MICRONUTRIENTS COMPOSITION OF SELECTED SUN-DRIED AND COOKED INDIGENOUS LEAFY VEGETABLES IN DODOMA, TANZANIA.

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ABSTRACT

Indigenous leafy vegetables are important in human diet as they supply a number of important nutrients for human health. A cross-sectional study was carried out at Chamwino District (Mzula and Chinoje villages), Dodoma to assess the effect of drying and cooking on nutrients composition of selected indigenous leafy vegetables. A total of 120 randomly selected participants were interviewed using pretested structured questionnaires with the main focus on vegetable production, processing and storage practices. For laboratory analysis, three commonly consumed varieties of indigenous leafy vegetables namely "Amaranthus" (*Amaranthus hybridus*), "Jute mallow" (*Corchorus olitorius L.*) and "Spider flower" (*Cleome gynadra L.*) were selected from each village and divided into three groups; uncooked (fresh) to serve as control samples, the dried-cooked samples and fresh-cooked samples. The samples were analysed for β-carotene by using Ultra Violet Visible Spectrophotometer; Vitamin C by titration method and minerals (iron, calcium and zinc) by Atomic flame emission Spectrophotometer. The results showed that the concentration of β-carotene in indigenous leafy vegetables ranges from 328 - 179 µg/ g, vitamin C (89 - 23 mg/100 g), iron (46 - 27 g/100 g), calcium (62 - 31 g/100 g) and zinc (45 - 13 g/100 g). Sun-drying and cooking had significant ($p<0.05$) impact in reduction of micronutrients in the selected vegetables. The β-carotene was reduced by 64% in sun-dried and by 90% in dried cooked vegetables; Vitamin C was reduced by 33% in sun-dried and by 64% in dried cooked; Iron was reduced by 34% in sun-dried and by 57% in cooked dried, calcium by 21% in sun-dried and by 65% in cooked dried. The highest percentage retention of β-carotene was seen in *Corchorus olitorius L.* (36%), Vitamin C in *Amaranthus hybridus L.* (67%), Zinc in *Amaranthus hybridus L.* (92%), Calcium in *Cleome gynadra L.* (79%) and Iron in *Amaranthus hybridus L.* (65%). The results from the present study

demonstrate that there is need to sensitize the community on suitable processing and preparation methods that minimize loss of micronutrients.

DECLARATION

I, Naamani John Mwaisenye, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work done within the period of registration and that it has neither been submitted nor being concurrently submitted in any other institution.

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Dr. R.J. Mongi   Date
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DEDICATION

I am dedicating this work to my late father Mr. John Iross Mwaisenye and late uncle Mr. Japhet Iross Mwaisenye and my mother Euodia Noah Mwaisenye who laid the foundation for my education and who shaped me into what I am today.

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LIST OF SYMBOLS AND ACRONYM

µg	microgram
ANOVA	Analysis of Variance
AOAC	Association of Official Agricultural Chemists
AVRDC	Asian Vegetable Research and Development
BP	Boiling Point
Ca	Calcium
C.I	Confidence Interval
CRBD	Complete Randomized Block Design
DFTNCS	Department of Food Technology, Nutrition and Consumer Sciences
ELVs	Exotic Leafy Vegetables
FAO	Food and Agriculture Organisation
Fe	Iron
g	gram
ILVs	Indigenous Leafy Vegetables
IPGRI	International Plant Genetic Resources Institute
mg	milligram
ml	millilitre
TFNC	Tanzania Food and Nutrition Center

nm	nanometer
NRI	Natural Resources Institute
^{o}C	Centigrade
SPSS	Statistical Package for the Social Science
SUA	Sokoine University of Agriculture
TCA	Trichloroacetic
UV	Ultra Violet
Zn	Zinc
α	Alpha
β	Beta
γ	Gamma

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Indigenous leafy vegetables are very important in human diet as they supply a number of nutrients important for normal health conditions (Grosso *et al.*, 2013; Gogo *et al.*, 2017a). Studies have shown that consumption of vegetables and fruits are associated with reduced risk of non-communicable diseases such as high blood pressure, diabetes mellitus and certain types of cancer (Kiremire *et al.*, 2010; Daramola *et al.*, 2016; Jimenez-Aguilar *et al.*, 2017).

In rural areas of Dodoma region, indigenous leafy vegetables are one of the major parts of diet that are used in different meals. However leafy vegetables are seasonal and highly perishable which are abundant shortly after the rainy seasons but become scarce during dry season (Gupta *et al.*, 2013). According to the Ministry of Agriculture, Food Security and Cooperatives (2009), post-harvest losses of vegetables in Tanzania is about 30-40%, hence processing treatments to prevent the losses is of greater importance.

The main physiological, physical and environmental causes of post-harvest losses include crop perishability, mechanical damage, excessive exposure to high ambient temperature, fungal and bacterial contamination, relative humidity, invasion by birds, rodents, insects and other pests and inappropriate handling, storage and processing techniques (World Bank *et al.*, 2011).

Drying has been used as one of the food preservation methods since ancient times which is intended to extend shelf life and availability of agricultural produces including indigenous vegetable (Mepba *et al*., 2007), whereby different techniques have been employed. Open sun drying is one of the reliable food preservation techniques, because it is simple, cheap and most common vegetable preservation method in rural areas in developing countries. Rural families have traditionally made conscious efforts to preserve these plants around their homesteads, in crop fields and communal lands (Chagomoka *et al*., 2013).

However, the quality of open sun dried vegetables is compromised due to physical, biological and environmental factors such as rain, radiations, oxygen, moisture, dust, insects, animals and human activities leading to change in nutritional and sensory qualities. For instance, studies have shown that some nutrients like vitamins A and C and sensory properties such as color and aroma of the dried vegetables are severely affected due to exposure to the sunlight (Mongi *et al*., 2015; Hussein *et al*., 2016).

Most vegetables are commonly cooked before being consumed. It is known that cooking induces significant changes in chemical composition, influencing the concentration and bioavailability of bioactive compounds in vegetables (*Cristiana et al., 2008*). Physical properties of vegetables are also affected by heat treatments. Texture and color are considered very important quality parameters of cooked vegetables, and may influence consumer acceptability and purchasing decision of these food items (Cristiana *et al*., 2008). However, cooking as a processing and preservation method for leafy vegetables in different countries vary according to culture and traditions. Depending on the type of vegetable, they can be cooked when dried or fresh or they can be stewed directly or mixed with other foods (Mwanri, 2011).

Recent studies have shown that proper selection of cooking method can enhance the availability of healthy nutrients in leafy vegetables (Dos *et al*., 2015; Bongoni *et al*., 2014 and Poelman *et al*., 2013). Furthermore, cooking time is also a major important factor, which influences the nutritional quality of indigenous vegetables (Poelman *et al*., 2013). Extensive thermal application may result into high losses of nutrient contents in indigenous vegetables. This study was conducted to determine the effect of these processing treatments (drying and cooking) on the nutritive properties of indigenous leafy vegetables in Chamwino district, Dodoma region.

1.2 Problem Statement and Justification of the Study

Vegetables play a key role in human diet and health because they contain nutritional and bioactive compounds. However, vegetables are seasonal and highly perishable resulting into both nutritional and economic losses especially in Sub-Saharan countries (Rwubatse *et al*., 2014).

Direct open sun drying method of preserving indigenous vegetables has been widely practiced since ancient time and it is still in use in developing countries due to the fact that advanced technologies for drying and preservation technologies such as freeze drying, mechanical industrial dryers and refrigeration are expensive or unavailable (William, 2009; Gogo *et al*., 2017b).

However, despite of the fact that sun drying method is simple, cheap and dries quickly, it is associated with shortcomings such as contamination by foreign materials such as dirt, dust and windblown debris and insect infestation as well as uneven drying (William, 2009).

In Dodoma region characterized with short rains where most of it (85%) fall between December and April (Sakai, 2012) as well as frequent famines caused by semi-arid natural conditions (Ndaga, 2012).

In Chamwino district, vegetables to be dried are placed on mats, roofs or the bare ground and exposed to direct sunlight which is detrimental to nutritional, sensory and safety qualities as previously reported by Kiremire *et al*., (2010). Consequently, this practice leads to deficiency of micronutrients such as vitamins and minerals in the diets of many people in the community who rely on plant based foods their main source of micronutrients (Musa and Ogbadoyi, 2012).

Most of the rural households are less concerned about nutritive value of indigenous vegetables and instead they are more interested in what they prefer most is sensory characteristic of vegetables (Mehmet *et al*., 2017). Inappropriate traditional cooking conditions have adverse effects in vegetables. They lead to destruction of their nutritive properties which in turn results into micronutrients deficiency particularly in rural areas (Mehmet *et al*., 2017). Hence, both inappropriate drying and cooking conditions ultimately double the magnitude of nutrients loss from the vegetables (Ojo *et al*., 2015).

Based on those circumstances, there is a need for a study to assess the effects of drying, cooking and storage techniques on the micronutrient composition of selected indigenous vegetables in Dodoma rural settings particularly in Chinoje and Mzula villages.

Results from this study will serve as basis for identification of the best processing technique which retains most of the nutrients and advice farmers and food processors on the proper ways of processing and preserving indigenous leafy vegetables for maximum utilization of available nutrients.

1.3 Objectives of the study

1.3.1 General Objective

To assess the effect of drying and cooking techniques on nutritional quality of selected indigenous leafy vegetables in Chamwino district, Dodoma region.

1.3.2 Specific Objectives

i. To examine the production, processing and storage practices of selected indigenous vegetables.

ii. To assess the economic and social importance of indigenous leafy vegetables.

iii. To determine the effect of drying and cooking on vitamins and minerals levels in selected of selected indigenous leafy vegetables.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction to Indigenous Leafy Vegetables

For purpose of this research study, indigenous leafy vegetables refers to vegetables species or a variety genuinely native to a region, or introduced into a region where over a period of time it has evolved, although the species may not be native. Bred vegetables are excluded from the definition of this study (Weinberger and Msuya, 2004). Indigenous leafy vegetables mostly are the edible, usually succulent parts of plant or portion of it consumed when cooked with a main dish or in a mixed dish (Mongi, 2013).

2.2 Green Leafy Vegetables

Green leafy vegetables; are rich in carotene (depending on the intensity of green coloration), are fair sources of protein and good sources of vitamins and minerals (Funke, 2011). Some contain anti-nutrients as reported by Raheena (2007) and Salawu and Akindahunsi (2005); like phytic acid, oxalates, pro-anthrocyanidin, tannin and dietary fibres that are claimed to interfere with nutrient absorption by reducing their bio-availability. Green leafy vegetables are the power-house of health promoting phytochemicals and can be used by the people of all ages and are useful to alleviate and combat many deficiency diseases (Saha *et al*., 2015).

Green leafy vegetables act as a buffer and maintain the proper alkalinity of the blood by balancing acid producing foods like meats and good sources of micronutrients including iron and calcium as well as vitamins A, C and E (Funke, 2011). For example amaranth, contains more of such nutrients compared to a typical exotic leafy vegetable like white cabbage (Tanzania Food and Nutrition Center, 2007).

Besides, they have numerous health potentials; for instance amaranth vegetables are eaten and used for protection against respiratory disorders, defective vision, recurrent colds, retarded growth and functional sterility (Henriques *et al.,* 2012). These vegetables have been at times recommended by doctors for people with low red blood cell count because vitamin C promotes iron absorption from the small intestine (Tanzania Food and Nutrition Center, 2007).

2.3 Description of selected ILVs

2.3.1 Jute Mallow (*Corchorus olitorius L.*)

As supported by Islam (2013), *C. olitorius* is an erect, stout, branched to 1.5 m high. Leaves lanceolate to ovate-lanceolate, subobtuse at base, serrate at margin with basal most serrations extending into filiform processes, acute at apex, petioles 2-3 cm long, pubescent; stipules subulate, 8-12 mm long, glabrous (Plate 1). The flowers are hermaphrodite, and are pollinated by insects. The flowers are small (2 - 3 cm diameter) and yellow, with five petals (Makinde *et al*., 2009). *Corchorus olitorius* was reported to be wild and grows on its own and consumed along with petiole when cooked (Choudhary *et al*., 2013).

Also known as jute mallow, *C. olitorius* belongs to the *Tiliaceae* family with oblong leaves that have serrated margins, distinct hair-like teeth at the base (Van Wyk and Gericke, 2000). Jute mallow (*C. olitorius*) prefers warm, humid conditions and performs well in areas with high rainfall and high temperature (30 °C during the day and 25 °C at night) (Rensburg *et al*., 2007).

Plate 1: Jute mallow (*C. olitorius L.*) [Source: Photo taken during field survey (2018)]

The leaves of this plant are simple and may have slightly serrated edges. When harvested young, are flavorful and tender; older leaves tend to be more woody and fibrous, making them less ideal for consumption (Islam, 2013).

When cooked, *C. olitorius* has a mucilaginous texture and in some African countries, bicarbonate of soda is added to the cooking water to reduce the sliminess (Rensburg *et al.*, 2007), while in East Africa, *C. olitorius* sometimes combined with other African leaves such as cowpea leaves because it is mere slimy when prepared on its own (Woomer and Imbumi, 2003).

2.3.2 Nutritional Potential

Nutritionally, *C. olitorius L.* is claimed to be rich in vitamins and minerals. The claims supported by laboratory analysis conducted in the current study which revealed that *C.olitorius L.* contains vitamin A and Vitamin C. The vitamin A was found to be 276.2 µg/ g from Mzula village and 247.3 µg/ g from Chinoje village while Vitamin C was found to be 89.3 mg/ 100g and 23.6 mg/ 100g from Mzula and Chinoje villages respectively. Zinc, Calcium and Iron were 45.4, 60.7 and 27.1 g/ 100g respectively from Mzula village while 39.4, 31.5 and 41.1 g/ 100g were from Chinoje village.

This study finds support the study done by Adebayo (2010), whereby it was observed that *C.olitorius* is a good source of micronutrients among them are Iron, Zinc (Zn), Calcium (Ca), vitamin A and Vitamin C.

2.3.3 Acquisition and Processing

Leaves form the edible part of the C*orchorus olitorius* plant. The major method of acquisition involves plucking, especially the tender ones (Islam, 2013). The vegetable is processed by drying in the sunlight, sometimes processed without washing to remove sand and dirt. The open sun-drying to a small extent results into loss of the greenish colour. The dried form of the vegetable is usually kept in a vessel for instance a pot (Rensburg *et al*., 2007). The desired amount is taken when needed and boiled/cooked following the normal cooking procedures.

2.4 Amaranths (*Amaranthus hybridus*)

2.4.1 Morphological Description

The study done by Akubugwo *et al*. (2007), reported that *Amaranthus hybridus* is an annual herbaceous plant, leaves are alternate petiole, 3 – 6 inches long, dull green, and rough, hairy, ovate or rhombic with wavy margins. The flowers are small, with greenish or red terminal panicles. Taproot is long, fleshy red or pink (Plate 2).

Plate 2: *Amaranths* (*A. hybridus*) [Source: Photo taken during field survey (2018)]

Amaranthus hybridus belongs to the family *Amaranthacae* (Akinnibosun and Adeola, 2015). The name 'amaranth' means ‘immortal’ or 'everlasting' in Greek (Mlakar *et al*., 2010) and its edible leaves and combined with condiments are used to prepare soup (Mepba, 2007). The leaves are cooked together with groundnut sauce when included in a meal (Akinnibosun and Adeola, 2015).

2.4.2 Nutritional Potential

It was reported that *A. hybridus L.* is one of the nutritious food and can be eaten alone as soup or mixed with other dishes. The vegetable contains a number of benefits to human health as it provides numerous micronutrients and anti-nutritional factors. The study done by Akubugwo (2011), revealed that *A. hybridus L.* contains minerals such as Zinc (Zn), Iron (Fe) , Magnesium (Mg), Potassium (K) and Calcium (Ca), also contains β- carotene and Ascorbic Acid. The study also showed high contents of anti-nutrients such as tannins and phytic acid.

2.4.3 Acquisition and Processing

Leaves form the edible part of the *Amaranthus hybridus* plant and sometimes stalks are mixed together when cooked. The major method of acquisition involves plucking, especially the tender ones. The vegetable is dried in a sunlight to remove moisture for longer use especially during a dry season (Akubugwo, 2011). The leaves with or without stalks are washed to remove sand and dirt. Then, leaves are spread on mats or floors for sun drying. The dried form of the *Amaranthus hybridus* vegetable; usually kept in a vessel for instance a pot and when needed, the desired amount is taken and cooked following the normal cooking procedures.

2.5 Spider flower (*Cleome gynadra L.*)

2.5.1 Morphological description

Spider flower (*Cleome gynadra L.*) is an erect, annual herb up to 250-600 mm tall; much branched and sometimes becomes woody with age. Leaves are palmate compound, with 3-5 leaflets. The leaf stalk is 20-50 mm long with glandular hairs (Mishra *et al*., 2011).

Plate 3: Spider flower (*C. gynadra*) [Source: Photo taken during field survey (2018)]

Cleome gynandra belongs to the botanical family Capparaceae (formerly Capparidaceae), subfamily *Cleomoideae*. The family contains about 700-800 species, divided into 45 genera (Mnzava and Ngwerume, 2004). *Cleome gynandra* is a common, widespread plant occurring in Northern Africa (Egypt), Western Africa (Cameroon), Central Africa (Angola), Eastern Africa (Tanzania), Middle East (Oman), Far East (Afghanistan) and Asia (India) (Mishra *et al*., 2011).

2.5.2 Nutritional Potential

Cleome gynadra L. leaves are delicious and nutritious and its tender leaves or young shoots are the ones consumed. It can be mixed with other leaves or cooked alone. The study done by Heever and Venter (2006), found that *C. gynadra* was rich in minerals (Calcium and Iron) and vitamins (Vitamin A and C) and found that boiling of *C. gynadra* reduces vitamin content by 81% while drying reduces by 95%.

2.5.3 Acquisition and Processing

Spider flower is harvested by uprooting and ratoon harvesting (Schippers, 2000; Asian Vegetable Research and Development, 2003). Leaves form the edible part of the *Cleome gynandra* and sometimes mixed with other leafy vegetables during cooking. The vegetable is dried form for longer use especially during off season period. The leaves without stalks are washed to remove sand and dirt. Then, leaves are spread on mats or floors for sun drying. Some amount is taken when needed for use in meal preparation.

2.6 Indigenous Leafy Vegetables (ILVs) versus Exotic Leafy Vegetables (ELVs)

Several studies have shown that the nutritional composition of wild plants revealed higher micronutrients levels than those found in most exotic species (Nesamvuni *et al.*, 2001; Odhav *etal., 2007*; Ndlovu and Afolayan, 2008). For example, International Plant Genetic Resources Institute, (2003) reported high mineral contents of *Amaranthus spp,* which contains 57 times more vitamin A, 13 times more iron and about 9 times more calcium than cabbage which is exotic. In a similar study, Ndlovu and Afolayan (2008), reported high contents of crude protein and magnesium in wild jute mallow (*Corchorus olitorius L.*) when compared with cabbage (*Brassica aoleracea*).

From the study done by Weinberger and Msuya, (2004), African spider flower (*Cleome gynandra L.*) had higher contents of iron than the commonly cultivated and consumed amaranth and pumpkin leaves. Several studies have indicated that leafy vegetables consumed in Africa contain higher level of micronutrient than those found in most exotic areas (Weinberger and Msuya, 2004; Steyn *et al*., 2001).

2.7 Nutrients and Micronutrients Contribution

Hunger and malnutrition threaten millions of people in sub-Saharan and the increase in consumption of indigenous leafy vegetables (ILVs) can have a positive effect on nutrition and health well-being of both rural and urban populations (Acho *et al*., 2015; Sowunmi, 2015). Vegetables contribute substantially to protein, minerals, vitamins, fiber and other nutrients which are usually in short supply in the daily diets (Ojo *et al.*, 2015). Consumption of indigenous leafy vegetable ensures the intake of various essential vitamins and mineral elements thus alleviating the problem of micronutrient deficiency (Kamga *et al.*, 2013).

2.8 Vegetable Drying

Vegetable drying has played a pivotal role in many societies in ensuring reliable supply of food during off season period. Drying is an important operation on vegetable processing and storage, because this step guarantees that the necessary moisture content for the product storage be reached. During the drying operation, physical, structural, chemical, nutritional changes in the vegetables may occur, and that can affect the quality attributes like texture, color, flavor and nutritional value of a vegetable product (Scala and Crapiste, 2008). The main purpose of drying is to remove moisture from foods, so as to prevent deterioration within a certain period of time (Bvenura and Dharini, 2017).

2.9 Effects of Drying on Quality of Indigenous Leafy Vegetables

Vegetables are very sensitive to oxygen, heat and uncontrolled direct sun drying. Such factors may cause degradation by oxidation, discoloration, shrinkage or loss of tissue and change of nutritional value (Ozgur *et al.*, 2011).

There are several factors that determine quality of product after processing. One of the main factor is the temperature under which the product is dried. This is because temperature has influence on the physiochemical composition which affects the final moisture content, nutritional composition, color and texture of a product (Gamboa-Santos *et al.,* 2014; Henriques *et al.,* 2012). Other factors include the type of processing technique that was applied and duration of exposure to the processing method. According to Giri and Prasad (2009) and Sagar and Suresh (2010), the quality of food in terms of flavor, color, texture, nutrient quality and microbiological safety is a key determinant of product acceptability by the consumers. Hence, it is critical to ensure that an acceptable level of quality in any processed food item is retained.

2.10 Effects of Boiling and Shallow Frying on Quality of Indigenous Leafy Vegetables

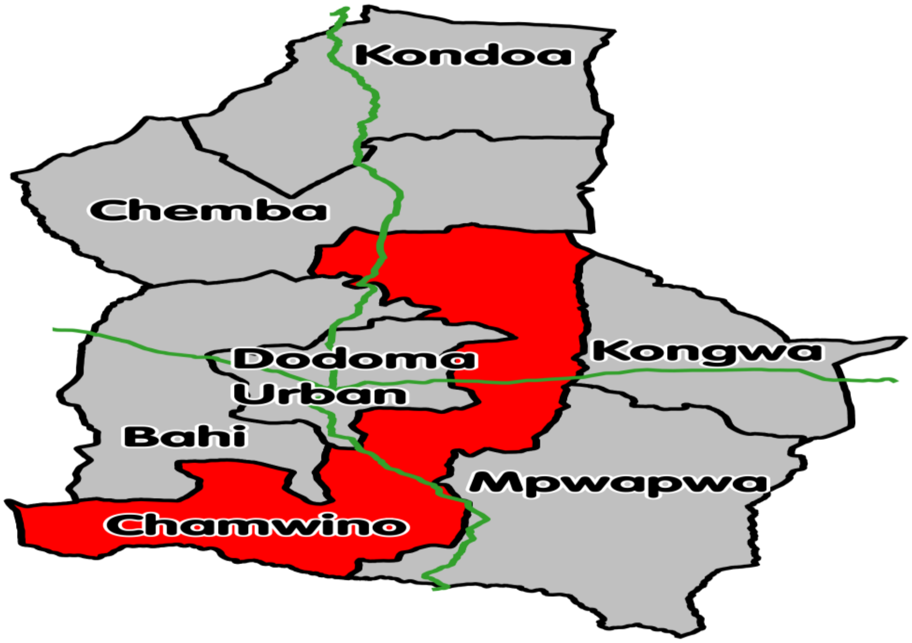
Boiling and shallow frying may cause changes in chemical, physical-chemical, nutritional and sensory aspects of vegetables (Ana *et al*., 2017). Studies have shown that cooking practices have profound effect on nutrient contents and quality of food consumed. Pro-vitamin A is best retained when the vegetables are boiled or steamed in water and iron and zinc are mostly preserved during cooking (with or without soaking in water) while Vitamin C is not retained through such cooking methods (Bechoff *et al*., 2017; Silvie *et al*., 2015).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study area

This study was carried out at Chamwino district (Mzula and Chinoje villages) in Dodoma. Chamwino district is among of seven districts of the Dodoma region of Tanzania (Plate 4). It is bordered to the North by Chemba district, to the East by Manyara region, Kongwa district and Mpwapwa district, to the South by Iringa region and to the West by Singida region, Bahi district and Dodoma district. Chamwino district lies on the coordinates 06^{0}05'55"S 36^{0}02'17"E. Sample collection, drying and cooking activities were done at the villages while laboratory analysis was conducted at the Department of Food Technology, Nutrition and Consumer Sciences of Sokoine University of Agriculture, Morogoro.



Key: Study area

Plate 4: Map of Dodoma region showing study area

3.2 Materials and subjects selection

Highly consumed indigenous leafy vegetables were selected for the study and only households that were willing to participate and involved in processing, cooking and storage of the selected indigenous leafy vegetables were included in the study.

3.2.1 Vegetable Samples

Three mostly common consumed varieties of indigenous vegetables Amaranthus (*Amaranthus hybridus*), Jute mallow (*Corchorus olitorius L.*) and Spider flower (*Cleome gynadra L.)* were selected from the two villages (Scale-N survey, 2016). A total of eighteen samples (1kg each) were collected whereby nine samples of selected indigenous vegetables were collected from each village and divided into three groups of six (6) samples. The first group was composed of uncooked (fresh) vegetables which served as control samples, the second group was dried cooked vegetable samples and the last group was freshly cooked samples as summarized in Appendix 1**.** Fresh samples were washed and collected in freezer bags for laboratory analysis and cooked samples were packed in a special container after being cooked by a procedure described at 3. 5. 2 and transported in a cooling box for laboratory analysis at the Sokoine University of Agriculture Laboratory. All samples were wrapped in an aluminium foil to prevent the detrimental effect of sunlight to the vitamins.

3.2.2 Drying materials

Local drying materials namely mats (for displaying the vegetables) were purchased and used in drying process. Drying material were mats (displaying vegetables) Thermometer for measuring daily temperature was also purchased.

3.2.3 Chemicals and reagents

Analytical food grade chemicals and reagents were purchased and used in chemical analyses. These included: 3% trichloroacetic (TCA) acid solution; 0.04 M ferric chloride; 1.5 N NaOH; hot 3.2 N nitric acid solution; distilled water; 70 ml and 20 ml of 1.5 N potassium thiocyanate; 4.33 mg/ml $Fe(NO3)_3$; water bath; 0.1000 g thiamine HCl; serially deionized water; 0.1M $Fe(NO_3)_3.9H_2O$; 0.1M $K_3[Fe(CN)6]$; 1 g of standard (EC 25 No 201-507-1, Sigma); 0.1 N HCI; 1.0 N Sodium Hydroxide; glacial acetic acid; 4% KMnO4; 3% H_2O_2; 1 N sulphuric acid; ammonium sulphate; 2.0 N NH_4OH; 10% sulphuric acid; cyanobromide solution; 2,6-dichorophenol indophenol; cold acetone; petroleum ether (BP 40-60^oC) layer; activated anhydrous sodium sulphate; standard β-carotene; dry petroleum ether; methyl red indicator.

3.3 Methods

3.3.1 Research Designs

Cross section study design was used to collect the survey data. Information on demography, production, processing, storage practices, economic and social importance of indigenous vegetables was collected. This was useful to obtain the overall picture of the situation at the time of study.

A complete randomized block design (CRBD) was used in this study with processing methods (Fresh, boiling and drying) and vegetable types being the principal factors. The effect of these factors on the nutrients differences in vegetables were assessed and compared. Mathematical model used is shown in Equation 1.

$$y_{ij} = \mu + \tau_i + \varepsilon_{ij} \quad \text{(Eq. 1)}$$

Where: μ is the overall mean, τ_i is i^{th} treatment effect and ε_{ij} is the random effect due to j^{th} replication receiving i^{th} treatment.

3.3.2 Sampling and sample size for the households

Selection of the households was done purposefully using the sampling database which was used by Scale-N project. A desirable number of households from among those which are involved in processing and storage of indigenous leafy vegetables were randomly selected for the study.

The households sample size was determined by using a formula by Fisher *et al.* (1991) as depicted in Equation 2.

$$n = z^2pq/d^2 \quad \text{(Eq. 2)}$$

Whereby; n= the desired sample size, z = the standard normal deviate (which is 1.96 corresponding to 95% CI, p = proportional in the target population with certain characteristics (0.172), q = 1-p, d = degree of accuracy desired (0.05). In view of the above,

$n= 1.96^2*0.172*0.828/0.05^2$

n= 218

However, only 120 households (60 households from each village) were included in the study due to financial and time limitations.

3.3.3 Questionnaires for data collection

Structured questionnaires with both closed and open ended questions were prepared to solicit information targeted at fulfilling the first and second objectives . The questionnaire consisted of three parts (A, B and C) as shown in Appendix 2. Part A covered information on household demographic data which included sex of respondent, level of education, age and marital status. Part B covered for vegetable production, processing and storage practices. Part C was about economic and social importance of indigenous leafy vegetables to the people of Mzula and Chinoje villagers.

Pre- testing of the questionnaires was done to 5 respondents at Idifu village in Chamwino district to the households with the eligible characteristics. Then the appropriate corrections were made to the questions which were found to be unclear to the respondents.

3.3.4 Training of Enumerators

Two enumerators were identified to assist in data collection and were trained for two days before going to the field. Training was based on ethics of research, probing in order to get accurate information and to observe the drying and storage practices done at the household level.

3.3.5 Administration of the questionnaires

The respondents (women) were interviewed face to face at the households by using tested questions during the day time from 8:00 a.m to 4:00 p.m.

3.5 Determination of the Effects of Drying and Cooking Methods on Vitamins and Minerals Contents of the Selected Indigenous Leafy Vegetables

3.5.1 Drying of Vegetables

One kilogram for each of selected indigenous leafy vegetables was washed and cut into thin slices and spread on mats or sacks on a floor for drying (similar to farmers drying procedures). Samples were sun-dried for nine hours daily for three consecutive days at temperature ranging from 30-32^{o}C and relative humidity of 40%. The drying procedure is summarized as; Acquisition/ Plucking: Fresh (young and tender) leaves were harvested in the morning; Sorting: Removal of unwanted leaves and dirty; Washing: Leaves were washed by clean water to remove soil or dirty; Cutting: Cutting of leaves in a medium size; Drying: Displaying leaves over mats in the direct sunlight; Sorting: Removal of any unwanted materials; Storing: The dried leaves stored in a pot, bucket or polyethylene bags in a room temperature (figure 1).

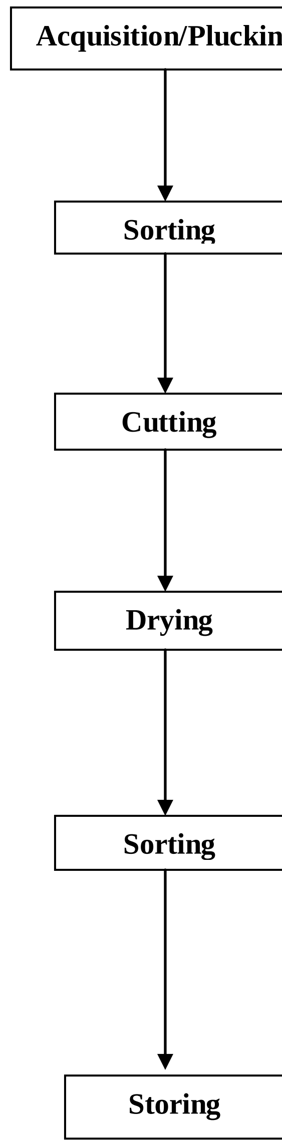


Figure 1. Open sun-drying Procedure for vegetables [Source: Field survey (2018)]

3.5.2 Cooking of Vegetables

Two hundred and fifty grams (250 g) each of fresh and sun-dried Jute mallow (*Corchorus olitorius L.*) was separately pound in a mortar and, Mixture of 300 milliliters water and vegetable boiled at 80^{o}C and cooked for 5 minutes. Two hundred and fifty grams of fresh and dried Amaranths (*Amaranthus hybridus*) and Spider flower (*Cleome gynadra L.*), were separately cooked for 5 minutes at 80 ^{o}C. The cooking procedures were similar to how farmers cook these selected vegetables in their households. During cooking process (boiling and shallow frying) salt, onions, tomatoes and cooking oil were added. The cooking procedure is summarized in figure 2 and 3. Freshly uncooked control samples were taken to the laboratory for analysis in order to get basis of comparison with freshly cooked and dried cooked.

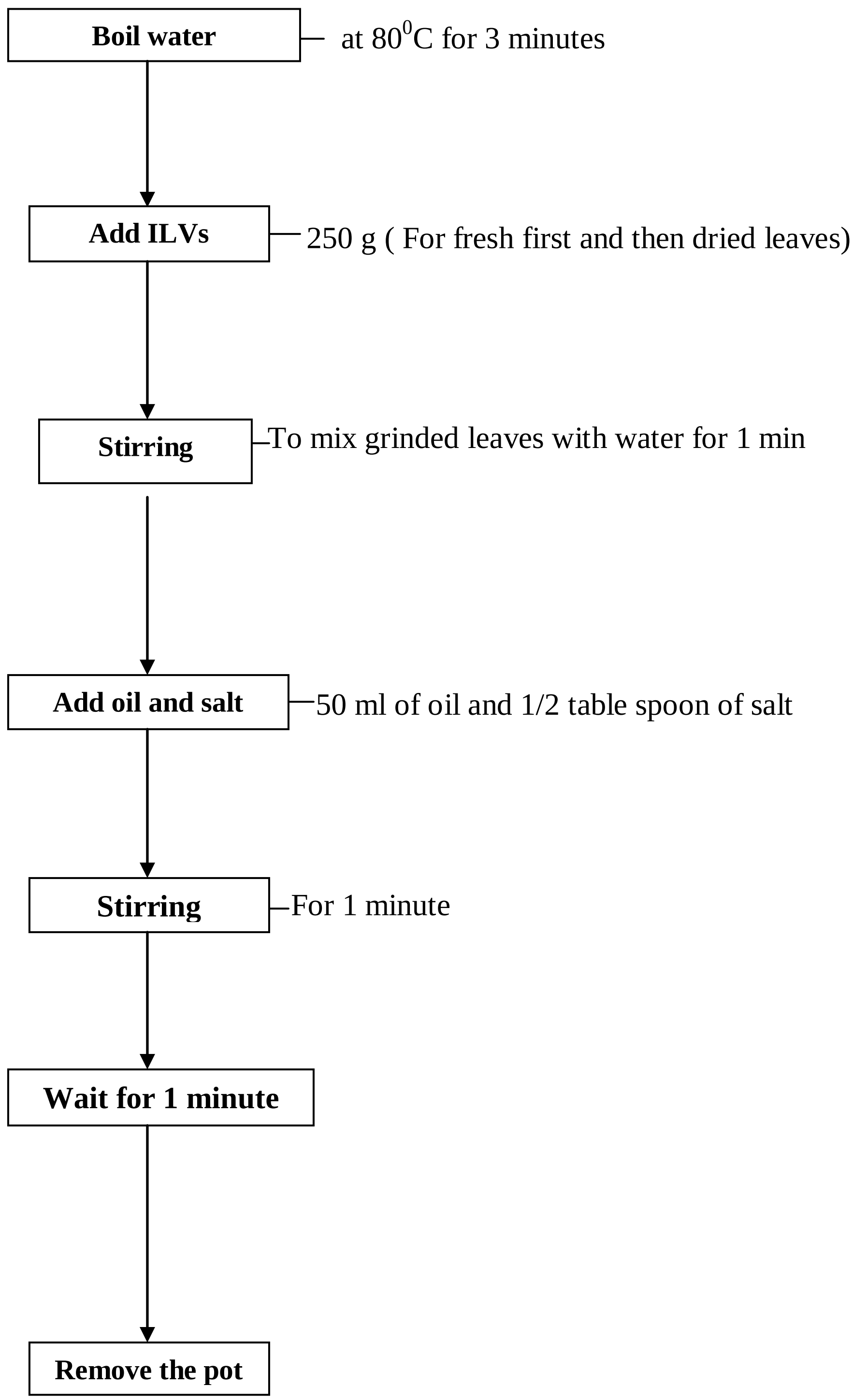


Figure 2. Procedure for cooking (boiling) *C. olitorius*

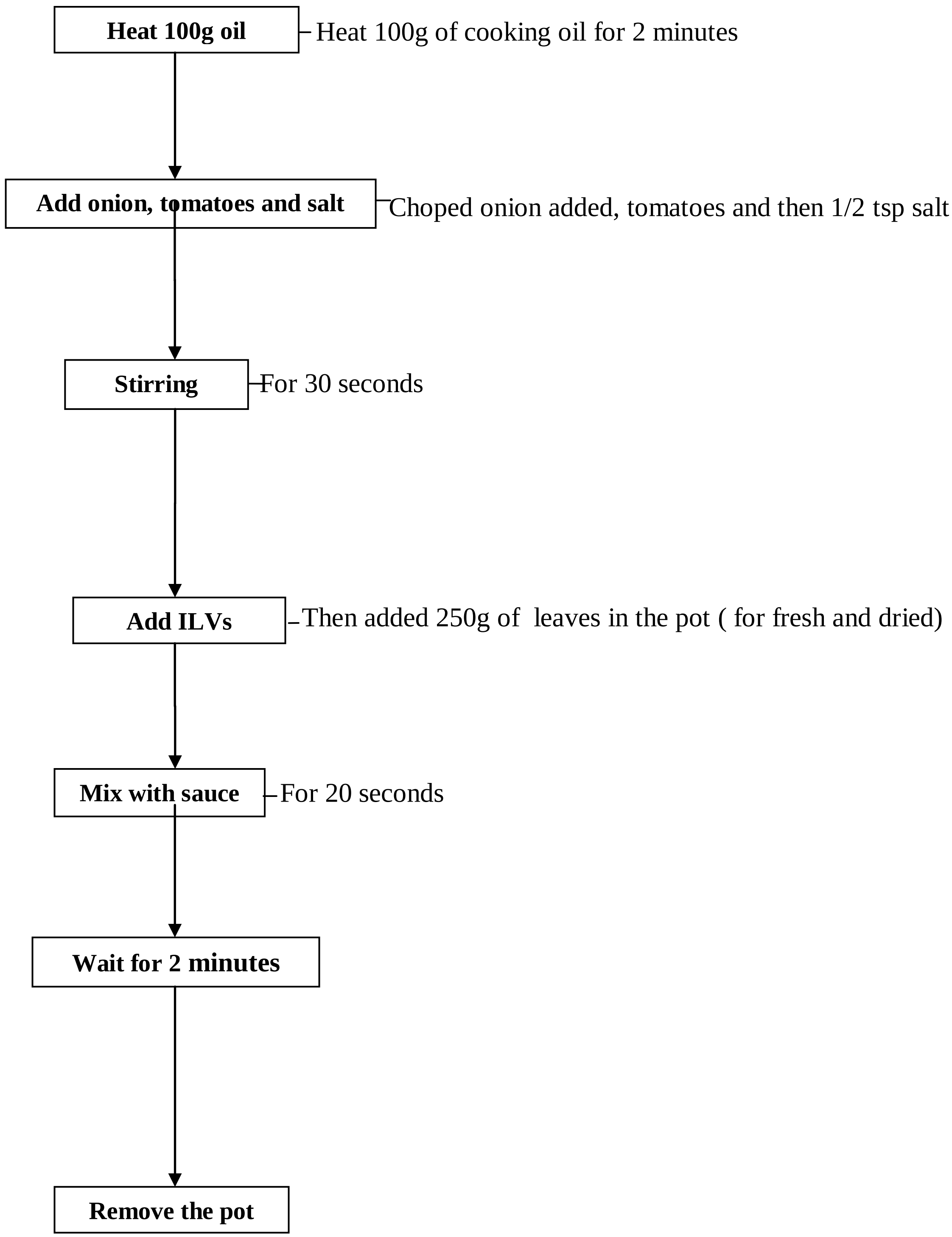


Figure 3. Procedure for cooking **(**frying) fresh and dried C. *gynadra L.* and *A. hybridus L.*

3.5.3 Chemical analysis

3.5.3.1 Moisture content determination

Moisture content was determined using the oven drying method as per AOAC method 920.151 (1990). Five grams of a food sample was weighed into a previously dried and weighed glass crucible. The crucible and its content were placed in a thermostatically controlled oven at 100ºC for 24 h. The contents were cooled in desiccators and then weighed. The loss in weight was recorded as moisture content and expressed as a percentage of the total weight of sample used; using the Equation 3:

$$\% \text{ moisture} = \frac{(W1 - W2)}{(W1 - W0)} \times 100 \quad \text{(Eq. 3)}$$

Whereby: W_0= weight of empty crucible (g), W1=weight of container + sample before drying (g), W2= weight of container + sample after drying.

3.5.3.2 Laboratory Analysis of Vitamins and Minerals

(i) Analysis of Vitamin A (beta- carotene)

Beta- Carotene was determined using standard AOAC Method 2005.07 (2005). Ten milliliters (10 ml) of water were warmed in a water bath to 40 ^{o}C. Beta- Carotene was extracted from the sample with 150 ml cold acetone and poured into 30 ml petroleum ether (BP 40-60 ^{o}C) layer, washed with distilled water until free from any acetone. The clear extracted carotenoids were then passed through the activated anhydrous sodium sulphate, collected into 27 ml volumetric flask. Absorbances were read at 450 nm using UV-Visible spectrophotometer. Beta carotene standard solution was prepared by dissolving 1.0 mg of standard β-carotene into 100 ml (10.0 mg/ ml) dry petroleum ether. The stock solution was then diluted serially to obtain the standard range (0 – 10 mg/ ml) beta carotene. Absorbances were read at 450 nm. Samples concentrations were calculated using the linear regression equation (Appendix 3).

(ii) Analysis of Vitamin C

Vitamin C content was determined using 2, 6-dichorophenol indophenol method as per AOAC Method 967.21 (2005); where 5 g of the sample were weighed accurately and mixed with acid washed sand and TCA solution. The mixture was quantitatively transferred into 100 ml volumetric flask by using TCA to the mark and mixed well. The sample solution (1 ml) was titrated by 2, 6-dichorophenol indophenol solution until light/rose pink color appeared. Vitamin C content was calculated using the equation 4:

$$\text{Vitamin C content (mg/100g)} = \frac{(A-B) \times C \times 100}{10 \times S \times 100} \quad \text{..(Eq. 4)}$$

where; A= volume (ml) of the 2,6-dichorophenol indophenol used for sample,B= volume (ml) of the 2,6-dichorophenol indophenol used for blank, C= mass in mg of ascorbic acid equivalent to 0.1 ml of standard 2,6-dichorophenol indophenol, S= weight of the sample (g) taken.

3.6.3.3 Analysis of Minerals (Ca, Fe and Zn)

Mineral contents were determined using atomic flame emission spectrophotometer (AA-6200 Shimadzu Corp, Kyoto Japan) as per the AOAC procedures (AOAC, 1990). The ash content was used for analysis of the minerals according to the AOAC (1990) procedures. The ash was dissolved in 20 ml of 1 N HCl and heated for 5 minutes at 80-90 ºC. The solute was then transferred quantitatively to a 100 ml volumetric flask and made to level with distilled water. Ca, Fe and Zn were determined using atomic flame emission spectrophotometer (AA-6200 Shimadzu Corp, Kyoto Japan) with air acetylene flame at 722 nm. Each sample was analyzed in duplicate. Quantification was accomplished by comparison with standard curves (Appendix 4) drawn using standard solution of known concentration at 0 to 4 ppm and was expressed using the equation 5:

Mineral content (mg/100g) = ((R x EV x DF)/ (1000ml x SW)) x (100)……….. (Eq. 5)

Where; R = Reading in parts per million, EV = Volume of sample made (ml)/Extraction volume, D.F = Dilution factor 1000 = Conversion factor to mg/100g, SW= Sample weight.

3.7 Statistical data analysis

Data obtained were analysed using Statistical Package for the Social Science (SPSS) software version 20.0. Descriptive statistics such as frequencies and percentages were computed for survey data. Two-Way ANOVA was done to determine significant variations of processing on indigenous leafy vegetables. Mean were separated using least square significant difference at $p<0.05$. Results were expressed as frequencies, proportions and means ± standard deviation and presented in tabular and graphical forms.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1. Demographic Characteristics of Respondents

Results for demographic information of respondents are shown in Table 1. Majority, 113 (94.5%) of the respondents were female, about 41% of all respondent had age group ranging between 30-39 years old and most of them were married 98 (82%). About 79 (66%) respondents completed primary education, 82 (68%) depended on agriculture as their main economic activity, while other households 32 (32%) earned some income through casual labor in intra-region or inter-region as their household income. The results found out that, more women participated in the study due to their role of taking care of children and house while men were the ones responsible go out to engage in income generating activities to feed the family (Heather and Elizabeth, 2008).

Table 1: Demographic characteristics of the respondents (N=120)

Attributes	Frequency (n)	Percentage (%)
Age		
<29	21	17.5
30-39	49	40.8
40-49	27	22.5
50-59	14	11.7
>60	9	7.5
Sex		
Male	7	5.8
Female	113	94.5
Marital status		
Married	98	81.7
Widow	10	8.3
Divorced	12	10
Educational level		
Informal education	40	33.3
Primary education	79	65.8
Secondary education	1	0.8
Major income source		
Agriculture	82	68.3
Casual labour	38	31.7

4.2. Production, preservation and storage practices of the selected indigenous vegetables

4.2.1 Production of vegetables at household

Figure 4 shows distribution of home grown vegetables. Exotic leafy vegetables have taken larger proportions of leafy vegetables produced at home. Chinese cabbage and Spinach were mostly produced compared to other vegetables. However, exotic amaranthus was the least leafy vegetable produced at home.

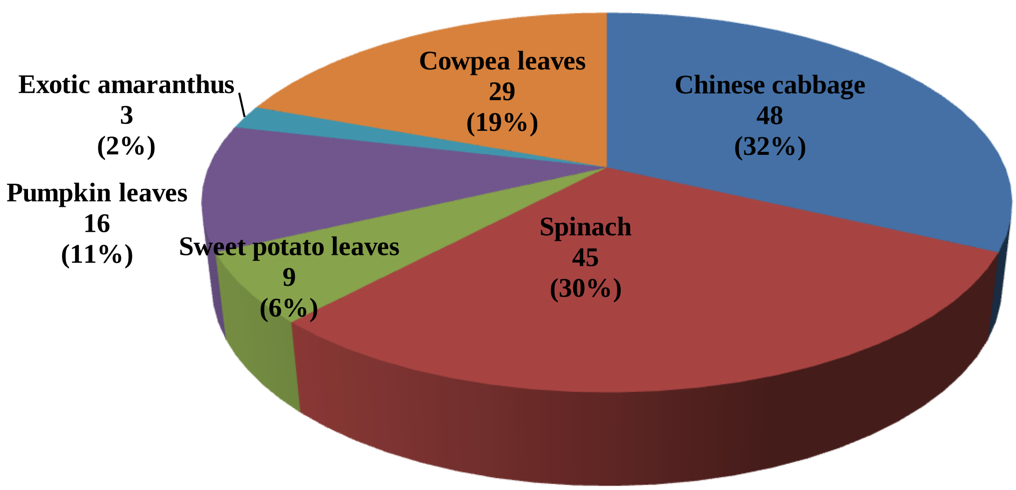


Figure 4: Home based vegetable production

Chinese cabbage and spinach were highly grown at home by most farmers people. This could be due to the pocket garden education and training provided by Scale-N project intervention in the villages and many other villagers have also adopted this knowledge. However, the low production of exotic amaranthus could probably be due to lack of enough organic sufficient for pocket gardens, lack of sufficient water and negative ideology of some villagers about exotic vegetables on health issues (Amuri *et al.*, 2017).

4.2.2 Indigenous vegetables gathered outside home

Many indigenous leafy vegetables are gathered outside of the farmers' homesteads or around farmers' cropped fields as depicted in Figure 5. Jute mallow (*Corchorus olitorius L.)* was the most found vegetable along the farmers' cropped fields or in the forests with 116 (28%) responses. However, Baobab leaves (*Adansonia digitata L.*) have shown to have a lowest proportion among vegetables which were gathered with only 6 (2%) responses.

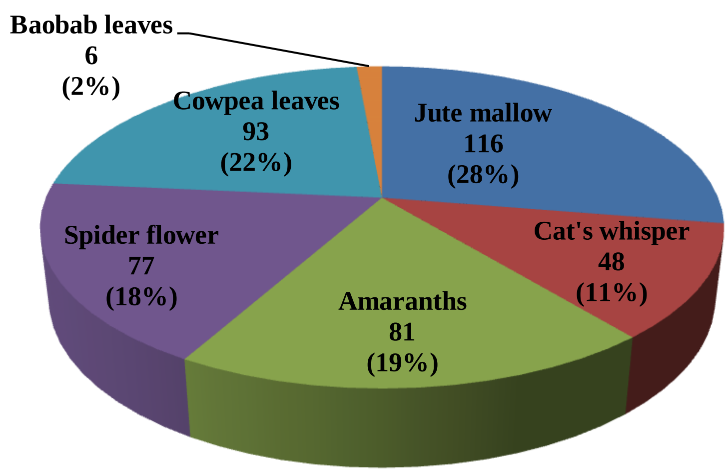


Figure 5: Common vegetables gathered from the forest or around the farms

4.2.3 Processing, preservation and storage practices for vegetables

4.2.3.1 Methods

Table 2 shows distribution of respondents according to their responses on storage and processing methods of each vegetable at the villages. Jute mallow (*Corchorus olitorius L.*) and Cowpea leaves (*Vigna unguiculata L.*) were observed to be the most stored vegetables by respondents with 116 (96.7%) and 103 (85.8%) responses respectively whereby 74 (61.7%) and 77 (64.2%) respondents reported to store Spider flower (*Cleome gynadra L.*) and Amaranths (*Amaranthus hybridus*) respectively. Baobab leaves (*Adansonia digitata L.*) was the least stored vegetable for future use particularly during off season with only 5 (4.2%) responses (Table 2).

Baobab leaves (*Adansonia digitata L.*) was reported to be the only indigenous leafy vegetable that is not dried hence only cooked when fresh. Other vegetables; Jute mallow (*Corchorus olitorius*), Cowpea leaves (*V. unguiculata L.*), Spider flower (*Cleome gynadra* boiling whereas 99 (82.5%), 74 (61.7%), 77 *L.*), Amaranths (*Amaranthus hybridus*) and Cat's whispers (*Cleome hirta*) were reported to be sun-dried before cooking. Furthermore, majority over 90% of respondents cook Jute mallow (*Corchorus olitorius*) and Baobab leaves (*Adansonia digitata L.*) respectively by (64.2%) and 44 (36.7%) were reported to cook Cowpea leaves (*V. unguiculata L.*), Spider flower (*Cleome gynadra*), Amaranthus (*Amaranthus hybridus*), and Cat's whiskers (*Cleome hirta*) respectively by shallow frying method (Table 2).

Table 2: Preservation and processing of ILVs (N=120)

Vegetable	Botanical name		Storage		Drying		Cooking method		
			N	**(%)**	**N**	**(%)**	**Method**	**N**	**(%)**
Jute mallow	*Corchorus olitorius L.*	Yes	116	96.7	116	96.7	Boiling	116	96.7
Cowpea leaves	*Vigna unguiculata L.*	Yes	103	85.8	103	96.7	Brying	99	82.5
Spider flower	*Cleome gynadra L.*	Yes	74	61.7	74	61.7	Frying	74	61.7
Amaranths	*Amaranthus hybridus*	Yes	77	64.2	77	64.2	Frying	77	64.2
Cat's whiskers	*Cleome hirta*	Yes	45	37.5	45	37.5	Frying	44	36.7
Baobab leaves	*Adansonia digitata L.*	Yes	5	4.2	1	0.8	Boiling	115	95.8

Jute mallow (*Corchorus olitorius L.*) and Cowpea leaves (*V. unguiculata L.*) are abundantly available and easily collected just outside of their homestead or along their crop fields during the rainy season. They are mostly harvested, processed and stored so as to make them available during drought period. Jute mallow (*Corchorus olitorius*) is the mostly preferred vegetable specie, easily dried, collected in bulky for preservation, while Baobab leaves (*Adansoni adigitata L.*) is the least preferred specie, not easily harvested and dried, farmers consume only if other vegetables are not available. Imposed cooking knowledge over a period of time has hindered villagers to learn about different cooking techniques (knowledge barrier). For example; boiling Jute mallow (*Corchorus olitorius L.*) and shallow frying Amaranths (*Amaranthus hybridus L.*) are traditional ways of cooking that has been existed over a long period of time, beginning from their ancestral times. There is no other way of cooking which is different from what they are used to (attitude barrier).

The result from the study done by Karanja *et al*. (2012) supports that *C. olitorius* was available shortly after rainy season and become scarce during the dry season which force farmers to store in a bulk for using during off season. A study by Ngomuo *et al*., 2017, found that *C. olitorius* was preferred by many villagers and usually dried on the bare ground, a method that is believed to improve flavor and best eaten when boiled while Baobab leaves (*A. digitata L.*) is less preferred due to its taste and inability to be dried. There are no other cooking technique for Baobab leaves (*A. digitata L.*) which is known to many villagers (Selvarani, 2009).

4.2.3.2 Preservation and storage responsibility

The study found out that in Chinoje and Mzula villages, preservation and storage of vegetables were commonly done by women (92%) (Figure 6).

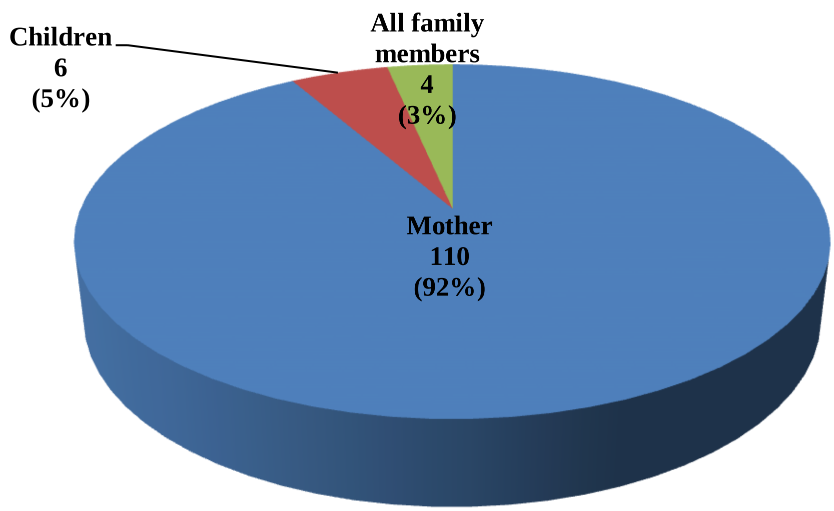


Figure 6: Responsibility to preserve and store indigenous leafy vegetables

According to African customs and traditions, women have responsibilities for food preservation and storage (Fatma, 2012). In view of this, they have to make sure the food was properly stored. Traditionally, a mother has a responsibility to pass on food preservation and storage knowledge and experience to her daughters, so that the knowledge and experiences of the past lives on (Fatma, 2012).

Studies by Ntuli *et al*. (2012) and Weinberger and Msuya, (2004) also support that women are responsible for preservation and storage of indigenous leafy vegetables for their households as one of women gender roles in Tanzanian societies. Pablo *et al*. (2014) and Carey *et al*. (2003) have also shown that, long time taken to preserve, store and prepare foods is one of the hindering factors for men to be involved because they need engage into income generating activities and leaves that task for women.

Other studies have reported about shift of roles of food preservation and food handling from women to men due to cultural change (Debbie, 2000; Kwadwo, 2017). Currently, women are working outside home and involved in income generating activities as compared to the past. Food preservation, storage and preparation therefore become responsibilities which are shared between men and women (Melissa, 2004; Kwadwo, 2017).

4.2.3.3 Reasons for choice of method of preservation/processing of vegetables

Majority of respondents (82%), reported that adoption from their ancestors was their main reason for choosing preservation method (Figure 7) while 10% was for texture improvement, 5% was for longer storage and 3% was for convenience.

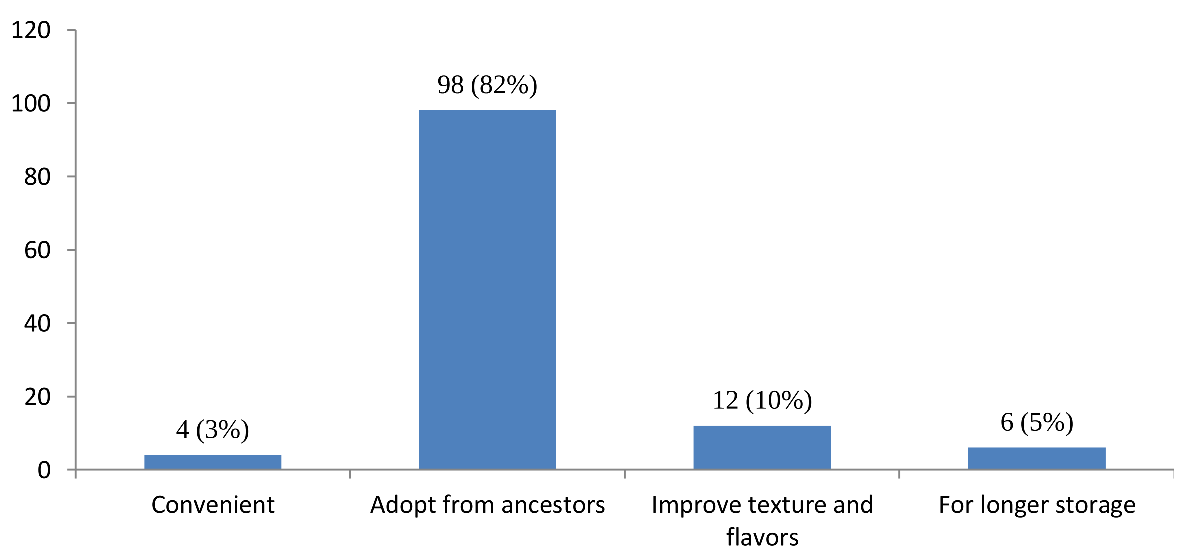


Figure 7: Main reason for choice of processing method

Lack of resources and alternative means of processing has led to reliance on available traditional processing techniques. The underlying reason for villagers to fail to adopt other processing method was due to lack of exposure to other alternative sources of processing methods such as electricity for refrigeration of indigenous leafy vegetables and microwaving (Masarirambi *et al*., 2010). Some other studies also reported that lack of proper knowledge on preservation and processing techniques can lead to poor quality of processed products (Weinberger and Msuya, 2004; Pablo *et al*., 2014; Jimenez-Aguilar *et al*., 2017).

4.2.3.4 Challenges Associated with Drying of Vegetables

Dusts, rainfalls and free range chickens were reported as the major problems which hinder effective drying of indigenous leafy vegetables drying process as depicted in Table 3. To minimize contamination farmers use techniques such as covering vegetables with nets and drying vegetables on the roofs tops.

Dusts and free range chickens when contaminate indigenous leafy vegetables spoil its nutritional quality and make unsuitable for human health after consumed. Rainfall hinders proper drying and prolongs the time taken for vegetables to dry and this cause food insecurity to farmers' households.

Table 3: Vegetable processing and preservation challenges and solutions (N=120)

Attribute(s)	Frequency (n)	Percent (%)
Challenges		
No problem	40	33.3
Limited drying	4	3.3
Limited preservation and processing knowledge	4	3.3
Insects, pests and moulds losses	22	18.3
Limited facilities	3	2.5
Dusts, rainfall and chicken	47	39.2
Solutions		
Do nothing	26	21.7
Using nets and drying on house roofs	56	46.7
Not applicable	38	31.7

4.2.3.5 Period of storage of Vegetables

The main aim for storing ILVs by majority of respondents is preventing food shortage 114 (95%) particularly during off season. This study revealed that, most of farmers 68 (56%) start to prepare ILVs during late rains and store them in March. The larger the stock of indigenous leafy vegetables, the more the household is food secured (Table 4).

Table 4: Period of storage of Vegetables (N=120)

Attribute (s)	Frequency (n)	Percent (%)
Months		
February-December	3	2.5
March-December	68	56.7
April-December	44	36.7
May-December	4	3.3
June-December	1	0.8
Reason		
Form of saving	5	4.2
Exchange with other commodities	1	0.8
Food shortage prevention	114	95.0

Drought natural condition of Dodoma rural region with short rains forces farmers to store indigenous leafy vegetables in order to prevent food shortage in the future (Sakai, 2012).

4.3. Economic and Social Importance of Indigenous Leafy Vegetables

4.3.1. Economic importance of Indigenous leafy vegetables

About 113 (94%) of the respondents reported that indigenous leafy vegetables were very important for minimizing household money expenditure for buying other vegetables especially during scarcity period and 95 (79%) of them, did not engage on selling of indigenous vegetables. However, for those who were engaging in selling indigenous leafy vegetables (18%) had never been satisfied with the amount of money earned from the business, since it is not sufficient to meet their needs (Table 5). Moreover, about 18% reported that, the amount of income or profit from indigenous vegetable business does not reflect the amount needed in the household for other expenses. However, about 2.5% of them were satisfied with the amount of money earned and said that it can help to buy other household needs.

Table 5: Economic Importance ILVs (N=120)

Attribute(s)	Frequency(n)	Percent (%)
Economic importance		
Low price/not sold	5	4.2
Household expenses reduction	113	94.2
Save time	2	1.7
Amount household store (kg)		
10-15	4	3.3
20-25	7	5.8
25-30	3	2.5
>30	11	9.2
NA	95	79.2
Amount earned after selling (Tsh)		
<2000	4	3.3
2000-5000	7	5.8
5000-8000	2	1.7
8000-11000	3	2.5
11000-14000	1	0.8
>14000	8	6.7
NA	95	79.2
Is the earned amount, enough?		
Yes	3	2.5
No	22	18.3
Not applicable	95	79.2
Economic satisfaction		
Does not meet household needs	22	18.3
Enough to meet household needs	3	2.5
Not applicable	95	79.2

4. 3.2 Social Importance of Indigenous Leafy Vegetables

About 50% of studied households regarded eating of indigenous leafy vegetables as an important part of a meal (Table 6), while, more than 43% perceive consumption of indigenous leafy vegetables as a sign of poor economic power and poverty. Indigenous leafy vegetables are also used in rituals such as circumcision (29%) and wedding ceremonies (27%).

Table 6: Social Importance of Indigenous Leafy Vegetables (N=120)

Attribute(s)	Frequency(n)	Percent (%)
How eating of ILVs is perceived		
Sign of poverty	52	43.3
Important part of a meal	60	50
Do not know	8	6.7
Traditional use of ILVs		
Rituals	35	29.2
Ceremony	32	26.7
Do not know	53	44.2

The study done by Berinyuy and Fontem, (2011), showed that, earnings from selling indigenous vegetables were lower than those from exotic vegetables. However, many people regard indigenous leafy vegetables as ‘hunger food’ and grown by subsistence farmers only and consumed during in need and drought, so its market value is undermined (Weinberger and Pichop, 2009; Oladele, 2010). The profitable period of indigenous leafy vegetables is during the rainy season when they are sold in town markets but still at a lower price than exotic vegetables (Iyiade, 2013). Furthermore, Kimiywe *et al*. (2007) reported that most urban people buy indigenous vegetables for medicinal value attached to them.

4.4 Effects of cooking and drying on micronutrients content of selected indigenous leafy vegetables

4.4.1 Effect of cooking on vitamin contents of each type of vegetable

Results showed that the levels of β-carotene and vitamin C concentration decreased significantly ($p<0.05$) on cooking. The freshly cooked samples had the highest concentrations than those which were cooked after drying. The highest (36%) and lowest (5.7%) β-carotene retention were observed in a cooked fresh *Corchorus olitorius L.* and dried cooked *Amaranthus hybridus* respectively, both from Chinoje village. The highest (67%) and lowest (20%) vitamin C concentration were found in a freshly cooked and dried cooked *Corchorus olitorius* from Mzula and Chinoje villages respectively (Table 7).

Table 7: The vitamin contents of selected vegetable in each village

Location	Vegetable type	State of ILVs	Beta carotene (µg/g)	Retinol Equivalent (µg/g)	Vitamin C (mg/100g)
Mzula village			**Mean ± SD (% retention)**	**Mean ± SD (% retention)**	**Mean ± SD (% retention)**
	C. olitorius L.	Fresh	276.2 ± 1.07[a]	46.0 ± 0.18[a]	64.9 ± 1.85[a]
		Cooked -fresh	79.2 ± 0.14[b] (28.6%)	13.2 ± 0.02[b] (28.7%)	43.2 ± 1.85[b] (66.6%)
		Cooked-dried	37.2 ± 0.09[c] (13.5%)	6.2 ± 0.01[c] (13.5%)	17.0 ± 1.85[c] (26.22%)
	A. hybridus L.	Fresh	236.4 ± 0.63[a]	39.4 ± 0.11[a]	72.1 ± 9.26[a]
		Cooked -fresh	57.9 ±0.15[b] (24.5%)	9.7 ± 0.02[b] (24.5%)	39.3 ± 11.11[ab] (54.5)
		Cooked-dried	29.1 ± 0.07[c] (18.3%)	4.9 ± 0.00[c] (18.3%)	28.0 ± 1.85[b] (28.8%)
	C. gynadra L.	Fresh	246.6 ± 0.67[a]	43.5 ± 3.44[a]	55.0 ± 11.11[a]
		Cooked -fresh	53.4 ± 0.43[b] (21.6%)	8.9 ± 0.07[b] (21.6%)	28.8 ± 3.70[ab] (52.4%)
		Cooked-dried	17.7 ± 0.01[c] (7.2%)	3.0 ± 0.01[b] (7.2%)	13.1 ± 3.70[b] (23.8%)
Chinoje village					
	C. olitorius L.	Fresh	247.3 ± 0.61[a]	41.2 ± 0.10[a]	23.6 ± 0.00[a]
		Cooked -fresh	88.8 ± 0.07[b] (35.9%)	14.8 ± 0.01[b] (35.9%)	13.1 ± 0.00[b] (55.6%)
		Cooked-dried	35.1 ± 0.28[c] (14.2%)	5.9 ± 0.50[c] (14.2%)	10.5 ± 3.71[b] (24.4%)
	A. hybridus L.	Fresh	328.4 ± 10.40[a]	54.7 ± 1.73[a]	66.8 ± 1.85[a]
		Cooked -fresh	30.8 ± 0.27[b] (9.4%)	5.1 ±0.05[b] (9.4%)	21.0 ± 3.71[b] (31.4%)
		Cooked-dried	18.8 ± 0.07[b] (5.7%)	3.1 ± 0.00[b] (5.7%)	13.4 ± 0.00[c] (20.1%)
	C. gynadra L.	Fresh	179.7 ± 0.95[a]	30.0 ± 0.16[a]	89.1 ± 11.11[a]
		Cooked -fresh	58.3 ± 0.53[b] (32.4%)	9.7 ± 0.09[b] (32.4%)	34.1 ± 3.71[b] (38.2%)
		Cooked-dried	14.5 ± 0.04[c] (8.1%)	2.4 ± 0.00[c] (8.1%)	32.8 ± 1.85[b] (36.8%)

Data are expressed as mean ± SD (n=2). Data in parenthesis are percentage retention. Mean values with different superscript along the column are significantly different at $p<0.05$.

4.5 Effect of Drying and Cooking method on Micronutrients

4.5.1 Effect of drying on Vitamin content vegetables

Open sun-drying method had significantly impact ($p<0.05$) in reducing the concentrations of β-carotene and vitamin C in indigenous leafy vegetables. There was a significant loss of beta carotene and vitamin C after processing by open sun-drying technique. The results showed that concentration of β-carotene in *Corchorus olitorius* L. was the highest (88.8 µg/ g) and lowest (30.8 µg/ g) found in *Amaranthus hybridus* from Chinoje village. Concentration of vitamin C was the highest (51.5 mg/ 100g) in *Corchorus olitorius L*. from Mzula and the lowest (30.4 mg/ 100g) was in *Amaranthus hybridus* from Chinoje village (Table 8).

Table 8: The vitamin contents of each vegetable in Open sun-drying method

Location	Vegetable type	Beta carotene (µg/g)	Retinol Equivalent (µg/g)	Vitamin C (mg/100g)
		Mean ± SD (% retention)	**Mean ± SD (% retention)**	**Mean ± SD (% retention)**
Mzula village				
	C. olitorius L.	276.2 ± 1.07[a]	46.0 ± 0.18[a]	89.3 ± 0.64[a]
Fresh vegetable	*A. hybridus L.*	236.4 ± 0.63[c]	39.4 ±0.11[a]	35.2 ±9.26[a]
	C. gynadra L.	246.6 ± 0.65[b]	43. 5 ±3.44[a]	55.0 ± 11.12[a]
Sundried vegetable	*C. olitorius L.*	85.3 ±0.24[a] (31 %)	13.2 ± 2.02[a] (28.6%)	51.5 ±1.95[a] (66.6%)
	A. hybridus L.	59.9 ±0.14[b] (24.5%)	9.7 ±0.02[b] (24.5%)	30.3 ±11.12[a] (54.5%)
	C. gynadra L.	56.4 ±1.43[c] (21.6%)	8.9 ±0.07[c] (21.6%)	32.8 ±3.71[a] (52.4%)
Chinoje village				
	C. olitorius L.	247.3 ± 0.61[b]	41.2 ± 0.10[b]	23. 6 ± 0.00[b]
Fresh vegetable	*A. hybridus L.*	328.4 ± 10.40[a]	54.7 ± 1.73[a]	66.8 ± 1.85[a]
	C. gynadra L.	179.7 ± 0.95[c]	30.0 ± 0.16[c]	89.1 ± 11.11[a]
	C. olitorius L.	88.8 ±0.07[a] (35.9%)	14.8 ±0.01[a] (35.9%)	10.1 ±0.00[b] (55.6%)
Sundried vegetable	*A. hybridus L.*	30.8 ± 0.27[c] (9.4%)	5.1 ± 0.05[c] (9.4%)	30.4 ± 3.71[a] (31.4%)
	C. gynadra L.	58.3 ± 0.53[b] (32.4%)	9.7 ± 0.09[b] (32.4%)	35.1 ± 3.71[a] (38.2%)

Data are expressed as mean ± SD (n=2). Data in parenthesis are percentage retention. Mean values with different superscript along the column are significantly different at $p<0.05$.

Generally, the results (Table 7 and 8) indicate that indigenous leafy vegetables are rich source of vitamin A. The vitamin A occurs as pro-vitamin A carotenoids such as α-γ-or β-carotene, lutein, violaxanthin. Likewise, the vegetables contain a significant amount of Vitamin C (Uusiku *et al.*, 2010; Jaarsveld *et al.*, 2014). Cooking of indigenous leafy vegetables resulted into a loss of vitamins C and A. The high solubility of ascorbic acid in water and it's susceptibility to oxidized make this vitamin unstable under certain processing conditions (Mebpa, 2007; Adebayo, 2010). A similar observation has been reported by Musa and Ogbadoyi (2012) which showed that in a cooked *Corchorus olitorius*, vitamin A and vitamin C retention were retained at 36% and 66% respectively. Mebpa (2007) reported that, the level of vitamin C in Amaranths (20.5 mg/100g) and Cocoyam leaves (27.8 mg/ 100g) which are quite close to vitamin C concentration levels of indigenous leafy vegetables found in this study (30.2 mg/ 100g) . The study done by Islam (2013), showed that, vitamin C in *Corchorus olitorius* was 95 mg/100g which was slightly higher than the one found in the study (89.3 mg/ 100g) . The lower level of vitamin C observed could be due to agronomic or soil condition of particular villages (Amuri *et al.*, 2017).

Other studies; for example, a study done by Mishra *et al.* (2011) has shown the amount of β-carotene content of Cleome *gynadra L.* to be 6.7 mg/ 100g and Van der Walt *et al.* (2009) also found to be 1.7 mg/ 100g which were higher than concentrations found in this study (0.85 mg/ 100g). Variations observed could be due to the fact that in indigenous leafy vegetables, bioavailability components may vary with vegetable species, chemical nature, processing methods, storage time and conditions.

High amount of β-carotene in *Corchorus olitorius L.* maybe attributed to dark green color compared to other selected leafy vegetables (Mwanri, 2011). Similar high concentration of β-carotene was observed by Ukegbu and Okereke (2013) in *Amaranthus hybridus L.* Delays between harvest and analysis of indigenous leafy vegetables may have also contributed to loss of nutritional quality. However, cooking and processing methods can greatly affect the water soluble vitamins in vegetables (Kader, 2001).

4. 5.2 Effect of cooking on mineral contents on the vegetables

Results (Table 9) showed that cooking indigenous leafy vegetables reduced mineral content significantly ($p<0.05$). Fresh cooked *A. Hybridus L.* from Mzula had the highest retention of Zinc concentration (91.5%), while dried cooked *C. olitorius L.* from Chinoje had the lowest Zinc retention (20.2%). Fresh cooked and dried cooked *C. gynadra L.* from Mzula and Chinoje demonstrated to have the highest (79%) and the lowest (12.4%) retention of Calcium respectively. Furthermore, dried cooked and fresh cooked *A. hybridus L.* from Mzula and Chinoje villages were observed to have the lowest and highest iron retention (14.2%) and (65.4%) respectively.

Table 9: **The mineral contents of each vegetable in each village (g/100g)**

Location	State of ILVs	Zinc	Calcium	Iron
		Mean ± SD (% retention)	**Mean ± SD (% retention)**	**Mean ± SD (% retention)**
Mzula village				
	Fresh	45.4 ± 0.67[a]	60.7 ± 1.44[a]	27.1 ± 0.02[a]
	Cooked-fresh	30.8 ± 0.00[b] (68%)	21.1 ± 0.01[b] (34.8%)	12.1 ± 0.01[b] (44.7%)
C. olitorius L.	Cooked-dried	10.8 ± 0.01[c] (23.9%)	11.3 ± 0.06[c] (18.6%)	6.8 ± 0.04[c] (24.9%)
.	Fresh	13.8 ± 0.01[a]	40.5 ± 0.01[a]	39.2 ± 0.02[a]
	Cooked-fresh	12. 6 ± 0.01[b] (91.5%)	20.3 ± 0.01[b] (50.2%)	16.7 ± 0.01[b] (42.7%)
A. hybridus L.	Cooked-dried	9.8 ± 0.01[c] (71.6%)	10.2 ± 0.01[c] (25.1%)	5. 6 ± 0.01[c] (14.2%)
	Fresh	33.7 ± 1.12[a]	48. 6 ± 2.84[a]	31.1 ± 0.01[a]
	Cooked-fresh	12.3 ± 0.05[b] (36.4%)	38.4 ± 0.01[b] (79%)	13.4 ± 0.00[b] (43.2%)
C. gynadra L.	Cooked-dried	8. 6 ± 0.01[c] (25.4%)	9.1 ± 0.01[c] (18.8%)	9.3 ± 0.01[c] (30%)
Chinoje village				
	Fresh	39.4 ± 0.11[a]	31.5 ± 0.08[a]	41.1 ± 0.04[a]
	Cooked-fresh	32.7 ± 0.66[b] (82.9%)	19.5 ± 0.04[b] (61.8%)	21.1 ± 0.02[b] (51.2%)
C. olitorius L.	Cooked-dried	8.0 ± 0.00[c] (20.2%)	6.2 ± 0.01[c] (19.7%)	11.0 ± 0.01[c] (26.8%)
	Fresh	29.0 ± 0.03[a]	62.4 ±0.09[a]	29.1 ± 0.01[a]
	Cooked-fresh	13.1 ± 0.20[b] (45.2%)	31.4 ± 0.14[b] (50.4%)	19.0 ± 0.00[b] (65.4%)
A. hybridus L.	Cooked-dried	10.0 ± 0.00[c] (34.4%)	12.2 ± 0.00[c] (19.6%)	9.1 ± 0.00[c] (31.2%)
	Fresh	14.8 ± 0.00[a]	40.9 ± 0.54[a]	46.3 ± 0.01[a]
	Cooked-fresh	9.9 ± 0.06[b] (66.8%)	16.5 ± 0.00[b] (40.5%)	23.8 ± 0.02[b] (51.3%)
C. gynadra L.	Cooked-dried	7. 5 ± 0.04[c] (50.4%)	5.1 ± 0.01[c] (12.4%)	12.0 ± 0.02[c] (25.8%)

Data are expressed as mean ± SD (n=2). Data in parenthesis are percentage retention. Mean values with different superscript along the column are significantly different at $p<0.05$.

4.5.3 The mineral contents of each type of vegetable by drying method

Mineral contents are also affected by open sun-drying method. Evidently as shown in the Table 10, fresh samples concentrations had higher mineral content compared to sun-dried samples of vegetables.

Table 10: The mineral contents of each type of vegetable by drying method (g/ 100g)

Location	Vegetable type (State)	Zinc	Calcium	Iron
		Mean ± SD (% retention)	**Mean ± SD (% retention)**	**Mean ± SD (% retention)**
Mzula				
Fresh	*C. olitorius L.*	45.4 ± 0.57[a]	60.7 ± 1.44[a]	27.1 ± 0.02[c]
	C. gynadra L.	13.8 ± 0.01[c]	40.5 ± 0.01[c]	39.2 ± 0.02[a]
	A.hybridus L.	33.7 ± 1.12[b]	48.6 ± 2.84[b]	31.1 ± 0.2[b]
Sun-dried	*C. olitorius L.*	30.8 ± 0.00[a] (68%)	21.1 ± 0.01[b] (34.8%)	12.1 ± 0.01[c] (44.7%)
	A.hybridus L.	12.6 ± 0.01[b] (91.5%)	20.3 ± 0.01[c] (50.2%)	16.7 ± 0.01[a] (42.7%)
	C. gynadra L.	12.3 ± 0.05[c] (36.4%)	38.4 ± 0.01[a] (79%)	13.4 ± 0.00[b] (43.2%)
Chinoje				
	C. olitorius L.	39.4 ± 0.11[a]	31.5 ± 0.08[c]	41.1 ± 0.04[b]
	A.hybridus L.	29.0 ± 0.03[b]	62.4 ± 0.09[a]	29.1 ± 0.01[c]
Fresh	*C. gynadra L.*	14.8 ± 0.00[c]	40.9 ± 0.54[b]	46.3 ± 0.01[a]
	C. olitorius L.	32.7 ± 0.66[a] (82.9%)	19.5 ± 0.04[b] (61.8%)	21.1 ± 0.02[b] (51.2%)
Sun-dried	*A.hybridus L.*	13.1 ± 0.20[b] (45.2%)	31.4 ± 0.14[a] (50.4%)	19.0 ± 0.01[c] (65.4%)
	C. gynadra L.	9.9 ± 0.06[c] (66.8%)	16.5 ± 0.01[c] (40.5%)	23.8 ±0.02[a] (51.3%)

Data are expressed as mean ± SD (n=2). Data in parenthesis are percentage retention. Mean values with different superscript along the column are significantly different at $p<0.05$.

The reduced mineral contents of cooked vegetables could be caused by the drainage of water from samples. Other, studies have reported that, cooking significantly reduces minerals contents in indigenous leafy vegetables (Schonfeldt and Pretorius, 2011; Mepba *et al.*, 2007; Uzoekwe and Ukhun, 2005). Oladunmoye *et al.*, 2005 also observed reductions in calcium and iron contents of cooked tender and matured cassava leaves.

Sun-drying method had also detrimental effect on mineral composition of leafy vegetables consumed in Chinoje and Mzula villages, Dodoma region (Table 10). Acho *et al*., 2015, has shown high concentrations of zinc (30.24 mg/ 100g), iron (42.61 mg/ 100g) and calcium (86.83mg/100g) in dried *Corchorus olitorius L*. Iron is known to be an essential part of red blood cells (haemoglobin) and enzymes (cytochromes) and consumption of these leafy vegetables could reduce considerably the risk of anemia (Soetan *et al*., 2010).

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The commonly consumed indigenous leafy vegetables were Jute mallow, Amaranths and Spider flower and they are the ones that were widely collected in the forests and along the crop fields shortly after the rainy season while Chinese cabbage, Spinach, pumpkin leaves and Cowpea leaves were particularly grown in the households. The commonly used preservation method was open sun-drying because it is cheap and quick and mainly used for Jute mallow, Amaranths, Spider flower, Cowpea leaves while Baobab leaves were normally consumed without drying. Availability of dried indigenous leafy vegetables in the households help farmers to reduced household financial expenditure to buy vegetables especially during off season period instead it can be allocated for other household expenses. Indigenous leafy vegetables used as special cuisine during traditional ceremonies. Evidently, this study has shown that indigenous leafy vegetables are rich source of micronutrients but proper processing drying and cooking is needed to prevent extensive loss of micronutrients.

5.2 Recommendations

Suggested recommendations for maximization of micronutrients retention are as follows:

a) To promote improved processing techniques such as solar dryers to minimize micronutrients losses.

b) To provide education on cooking leafy vegetables in a way that prevents/ minimizes micronutrients losses during preparation and cooking of vegetables.

c) To conduct studies to assess nutritional contents of selected indigenous leafy vegetables in different seasons.

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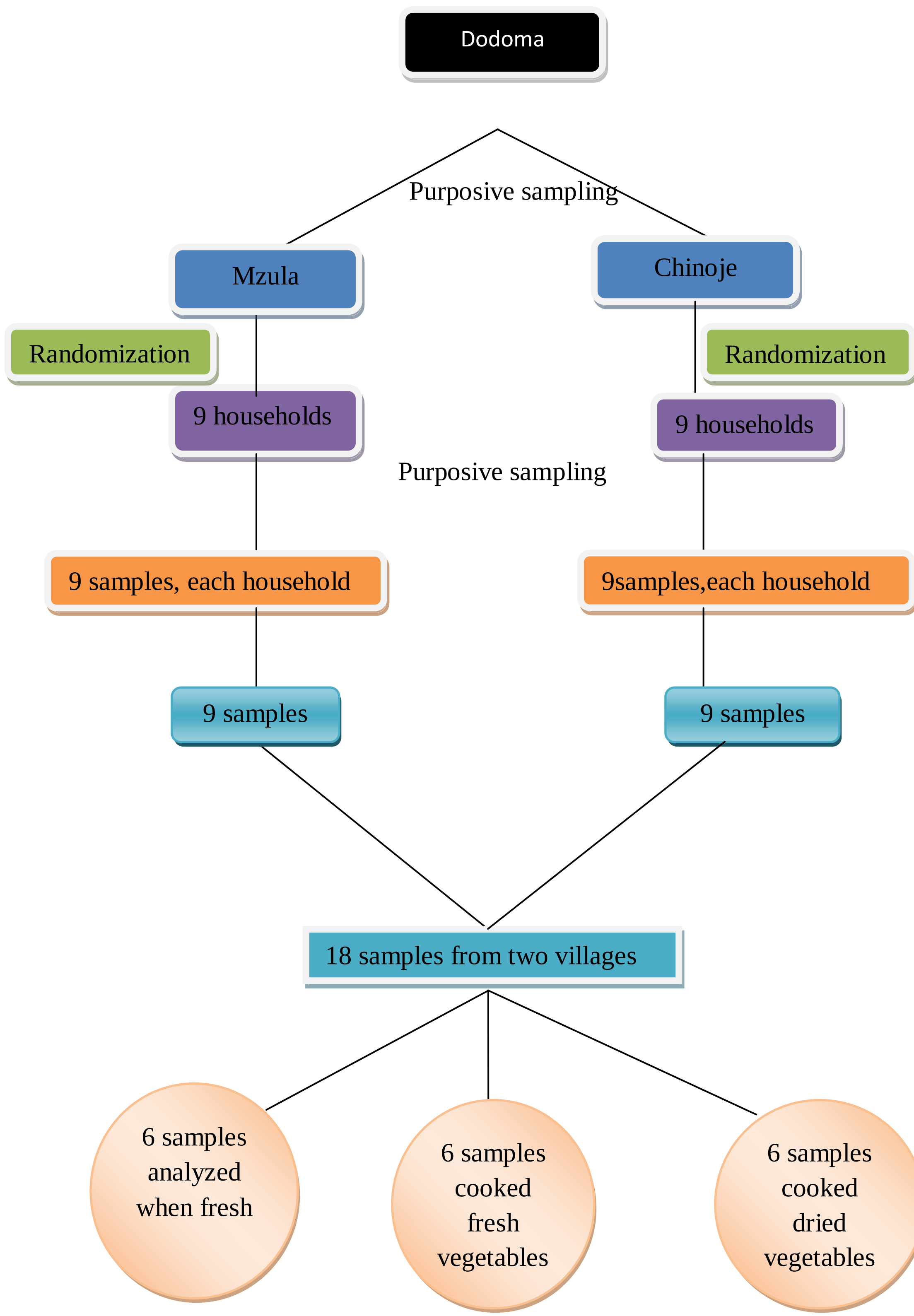
APPENDICES

Appendix 1: Research design model



Appendix 2: Questionnaire for data collection

MICRONUTRIENTS COMPOSITION OF SELECTED SUN-DRIED AND COOKED INDIGENOUS LEAFY VEGETABLES IN DODOMA, TANZANIA

Questionnaire to examine the processing and storage practices and assessing the economic and social importance of selected indigenous vegetables in Mzula and Chinoje villages, Dodoma region. Tanzania.

Introduction

My name is....................................... (*Mention your name*), I am a Masters student from Sokoine University of Agriculture, pursuing MSc. in Human Nutrition. This questionnaire is intended to gather information about the indigenous vegetables you process and store. There are no 'right' or 'wrong' answers. Accurate and thoughtful responses will allow us to pinpoint general situation of processing and preserving in your household. All of the data collected is anonymous and your answers will be held in strict confidence.

Name of interviewee..

Respondent no.............

Date............Region.................District................Ward....................Village...............

Section A. DEMOGRAPHIC INFORMATION

1. Age of the respondent...................... (Years)

2. Sex (a) Male (b) Female

3. Marital status

a) Single
b) Married
c) Widowed
d) Divorced
e) Cohabitation

4. Highest level of education you have attained?

a) Informal education
b) Primary education
c) Secondary education
d) University level

5. Occupation

a) Farmer
b) Employed
c) Unemployed

d) Others, specify.......................

6. Major source of income in your household
   a) Salary/ wages
   b) Agriculture
   c) Casual labor
   d) Others specify.................................

Section B. VEGETABLE PROCESSING AND PRESERVATION

7. (a) Which vegetables are produced at home?

   1. ....
   2. ....
   3. ....
   4. ....

   (b) Which vegetables are gathered from the forest/around the farm?
   1..
   2..
   3..
   4..

8. Do you preserve indigenous vegetables?

   a) YES
   b) NO

9. What type of indigenous vegetables are you preserving mostly?

   a) ....
   b) ....
   c) ....
   d) ....

10. Who is responsible to preserve indigenous vegetables in the household?

   a) Mother
   b) Father
   c) Children
   d) All family members

11. What are the methods do you use to process indigenous vegetables?

   a) Boiling
   b) Washing
   c) Grinding
   d) Pounding

e) Others, specify...

12. What are the main reasons to choose these processing methods of indigenous vegetables?

a) ....
b) ....
c) ....
d) ....

13. Do you preserve indigenous vegetables by drying methods?

i. YES (ii) NO

14. What are the main reasons to choose this preserving method of indigenous vegetables?

a) ....
b) ....
c) ....
d) ....

15. What are problems do you face to preserve indigenous vegetables by drying method?

a) No problems
b) Limited drying
c) High preservation and storage cost
d) Limited knowledge on processing and preservation
e) Losses from insects and moulds
f) Limited facilities
g) Others, specify...

16. What did you do to address these problems?

a) Did nothing
b) Improved solar systems
c) Use government storage system
d) Others specify.....................................

17. Do you store indigenous vegetables?

a) YES
b) NO

18. Who is responsible to store indigenous vegetables in the household?

a) Mother
b) Father
c) Children
d) All family members

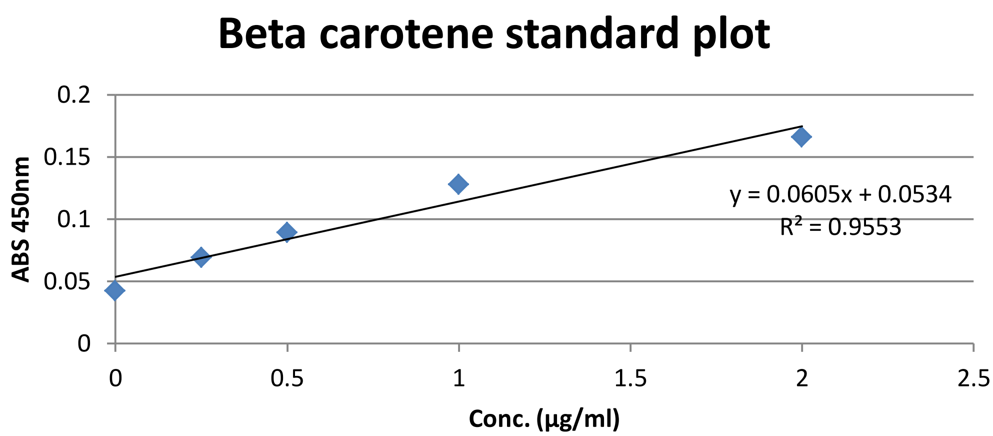
19. What are the main reasons to store indigenous vegetables?
    a) To get higher prices
    b) As a form of saving
    c) For later exchange with other commodities
    d) Prevent food shortage
20. Which months do you store indigenous vegetables?
    a) ....
    b) ....
    c) ....
21. Which cooking methods do you use in cooking indigenous vegetables?
    a) Grilling
    b) Boiling
    c) Stewing
22. Why do you use this method?
    Reasons: a)...
    b)...
    c)...

Section C. ECONOMIC AND SOCIAL IMPORTANCE OF INDIGENOUS VEGETABLES

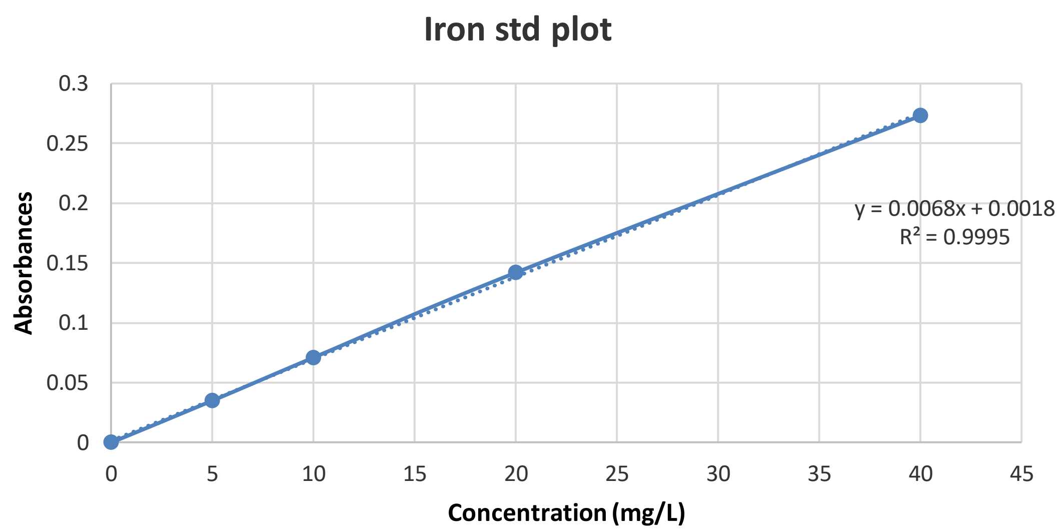
23. What are economic importances of indigenous vegetables in your households? (multiple responses, if necessary)
    a) Low prices/not sold
    b) Reduces household expenses
    c) Save time
    d) Others, specify.................................
24. How much do you store for selling during harvesting season?..........................in kg
25. How much do you earn after selling indigenous vegetables?............................in Tsh
26. The amount (Tsh) you earn, is it enough for the household expenses?
    a) YES
    b) NO
27. Give your reason(s) for the above question..
28. How, indigenous vegetables regarded in your community..
29. How indigenous vegetables used traditionally in your community?
    a) ....
    b) ....
    c) ....

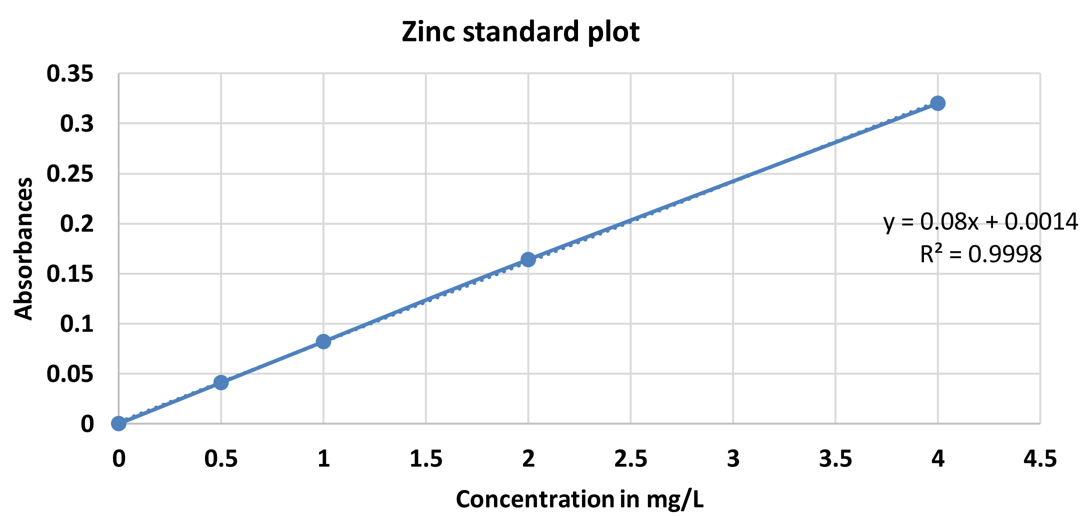
********************Thank you for your cooperation**************

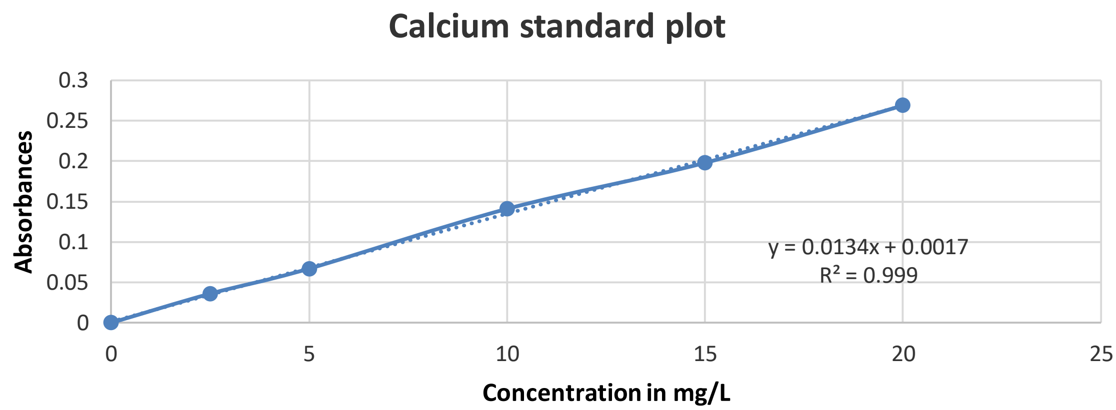
Appndix 3: Standard curve for vitamin A



Appndix 4: Standard curves for Fe, Zn and Ca






Calcium standard plot
Absorbances
Concentration in mg/L
y = 0.0134x + 0.0017
R² = 0.999
0
0.05
0.1
0.15
0.2
0.25
0.3
0
5
10
15
20
25