop and promote locally appropriate processing technique and ensure regular supplies of leafy vegetables from the production areas to consumers in peri-urban and urban cities. This study therefore investigated the retention of key nutrients in three ALVs species during solar drying and cooking treatments.
CHAPTER THREE: METHODOLOGY

3.1 Study Design

The study adopted an experimental design to determine nutrient retention in solar dried ALVs while sensory evaluation was conducted to evaluate the acceptability of these ALVs among women of reproductive age. Laboratory analysis was conducted on the vegetables samples to determine the content of Iron, Zinc, Beta Carotene, and Vitamin C (Appendix D).

3.2 Study Variables

The variables of this study included three ALVs i.e. Pumpkin leaves, fig-leaf gourd leaves and stinging nettle leaves and the processing treatments i.e. solar–drying, blanching, and cooking as the independent variables while the nutrient content and retention of Iron, Zinc, Beta Carotene, as well as Vitamin C and sensory acceptability were dependent variables.

3.3 Study Location

The samples were purchased from Ruiru market early in the morning and it was assumed they were delivered from their place of origin which is in Kiambu County.

3.4 Study Participants

Women of reproductive age who are residence of Kiambu County capable of discriminating differences and communicating their reactions and are familiar with African leafy vegetables were purposively sampled. The participants sampled met the following conditions; had a sound health without any defect in sensory perception, average sensitivity, capable of independent judgments, ability to concentrate, be trained, and learn, and willingness to spend time in evaluation and had freedom from prejudices in respect to particular food product. The panelists were not trained
formally but they were capable of following instructions given at the evaluation session. A total of thirty participants who met the criteria were enrolled based on the recommendations by (Duxbury, 2005) and Gacula (1997) for pilot effective studies and descriptive sensory tests.

3.4 Study Instruments

Nutrient Data sheets (Appendix B) were used to record data on nutrient analysis. Information on the sensory rating of the products was collected by means of structured questionnaire based on the 9-point hedonic scale (Appendix C).

3.5 Treatment and Processing of the ALVs

Ten kilograms each of fresh samples of pumpkin leaves (*Curcubita maxima*), Stinging nettle (*Urtica dioica*) and fig-leaf gourd (*Cucurbita ficifolia*) were purchased early in the morning from Ruiru Market as they were being delivered from their origin in Kiambu County, packaged in perforated polythene bags and immediately transported to the Kenyatta University laboratories for analysis using a cool box at 15°C. The samples were stored in refrigerator at 5°C prior to analysis/processing. Appendix D shows a flow diagram of the different sequences of sample treatments and processing of ALVs.

Sample preparation was done by sorting and separating the leaves from the stalks, followed by washing under cold distilled water. The cleaned leaves were then placed in a cooking pot that were of stainless steel with boiling water whereby it was water blanched for 5 min to inactivate enzymes and fix color (Kendall, 2003) followed by plunging the vegetables into a large quantity of water of ice water for cooling for 30 seconds and thereafter the vegetables were removed from the cold while straining to
remove excess water. The blanched leaves were then divided into two lots: one lot was taken for nutrient analysis as described under sections 3.6 and 3.7. The second lot that was blanched and the un–blanched sample were solar dried using a locally fabricated solar dryer according to James (2003). The leaves were introduced onto the drying trays and evenly spread without overlapping. The trays were then placed into the solar boxes for drying. Drying proceeded until a moisture content of 4–8% was attained as determined by oven drying for 3 hours at 105°C. The dried vegetables were then packaged in sealed polythene bags to prevent reabsorption of moisture, and they were stored in the dark at room temperature prior to nutrient analysis.

3.6 Cooking of ALVs Vegetables

3.6.1 Cooking of ALVs for Nutrient Analysis
About 100g of each single ALV, blanched and un–blanched were cooked with 20ml oil, 15g onions, 25g tomatoes, 1g salt and 30ml of distilled water using ohms model electrical cooker with four plates set at medium temperature 165°C for 30 minutes. Cooking time of 30 minutes was used as indicated by (Rodriguez-Amaya, 1997) to give good retention of vitamins in vegetables. All the cooking pot (stainless steel) were washed and rinsed with distilled water before cooking the next sample. The cooked samples were rapidly cooled to room temperature before being subjected to nutrient analysis.

3.6.2 Cooking of ALVs for sensory evaluation
About one kilogram of fresh ALVs were weighed using electronic balance model NBY323/64 and shallow fried together with 150g pre–shredded onions, 250g tomatoes, 200ml of vegetable oil and 10g salt in a saucepan for 30 minutes using ohms model electrical cooker with four plates set at medium temperature (149°C –
177°C). The cooked samples were coded and given to the panelist at random. One kilogram solar dried ALVs samples were first soaked with 200ml distilled water and subjected to the same cooking condition as the fresh samples.

3.7 Nutrient Analysis

3.7.1 Determination of Moisture Content

Moisture content (MC) was determined using the oven drying method as described in AOAC methods (Association of Official Analytical Chemists, 2005). Five grams of vegetable samples were exactly weighed using analytical balance in triplicate and dried in a hot air oven (Lab Tech model LDO-080H) at 105°C for 3 hours. The vegetable samples were then cooled in a desiccator for 30 minutes and the weight of the dried samples taken using an electronic weighing balance model NBY323/64. The final weight of the dried samples was noted and MC was calculated as:

\[
\%MC = \frac{(\text{Weight of dish + fresh sample})-(\text{weight of dish + dry sample})}{\text{Weight of dish + fresh sample}} \times 100
\]

3.7.2 Extraction and HPLC Analysis of β-Carotene

Beta-carotene was extracted according to (Association of Official Analytical Chemists, 2005). Five grams of the vegetables samples was exactly weighed using analytical balance model NBY323/64 and ground using a pestle and mortar then transferred into a 250ml conical flask, 50ml of a mixture of acetone–hexane (3:2 v/v) containing 0.1% Butylated Hydroxytoluene (BHT) was then added. The BHT was used to prevent the oxidation of the β-carotene in the vegetable samples. The mixture was then mechanically shaken for 10 minutes followed by centrifuging the solution for 10 minutes at 1000rpm to separate mixture into organic solvent and aqueous layers. The organic solvent was transferred into a separating funnel and 25ml of 0.5M
methanolic potassium hydroxide added to saponify the potentially interfering oils. The saponified extract then shaken and allowed to settle for 30 minutes followed by washing the solution with 100ml of 10% sodium chloride solution and three more time with distilled water to remove the acetone while discarding the aqueous layer continuously. The extract was then filtered over anhydrous sodium sulphate and concentrated in rotary evaporator at 45°C. The filtrate was then reconstituted to 50ml using methanol in a 50ml volumetric flask. The volumetric flask was covered with alluminium foil to minimize the destruction of β-carotene by light.

Beta-carotene was identified and quantified according to the method of (Bansode et al., 2018). Exactly 20μl of standard and Sample solution was injected into Reverse Phase High Pressure Liquid Chromatography (RP- HPLC, Shimadzu 20A Kyoto, Japan) consisting of a column oven (model CTO–10 AS VP), a degasser (Model DGU–20A5R), an LC pump (model LC-20AD), a UV–Visible diode- array detector (model SPD -20A) and an auto sampler (model SIL-20AHT). Sample elution was carried out in a reverse phase C_{18} column (Phenomenex C18, 250 x 4.6mm, 5μm particle size, Luna 5u) using a mobile phase consisting of Acetonitrile, Dichloromethane and Methanol in the ratio of 70:20:10 respectively at the rate of 2ml per minute. Detection of β–carotene was achieved using UV–detector (shimadzu SPD–20A model) at 452nm.

Beta–Carotene standard solution was prepared by weighing 10 mg of 95% UV β–carotene Type 1 (Sigma Aldrich) in 100ml volumetric flask and the solution made to the mark with 100ml n-Hexane giving a concentration equal to 100ppm. Different known concentrations e.g. 20, 40, 60, 80 ppm were prepared by diluting the stock solution with N–Hexane. β–carotene standard curve was obtained by plotting the peak
area against various concentrations of the standard. The concentration of β-carotene in
the sample was obtained by extrapolation from standard curve.

3.7.3 Extraction and HPLC Analysis of Ascorbic Acid (Vitamin C)

Vitamin C was extracted according to the procedure described by (Latimer, 2012). Ten grams of the vegetable samples were ground using a pestle and mortar and then mixed with 50ml of extracting solution. The extraction solution consisted of 3% Meta phosphoric acid (MPA) and 8% acetic acid prepared by dissolving 15g of MPA in 40ml acetic acid and 200ml of distilled water and made to 500ml mark using distilled water. The extract was filtered using what man filter paper no. 42 and transferred to 100ml volumetric flask and made to the mark with extraction solution.

Vitamin C standard 100mg was weighed using analytical balance model (NBY323/64) into 100ml beaker and dissolved with 45ml of the extraction solution. The solution was then transferred into 100ml volumetric flask rinsing the beaker three times with extraction solution and transferring the solution to the volumetric flask. The volumetric flask was then filled to the mark using the extraction solution and the concentration was equal to 100ppm. Standards of different known concentration i.e. 10,20,40,60, 80 and 100ppm were prepared by diluting the stock solution with the extraction solution and used for preparing the standard curve.

The concentration of Vitamin C was determined after the extracted ascorbic acid solution was centrifuged at 10,000rpm. The supernatant was then filtered and diluted with 10ml of 0.8% metaphosphoric acid which was later passed through 0.45µm filter membrane. Identification and quantification of AA was performed using Reverse Phase High Pressure Liquid Chromatography (RP- HPLC Shimadzu 20A Kyoto, Japan) consisting of a column oven (model CTO–10 AS VP), a degasser (Model
DGU–20A5R), an LC pump (model LC- 20AD) a UV–Visible diode- array detector (model SPD-20A) and an auto sampler (model SIL-20AHT). Sample separation was carried out in a reverse phase C$_{18}$ column (Phenomenex C18, 250 x 4.6mm, 5μm particle size, Luna 5u).

The separation of AA was done isocratically using mobile phase consisting of 0.8% metaphosphoric acid at a flow rate of 1.2ml/min and wavelength of 266nm as described by Otieno et, al (2017). The AA was detected at 266nm using prominence UV/VIS detector (Shimadzu UFLC SPD-20A). Exactly 20μl of standard and sample extract were injected into the column. The concentration of AA in sample was obtained by extrapolation from the standard curve.

3.7.4 Digestion of Vegetable samples for Iron and Zinc Analysis

Digestion of vegetable samples for Iron and Zinc analysis was done according to procedure described by Wakhanu et al., (2014). One gram of the vegetable sample was weighed in 250ml digestion tube followed by addition of 10ml of concentrated nitric acid and heating at 90°C in an electric hot plate for 10 minutes subsequently 30% hydrogen peroxide was added drop by drop until the solution was clear. The digested sample was then filtered using filter paper (whatman no. 1) into 100ml volumetric flask and made to the mark with distilled water. The solution was then transferred into a labeled plastic container awaiting analysis.

Zinc and iron standard (sigma Aldrich) of 1000ppm each were used to prepare stock solution for Zinc and Iron by dissolving 25ml of 1000ppm in 50ml distilled water, then transferred quantitatively into a 250ml volumetric flask and making to the mark using distilled water respectively. The concentration of the resulting solution was equal to 100ppm each.
Preparation of working standards of 2, 4, 6, 8 ppm was carried out by diluting the stock solution of iron and Zinc with distilled water. Zinc and Iron standard curves were prepared by plotting the concentrations of Zinc/ iron against their absorbance. The standard and the sample were analyzed using Flame Atomic Absorption Spectrophotometer (FAAS) at 213.9nm with a slit of 0.7nm using air acetylene flame at a flow rate of 2.0 l/min lamp mode BGC-D₂ and lamp current of 12mA, while Iron was analyzed at 248.3nm with a slit of 0.2nm using air acetylene flame and a flow rate of 2.2 l/min. lamp mode BGC-D₂ and lamp current of 12mA. The standards and samples were analyzed in triplicate and mean concentration of each sample calculated.

3.7.5 Determination of Percentage Recovery of β – carotene and Ascorbic Acid

The accuracy of the HPLC method used for the analysis of β - carotene and ascorbic acid was verified by the recovery studies where by the β – carotene and ascorbic acid extraction were repeated as outlined in 3.7.2 and 3.7.3 respectively only that before extraction the samples were spiked with 100ppm β – carotene standard and 1 ppm ascorbic acid standard. The accuracy of the method was evaluated by the recovery test, according to equation 9 of (Eurachem, n.d.)

\[
% \text{recovery} = \left(\frac{C_f - C_u}{C_a}\right) \times 100 \quad \text{eq (9)}
\]

Where
- \( C_u \) was the concentration of the un-spiked sample
- \( C_f \) was the concentration determined in the spiked sample
- \( C_a \) was the concentration of the Standard used to spike the samples

3.7.6 Sensory Evaluation

A sample size of between 8 and 12 semi – trained panelists is recommended for descriptive sensory test hence 30 women of reproductive age were purposively
selected from Kiambu County and enrolled for the sensory evaluation exercise which was carried out in the Kenyatta University Food preparation Laboratory in the morning hours and panelists were provided with transport to Kenyatta University and back since it was a pilot sensory evaluation among women of reproductive age Kebebu, Whiting, Dahl, & Henry, 2013; Ndife, Obiegbunna, & Ajayi, 2013. The exercise was conducted in a well-lit room. The sensory evaluation followed the procedure described by Dalton, Wittuhn, Smuts, Wolmarans and Nel (2006). An hour before the sensory evaluation took place; the participant ate a sandwich spread with margarine to prevent potential hunger from influencing the rating of the different vegetables samples.

The sensory evaluation participants 15 per session were briefed on the procedure and the score sheet. The participants were required to rate the sensory attributes in terms of color, taste, texture/mouth feel, aroma and overall acceptability of the samples based on their degree of like or dislike using a 9 point descriptive scale which is the most commonly used with values ranging from 9 for dislike extremely to 1 for like extremely (Tuorila et al., 2008) (Appendix C).

The participants were provided with 30g of each of the coded vegetable samples at random. In between the samples the participants were provided with drinking water to rinse the mouth and eat a small piece of apple to cleanse the palate in order to reduce the possibility of overlap of flavors (Meilgaard, Civille & Carr, 2007).

3.12 Statistical Analysis

Data was analyzed using SPSS statistical computer software version 22.0 and presented in form of tables and charts. All determinations were carried out in triplicate and the mean values computed. Descriptive statistics: frequencies, means and
percentages were used to describe nutrient content and sensory acceptability outcomes: students t-test, analysis of variance (ANOVA) and Fisher's Least Significant Difference (LSD) were used to make comparisons and test for differences of means at 95% confidence levels (p<0.05), in the dependent variable, between the control (fresh) and experimental (fresh cooked; solar dried and solar dried cooked) vegetable samples.

3.13 Logistical and Ethical Considerations

Research authorization was cleared from the Graduate School of Kenyatta University (Appendix N). Ethical clearance was obtained from Kenyatta University Ethical Review Committee (KUERC) (Appendix M) while a research permit was obtained from the National Council for Science, Technology, and Innovation (NACOSTI/P/18/62543/21148) (Appendix L). Informed consent was obtained from all research participants. Confidentiality was assured by use of coded names. The outcomes of the study are also intended for publication.
CHAPTER FOUR: FINDINGS

4.1 Moisture Content of Vegetables

The Moisture content of fresh and treated vegetable samples were determined by oven drying method and the results are presented in table 4.1

Table 4.1: Moisture Content of Fresh and Treated ALVs

<table>
<thead>
<tr>
<th></th>
<th>Pumpkin Leaves %</th>
<th>Gourd Leaves %</th>
<th>Stinging Nettle %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh samples</td>
<td>92.34</td>
<td>91.50</td>
<td>89.94</td>
</tr>
<tr>
<td>Blanched samples</td>
<td>89.12</td>
<td>89.98</td>
<td>88.62</td>
</tr>
<tr>
<td>Cooked samples</td>
<td>89.75</td>
<td>90.82</td>
<td>89.12</td>
</tr>
<tr>
<td>Solar dried samples</td>
<td>8.87</td>
<td>8.40</td>
<td>7.63%</td>
</tr>
</tbody>
</table>

4.2 Nutrient content in Fresh Selected ALVs

Nutrient analyses were conducted for fresh pumpkin leaves, fig-leaf gourd, and stinging nettle and the results were used for comparison with other treated vegetable samples. Sample preparation was done as in (Appendix D).

As shown in Table 4.2, pumpkin leaves had the highest content of iron (29.331 ± 0.474 mg/100g dw) followed by fig-leaf gourd at 25.38 ± 0.06 mg/100g dw and stinging nettle leaves at 13.94 ± 0.14 mg/100g dw. Fig-leaf gourd had the highest content of zinc (5.51 ± 0.08 mg/100g dw) followed by pumpkin leaves at 3.307 ± 0.055 mg/100g dw. Stinging nettle leaves had the lowest zinc content (2.09 ± 0.04 mg/100g dw) among the three vegetables. Stinging nettle leaves had the highest provitamin A (β-carotene) content of 34.69± 0.14 mg/100g dw followed by pumpkin leaves and fig-leaf gourd which each contained 25.86± 0.008 mg/100g and 18.46± 0.03 mg/100g β-carotene respectively. Vitamin C was highest in stinging nettle leaves.
(228.60 ± 1.81 mg/100g dw) followed by fig-leaf gourd (122.59 ± 0.09 mg/100g dw) while pumpkin leaves had the lowest (118.73 ± 0.15 mg/100g dw) among the three vegetables.

Table 4.2 Nutrient Content in Fresh Vegetables (mg/100g dw)

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Type of sampled vegetable</th>
<th>Pumpkin leaves</th>
<th>Stinging nettle leaves</th>
<th>Fig-leaf gourd Leaves</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron</td>
<td></td>
<td>29.33 ± 0.47</td>
<td>13.94 ± 0.14</td>
<td>25.38 ± 0.06</td>
</tr>
<tr>
<td>Zinc</td>
<td></td>
<td>3.31 ± 0.06</td>
<td>2.09 ± 0.04</td>
<td>5.51 ± 0.08</td>
</tr>
<tr>
<td>B-carotene</td>
<td></td>
<td>25.86 ± 0.01</td>
<td>34.69 ± 0.14</td>
<td>18.46 ± 0.03</td>
</tr>
<tr>
<td>Vitamin C</td>
<td></td>
<td>118.73 ± 0.15</td>
<td>228.60 ± 1.81</td>
<td>122.59 ± 0.09</td>
</tr>
</tbody>
</table>

4.3 Nutrient content of Cooked Fresh Selected ALVs

Iron and zinc in fresh leaves were not significantly (p ≤ 0.05) affected by cooking, while beta carotene increased after cooking. Vitamin C reduced significantly after cooking with a reduction of 47.3 mg/100g dw from 118.7 mg/100g dw observed in pumpkin leaves. (Table 4.3)

Table 4.3 Nutrient Content in Cooked Fresh Vegetables (mg/100g dw)

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Type of sampled vegetable</th>
<th>Pumpkin leaves</th>
<th>Stinging nettle leaves</th>
<th>Fig-leaf gourd Leaves</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron</td>
<td></td>
<td>28.009 ± 0.092</td>
<td>13.181 ± 0.035</td>
<td>25.168 ± 0.041</td>
</tr>
<tr>
<td>Zinc</td>
<td></td>
<td>3.021 ± 0.555</td>
<td>1.820 ± 0.004</td>
<td>5.165 ± 0.025</td>
</tr>
<tr>
<td>B-carotene</td>
<td></td>
<td>26.29 ± 0.35</td>
<td>34.59 ± 0.58</td>
<td>19.78 ± 0.08</td>
</tr>
<tr>
<td>Vitamin C</td>
<td></td>
<td>47.253 ± 1.116</td>
<td>103.94 ± 0.06</td>
<td>49.215 ± 0.253</td>
</tr>
</tbody>
</table>
4.4 Effect of Blanching, Solar-drying and Cooking on the Nutrient Content of Selected ALVs

4.4.1 Pumpkin Leaves

The content of iron, zinc, beta carotene and vitamin C in fresh pumpkin leaves was found to be 29.33 ± 0.47, 3.31 ± 0.06, 25.86 ± 0.01 and 118.734 ± 0.147 mg/100g dw respectively.

ANOVA test showed significant differences (p value <0.05) in the contents of each of the four micronutrient under investigation after various processing treatments. Post-hoc analysis (LSD) revealed that iron content in both blanched and cooked pumpkin leaves were significantly lower than in fresh samples. However, there was no significant difference in iron content between fresh and solar-dried pumpkin leaves samples although the latter had lower values. (Table 4.4)

In this study the fresh and un-blanchd solar dried pumpkin leaves were found to have the highest concentration of zinc. The zinc contents of both blanched and solar-dried pumpkin leaves samples were not significantly different (p ≤ 0.05) from that of fresh samples. Vitamin C content of pumpkin leaves was significantly lower after each of the processing treatments (blanching, cooking and solar-drying as well as combined treatments). There was no significant (p ≤ 0.05) difference in β-carotene content between fresh and blanched samples. Cooking as well as combined cooking and blanching treatments resulted in significant (p ≤ 0.05) increase in β-carotene content of pumpkin leaves relative to fresh samples while solar-dried pumpkin leaves had significantly (p ≤ 0.05) lower content of β-carotene than fresh samples. Un-blanched solar dried (UBSL) and un-blanchd solar dried cooked (UBSCL) pumpkin leaves had the lowest β-carotene content at 20.30±0.22 mg/100g dw and 20.63±0.06
mg/100g dw respectively. These values were significantly lower than that in fresh leaves

Table 4.4 Mean nutrient content of fresh and treated pumpkin leaves

<table>
<thead>
<tr>
<th>Sample</th>
<th>Nutrient content per mg/100g dw</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Iron</td>
</tr>
<tr>
<td>FL</td>
<td>29.331±0.474&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>BL</td>
<td>28.381±0.475&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>UBCL</td>
<td>28.009±0.092&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>BCL</td>
<td>27.595±0.241&lt;sup&gt;cd&lt;/sup&gt;</td>
</tr>
<tr>
<td>UBSL</td>
<td>28.980±0.637&lt;sup&gt;ab&lt;/sup&gt;</td>
</tr>
<tr>
<td>BSL</td>
<td>27.675±0.224&lt;sup&gt;cd&lt;/sup&gt;</td>
</tr>
<tr>
<td>UBSCL</td>
<td>27.143±0.035&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>BSCL</td>
<td>26.842±0.061&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

**Key:** FL = fresh leaves ∞ BL = blanched leaves ∞ UBCL = un-blanched cooked leaves ∞ BCL = blanched cooked leaves ∞ UBSL = un-blanched solar-dried leaves ∞ BSL = blanched solar-dried leaves ∞ UBSCL = un-blanched solar-dried cooked leaves ∞ BSCL = blanched solar-dried cooked leaves

**N/B:** Superscripts with different letters in the same column indicate significantly different values at P ≤ 0.05

4.4.2 Fig-leaf gourd

Fresh guard leaves were found to contain 25.381 ± 0.064, 5.505 ± 0.076, 18.46 ± 0.033 and 122.585 ± 0.093 mg of iron, zinc, β-carotene and vitamin C per 100g dw respectively.(Table 4.5)
Table 4.5 Mean values for nutrient content of fig-leaf gourd samples

<table>
<thead>
<tr>
<th>Sample</th>
<th>Nutrient content per mg/100g dw</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Iron</td>
</tr>
<tr>
<td>FL</td>
<td>25.38±0.064a</td>
</tr>
<tr>
<td>BL</td>
<td>25.24±0.204ab</td>
</tr>
<tr>
<td>UBCL</td>
<td>25.16±0.041b</td>
</tr>
<tr>
<td>BCL</td>
<td>25.13±0.068b</td>
</tr>
<tr>
<td>UBSL</td>
<td>25.26±0.079ab</td>
</tr>
<tr>
<td>BSL</td>
<td>25.13±0.035b</td>
</tr>
<tr>
<td>UBSCL</td>
<td>25.14±0.170b</td>
</tr>
<tr>
<td>BSCL</td>
<td>25.09±0.317b</td>
</tr>
</tbody>
</table>

Key: FL = fresh leaves ∞ BL = blanched leaves ∞ UBCL = un-blanched cooked leaves ∞ BCL = blanched cooked leaves ∞ UBSL = un-blanched solar-dried leaves ∞ BSL = blanched solar-dried leaves ∞ UBSCL = un-blanched solar-dried cooked leaves ∞ BSCL = blanched solar-dried cooked leaves ∞ dw = dry weight

N/B: Superscripts with different letters in the same column indicate significantly different values at P ≤ 0.05

ANOVA test showed that the micronutrient content of fig-leaf gourd samples was significantly altered (p value <0.05) during the various processing treatments. Post-hoc analysis (LSD) revealed that Iron contents of both blanched and solar dried samples were lower relative to fresh samples although the difference was not significant (p>0.05). Cooking resulted in significant reduction in iron content relative to the fresh vegetable samples (p<0.05). Zinc content in both blanched and un-blanched cooked fig-leaf gourd was significantly lower than that of fresh samples. However, there was no significant difference in the zinc content of fresh fig-leaf gourd and solar dried fig-leaf gourd samples. Vitamin C contents of the fig-leaf gourd vegetable samples were significantly reduced after each of the three processing treatment (solar drying, blanching, and cooking) relative to fresh samples. Apparently,
β-carotene content of fig-leaf gourd was significantly increased in both blanched and cooked samples compared to fresh samples. Conversely, the content of β-carotene in solar dried samples was significantly lower relative to that of fresh samples. (Table 4.5)

4.4.3 Stinging Nettle Leaves

The effect of different treatments on the nutrient content of Stinging nettle leaves is shown in Table 4.6. The iron, zinc, β-carotene and vitamin C content of fresh stinging nettle leaves was found to be 13.935 ± 0.138, 2.086 ± 0.041, 34.69 ± 0.14 and 228.6 ± 1.81mg/100g dw respectively.

Table 4.6 Mean values for nutrient content of stinging nettle leave samples

<table>
<thead>
<tr>
<th>Sample</th>
<th>Nutrient content per mg/100g dw</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Iron</td>
</tr>
<tr>
<td>FL</td>
<td>13.935±0.138a</td>
</tr>
<tr>
<td>BL</td>
<td>13.383±0.059b</td>
</tr>
<tr>
<td>UBCL</td>
<td>13.181±0.035c</td>
</tr>
<tr>
<td>BCL</td>
<td>13.053±0.020d</td>
</tr>
<tr>
<td>UBSL</td>
<td>13.857±0.051a</td>
</tr>
<tr>
<td>BSL</td>
<td>13.367±0.036b</td>
</tr>
<tr>
<td>UBSCL</td>
<td>13.203±0.062c</td>
</tr>
<tr>
<td>BSCL</td>
<td>13.027±0.017d</td>
</tr>
</tbody>
</table>

Key: FL = fresh leaves ∞ BL = blanched leaves ∞ UBCL = un-blanched cooked leaves ∞ BCL = blanched cooked leaves ∞ UBSL = un-blanched solar-dried leaves ∞ BSL = blanched solar-dried leaves ∞ UBSCL = un-blanched solar-dried cooked leaves ∞ BSCL = blanched solar-dried cooked leaves

N/B: Superscripts with different letters in the same column indicate significantly different values at p ≤ 0.05
The iron content of blanched stinging nettle leaves (BL) (13.383±0.059 mg/100g dw) and blanched cooked (BCL) (13.181±0.03581 mg/100g dw) stinging nettle leaves were each significantly lower than that of fresh samples. However, the difference between the iron contents of fresh and solar-dried samples was not significant. Likewise, the drop in zinc content of stinging nettle leaves during solar drying was not significant relative to the original content in fresh samples. However, the zinc content of both blanched (BL) and blanched cooked (BCL) stinging nettle samples were significantly lower than that of the fresh leaves. Insignificant drop was realized in the content of β-carotene of both blanched (BL) and blanched cooked (BCL) stinging nettle leaves relative to the fresh leaves while the content of β-carotene in solar-dried leaves was significantly lower than that of fresh leaves. The different processing treatments resulted in significant drop in the content of vitamin C compared to the original values for fresh stinging leaves.

4.5 Nutrient Retention in Selected ALVs Subjected to Solar-drying, Blanching and Cooking treatments

4.5.1 Effect of Solar-drying, Blanching, and Cooking Treatments on Nutrient Retention in Pumpkin Leaves

The effect of solar-drying, blanching, and cooking treatments on the retention of nutrients in pumpkin leaves is shown in Table 4.7. Iron retention during solar-drying, blanching, and cooking, treatments was 98.8%, 96.8%, and 95.5%, respectively. Furthermore, 92.5% and 91.5% of iron was retained after cooking of un-blanched solar-dried (UBSL) and blanched solar-dried (BSL) vegetable samples respectively. The percentage retention of zinc during solar-drying, blanching, and cooking, treatments was 98.8% 95.5%, and 91.3%, respectively while 86.1% and 80.5% of the mineral were retained in un-blanched solar dried cooked (UBSCL) samples and
blanched solar-dried cooked (BSCL) samples respectively. β-carotene retention was high at 99.3% and 101.7% during the respective heat treatments (blanching and cooking) but dropped to 78.5% during solar drying. Un-blanched solar-dried cooked (UBSCL) pumpkin leaves had retention of 79.8% β-carotene while the blanched solar-dried cooked (BSCL) samples retained 91.9% of β-carotene. The retention of vitamin C in blanched, cooked, and solar-dried pumpkin leaves was 50.9%, 39.8%, and 59.8% respectively. Un-blanched solar-dried cooked (UBSCL) samples retained 31.7% while blanched solar-dried cooked leaves (BSCL) retained 29.7% of vitamin C.
Table 4.7 Effect of Solar-drying, Blanching, and Cooking Treatments on Nutrient Retention in Pumpkin Leaves

*Values in parenthesis indicate the percent of nutrient retention in treated samples relative to fresh samples*

<table>
<thead>
<tr>
<th>Sample</th>
<th>Nutrient content (mg/100g dw)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FL</td>
<td>Iron 3.307±0.055 (100)</td>
</tr>
<tr>
<td>BL</td>
<td>Iron 3.158±0.037 (95.5)</td>
</tr>
<tr>
<td>UBCL</td>
<td>Iron 3.021±0.555 (91.3)</td>
</tr>
<tr>
<td>BCL</td>
<td>Iron 2.942±0.024 (88.4)</td>
</tr>
<tr>
<td>UBSL</td>
<td>Iron 3.266±0.035 (98.8)</td>
</tr>
<tr>
<td>BSL</td>
<td>Iron 3.141±0.069 (95.0)</td>
</tr>
<tr>
<td>UBSCL</td>
<td>Iron 2.847±0.016 (86.1)</td>
</tr>
<tr>
<td>BSCL</td>
<td>Iron 2.662±0.016 (80.5)</td>
</tr>
</tbody>
</table>

Key: **FL** = fresh leaves  **BL** = blanched leaves  **UBCL** = un-blanched cooked leaves  **BCL** = blanched cooked leaves  **UBSL** = un-blanched solar-dried leaves  **BSL** = blanched solar-dried leaves  **UBSCL** = un-blanched solar-dried cooked leaves  **BSCL** = blanched solar-dried cooked leaves
4.5.2 Effects of Solar-drying, Blanching, and Cooking on Nutrient Retention in Fig-leaf gourd

As shown in Table 4.8, iron retention in fig-leaf gourd was high during all the three processing treatments (solar-drying, blanching, and cooking) with retention of over 99%. Higher zinc retention was realized during solar drying (99.7%) as compared to blanching (94.9%) and cooking (93.8%) treatments. Ultimate zinc retention in un-blanched solar-dried cooked (UBSCL) and blanched solar dried cooked (BSCL) fig-leaf gourd was 91.4% and 83.4% respectively. The heat treatments had enhanced the β-carotene contents of fig-leaf gourd samples with retentions of 103.7% and 107.2% during blanching (BL) and cooking (UBCL) respectively while 82.8% of β-carotene was retained during solar drying treatment (UBSL). Un-blanched solar dried cooked (UBSCL) and blanched solar dried cooked (BSCL) fig-leaf gourd samples retained 83.5% and 89.1% of β-carotene. All the processing treatments resulted in major losses of vitamin C with about half of the vitamin retained during blanching (BL) (53.3%) and cooking (UBCL) (40.1%). Seventy two percent of the vitamin was retained during solar drying (UBSL). Low retentions of 39.8% and 35.6% vitamin C were achieved in un-blanched solar-dried cooked (UBSCL) and blanched solar-dried cooked (BSCL) fig-leaf gourd samples respectively.
Table 4.8 Effects of Solar-drying, Blanching, and Cooking on Nutrient Retention in Fig-leaf gourd

Values in parenthesis indicate the percent of nutrient retention in treated samples relative to fresh samples

<table>
<thead>
<tr>
<th>Sample</th>
<th>Iron</th>
<th>Zinc</th>
<th>β-carotene</th>
<th>Vitamin C</th>
</tr>
</thead>
<tbody>
<tr>
<td>FL</td>
<td>25.381±0.064 (100)</td>
<td>5.505±0.076 (100)</td>
<td>18.46±0.033 (100)</td>
<td>122.585±0.093 (100)</td>
</tr>
<tr>
<td>BL</td>
<td>25.246±0.204 (99.5)</td>
<td>5.225±0.021 (94.9)</td>
<td>19.14±0.010 (103.7)</td>
<td>65.379±1.188 (53.3)</td>
</tr>
<tr>
<td>UBCL</td>
<td>25.168±0.041 (99.2)</td>
<td>5.165±0.025 (93.8)</td>
<td>19.78±0.008 (107.2)</td>
<td>49.215±0.253 (40.1)</td>
</tr>
<tr>
<td>BCL</td>
<td>25.135±0.068 (99.0)</td>
<td>4.882±0.028 (88.7)</td>
<td>20.13±0.039 (109.0)</td>
<td>46.704±0.460 (38.1)</td>
</tr>
<tr>
<td>UBSL</td>
<td>25.269±0.079 (99.5)</td>
<td>5.487±0.012 (99.7)</td>
<td>15.29±0.006 (82.8)</td>
<td>88.525±0.683 (72.2)</td>
</tr>
<tr>
<td>BSL</td>
<td>25.138±0.035 (99.0)</td>
<td>5.198±0.037 (94.4)</td>
<td>16.63±0.000 (90.1)</td>
<td>59.690±0.924 (48.7)</td>
</tr>
<tr>
<td>UBSCL</td>
<td>25.148±0.170 (99.1)</td>
<td>5.032±0.029 (91.4)</td>
<td>15.42±0.01 (83.5)</td>
<td>48.743±0.063 (39.8)</td>
</tr>
<tr>
<td>BSCL</td>
<td>25.090±0.317 (98.9)</td>
<td>4.593±0.028 (83.4)</td>
<td>16.44±0.015 (89.1)</td>
<td>43.634±1.093 (35.6)</td>
</tr>
</tbody>
</table>

Key:  FL = fresh leaves  BL = blanched leaves  UBCL = un-blanched cooked leaves  BCL = blanched cooked leaves  UBSL = un-blanched solar-dried leaves  BSL = blanched solar-dried leaves  UBSCL = un-blanched solar-dried cooked leaves  BSCL = blanched solar-dried cooked leaves
4.5.3 Effects of Solar-drying, Blanching, and Cooking Treatments on Nutrient Retention in Stinging Nettle Leaves

Table 4.9 summarizes the percent nutrient retention during various processing treatment of stinging nettle leaves. Iron retention in stinging nettle leaves was 99.4%, 96.0%, and 94.6% during solar-drying (UBSL), blanching (BL), and cooking (UBCL), treatments respectively. Un-blanched solar-dried cooked (UBSCL) and blanched solar-dried cooked (BSCL) samples retained 94.7% and 93.5% of the iron respectively. Retention of zinc was high (99.1%) during solar-drying (UBSL) but comparatively lower during blanching (BL) (91.5%) and cooking (UBCL) (87.2%) treatments.

Appreciably lower percent zinc was retained in blanched solar-dried cooked (BSCL) samples (85.0%) than in un-blanched solar-dried cooked (UBSCL) stinging nettle samples (94.4%). High percent retention of β-carotene was realized during the both heat treatments i.e. blanching (BL) (99.9%) and cooking (UBCL) (99.7%). Solar-drying (UBSL) however resulted in lower retention (71.1%) of β-carotene. About 69.21% and 71.46% of β-carotene was retained in un-blanched solar-dried cooked (UBSCL) samples and blanched solar-dried cooked (BSCL) samples respectively. Just over half (52.5%) of the initial vitamin C content was retained in blanched (BL) stinging nettle leaves with even lower percentage (45.4%) retained in cooked (UBCL) samples. Solar-dried (UBSL) samples had comparatively better retention (61.1%) of the vitamin C. Less than 40% of the initial vitamin C content was retained in un-blanched solar-dried cooked (UBSCL) samples (31.7%) and blanched solar-dried cooked (BSCL) samples (28.7%).
Table 4.9 Effects of Solar-drying, Blanching, and Cooking Treatments on Nutrient Retention in Stinging Nettle Leaves

*Values in parenthesis indicate the percent of nutrient retention in treated samples relative to fresh samples*

<table>
<thead>
<tr>
<th>Sample</th>
<th>Nutrient content per 100g dw</th>
<th>Nutrient</th>
<th>FL</th>
<th>BL</th>
<th>UBCL</th>
<th>BCL</th>
<th>UBSL</th>
<th>BSL</th>
<th>UBSCL</th>
<th>BSCL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Iron</td>
<td>13.935±0.138 (100)</td>
<td>13.383±0.059 (96.0)</td>
<td>13.181±0.035 (94.6)</td>
<td>13.053±0.020 (93.7)</td>
<td>13.857±0.051 (99.4)</td>
<td>13.367±0.036 (95.9)</td>
<td>13.203±0.062 (94.7)</td>
<td>13.027±0.017 (93.5)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Zinc</td>
<td>2.086±0.041 (100)</td>
<td>1.909±0.012 (91.5)</td>
<td>1.820±0.004 (87.2)</td>
<td>1.752±0.012 (84.0)</td>
<td>2.067±0.044 (99.1)</td>
<td>1.826±0.023 (87.5)</td>
<td>1.969±0.025 (94.4)</td>
<td>1.774±0.005 (85.0)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>β-carotene</td>
<td>34.69±1.43(100)</td>
<td>34.65±0.65(99.9)</td>
<td>34.59±0.58(99.7)</td>
<td>30.89±2.95(89.1)</td>
<td>24.66±1.69(71.1)</td>
<td>23.06±2.27(66.5)</td>
<td>24.01±1.92(69.2)</td>
<td>24.79±0.57(71.5)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Vitamin C</td>
<td>228.6±0.18 (100)</td>
<td>120.12±0.16 (52.5)</td>
<td>103.94±0.06 (45.4)</td>
<td>78.89±0.08 (34.5)</td>
<td>139.62±0.12 (61.1)</td>
<td>87.56±0.10 (38.3)</td>
<td>72.50±0.06 (31.7)</td>
<td>65.63±0.09 (28.7)</td>
</tr>
<tr>
<td></td>
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<td></td>
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<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Key:  
FL = fresh leaves  
BL = blanched leaves  
UBCL = un-blanched cooked leaves  
BCL = blanched cooked leaves  
UBSL = un-blanched Solar-dried leaves  
BSL = blanched solar-dried leaves  
UBSCL = un-blanched solar-dried cooked leaves  
BSCL = blanched solar-dried Cooked leaves
4.6 Sensory Evaluation

4.6.1 Effects of Solar-drying and Cooking Treatments on the Sensory Acceptability of Selected ALVs

4.6.1.1 Pumpkin leaves

Sensory evaluation of different treated vegetables samples was carried out using 9-point hedonic scale to determine their acceptability with values ranging from 9 for dislike extremely to 1 for like extremely.

Sensory evaluation of cooked samples showed that there was significant (p<0.05) difference between the sensory rating of fresh cooked and that of solar-dried cooked pumpkin leaves with regard to all the sensory attributes: the cooked solar-dried leaves were found to be organoleptically less acceptable compared to fresh cooked pumpkin leaves. Panelists expressed a slight dislike (score of 6.03) in their overall sensory rating of the samples as shown in Table 4.10.

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Sensory scores</th>
<th>t-test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fresh cooked</td>
<td>Solar-dried cooked</td>
</tr>
<tr>
<td>Colour</td>
<td>2.03 ± 0.85</td>
<td>3.70 ± 1.54</td>
</tr>
<tr>
<td>Taste</td>
<td>1.63 ± 0.72</td>
<td>6.30 ± 1.93</td>
</tr>
<tr>
<td>Aroma</td>
<td>2.37 ± 1.03</td>
<td>4.93 ± 2.07</td>
</tr>
<tr>
<td>Mouth-feel</td>
<td>2.10 ± 0.92</td>
<td>6.67 ± 2.04</td>
</tr>
<tr>
<td>Overall acceptability</td>
<td>2.10 ± 0.67</td>
<td>6.03 ± 1.87</td>
</tr>
</tbody>
</table>
4.6.1.2 Fig-leaf gourd

As shown in Table 4.11, solar-dried cooked fig-leaf gourd samples were found to be significantly less acceptable (p < 0.05) than the fresh cooked samples with regard to all the sensory attributes under investigation. The overall acceptability of the solar-dried fig–leaf gourd was given a score of 5.33 (neither like nor dislike).

Table 4.11 Mean sensory scores between cooked fresh and cooked solar-dried fig-leaf gourd leaves

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Sensory scores</th>
<th>Comparison (t-test)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fresh cooked</td>
<td>Solar-dried cooked</td>
</tr>
<tr>
<td>Colour</td>
<td>2.40 ±1.40</td>
<td>3.50 ± 1.83</td>
</tr>
<tr>
<td>Taste</td>
<td>2.93 ± 1.48</td>
<td>5.40 ± 2.40</td>
</tr>
<tr>
<td>Aroma</td>
<td>3.40 ±1.67</td>
<td>4.90 ± 1.83</td>
</tr>
<tr>
<td>Mouth-feel</td>
<td>3.10 ± 1.52</td>
<td>5.77 ± 2.50</td>
</tr>
<tr>
<td>Overall acceptability</td>
<td>2.70 ± 1.21</td>
<td>5.33 ± 2.34</td>
</tr>
</tbody>
</table>

4.6.1.3 Stinging Nettle

Solar-dried cooked stinging nettle leaves had better sensory rating than fresh cooked samples with regard to all the sensory attributes except color. However, the differences in sensory rating were not statistically significant (p > 0.05). The overall sensory acceptability of the solar-dried leaves was given a score of 4.4 (slightly like).

Table 4.12.
Table 4.12 Comparison of mean sensory scores between cooked fresh and cooked solar-dried stinging nettle leaves samples

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Sensory scores</th>
<th>t-test</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fresh cooked</td>
<td>Solar-dried cooked</td>
<td>df</td>
</tr>
<tr>
<td>Color</td>
<td>2.93 ± 1.70</td>
<td>3.20 ± 1.56</td>
<td>58</td>
</tr>
<tr>
<td>Taste</td>
<td>4.97 ± 2.50</td>
<td>4.17 ± 1.58</td>
<td>48.966</td>
</tr>
<tr>
<td>Aroma</td>
<td>4.93 ± 2.21</td>
<td>4.07 ± 1.80</td>
<td>58</td>
</tr>
<tr>
<td>Mouth-feel</td>
<td>5.13 ± 2.35</td>
<td>4.57 ± 1.68</td>
<td>52.481</td>
</tr>
<tr>
<td>Overall acceptability</td>
<td>4.93 ± 2.24</td>
<td>4.40 ± 1.55</td>
<td>51.461</td>
</tr>
</tbody>
</table>

4.6.2 Comparison of sensory scores of the three types of vegetables

Computation of the sensory mean scores for the three fresh cooked vegetables showed that pumpkin leaves had the best overall acceptability score (2.10 ± 0.66), while stinging nettle leaves had the highest mean score (poorest rating) in overall acceptability (4.93 ± 2.24). Conversely, among the solar-dried cooked samples, stinging nettle leaves had the lowest mean score (best rating) compared to the other two vegetables under study. Table 4.13 and 4.14 show the results of anova test for the three vegetables under two different treatments: Initial Anova results showed significant differences in the sensory ratings of the three vegetables. A posthoc test of LSD used to separate the means revealed that for fresh cooked samples stinging nettle leaves had significantly poorer rating that pumpkin leaves and fig-leaf gourd whose overall acceptability rating did not differ significantly. For solar-dried cooked samples, stinging nettle leaves had significantly better rating for overall acceptability compared to pumpkin leaves.
Table 4.13 ANOVA test for sensory scores of cooked fresh samples of the three vegetables

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Mean sensory scores</th>
<th>ANOVA test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pumpkin leaves</td>
<td>Fig-leave gourd</td>
</tr>
<tr>
<td>Color</td>
<td>2.03 ± 0.85&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.40 ± 1.40&lt;sup&gt;ab&lt;/sup&gt;</td>
</tr>
<tr>
<td>Taste</td>
<td>1.63 ± 0.72&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.93 ± 1.48&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Aroma</td>
<td>2.37 ± 1.03&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.40 ± 1.67&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Mouth-feel</td>
<td>2.10 ± 0.92&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.10 ± 1.52&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Overall acceptability</td>
<td>2.10 ± 0.66&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.70 ± 1.21&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

N/B: Superscripts with different letters in the same row indicate significantly different values at p ≤ 0.05

Table 4.14 ANOVA Test for Sensory Scores of Cooked Solar-dried Samples of the three vegetables

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Mean sensory scores</th>
<th>ANOVA test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pumpkin leaves</td>
<td>Fig-leave gourd</td>
</tr>
<tr>
<td>Colour</td>
<td>3.70 ± 1.54&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.50 ± 1.83&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Taste</td>
<td>6.30 ± 1.93&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.40 ± 2.40&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Aroma</td>
<td>4.93 ± 2.07&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.90 ± 1.83&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Mouth-feel</td>
<td>6.67 ± 2.04&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.77 ± 2.50&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Overall acceptability</td>
<td>6.03 ± 1.87&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.33 ± 2.34&lt;sup&gt;ab&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

N/B: Superscripts with different letters in the same row indicate significantly different values at p ≤ 0.05
CHAPTER FIVE: DISCUSSION

5.1 Introduction

The concentration of Iron, Zinc, Ascorbic acid, and β-Carotene was analyzed in the three ALVs purchased from Kiambu markets in Kiambu County. Identification and quantification of Zinc and iron was carried out using Atomic Absorption Spectrophotometer while Ascorbic acid and β-Carotene were quantified and identified using high pressure liquid chromatography. These nutrients were quantified after extraction from samples subjected to solar-drying, blanching, and cooking treatments. Sensory evaluation of these selected ALVs was also tested on women of reproductive age purposively selected from Kiambu County. The concentration of these micronutrients is reported in mg/100g of dry weight while the result on sensory acceptability was given as either liked or disliked using a 9-point hedonic scale with 1 being highly liked and 9 being highly disliked. The results of the analyses are discussed in the following sections.

5.2 Nutrient Content of Fresh Vegetables

5.2.1 Vitamin C Content in Fresh Selected ALVs

Vitamin C content of fresh pumpkin leaves obtained in the study (118.73 mg/100g dw) is higher than those in the West African Food Composition Tables (114.58 mg/100g dw) but are lower than USDA values (154.49 mg/100g dw). Okpalamma, Ojimelukwe, and Mazi, (2013) reported Vitamin C content of 160.15 mg/100g dw in raw fluted pumpkin leaves.

The vitamin C content of fresh fig-leaf gourd was 122.59 mg/100g dw which is far below the one found by Vyankatrao, et al 2014 at 267mg/100g dw for the fresh Bitter guard vegetable sample during his study on effect of different drying methods. The
vitamin C content of fresh fig leaf gourd leaves obtained in the current study fall within the range of values reported for other African Leafy Vegetables including jute mallow (153.7mg/100g dw), slender leaf (92.8mg/100g dw), black nightshade (104.3mg/100g dw) and spinder plant (62.6mg/100g dw) (Gockowski, Mbazo’o, Mbah, & Moulende, 2003; Gupta, Lakshmi, Manjunath, & Prakash, 2005; Patrick Maundu, Achigan-Dako, & Morimoto, 2009)

The current study results of vitamin C of fresh stinging nettle (228.60 mg/100g dw) are on the higher when compared with values of 22.0 mg/100g dw reported by Mahlangeni, Moodley, and Jonnalagadda (2016) and those in the KFCTs (25.0 mg/100g dw) Bhattarai, Tharpaliya, and Khadka, (2017) reported a content of 28.6 mg/100g dw in stinging nettle shoots (Urtica plaviflora) which are still on the lower as those of the current study. Shonte (2017) reported a value of 83.8 mg/100g dw for vitamin C content in stinging nettle leaves. Ioana et al (2013) showed that the vitamin C content of stinging nettle leaves is influenced by the stage of maturity of the leaves with younger leaves having higher vitamin C content than more mature leaves. They obtained values ranging from 8.6mg/100g dw to 40.51 mg/100g dw for vitamin C content of Urtica dioica at different stages of leaf maturity.

The vitamin C contents of stinging nettle leaves reported by other authors range from 36 to 269 mg/100g dw (Guil-Guerrero, Rebolloso-Fuentes, & Isasa, 2003; Ioana, Viorica, Ilies, and Radulescu, 2013; Rutto, Xu, Ramirez, &Brandt, 2013; waheed-uz-zaman & rehman, 2013) . The difference in values obtained by different authors could be attributed by different level of maturity of the stinging nettle leaves as well as the ecological system where the stinging nettles are grown.
5.3.2 β-carotene Content in Fresh Pumpkin Leaves, Fig - leaf gourd and Stinging Nettle leaves.

The content of β-carotene of 25.86 mg/100g dw obtained for fresh pumpkin leaves in the current study compares well with those in the West African Food Composition Tables (23.95 mg/100g dw). However, according to the Kenya Food Composition tables fresh pumpkin leaves contains 13.35 mg/100g dw β-carotene which is way below the values obtained in the current study (Government of Kenya and Food and Agriculture Organization of the United Nations, 2018). According to Okon, Abraham, and Akpan, (2014), fresh pumpkin leaves have a content of 31.42 mg/100g dw of the vitamin

Current findings on β-carotene content of fresh stinging nettle leaves 34.69mg/100g dw) fall below the value of 44.16 mg/100g dw reported by Shonte (2017).β- Carotene content of the fresh fig- leaf gourd in this study was found to be 18.46mg/100g dw which is in the range of the values reported for pumpkin leaves due to the fact that they are both of the same family. Literature review did not yield any other studies that have previously determined the β-carotene content of fig- leaf gourd leaves.

5.3.3 Iron Content in Fresh Pumpkin Leaves, Fig – Leaf gourd and Stinging nettle leaves.

The iron content of 29.33mg/100g dw in fresh pumpkin leaves obtained in the current study corroborates with the values of 30.90 mg/100g dw posted in the USDA nutrient database (USDA, 2016) and 29.2 mg/100g dw reported by Gupta, Lakshmi, Manjunath, and Prakash (2005). It however falls below the values of 104.0 and 44.1 mg/100g dw reported by Okon, Abraham, and Akpan (2014) and the Kenya Food Composition Tables (2018) respectively. Furthermore it is higher than 7.4 ,10.9 mg/100g and 24.97 mg/100g dw reported by Maina and Mwangi (2008), Rutto, Xu,
Ramirez, and Brandt (2013) and Ifeoma (2014) respectively. The differences in the iron content of pumpkin leaves reported by various authors could be attributed to differences in the agronomical conditions such as soil fertility and differences in accuracy of analytical methods. High soil nutrient levels clearly influence the levels of iron in the leaves of pumpkins (Echessa, 2012). Thus, variation in trace elements in vegetables is influenced by their levels in the soil environment. Generally, mineral levels in crops can be affected by factors such as variety, time of harvest, climate, and soil conditions including fertilizer application (Peter, 2011).

A major gap in literature on the nutrient composition of fig-leaf gourd was noted in this study, an observation that is supported by McMullin, (2017). A study by Edeoga and Osugwu (2014) only reported the proximate content of leaves, seeds and pericarp. However, the content of the nutrient determined in the current study were found to be close to the values obtained for pumpkin leaves. This could be explained by the fact that the two vegetable species are members of the same family.

In the current study on the iron content of fresh stinging nettle leaves was found to be 13.935±0.138 mg/100g dw. These values are lower than those posted in the Kenya Food Composition Tables (36.0 mg/100g dw). In his study on sensory and nutritional properties of stinging nettle (Urtica dioica L.) leaves and leaf infusions, Shonte (2017) reported that iron content of 17.9 mg/100g in stinging nettle leaves. Among the factors influencing the mineral composition of leafy green vegetables, soil fertility or type and quality of fertilizer used is perhaps the most important. This could be the reason for the wide variation observed in some of the published data for leafy vegetable (Ifeoma, 2014). Literature revealed minimal research on the nutrient composition of stinging nettle leaves: Most studies involving stinging nettle had
focused on bio-active components as it relates to the neutraceutical value of the plant. (Namazi et al., 2003).

5.3.4 Zinc Content in Fresh Pumpkin Leaves, Fig – Leaf gourd and Stinging nettle leaves.

In the current study, the zinc content of fresh pumpkin leaves was observed to be 3.307±0.055 mg/100g dw which fall below values (4.13 and 7.1 mg/100 dw) reported by Gupta et al., (2005) and the Kenya Food Composition Tables (2018) respectively but above the value of 2.8 mg/100g dw contained in the USDA nutrient database. Data on the micronutrient composition of fig-leaf gourd was found to be severely lacking in published literature, an observation that in agreement with McMullin, (2017). A study by Edeoga and Osugwu, (2014) only reported the proximate content of leaves, seeds and pericarp. However, the nutrient content of fig-leaf gourd was, for all the components investigated found to be close to the values for pumpkin leaves. This could be explained due to the fact that the two vegetable species are members of the same family.

Current findings on the zinc of fresh stinging nettle leaves 2.086±0.041 mg/100g dw fall below those posted in the Kenya Food Composition Tables (KFCT) of 5.0 mg/100g dw.

5.4 Effects of Solar-drying, Blanching and Cooking Treatments on Retention of Nutrients

5.4.1 Effects of Solar-drying, Blanching and Cooking Treatments on the Retention of Vitamins in the selected ALVs

All the treatments applied to pumpkin leaves were found to significantly decrease the concentration of vitamin C, with blanching appearing to have the highest effect on
decreasing vitamin C content. Blanching alone decreased the vitamin C content to 50.9%. Other treatment combinations involving blanching i.e. blanching and cooking, blanching and solar drying, blanching solar drying and cooking further decreased the vitamin C content to 33.9%, 42.7% and 29.7% respectively. The effect of blanching on decrease of vitamin C content could have been due to leaching of the vitamin in the blanching water.

Cooking un-blanched pumpkin leaves retained more vitamin C (39.8%) than cooking blanched ones (33.9%). It was observed that the more the treatments involving heating were applied, the more vitamin C was lost with the combination of blanching, solar drying and cooking having the lowest (29.7%) retention of vitamin C.

A similar observation was made for vitamin C retention in fig leaf gourd and stinging nettle whereby all treatments combinations involving blanching resulted in higher losses of vitamin C compared to those treatments combinations that did not involve blanching. The highest vitamin C retention for the three vegetables was observed in leaves that were solar dried without blanching and cooking, an indication that leaching and exposure to high temperatures play significant role in degradation of Vitamin C in vegetables.

In the current study, treatment combinations that showed the highest beta carotene retention in pumpkin leaves were blanching (99.3%), cooking prior to blanching (101.7%) and blanching and cooking (103.9%). The same trend was also observed in fig leaf gourd. Previous studies have indicated that thermal treatment increases the beta carotene content of vegetables (Dietz & Erdman, 1989). This has been attributed to increase extractability of beta – carotene due to matrix disruption that occurs during heating.
In fig leaf gourd and pumpkin leaves that were solar dried or cooked prior to blanching, the retention of beta – carotene was lower. Un-blanching solar dried pumpkin leaves and fig leaf gourd leaves retained 78.5% and 82.8% beta – carotene respectively while un-blanching solar dried cooked (UBSCL) pumpkin and fig-leaf gourd leaves retained 79% and 83.5% beta – carotene respectively. This indicated that the blanching treatments enhanced beta – carotene retention during solar drying. This could be attributed to inactivation of endogenous beta – carotene degrading enzymes such as lipoxygenase by the blanching treatments.

In stinging nettle leaves, the highest beta – carotene retention was observed in samples subjected to blanching at (99.9%) and un-blanching cooked (99.7%) treatments. All the other treatments combination further decreased the beta–carotene content of stinging nettle leaves in the presence or absence of blanching as opposed to the observed benefit of increased beta–carotene retention after blanching of pumpkin leaves and fig gourd leaves. Blanching in combinations with other treatments i.e. (solar drying and cooking) did not seem to result in better beta–carotene retention in stinging nettle. This could be a pointer to differences in activities of endogenous enzymes and matrix composition.

5.4.2 Effects of Solar-drying, Blanching and Cooking Treatments on the Retention of Minerals (Iron and Zinc) in the selected ALVs

Current finding show that both blanching and cooking of pumpkin leaves had retention of (96.8%, 95.5%) and (95.5%, 91.3%) iron and zinc content respectively, a finding supported Mepba, Eboh, and Banigo, (2007). Blanched solar dried cooked leaves (BSCL) had the lowest retention of 91.5 % iron and 80.5% zinc respectively, while un-blanching solar dried leaves (UBSL) had the highest retention of iron and zinc in the pumpkin leaves at 98.8%. A similar trend was observed with fig–gourd
leaves with un-blanched solar dried leaves (UBSL) giving a higher retention of iron and zinc at 99.5% and 99.7% respectively. Stinging nettle had iron retention of over 92% in all method of treatment applied but significantly reduced in zinc retention to 84% in blanched cooked leaves (BCL).

According to USDA nutrient database, cooked pumpkin leaves contain 42.7 mg/100g and 10.7 mg/100g iron and zinc respectively which are higher than current findings of 28.01±0.09 mg/100g and 2.69±0.56 mg/100g iron and zinc respectively. The KFCTs report iron and zinc content of cooked (boiled and drained) pumpkin leaves to be 32.2 mg/100g dw and 5.29 mg/100g dw respectively which compare with current results. Okpalamma, Ojimelukwe, & Mazi, (2013) reported content of 8.05 mg/100g, 1.7 mg/100g, of iron and zinc, respectively in cooked fluted pumpkin leaves (fresh weight basis). Variations in results could be due to variations in cooking conditions e.g. the amount of cooking water used. Iron and zinc are relatively soluble and tend to leach into the cooking water. Iron (Fe) is required for hemoglobin formation and its deficiency leads to anemia. (Fai et al., 2013). It is also important as an integral part of the electron transport system in the body (Gupta, 2014)

Current retention in this study of 98.8% for both iron and zinc in pumpkin leaves in un-blanched solar dried (UBSL) respectively do not vary significantly from the fresh samples. Cooked samples of solar-dried pumpkin leaves (UBSCL) had iron and zinc retention of 92.5% and 86.1% respectively. Other studies have reported significant increases in the contents of iron and zinc during the drying of particular vegetables including Moringa oleifera and carrots leaves (James & Matemu, 2016).

Heat treatment (blanching or cooking) led to significant decreases in the content of iron and zinc in fig- leaf gourd and the extent of change appear to be varied. This
would depend on the nature and method of heat treatment e.g. time-temperature-water conditions of heat treatments. The results indicate that solar drying does not cause significant increases in the mineral content of the Fig-leaf gourd with over 98% retention. Further cooking of the solar-dried sample did not significantly reduce the iron content of the vegetable.

Mahlangeni et al., (2016) reported iron and zinc contents in cooked stinging nettle leaves to be 31.9 mg/100g dw and 2.6 mg/100g dw respectively which are higher than current findings of 13.181±0.035 and 1.820±0.004 for iron and zinc respectively. The content of minerals in cooked samples would partly depend on their contents in raw samples.

According to current study results, un-blanched solar-dried stinging nettle leaves had the highest retention 99.4% and 99.1% of iron and zinc respectively which do not differ significantly from the contents in the fresh samples. Cooking of the solar dried samples, however significantly reduced the contents of the minerals to 94.6% and 87.2% of iron and zinc respectively. This could probably be due to their leaching in the cooking water.

5.5 Comparison of the retention of nutrients in the selected ALVs subjected to Solar-drying, Blanching and Cooking treatments

5.5.1 Retention of Minerals (Iron and Zinc) in treated vegetables

Fig-gourd leaves had iron retention of 99.5% which was the highest compared to pumpkin leaves 96.8% and stinging nettle 96% after blanching the vegetable samples for 5 minutes at 100°C. A study by Njoroge et al (2015) reported iron retention of 90% in tender leaf when blanched at 80°C for 10 minutes results that are much lower
compared with the current study hence the time and temperature used during blanching could have been the cause of the disparity.

There are four major types of blanching i.e. steam, water, gas and microwave blanching. Blanching is the process of removing air in the product prior to canning, destroy the enzymatic activity and also to fix the colour in the food product (De Corcuera et al., 2004). Blanching also involves interaction of leaves with hot water which may rupture the cell wall thereby allowing soluble minerals to leach out into blanching water. This leaching could account for the losses incurred in the blanched leaves (Rajeswari, Bharati, Naik, & Naganur 2013). In the current study, water blanching was investigated on three ALVs to determine its effect on retention of nutrient content. The retention of iron in water blanched samples as obtained by current study was high (> 95%) for all the three vegetables. Similarly zinc retention in blanched samples was high (> 91%) in all the three vegetables.

The retention of iron in cooked samples was high (>94%) in all the three vegetable. While zinc retention was above 91% in pumpkin leaves and fig-leaf gourd and 87.2% on cooked stinging nettle, leaves. These values compare favorably with the retention values of 100% posted in the KFCTs for both iron and zinc in stewed leafy vegetables. However, lower retention values of 75% for both iron and zinc are given in both the KFCTs and WAFCTs for boiled vegetables. Mwanri, Kogi-Makau, and Laswai (2011) found iron retention in cooked sweet potato leaves to be 98.0% which further corroborates the current results. The results presented in this report are in agreement with those of Rutto et al. (2013) who reported that *U. dioica* retains significant amounts of minerals, vitamins, and other functional values after blanching or cooking and recommended processing and selling of *U. dioica* leaf as a highly
functional and nutritive food. Mziray (1999) however, reported iron retention of 64.3% in cooked drained amaranth leaves. He attributed the losses to leaching in cooking water. Retention of mineral in cooked vegetables is dependent on the cooking method for instance steaming and stewing leads to higher retention than boiling while cooking in dry heat results in best retentions due minimal losses through leaching (Khachik et al., 1992).

Current results show that solar drying did not have any significant effect on the mineral contents of the vegetables. There was high retention of over 98% for both iron and zinc in all the three vegetables. Other researchers have similarly reported high retentions of the minerals in solar-dried vegetables not subjected to other treatments (Mwanri et al., 2011; Stanley, Margaret, Ambuko, & Owino, 2017). As pointed out by Rajeswari et al., (2013) and Stanley et al.,(2017), dehydration of vegetables generally does not significantly affect the total mineral content or the contents of the individual specific mineral.

5.5.2 Retention of Vitamins (β-carotene and Vitamin C)

In the current study, the retention of β-carotene in all the three vegetables was high during both blanching and cooking treatments with over 100% retention observed in heat treatment of fig- leaf gourd and pumpkin leaves. Other studies have also reported a percent retention of β-carotene above 100%: Okpalamama, Ojimelukwe & Mazi, (2013) reported a high β-carotene retention of 230.76% in cooked fluted pumpkin leaves, *Telferia occidentalis*. Mziray (1999) reported β-carotene retention of 104% in cooked amaranth leaves.

 Blanching which is a short heat treatment can lead to loss of carotenoids although inactivation of oxidative enzymes can minimize loss before, during, and after thermal
processing. Contradictory reports indicating substantial loss to little or no loss and an increase in the amount of β-carotene levels in the processed foods due to blanching are available in the literature. Namitha & Negi (2010); Chandler and Schwartz, (1988); Khachik, et al. (1986); Speek, et al ( 1988); Nagra & Khan, (1989) have shown substantial loss of β-carotene during blanching while Godoy and Rodriguez-Amaya, (1987) and Khachik et al., (1992) reported little or no change in β-carotene levels. Gomez (1981) reported an increase in β-carotene levels. From the results reported by a number of studies, carotenoids in blanched and cooked vegetables appear to be relatively unaffected by heat processing (Imungi & Potter, 1983; Lee, Massey, & Van Buren, 1982).

Previous studies have shown that heat treatment enhances the bioavailability of carotenoids. Cooking process breaks down the food matrices and loosens the carotene-binding fibers, leading to nutrient loss; however, the bioavailability and sometimes even the carotene content can increase (Carvalho et al., 2014). As explained by Dietz and Erdman (1989), cooking results in greater than 100% retention of β-carotene in vegetables, because denaturation of carotene binding proteins releases the carotenoids so that they can be extracted more easily. According to Imungi & Potter, (1983) the increase in beta-carotene contents during cooking could be attributed to losses in soluble solids through leaching into the cooking water, so that when expressed on dry matter basis, the beta-carotene which remains unaltered by cooking shows an apparent increase. The results of the current study agree quite well with reports by Lee et al. (1982) and (Imungi & Potter, 1983) that carotenoids in blanched and canned leafy vegetables appeared to be relatively unaffected by heat processing.
A high loss of Vitamin C was observed during water blanching and cooking in all the three vegetables. The retention of the vitamin during water blanching was 50.9%, 53.3%, and 52.5% in pumpkin leaves, fig-leaf gourd, and stinging nettle respectively. Bhattarai, Tharpaliya, & Khadka, (2017) have reported 38.7% loss of vitamin C during water blanching of stinging nettle leaves which corroborate the current results. Blanching is a prerequisite for preservation of green leafy vegetables. It is aimed at inactivating enzymes to prevent enzymatic browning and nutrients oxidation, sterilizing vegetables, structural softening to facilitate moisture removal during drying and evaporating herb like flavours (James & Matemu, 2016). However, it may cause partial degradation of vitamins such as ascorbic acid. Blanching conditions (time and temperature) need to be monitored to achieve the desired quality of dried products (Gupta, Gowri, Lakshmi, & Prakash, 2013; Negi & Roy, 2000).

A study by (Guiamba et al., 2018) reported that the vitamin C content of water blanched samples of green beans were higher than the vitamin C of those that were steam blanched. Water blanching usually results in a more uniform treatment allowing for a lower processing temperatures as compared with steam blanching which is more energy efficient and produces biological oxygen demand (Corcuera et al., 2004).

During cooking, 39.8%, 40.1% and 45.4% of the vitamin C was retained in pumpkin leaves, fig-leaf gourd and stinging nettle leaves respectively. Yuan, Sun, Yuan, & Wang, (2009) and Bhattarai et al (2017) also observed dramatic losses of vitamin C (33% and 38% respectively) in cooked vegetables. Mepba, Eboh, & Banigo (2007) reported cooking losses of vitamin C ranging between 64.3% and 67.5% among seven varieties of ALVs in Nigeria while blanching accounted for losses ranging between 44.8% and 47.1%. Mwanri, Kogi-Makau, & Laswai (2011) reported retention of 65%
vitamin C, in cooked sweet potato leaves. The magnitude of vitamin C loss in cooked vegetables has been shown to be greatly determined by the time-temperature combination (Njoroge et al., 2015). For retention of Vitamin C in cooked foods, it is recommended that foods containing Vitamin C be cooked as fast as possible with less heat and small amount of water (Singh & Harshal, 2016).

As pointed out by Gupta, Gowri, Lakshmi & Prakash, (2013), generally, vitamins are more prone to destruction on dehydration, relative to other components (minerals and proximate). In the current study the retention of β-carotene in pumpkin leaves, fig-leaf gourd and stinging nettle leaves subjected to solar drying alone was 78.5%, 82.8%, and 71.1% respectively while the retention of vitamin C in the three vegetables was 59.8%, 72.2%, and 61.1% respectively. The results for β-carotene retentions are corroborated by the findings of Chege, Kimiywe, & Nyambaka, (2014) who reported retentions of 77.5% for vitamin A, on solar drying of amaranth leaves while Stanley et al (2017) reported retentions of 68.02% for β-carotene during solar-drying of unblanched cow pea leaves. Carotene is degraded by free radical oxidation mechanism and the degree of oxidation depends on drying temperature (P. S. Negi & Roy, 2000b). A study by Kirakou et al. (2017) reported that cowpeas that were solar dried without blanching recorded the highest retention of 68.02% for beta carotene and 68.39% for ascorbic acid unlike in samples subjected to combination of blanching and solar drying which showed a retention of 52.78% and 20.24% for beta carotene and ascorbic acid respectively. The results are in contrast with those of the current study which showed that blanching combined with solar drying resulted in the highest retention at 89.8% and 90.1% for beta carotene unlike solar drying without blanching at 78.5% and 82.8% for pumpkin leaves and fig-leaf gourd respectively but close to the observation made in the current study on stinging nettle leaves which had a
retention of 71.1% for solar dried without blanching and 66.47% blanching with solar drying. Current results for ascorbic are in agreement with those of Kirakou et al. (2017) where by solar drying without blanching recorded the highest vitamin retention of 59.8% compared with 42.7% of blanched solar dried pumpkin leaves.

Stanley et al (2017) reported retentions 68.39% for ascorbic acid during solar-drying of un-blanched cow pea leaves which lie within the range of current findings. Bhattarai, Tharpaliya, & Khadka (2017) reported 50.24% loss of the vitamin C during oven drying of stinging nettle leaves. Mwanri, Kogi-Makau, & Laswai (2011) reported retentions of 15% for vitamin C in sundried sweet potato leaves. The observed high loss of vitamin C during sun drying as compared to other drying methods may be due to the sensitivity of vitamin C to atmospheric conditions such as oxygen, light and temperature which induce its oxidation (Bhosale & Arya, 2010). As observed by Chege et al (2014) solar drying of vegetables has been found to have a higher retention of micronutrients and color than sun drying. Drying in an appropriate solar drier leads to considerable reduction of drying time by up to 50% and a significant improvement in product quality in terms of color, texture, flavor, and nutrient retention (Mdziniso et al., 2006).

5.6 Sensory Evaluation

As similarly noted by Rajeswari et al (2013) consumer acceptance of the final product is a key consideration in the processing of food products. However nutritious a product may be, if not accepted by the target beneficiaries, the processing efforts might go into waste. In the current study cooked solar-dried vegetables were provided to a panel of 30 women of reproductive age for hedonic rating via-a-vis the corresponding fresh cooked samples. The organoleptic quality of pumpkin leaves and
fig-leaf guard leaves was significantly compromised by the solar drying treatment with their hedonic scores including overall acceptability being significantly higher (poorer sensory rating) in solar-dried cooked samples than in fresh cooked samples. Stanley et al (2017) similarly reported that fresh cow pea leaves had better sensory rating in all sensory attributes compared to solar dried leaves. The current results are in agreement with Mdziniso, Hinds, Bellmer, Brown, & Payton, (2006) who reported that the dehydration process affects, to varying degrees, the quality attributes of color, texture, and nutrient retention. Conversely, solar-drying treatment improved the sensory acceptability of stinging nettle leaves albeit insignificantly.

The best preserved sensory characteristic by solar drying was taste followed by aroma. Though fresh cooked samples had better scores, the color rating was maintained at the moderately acceptable range in the solar dried cooked samples in all the three vegetables while aroma rating stood at slightly acceptable range. Taste was the most sensitive attribute to solar-drying which while being compromised in Pumpkin Leaves and fig-leaf gourd was positively affected in stinging nettle leaves.

The sensory acceptance of solar-dried cooked stinging nettle leaves makes solar drying viable processing technique in ensuring the all year round availability of the vegetable. Better sensory rating for fresh cooked Pumpkin Leaves could be due to the fact that it is more commonly consumed by most people compared to stinging nettle leaves such that many of the panelists were already familiar with sensory characteristics. Sensory acceptance of new foods takes time and often require repeated exposure to the new food item (Nicklaus, 2016)
CHAPTER SIX: SUMMARY, CONCLUSION, AND RECOMMENDATION

6.1 Summary of the Finding

Fig-leaf gourd had the highest content of zinc while pumpkin leaves had superior iron content than the rest of the vegetables. Stinging nettle leaves had the highest β-carotene and vitamin C. Vitamin C is most sensitive to processing and was significantly reduced by each of the processing treatments in all the three vegetables. Heat treatment did not affect the β-carotene contents of the processed vegetables but significantly reduced the vitamin C content in all the three vegetables. While solar drying significantly reduced the β-carotene content of the vegetables.

Solar drying did not significantly affect the mineral content of the all vegetables; retention of both iron and zinc in solar-dried samples was high in all the three vegetables. However, solar drying had significant negative impact in the vitamin (both β-carotene and vitamin C) content of all the three vegetables. The retention of both of the minerals and vitamins particularly β-carotene in solar dried cooked vegetables was adequate to fulfill the daily dietary needs of the target group. Highest retention of nutrients during solar drying was seen in fig-leaf gourd followed by stinging nettle leaves. The minerals as well as β-carotene were best retained in fig-leaf gourd followed by pumpkin leaves during the heat processing while stinging nettle leaves had the best retention of vitamin C during heat processing.

Pumpkin leaves followed by fig-leaf gourd had the best sensory rating for the fresh cooked samples while Stinging nettle leaves followed by fig-leaf gourd had best sensory rating in solar-dried cooked samples. While in pumpkin leaves and fig-leaf gourd the fresh cooked samples were more organoleptically acceptable than the solar-dried cooked samples, the opposite was the case for stinging nettle leaves.
6.2 Conclusions

The three vegetables are good sources of important micronutrients (iron, zinc, β-carotene, and vitamin C) and could be of suitable use by women of reproductive age. The levels of nutrient retention after domestic processing support the inclusion of these vegetables in a daily diet to overcome deficiencies particularly in vitamin A, iron zinc. Vitamin C should also be supplemented in the diet as it is affected by solar-drying, blanching, and cooking.

For each of the three vegetables (Pumpkin Leaves, Fig-leaf gourd and Stinging nettle leaves), no significant differences were found in the content of iron and zinc between the fresh and solar-dried samples, Consequently, the first null hypothesis of the study was rejected

Significant differences were found to exist between the fresh and solar-dried samples with regard to both the β-carotene and vitamin C contents hence the second null hypothesis of the study failed to be rejected.

No significant differences in iron and vitamin C content were found between un-blanchned solar-dried cooked samples and blanchned solar-dried cooked samples of pumpkin leaves but significant difference in beta carotene and zinc was found in the same samples. With regard to all the nutrients investigated except β-carotene. Conversely, for fig-leaf gourd there was significant differences in nutrient content between un-blanchned solar-dried cooked samples and blanchned solar-dried cooked samples with regard to all the nutrients except iron. Furthermore, for stinging nettle leaves, significant differences existed in the nutrient content between un-blanchned solar-dried cooked samples and blanchned solar-dried cooked samples with regard to all the nutrients except β-carotene. These findings led to the consequent rejection of the third null hypothesis
While there were no significant differences in the mean hedonic scores between cooked fresh and cooked solar-dried stinging nettle leaves, the mean hedonic scores of cooked fresh samples were found to be significantly lower (better sensory rating) than those of the cooked solar-dried samples for both pumpkin leaves and fig-leaf gourd. The fourth null hypothesis was thus rejected since it did hold true for all the three vegetables.

The results of the present study indicate that solar drying with or without blanching is a viable means for preservation of green leafy vegetables. However, value addition through dehydration led to reduced nutrient contents, especially, ascorbic acid and beta carotene. The loss of the other iron and zinc was minimal.

6.3 Recommendations

6.3.1 Recommendation for Practice

- To encourage and popularization of solar-drying as a viable strategy to address seasonality gaps in the supply of the ALVs while ensuring retention of essential nutrients as well as improve postharvest handling and loss management

- Awareness campaigns on nutritional potential of ALVs particularly promotion of the consumption of underutilized species such as fig-leaf gourd and stinging nettle leaves for improved nutrition and health.

6.3.2 Recommendation for Policy

- The government should come up with agricultural policy incentives that will encourage the cultivation and utilization of ALVs particularly the underutilized species with potential to address nutritional challenges amongst
communities, successful promotion should result in ALVs forming part of the daily staple diet in Kenya.

6.3.3 Recommendation for Further Research

1. The study recommends an investigation of nutrient retention at different stages of vegetable maturity, storage temperatures, and the shelf-life of the solar-dried vegetables.

2. An investigation of changes in sensory acceptability at different stages in shelf-life of the solar dried vegetables is also recommended.
REFERENCES


Leaves and Its Product, the Leaf Curd. *IOSR Journal of Dental and Medical Sciences*, 13(9), 86–89. https://doi.org/10.9790/0853-13918689


Mavengahama, S. (2013). The contribution of indigenous vegetables to food security and nutrition within selected sites in South Africa [Stellenbosch University]. https://scholar.sun.ac.za/handle/10019.1/85565


Otieno, C. D. (2017). *Variation in levels of vitamins a and c with maturity of amaranthus hybridus (l) leaves grown in different soil-types in Kwale County, Kenya.*


Raneri, J., Padulosi, S., Meldrum, G., & King, O. I. (2019). *Promoting neglected and underutilized species to boost nutrition in LMICs.*


Appendix A: Informed Consent

My name is John Muniu Gachoya I am a Master student at Kenyatta University. I am conducting a study on “Nutrient Retention and Sensory Acceptability of Solar-Dried African Leafy Vegetables among Women of reproductive age in Kiambu County, Kenya” The information generated from this study will be used to support nutritional education programmes and seek to popularize the consumption of ALVs. The interview may require you to visit Kenyatta University Food and Nutrition Laboratory for sensory evaluation of the ALVs.

Benefits

If you participate in this study, you will help us to popularize the consumption of solar dried ALVs among women of reproductive age to improve their nutritional status.

Reward

If you agree to participate in this study, transport to Kenyatta University will be provided.

Confidentiality

The interviews and sensory evaluation of the ALVs will be conducted at Kenyatta University Food and Nutrition Laboratory and any information given will be treated with a lot of confidentiality. Your name will not be recorded on the questionnaire. The questionnaire will be kept in a locked cabinet for safekeeping at Kenyatta University. Everything will be kept private.
**Contact Information**

If you have any questions you may contact Prof Judith Kimywe on 0722915459 or Dr. Ann Munyaka on 0712108087 or the Kenyatta University Ethical Review Committee Secretariat on chairman.kuerc@ku.ac.ke, secretary.kuerc@ku.ac.ke, secretariat.kuerc@ku.ac.ke.

**Participant’s statement**

The above information regarding my participation in the study is clear to me. I have been given a chance to ask questions and my questions have been answered to my satisfaction. My participation in this study is voluntary. I understand that my records will be kept private and that I can leave the study at any time.

Name of Participant: ____________________________________________________________

_________________________ _______________________
Signature or Thumbprint Date

**Investigators Statement**

I, the undersigned, have explained to the volunteer in a language she understands the procedures to be followed in the study and the risks and benefits involved.

Name of interviewer: ____________________________________________________________

_________________________ _______________________
Signature or Thumbprint Date
## Appendix B: Nutrient Data Sheet

<table>
<thead>
<tr>
<th>Analyte (specify)</th>
<th>Sample No.</th>
<th>Fresh</th>
<th>Cooked fresh</th>
<th>Solar dried</th>
<th>Cooked Solar dried</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample vegetable</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pumpkin leaves</td>
<td>(Cucurbita maxima)</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mean</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fig-leaf Guard leaves</td>
<td>(Cucurbita ficifolia)</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
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<td></td>
</tr>
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<td></td>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mean</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stinging nettle</td>
<td>(Urtica dioica)</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td></td>
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</tr>
<tr>
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<td></td>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mean</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix C: Sensory Evaluation Questionnaire

Date -------------------------------- place -----------------------------time -----

Code number of panelist ------------------------------------------

Product code -----------------------------------------------

<table>
<thead>
<tr>
<th>Numerical score</th>
<th>Preference Rating</th>
<th>Scored Attribute</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>color</td>
<td>taste</td>
</tr>
<tr>
<td></td>
<td>aroma</td>
<td>Mouth feel</td>
</tr>
<tr>
<td></td>
<td>Overall acceptability</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Like extremely</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Like very much</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Like moderately</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Likely slightly</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Neither like nor dislike</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Dislike slightly</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Dislike moderately</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Dislike very much</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Dislike extremely</td>
<td></td>
</tr>
</tbody>
</table>
Appendix D: Flow diagram of sequences of different sample treatments

Pumpkin leaves, Fig – leaf Guard leaves and stinging nettle leaves randomly purchased from Local markets in Kiambu County

Washing in distilled Water

Blanching

Sub-sample: A Fresh Blanched

Nutrient Analysis

Sensory Evaluation

Sub-sample C: Fresh Blanched

Cook

Nutrient Analysis

Sub-sample B: Fresh Blanched

Solar Dry to constant MC

Cook

Nutritional Analysis

Sub-sample D: Fresh Unblanched

Nutrient Analysis

Solar Dry to constant MC

Cook

Cook

Nutrient analysis Sensory Evaluation
Appendix E: Chromatograph of Ascorbic acid standard

Appendix F: Chromatograph of Beta carotene standard
Appendix G: Zinc Standard Curve of Absorbance against Concentration

\[
y = 0.2342x - 0.0132 \\
R^2 = 0.9981
\]

Appendix H: Iron Standard Curve of Absorbance against Concentration

\[
y = 0.2723x - 0.0033 \\
R^2 = 0.999
\]
Appendix I: Beta- Carotene Standard Curve of Peak Area against Concentration

\[ y = 192251x - 1E+06 \]
\[ R^2 = 0.9894 \]

Appendix J: Ascorbic Acid Standard Curve of Peak Area against Concentration

\[ y = 186871x - 985867 \]
\[ R^2 = 0.993 \]
Appendix K: Nacosti Permit

THIS IS TO CERTIFY THAT:
MR. JOHN MUNIU GACHOYA
of KENYATTA UNIVERSITY, 0-200
NAIROBI, has been permitted to conduct
research in Kiambu County

on the topic: NUTRIENT RETENTION
AND SENSORY ACCEPTABILITY OF
SOLAR-DRYED AFRICAN LEAFY
VEGETABLES AMONG WOMEN OF
REPRODUCTIVE AGE, KIAMBU COUNTY,
KENYA

for the period ending:
8th February, 2019

[Signature]

Permit No: NACOSTI/P/18/62543/21148
Date Of Issue: 8th February, 2018
Fee Received: Ksh 1000

[Signature]

Director General
National Commission for Science, Technology & Innovation
Appendix L: Nacosti Research Authorization

Ref: NACOSTI/P/18/62543/21148

John Muniu Gachoya
Kenyatta University
P.O. Box 43844-00100
NAIROBI

RE: RESEARCH AUTHORIZATION

Following your application for authority to carry out research on “Nutrient retention and sensory acceptability of solar-dried African leafy vegetables among women of reproductive age, Kiambu County, Kenya,” I am pleased to inform you that you have been authorized to undertake research in Kiambu County for the period ending 8th February, 2019.

You are advised to report to the County Commissioner, the County Director of Education and the County Director of Health Services, Kiambu County before embarking on the research project.

Kindly note that, as an applicant who has been licensed under the Science, Technology and Innovation Act, 2013 to conduct research in Kenya, you shall deposit a copy of the final research report to the Commission within one year of completion. The soft copy of the same should be submitted through the Online Research Information System.

Godfrey P. Kalerwa
Godfrey P. Kalerwa MSc., MBA, MKIM
FOR: DIRECTOR-GENERAL/CEO

Copy to:
The County Commissioner
Kiambu County
Appendix M: Ethical Approval

KENYATTA UNIVERSITY
ETHICS REVIEW COMMITTEE

Fax: 8711242/8711575
Email: chairmain.kuerc@ku.ac.ke
secretary.kuerc@ku.ac.ke
Website: www.ku.ac.ke

Our Ref: KU/ERC/APPROVAL/VOL.1 (117) Date: 16th January, 2018

Gachooya John Munin
Kenyatta University
P.O. Box 43844-00100
NAIROBI.

Dear John,

APPLICATION NUMBER PKU/766/1834 “NUTRIENT RETENTION AND SENSORY ACCEPTABILITY OF SOLAR-DRIED AFRICAN LEAFY VEGETABLES AMONG WOMEN OF REPRODUCTIVE AGE, KIAMBU COUNTY, KENYA.”

1. IDENTIFICATION OF PROTOCOL

The application before the Committee is with a research topic Application Number PKU/766/1834 “Nutrient Retention and Sensory Acceptability of Solar-Dried African Leafy Vegetables among Women of Reproductive Age, Kiambu County, Kenya.” received on 8th November 2017 and discussed on 16th January, 2018.

2. APPLICANT

Gachooya John Munin

3. SITE

Kiambu County, Kenya

4. DECISION

The Committee has considered the research protocol in accordance with the Kenyatta University Research Policy (Section 7.2.1.3) and the Kenyatta University Review Committee Guidelines
AND APPROVED that the research may proceed for a period of ONE year from 16\textsuperscript{th} January 2018.

ADVICE/CONDITIONS
You must explain how the 30 women (page 14) will be selected from the women of reproductive age from Kiambu county.

In addition ensure that:

i. Progress reports are submitted to the KU-ERC every six months and a full report is submitted at the end of the study.

ii. Serious and unexpected adverse events related to the conduct of the study are reported to this committee immediately they occur.

iii. Notify the Kenyatta University Ethics Committee of any amendments to the protocol.

iv. Submit an electronic copy of the protocol to KUERC.

When replying, kindly quote the application number above.
If you accept the decision reached and advice and conditions given please sign in the space provided below and return to KU-ERC a copy of the letter.

\begin{center}
\includegraphics[width=0.5\textwidth]{signature.png}
\end{center}

DR. TITUS KAHIKA
CHAIRMAN ETHICS REVIEW COMMITTEE

\begin{quote}
GACHOYA MANYU JOHN accept the advice given and will fulfill the conditions therein.

Signature: \begin{flushright} John \end{flushright} Dated this day of 22 \textsuperscript{nd} January, 2018.
\end{quote}

C.c. DVC Research Innovation and Outreach
Appendix N: Kenyatta University Graduate school approval of research

Kenyatta University
GRADUATE SCHOOL

E-mail: dceu-graduate@ku.ac.ke
Website: www.ku.ac.ke

FROM: Dean, Graduate School
TO: John Gachoya M.
      C/o Food, Nutrition and Dietetics
      Department

DATE: 10th October, 2017
REF: H60/CTY/PT/29784/2014

SUBJECT: APPROVAL OF RESEARCH PROPOSAL

This is to inform you that Graduate School Board, at its meeting of 27th September, 2017 approved your Research Proposal for the M.Sc Degree Entitled, “Nutrient Retention and Sensory Acceptability of Solar-Dried African Leafy Vegetables among women of Reproductive Age, Kiambu County, Kenya”.

You may now proceed with data collection, subject to clearance with the Director General, Commission for Science, Technology & Innovation.

As you embark on your data collection, please note that you will be required to submit to Graduate School completed Supervision Tracking forms per semester. The form has been developed to replace the progress report forms. The supervision Tracking Forms are available at the University's website under Graduate School webpage downloads.

Thank you.

JULIA GITU
FOR DEAN, GRADUATE SCHOOL

c.c. Chairman, Department of Food, Nutrition and Dietetics

Supervisors:

1. Prof. Judith Kimiywe
   C/o Department of Food, Nutrition and Dietetics
   Kenyatta University

2. Dr. Ann Muyonja
   C/o Department of Food, Nutrition and Dietetics
   Kenyatta University
Appendix O: Photo Gallery

1. Researcher Extracting Beta carotene

2. Researcher operating Rotary Evaporator for beta carotene extraction
3.  Researcher changing HPLC Column

4.  Researcher inserting samples in the HPLC Auto – Sampler
5. Researcher setting the HPLC before analysis