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UNIVERSITY OF EDUCATION WINNEBA

COLLEGE OF TECHNOLOGY EDUCATION, KUMASI

PROXIMATE, ANTI NUTRITIONAL AND MINERAL COMPOSITION OF SOME INDIGENOUS VEGETABLES GROWN IN NORTHERN GHANA

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(200026710)

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DECLARATION

STUDENT'S DECLARATION

I, AFISAH ABU-JA-JAH, declare that this dissertation, with the exception of quotations and references contained in published works which have all been identified and duly acknowledged, is entirely my own original work, and that it has not been submitted, either in part or whole, for another degree elsewhere.

SIGNATURE: ……………………………………………

DATE: ………………………… …………………………

SUPERVISOR'S DECLARATION

I hereby declare that the preparation and presentation of this work were supervised in accordance with the guidelines on supervision of dissertation as laid down by the University of Education, Winneba.

NAME OF SUPERVISOR: DR. GILBERT OWIAH SAMPSON

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DEDICATION

This work is dedicated to my lovely husband, Mr Issahaku Isaah, my mom Hajia Fulera Iddrisu, my brothers and my children Rinat Issahaku, Rashida Adam, and Amina Adam Bawa.

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ABSTRACT

Little effort has been made to assess the nutritional value of traditional African vegetables and the products from these vegetables are under-utilized in Africa. Based on this, the study aimed at investigating the proximate, anti-nutritional composition and mineral composition of Amaranthus spp (*aleefu*) and Kenaf spp (*bra*) grown and commonly consumed in Northern Ghana. The leaves and seeds of the vegetables were collected from local farmers, processed and dried to constant mass. Using the AOAC official methods, proximate, mineral and and anti-nutritional compositions were determined. The minerals content was estimated by using Atomic Absorption Spectroscopy. Mean and standard deviation were calculated using SPSS version 23. Results from this study indicated that the ash content of Amaranthus "*Aleefu*" and Kenaf "*bra*" was 15.62% and 10.50%, respectively. The moisture content of "*aleefu*" leaves was 59.89% and that of "*bra*" leaves was 42.70%. The results obtained for anti-nutrient composition revealed low levels of phytate in "*Aleefu*" and *bra"/*Kenaf leaves and seed. *A*lkaloids found in "Aleefu" and *"bra"/*Kenaf leaves and seed were present in appreciable amounts (9.50% and 3.64%. It was established that significant difference ($p<0.05$) was found between the mean values of the samples with respect to proximate, anti-nutrients and mineral composition. The study concluded that the mineral content of "Aleefu" and *"bra"/*Kenaf leaves and seed were very good sources of calcium, potassium, and iron. Consequently, it is recommended that the Agricultural ministry should encourage the consumption of *Aleefu*" and *bra*"/Kenaf leave and seed that could help in alleviating the problem of hidden hunger at negligible cost.

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CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Vegetable consumption is essential towards health protection and disease prevention. Indigenous vegetables have high levels of micronutrients that play a critical role in nutrient metabolism and retard the progression of degenerative diseases (Chu, Sun, Wu & Liu, 2012). The World Health Organization (WHO) proposed that a minimum dietary intake of 400 g of fruit and vegetables is essential for the health and well-being of the body (WHO, 2013).

According to Smith and Eyzaguirre (2007), indigenous food crops of Africa are those that have their natural habitat in Sub-sahara Africa. Many have been introduced over a century ago and have been part of food culture in Ghana and Africa as a whole because of their long and continuous use (Kwenin, Wolli & Dzomeku, 2011). Kwenin et al. (2011) defined vegetables as plants whose leaves, roots or fruits are acceptable as consumable vegetables or for medicinal benefits. They are important for human growth and development as they are rich in essential nutrients such as proteins, vitamin C and iron (Karki, 2015; Maroyi 2013; Kwenin et al., 2011).

In Ghana, most people consume the leaves of indigenous plants as vegetables (Kwenin et al. 2011). Indigenous vegetables can play a major role in generating income and improving the living standards of farmers (Schippers, 2000) as well as rural dwellers. Their generally low labor intensive production processes, low levels of investment and higher yields makes vegetable cultivation a lucrative job to those outside the formal sector in urban and peri-urban areas (Schippers, 2000). Many of the indigenous African leafy vegetables have long been recognized and reported to

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promote health (Okeno, Chebet &Mathenge, 2003). For example, the roots, leaves, branches and the bark of the *Moringa oleifera* are reported to be used as medicines of the ancient world (Smith & Eyzaguirre 2007). In Ghana most people consume indigenous foods such as "Kontomire" cocoyam leaves, Amaranthus (Aleefu) leaves and Bokoboko water-leaves.

Indigenous vegetables have long been used in conventional diets in cultures around the world. In addition Amaglo & Nyarko (2012) evaluated the mineral composition of commonly used leafy vegetables in Northern Ghana but their study did not include the anti-nutritional and mineral composition of seeds and leaves of Amaranthus and Kenaf. The paucity of data regarding these in the Food composition database has the tendency to posing a great challenge to Nutritionist and Dietician in the local area when recommending meals for malnourished individuals.

1.2 Statement of the Problem

Sub-Sahara Africa is recorded as having the lowest intake of micronutrient rich fruits and vegetables with the average intake of less than half of the World daily intake guidelines of 400g per head per day in most nations (Seidu et al., 2012). In the Northern part of Ghana, malnutrition and hunger have threatened the food security of millions of people (Yakubu & Kumah 2019). An increase in indigenous vegetable intake can potentially have a direct positive effect on the economic well-being and health of the greater population. In addition to promoting good health as indigenous vegetables are consumed, increased intake of indigenous vegetables would lead to improved crop diversity, poverty alleviation and food security in the northern of Ghana.

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Though there are myriad of indigenous vegetables grown and consumed in the Northern regions of Ghana, Amaranthus and Kenaf are mostly consumed is often used to prepare the sauce for Tuo Zaafi, which is being introduced into the cuisine of weaned children especially in the Southern Ghana. The presence or otherwise of anti-nutrients in these vegetables needs to be determined to avert a future inadvertent challenge of under-nutrition.

1.3 Main Objective

The main objective of this research is to investigate the proximate, anti-nutritional and mineral composition of Amaranthus spp (*aleefu*) and Kenaf spp (*bra*) grown and consumed in Northern Ghana.

1.4 Specific Objectives

The specific objectives of the study were:

1. To determine the proximate composition of Amaranthus spp (*aleefu*) and Kenaf spp (*bra*) grown and consumed in Northern Ghana
2. To determine the anti-nutritional properties of Amaranthus spp (*aleefu*) and Kenaf spp (*bra*) grown and consumed in Northern Ghana
3. To determine the mineral composition of Amaranthus spp (*aleefu*) and Kenaf spp (*bra*) grown and consumed in Northern Ghana

1.5 Significance of the Study

The findings of the study will highlight the proximate composition, anti-nutritional, and mineral composition of Amaranthus spp (*aleefu*) and Kenaf spp (*bra*)

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grown and consumed in Northern Ghana. This will potentially encourage the increase in production, consumption and usage of indigenous vegetables. The report can also be used as learning material especially within areas related to production and consumption indigenous vegetables.

The results could also improve potential business prospects and consumer opportunities and raise farm income for poor households. In fact, this aims to minimize hidden hunger, which is one of the steps for the country's growth agenda. Consequently, the knowledge produced can be used to devise and enforce appropriate strategies for the commercialization of indigenous plants. Local farmers will self-reflect and promote efforts for indigenous vegetable cultivation and consumption. Understanding the nutritional content of indigenous vegetables can help create nutritional awareness and secure effective participation and consumption of Amaranthus spp (aleefu) and Kenaf spp (bra).

From the outcome of the study, nutritionists and dietitians may use the findings in strengthening recommendations related to the consumption of Amaranthus spp (*aleefu*) and Kenaf spp (*bra*) due to its nutritive nature and market potential. Finally, the research will serve as a critical reference point for future researchers to explore the nutritional benefits and consumption of these two vegetables and its associated studies.

1.6 Delimitation of the study

The study focused on some popular indigenous vegetables in Northern Ghana. The two commonly grown and consumed indigenous vegetables sampled wereAmaranthus spp (*aleefu*) and Kenaf spp (*bra*). The study specifically focuses on the nutrient composition, anti-nutritional properties and the mineral composition of

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Amaranthus spp (*aleefu*) and Kenaf spp (*bra)* grown and consumed in Northern Ghana.

1.7 Organisation of the study

The study was organized into six chapters. The first chapter contains the background to the study, statement of the problem, the purpose of the study, the objectives of the study, significance of the study, and delimitation of the study. Chapter two reviews the theoretical and empirical basis of the study. The literature reviewed was related to the topic under the following subheadings: overview of indigenous vegetables, domestication of indigenous vegetables, role of indigenous vegetables in food consumption, overview of Amaranthus spp (*aleefu*) and Kenaf spp (*bra*), and economic importance of indigenous vegetables.

Chapter three highlights the materials and methods with the following subheadings: study area, collection and preparation of leaf samples, determination of nutrient composition, determination of anti-nutrient composition, determination of minerals content, and data analysis. Chapter four contains the data analysis and presentation. The data obtained through the laboratory test was presented in this chapter. The presentation was captured in tables. Chapter five discusses the results emanated from the study. The aim of this chapter is to confirm with other studies conducted on the indigenous vegetables and draw out the comparative literature to prove the need to consume these two vegetables. Chapter six is the last chapter of the study and it reports on the summary, conclusions made based on the presentations, analysis and the recommendations.

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CHAPTER TWO

LITERATURE REVIEW

2.1 An overview of indigenous vegetables

Vegetables are the delicious foods of plants, nutritious when consumed in raw or in cooked form as additional food or side dishes and separate preparations (Yakubu and Kumah, 2019). They can be sweet, herbal, bitter, hot and tasteless and often need a lot of salt and seasoning to make them savory and appealing to the taste receptors of consumers. The diet of Western Africans is made up of vegetable items. Vegetables are essential as a source of food protection and are involved in disease prevention. Vegetables particularly the dark green leafy type possess high concentrations of micronutrients (vitamins and minerals) which play essential role in nutrient metabolism and disease prevention (Obel-Lawson, 2005). In Ghana,Wild and cultivated green leafy vegetables are used for food processing. More people, though, patronize cultivated exotic vegetables which are much more expensive than indigenous ones that are grown by local farmers or grown in the wild (Abbey, Bonsu, Glover & Ahenkora, 2006). Shei (2008) reported that factors including disapproval of native African plants and urbanization have contributed towards consumers' preference for tropical plants as opposed to indigenous plants. Although, vegetables constitute a major component of the West African diet, limited scientific evidence on African indigenous flora has significantly contributed towards consumers choice of exotic plants over indigenous ones.

Indigenous crops in Sub-Saharan Africa are those that grow in their natural environment (Adebooye & Opabode, 2004). Some of these plants were introduced over a century ago and have been accepted as part of the diets of many African States

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such as Ghana (Kwenin et al., 2011). Kwenin et al. (2011) defined indigenous vegetables as plants that are appropriate and suitable for consumption or for its use as culinary herbs usually in the form of their leaves, roots or berries. They have since been commonly described as vegetables that grow in their natural habitat or have been imported from other regions in a particular country. Mutimutema and Mvere (2000) noted that indigenous vegetables can be cultivated, semi-cultivating, or wild. These can be vegetables whose leaves and fruits are traditionally consumed by the majority of local populace. Most people in Ghana, use indigenous green leafy vegetables like "Kontomire" cocoa leaves, "Aleefu" amaranthus leaves and "Bokoboko" water leaf because of its medicinal properties.

Indigenous plants are branded as development opportunity crops (Temu & Marwa, 2007). They are listed as minor plants that are locally or internationally underutilized considering their comparatively low global production and market value (Freedman, 2015). Certain indigenous plant species though are widely spread worldwide are however limited to a more local method of production and consumption. Many are produced as fruit, fibre, fodder, oil and traditional source of medicine and are tropical plants. Consequently, they play a significant role in urban societies' sustainability. Indigenous vegetables are of special social, cultural and medicinal value. They are an important part of the local diet of societies that provide valued foods, which are often scarce in other staple crops since they respond well to often poor lands (Mavengahama, 2013).

As a part of the Green Movement initiative, many species and varieties of local and indigenous plants were replaced with highly productive exotic cultivars produced with modern breeding programmes (Afari-Sefa, 2012). Afari-Sefa (2012), further observed that indigenous vegetables typically do not meet modern standards

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for uniformity and other characteristics as they have been neglected by breeders from the private and public sectors. In Ghana, extension organizations and educational curricula have been demonstrated to encourage the breeding and cash production in agricultural communities of exotic vegetables. In this sense, in contrast to more commercial exotic cultivars, indigenous vegetables tend to be less affordable on the market.

Ghana has a number of indigenous vegetables that can increase the nutrient diversity of rural households and sources of income (Yakubu & Kumah, 2019). Over the evolution of these vegetables, these vegetables have been playing a significant role in risk management strategies for rural households. They grow in a wide range of environment including roadside, disrupted agriculture and backyards, with limited or no management. Their food availability potential varies with region, socio economic factors and seasons.

Onyango and Onyango (2005) noted that various African households predominantly cultivate in rural areas indigenous vegetables mainly its use as food for the family. Abbey et al. (2006), however, stated that farmers in Ghana cultivate for subsistence and trade informally in the communities to generate household income. Interestingly, there is evidence by (Mavengahama, 2013; Mwaura, 2013) that indigenous crops have long been commercialized in North Africa.

2.1.1 Biodiversity of indigenous vegetables in food systems

The variety of indigenous vegetables depends on traditional communal awareness, the number of crop varieties in the local climate, form of farming systems and crop developments, as well as the degree to which exotic variants have been incorporated in crop systems (Maundu et al., 2009). Therefore, diverse cultures must

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have accepted numerous indigenous species as vegetables because of their cultural diversity within an ecological zone (Keding et al., 2007; Maundu et al., 2009).

The variety of indigenous plants is steadily diminishing over time and if the pattern does not change, a lot of varieties will eventually go away entirely. Abucoutsa and Onyango (2005) reported that, at some point, indigenous vegetables had been neglected and under-utilized. Also, according to (Gotor & Irungu, 2010), Indigenous vegetables are Considered old-fashioned, poor man's food and therefore shameful to consume. The intense marketing of exotic species by research institutions and conservation agencies has also encouraged their genetic degradation of what? (Schippers, 2000; Abukutsa, 2007).

Current literature describing their meaning grew sparse and insufficient and thus their disappearance increased in rural communities (Gudrun, 2004; Laker, 2005). Moreover the occurrence of drought, changes in food preferences, reduced vegetal environments and depletion of indigenous knowledge is linked to their extinction due to the lack of systemic knowledge transfer between generations (Laker, 2005).The lack of quality seed and planting materials continuously contributed to poor yields and the disappearance of some varieties (Abukutsa, 2011). This ultimately resulted in low indigenous vegetable consumption.

Indigenous crops play an important role in soil erosion management and pesticide control in agricultural systems. Intercropping of cold or rose plants was found to minimize diamond moth populations and red spider mites (Schippers, 2002; Nyalala and Grout, 2007). Restauration and restoration of the biodiversity of indigenous vegetables within farming systems requires enhanced production and consumption levels, enhanced processing and marketing performance, and the transfer of expertise to the next generation to raise awareness.

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2.1.2 Contribution of indigenous vegetables to household food composition

While indigenous plant exploitation in poverty alleviation, malnutrition and food security is not completely achieved (Abukutsa, 2011), it makes a major contribution to food security in Africa (Abukutsa, 2011; Legwila et al., 2011). They are normally cooked individually and consumed with ugali (Vorster et al., 2007). Other types of indigenous vegetable find their use as soups and sauces. They can also be mixed with other food resources such as starchy food, meat and fish products before frying. Its ability to thrive in extreme climates makes it an essential source of nutrition, particularly among low income households during difficult times (Voster et al., 2007; Abukutsa, 2011). Their abundance often depends on differences in rainfall, with less fresh vegetables during dry spelling; thus, suitable strategies must be improved to encourage their contributions to food safety (Mavengahama *et al.,* 2013).

The processing of indigenous vegetable using technologies such as drying will ensure their availability and consumption, particularly in future during the dry seasons (Mavengahama et al. 2013; Voster et al., 2007). Increased indigenous vegetable yields could be enhanced through the use of irrigation systems in vegetable production (Abukutsa, 2010) thus reducing their seasonal consumption shifts (Oluoch and Chadha, 2003).

2.2 Nutritional benefits associated with indigenous vegetable consumption

Indigenous vegetables are rich in micronutrients (vitamins and minerals) and are essential source of food for rural feeding (Schippers, 2002; Abukutsa, 2003; Ngugi et al., 2007). Diets rich in indigenous vegetables contain a wide range of nutrients such as calcium, magnesium, potassium, phosphate, zinc, copper, proteins and carotenoids (Sehmi, 1993; Maundu et al., 1999; Kamga et al., 2013). The leaves

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of new amaranth, slender, spider, cowpea, pumpkin and yute mallow contain about 40% protein and about 100% of recommended daily vitamin and mineral requirements (Schippers, 2002; Abukutsa, 2003). It is reasonable to alternate the intake of food rich in indigenous vegetables because of the difference in the nutritional content of various types of autochthonous vegetables so that sufficient nutrients in the body are achieved.

Indigenous vegetables dietary adequacy will ensure the adequate provision of nutrients found to be lacking in their respective food supplements, (Kamga et al., 2013). Inadequate knowledge on the quantified dietary significance is due to their sub-usage in Sub-Saharan Africa (SSA) (Kamga et al., 2013) and hence their confirmation will improve market perception of its relevance (Pandey et al., 2006). Disseminating knowledge describing basic nutrients in various indigenous vegetation varieties alongside their adaptive healing importance will also minimize nutritional challenges in SSA significantly (Kamga et al., 2013).

2.3 Role of indigenous vegetables

The life-giving techniques of rural households require indigenous vegetables. This segment highlights some of these critical positions as an opportunity for collective marketing.

2.3.1 Food availability

A general shortage of exotic vegetables available between November and March for rural and urban Africa (Afari-Sefa, 2012). Due to the high temperatures that create low water table, exotic plant growth and production is adversely affected. This vacuum can be filled by indigenous vegetables. Their cultivation potential in difficult

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conditions can lead to a sustainable supply of food (Mavengahama, 2013; Afari-Sefa, 2012) leading to improved food security. Food security could be attained if adequate food of sufficient quality is distributed during the year by domestic cultivation and distribution (Mavengahama, 2013). Home-level food security influences greater productivity, steady demand and higher wages. Accessibility and affordability are the key aspects of availability (Chikobvu, 2011).

Indigenous vegetables can be obtained in the form of dry or fresh vegetables during the year. According to Ndoro (2007), in rural and urban areas, wild and semi cultivated crops are picked when their growth is stimulated by the first rains. A research conducted in Mutimutema & Mvere (2000) showed that in more rural areas than urban areas more indigenous vegetables are eaten. More than 75 per cent of Zimbabwe's population relies on fresh native food and dried native vegetables in the rainy season, and during the lean season. Households in the district of Wedza have said that they dry a further portion of their fresh indigenous vegetables during summer. This ensures that plants like pumpkin leaves are planted year round and are grown in irrigated gardens after summer. The production of indigenous vegetable products will result in the generation of steady incomes which could be seen as socio-economic protection networks for household livelihoods.

Qualitative impact assessment by Tamasese (2009) indicates that indigenous plants enhance access to a wide variety of foods, even during the winter, when dry native plants are eaten. Participating households noted that as food supply is growing, their diet is broader and their surplus is on sale. Thus increasing the possibility of food and income disparities becoming minimized for households in indigenous vegetables growing areas. Manwa & Mahundi (2015) stated that the elite and the educated classes had low-level indigenous vegetables in their diet. These communities have

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however, progressively changed their mindset and contributed to an increasing awareness of indigenous vegetables because of the high incidence of disease such as cancer.

2.3.2 Nutritional security

Indigenous plants provide populations with the supply of diverse nutrients. Various tropical plants contain increased nutrient composition in contrast to western exotic plants (Shackleton, 2009; Ebert, 2014). Indigenous food sources ranging from legumes, root and tuber, leaf and fruit plants can make a significant contribution to food and nutrition security (Mavengahama, 2013). Studies have shown that indigenous plants in contrast to exotic plants have higher amount of essential nutrients. Adebooye and Opabode (2004) have reported increased levels of protein, calcium, iron, vitamin A, C- and folic acids and phenolic compounds in indigenous vegetables.

WHO (1999) noted that some disease problems are associated with dietary deficiencies. Differentiating diets and integrating indigenous vegetables in nutritional systems may treat diseases such as anemia and eye disorders, which also impact children and older adults especially those in lower income classes. They further stressed that increased intake of adequate and diverse concentration of indigenous vegetables prevents a rise in starvation or chronic diseases such as cancer.

2.4 Factors influencing intensive consumption of indigenous vegetables

Indigenous vegetable consumption is influenced by household expectations (Vorster, 2007). In view of this, indigenous vegetables have been eaten more often than not over the years. The condition is obvious from the view that the taste of

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indigenous vegetables relative to exotic vegetables is deemed to be weaker. The low intake of indigenous vegetables is related to hunger and primitive practice, Kimiywe (2007) argued. Kimiywe (2007) notes that there is rising pressure on the use of autochthonous plants because they are associated with the idea of social backwardness and poverty. Vorster (2007) pointed out that the common view of indigenous vegetables as mediocre or behind-the-scenes clearly illustrates why young people shun indigenous vegetables. The bulk of indigenous vegetables have a uniquely bitter flavor.

Tavassoli and baron-cohen (2012) have proposed that young people have active taste buds which are replaced by bitter taste foods each time they develop, compared with those adults whose taste buds are not modified at the time of development. Older people therefore prefer to eat more indigenous plants than young people. Study has also shown that young people have little interest in eating indigenous vegetables because they are perceived to be backward and obsolete. The restricted cooking methods such as boiling as the most prevalent practice render young people less likely to choose indigenous vegetables. Many other socio-economic factors such as gender, schooling, household leaders' age, business and household monthly income affect consumption strength of indigenous vegetables. For example, Vorster (2007) stressed that men are less likely to consume indigenous vegetables than women. However, Kemiywe (2007) revealed that there is a differing geographic position and cultural norms for indigenous vegetable intake. Considerations such as the subsistence source and supply of organic vegetables in the local region have a detrimental effect on the intensive consumption of indigenous produce. Cash cropping activities in crops like tobacco has resulted in loss of diversity, hence factors such as livelihood source and availability of indigenous vegetables in the local area has

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negatively influenced the intensive consumption of indigenous vegetables.The vegetables have naturally been pushed out of land allocation decisions and hence from the consumer's table.

The pattern of consumption and desires of indigenous plants differ according to the household structure. In a study conducted by Danisile in Cape Town in 2013, livelihood sources have been one of the factors deciding vegetable preference and use. More casual workers and contractors have been found to eat more vegetables than staff (Kimiywe, 2007). The author noted that a resource defines time for indigenous vegetables to be purchased, processed and cooked. Monthly revenue from households impacted indigenous vegetable consumption rates (Kar, 2016). The economically disadvantaged classes ate more than their high incomes (Vorster, 2007). A research by Mpala (2015) has shown that the accessibility and affordability of indigenous vegetables have an impact on their patterns of use.

2.5 Indigenous vegetables in Northern Ghana

The future contributors of both micronutrients and bioactive compounds to communities in Ghana are being recognized gradually as indigenous vegetables. The soil is abundant with plants like Amaranth spp and Kenaf spp being among the commonly consumed vegetables in the Northern region of Ghana.

2.5.1 Amaranthus spp (*aleefu*)

Amaranthus belong to the plant genus Amaranth. Amaranths consist of 60-70 species (Xu & Sun 2001) comprising a minimum of 17 species with edible leaves and 3 grain amaranths cultivated for their grains (Grubben & Denton, 2004). While weeds are frequently regarded as various species, people around the world value amarants as

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leafy vegetables, cereals and ornamentals (Trucco & Tranel, 2011). The majority of amaranth species are harvested as a food resource in the wild. Only a small number is grown and are among the most common leafy types grown and sold in tropical African markets. For their seeds, Amaranthus may also be cultivated. This is the case in certain introduced American varieties (Wu et al. 2000). Grain amaranth in Africa is not widely grown (Grubben & Denton, 2004). In recent times, however, a few farmers have taken amaranth grain production seriously and supply thousands of supermarkets in Zimbabwe, Ghana, Kenya, Uganda, and Ethiopia. Amaranthus has been a promising food crop since 1980, primarily due to its high nutritional value of both seeds and leaves, drought, diseases and pests resistance (Wu et al., 2000).

According to Onyango (2010), improving amaranth by R&D will produce a simple and cost-effective solution to malnourishment, health promotion and food protection. Unfortunately, there are still gaps in knowledge of some popular amaranths of Africa and there are confusions in the nomenclature of species, for example the hybrid complex, while detailed nutrition profiles have yet to be compiled (Grubben & Denton, 2004). Little is also known about the reproductive capacity of wild families especially for sustainable use.

2.5.1.1 Systematic and taxonomy of economically important species

The species of Amaranthus are often difficult to characterize taxonomically, due to the overall similarity of many of them, small and difficult-to-see diagnostic parts, intermediate forms, and the broad geographical distribution, which is the reason for many synonyms (Mujica & Jacobsen 2003). Sauer (1967) described the two dioecious species of Acnida and Amaranthus (including the monoecious species), and the three subgenera of Mosyakin & Robertson (1996) of Sauer (1976). Inflorescencies

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and floral features of Acnida, Amaranthus, and Albersia. The need for violation or micro-classification of the genus has recently been raised (Das, 2012). Often morphological separation of organisms can be difficult. Examination of floral parts may nevertheless, contribute to the use of continuities to identify well-established taxa. characters (Trucco & Tranel, 2011).

Petal numbers and morphology are used to identify the taxonomy of Amaranths (Trucco & Tranel, 2011). Amaranth species may be categorized into three groups, according to Das (2012). These are: (1), Amaranthus vegetables for example Amaranthus tricolorvar. Amaranthus tricolor var, tricolored. Tristis; (2) Amaranthus grain including Amaranthus hypochondriacus, Amaranthus caudatus, Amaranthus cruentus, and (3) Weed Amaranthus with members including Amaranthus spinosus; Amaranthus viridis; and Amaranthus retroflexus; and Vegetable Amaranthus may well be differentiated from a flower bud of axil, 3 petal lobes, 3 stamens, brownish black seed, indeterminate growth habit through inflorescence, such as axil or short spikes. Amaranthus grain is characterized by broad to medium complex apical inflorescence, which includes cyme aggregates, 5 petal lobes, 5 branches, variable colored seed seed color and a well-defined flange, utric circumcisive (Das 2012). The Amaranthus species is seen in Figure 2.1.

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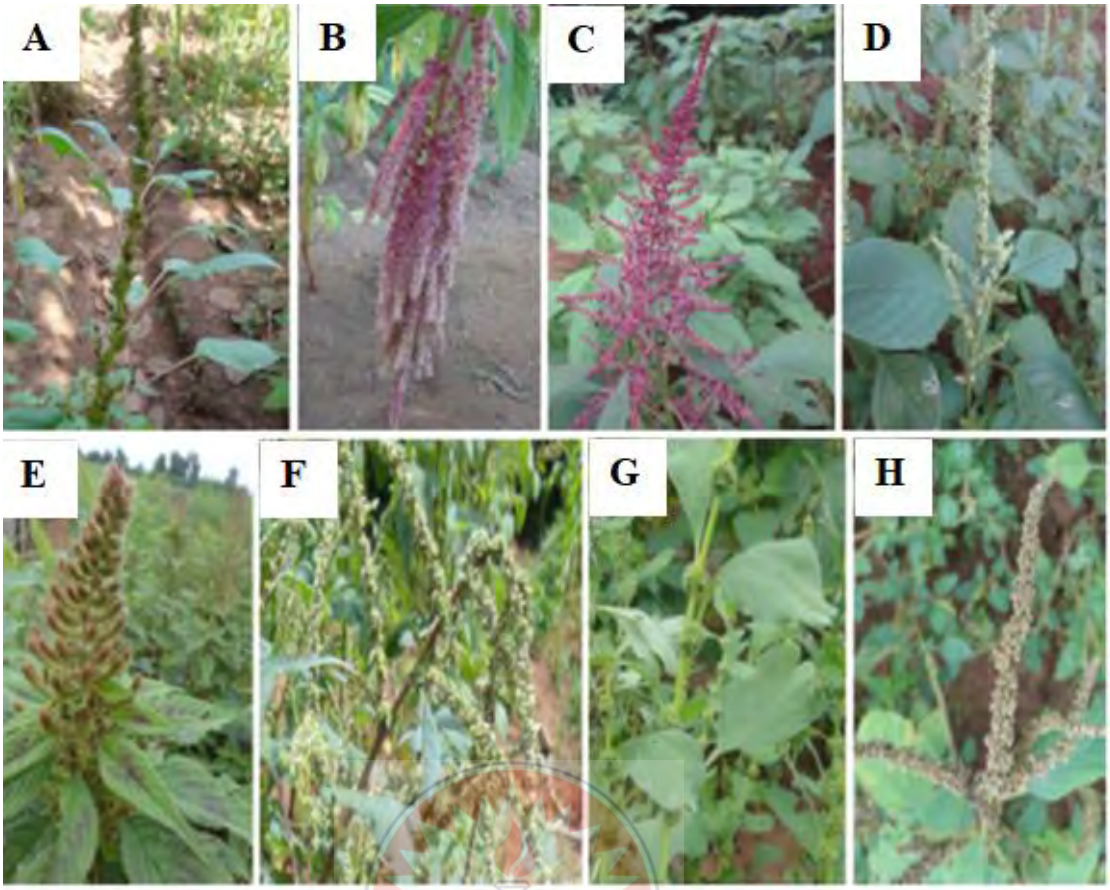

Figure 2. 1: Inflorescences of selected Amaranthus species

Key: ***(A)*** *Apical and axillary inflorescences of A. blitum;* ***(B)*** *Hanging inflorescence of A. caudatus;* ***(C)*** *Terminal inflorescence of A. cruentus;* ***(D)*** *Terminal inflorescence of A. dubius; (E) Inflorescence of A. hypochondriacus; (F) Apical and axillary inflorescences of A. spinosus;* ***(G)*** *Axillary clusters of A. tricolor;* ***(H)*** *Terminal inflorescence of A. viridis.* Source; Grubben & Denton (2004); Adjakidje` (2006)

Table 2.1 shows the classification for widely species used in Sub-Saharan African (Das 2012). With respect to weeds, some plants have a morphological commonality with leafy shape, others with Amaranthus grain shape. In demarcating Amaranthus vegetables, grain and herb, the seed attribute is often very usefully used. The crop group bears extraordinary resemblance to the weed group in possessing brownish, black or undifferentiated flange seeds.

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Table 2. 1: Description and uses of selected amaranths species

Species	Status	Uses	Botany/description	Seed maturity period
Amaranthus blitum L.	Wild and Cultivated	Leafy vegetable; medicine	Inflorescence an axillary many-flowered cluster, forming a false spike at apex of plant, with male and female flowers intermixed; flowers unisexual, with 3(−5) tepals; leaves lamina broadly cuneate at base, often deeply notched at apex; smooth and wrinkled fruits, shiny blackish seeds indehiscent or bursting irregularly	8 weeks after Sowing
Amaranthus caudatus L.	Cultivated	Pseudo-cereal; leafy vegetable; ornamental; medicine	Inflorescences dense spikes. Female flowers with 5 broad tepals, 3 internal obovate, rounded at apex, mucronate, 2 external spatulate, not rounded at the apex; spikes hanging from their base. Seed almost globose, smooth and shining, pale coloured (ivory), reddish or dark brown	−
Amaranthus cruentus L.	Cultivated	Leafy vegetable; grain; medicine; ornamental	Leaves lamina broadly lanceolate to rhombic-ovate; Inflorescence large and complex, consisting of numerous agglomerated cymes arranged in axillary and terminal racemes and spikes, the terminal one up to 45 cm long, usually with many lateral, perpendicular, thin branches. Flowers unisexual, subsessile, with 5 tepals 1−2 mm long, bracts as long as or slightly longer than the perianth. Seeds obovoid to ellipsoid, compressed, whitish to yellowish or blackish	12−20 weeks After sowing
Amaranthus dubius Marx. ex Thell.	Wild and cultivated	Leafy vegetable; Medicine	Inflorescence spikelike or paniculate, glomerules more or less isolated at base of inflorescence and clustered towards apex; leaves broadly triangular blade down; female flowers 5 tepals; Fruit an ovoid urceolate capsule, dehiscing circularly, blackish seeds	6 weeks after Sowing
Amaranthus hypochondriacus L.	Cultivated	Pseudo-cereal, ornamental	Inflorescence stiff with thick branches, bracteoles always longer than the tepals; tepals 5, lanceolate, with one equal to or longer than the fruit, the other 4 shorter; Fruit an obovoid to rhombic capsule. Seed obovoid to ellipsoid, whitish to yellowish or blackish	−
Amaranthus spinosus L.	Wild	Fodder, leafy vegetable, medicine	Inflorescence in spikes to upper nodes, axillary glomerules present or not. A pair of spines in the leaf axils, often dense presence of axillary 5−10 mm diameter fruit capsular, dehiscent. Seed shiny black or brownish-black with thin margin	−
Amaranthus thunbergii L.	Wild	Leafy vegetable	Leaves lamina narrowly elliptical to rhomboid or spatulate, sometimes with a dark purple blotch; Inflorescence an axillary cluster, bracts with long awn; flowers with 3 tepals; Fruit an ovoid-ellipsoid to pyriform capsule	4−8 weeks After sowing
Amaranthus tricolor L.	Cultivated	Leafy vegetable, ornamental, medicine	Inflorescence an axillary, globose cluster up to 2.5 cm in diameter, the upper clusters sometimes forming a terminal spike, with male and female flowers intermixed; brown or shiny black seeds, faintly reticulate	6 weeks after sowing
Amaranthus viridis L.	Wild and occasionall y cultivated	Leafy vegetable; fodder; medicine	Inflorescences spikes slender, not spiky, trimers female flowers, fruits strongly verrucose, apiculate, as long as the perianth, tearing irregularly; Seed subglobose, slightly compressed, margin acute, glossy black	−

Source: Grubben & Denton (2004); Adjakidje` (2006)

The amaranth grains are distinguished by discoid grains with a distinctive folded flange and seed cover color rather than black or brownish-black. Some of the weedy are grown and used as plants (Grubben & Denton, 2004). The most popular leafy vegetable in Kenya, for example, is dubius currently. Das' classification could be true for many widely used economically important species (Das, 2012). However, the entire spectrum of species diversity within Amaranthus genus needs to be

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thoroughly assessed. There is a persistent confusion between A. Cruentus and A. Hybridus while the other two domesticated species, A. hypochondriacus and A. caudatus evolved secondarily by repeated crossing of A. cruentu with two other wild species, A. powellii and A. quitensis, as the primary crop spread into their native ranges (Chan & Sun 1997), Sauer 1967, 1976).

An alternative hypothesis is that each of the grain species was domesticated independently in different regions and from different wild species: A. cruentus from A. hybridus presumably in central America, A. hypochondriacus from A. powellii in Mexico, and A. caudatus from A. quitensis in South America (Sauer 1967, 1976). A third hypothetic suggested that each of these three domesticated species was derived from independent domestication events from genetically distinct populations of A. hybridus (Mallory et al. 2008; Maughan et al. 2011). This can be attributed to taxonomic coverage or the type of markers used. This is why extensively selected amaranth taxa should use a combination of morphological and molecular markers to explain the relation between phenotypes and genomes.

The low degree of genetic variation found in A was proposed by Chan and Sun (1997). A. cruentus may be the product of a method of specialized domestication in which the original A was just a small subset. For unique agronomic characteristics the hybrid population was intensively artificially chosen. The standardized cultivation spectrum of A was hypothesized by Mallory et al. (2009). The level of genetic variation within the genus may have been further decreased by cruentus. Returning, A. Hybridus has demonstrated a high genetic diversity, a confirmed progenitor of grain amaranth species. Some scientists tend to put A on the spot. A and Cruentus. Hybridus within one genus (including some forms of A. hypochondriacus), A. With subsp, hybridus. Cross and subsp. Crosp. Hybrid Hybrid (Maundu et al., 2009).

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2.5.1.2 Nutritional value of amaranths

The high content of essential micronutrients such as b-carotene, iron, calcium, vitamin C and folic acid, gives amaranths an outstanding nutritional value (Priya et al. 2007). Amaranthus hybridus has a higher mineral content than the Telfairia occidentalis Hook.f, Vernonia amygdalina Delile. Gnetum africanum Welw. and Cucurbita pepo L (Aletor et al. 2002). A cup of baked, boiled and drained amaranth leaves provides 90% of daily value of vitamin C, 73% of vitamin A, 28% of calcium and 17% of iron. *Aspilia africana* (Pers.) C.D has a greater vitamin composition than those recorded in the fruit (Alabi et al. 2005).

Amarantha leaves and stems can compare with spinach leaves in terms of protein content as food in South-East Asia and Equatorial Africa (van Le et al., 1998). The particularity of amino acid profile of A. cruentus leaves is its methionine and lysine levels, which are the limiting amino acids in most plant protein (Fasuyi 2007). Wesche-Ebeling et al.(1995) reported that the wild species A. veridis, A. retroflexus, A. palmeri and A. blitoides had higher protein levels than the cultivated one A. hypochondriacus. A reported by Akubugwo et al. (2007), showed that protein content of A. caudatus was greater than protein content of A. Hybridus.

Andini et al., (2013) compared the protein contents of the vegetables (A.tricolor), grain (A. hypochondriacus, A. caudatus, A. cruentus) and Weedy (A.blitum, A. dubius, A. viridis) and indicated that the content of proteins in the leaves of the three weedy typeswas found to be 2% – 2.5% higher than that found in A. tricolor. Even though there is no doubt about the nutritional value of Amaranth leaves, the processing techniques positively and/or negatively affect the nutrient content. Boiling leaves have reduced ascorbic acid, phosphorous, nitrate and oxalates substantially in distilled water for example. However, nutrient cooking losses were

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just not significant while anti-nutrients decreased significantly (Mziray et al. 2001). Longer blanching periods cause greater loss of ascorbic acid and b-carotene in the leaf contents (Yadav & Sehgal, 1995). The nutritional content and bioavailability of minerals in food is determined by their quantity (Reddy & Love 1999). Blanching and cooking increases availability of minerals such as iron (Yadav & Sehgal 2002) as well as calcium and zinc (Yadav & Sehgal 2003). The most successful approach was to thermally treat these vegetables by squeezing, stir-frying and open pan boiling. B-carotene and stir-frying are beneficially bio accessible (Veda et al., 2010). The bioavailability of thiamine, vitamin B-6, niacin, and folate can also be improved with heat processing. There is however little proof that such bioavailability enhancements compensate for the lack of heat labile and water-soluble vitamins (Hotz & Gibson, 2007).

Grain from amaranth is also an important source of minerals. Minerals including calcium, magnesium, iron and zinc were stated to be less than 5.2-, 2,9-, 2,8- and 1.3-fold in the wheat grain than in amaranth seeds respectively (Alvarez-Jubete et al. 2010). Its high lysine content makes the application as a mixing food supply to improve the biological benefit of processed foods especially appealing. The lipids are high in tocotrienols and squalena, which have a beneficial effect on the reduction of low-density blood cholesterol in organic compounds. All grains, however, contain substantial quantities of phytic acid, an iron absorption agent and other minerals (Sanz-Penella et al. 2012).

2.5.2 Kenaf spp (Hibiscus cannabinus)

In most African countries, kenaf (Hibiscus cannabinus) is a widespread wild herb. Six thousand years ago in Sudan, it may have been domesticated. In the tropics

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and subtropics Kenaf is commonly recognized (Humphries, 2004). It is commonly cultivated as a vegetable in Africa and is much smaller in size cultivated for its fibre use. The crops in Côte d'Ivoire, Burkina Faso, Togola, Benin, Niger, Tanzania and Malawi have previously been important in commercial fiber production. India has long been the biggest kenaf fiber manufacturer.

Kenaf is a rapidly growing annual herbal plant. The cultivated plant does not have a significant ramification. Depending on the type of atmosphere it finds itself growing, it rises up to a height of 8-14ft and often reaches around 18ft. The bark of the stalk comprises a long flat, cordage and textile fiber. The color of the stem is green in most varieties, but some are red and purple. The leaf form differs considerably and Kenaf seedlings' first few leaves are not lobed, while some species grow post-youthful leaves with deep lobbying (Jones et al., 1995). With its deep root and widespread, lateral branches, the root system is extensive.

The fresh shoots leave, flowers and young fruit are sometimes used as vegetables. Kenaf is called Bra in the northern part of Ghana, bito in the south east, and bri in the upper west and its seed is enjoyed as a local delicacy. These are roasted, ground and pound, and the flour and skin are separated in water. The flour is usually discarded but the floating bits of skin are used to produce a paste combined with boiled pigeon peas. Because of its sweetness, children chew its bark. The stem is a fiber source used in the development of twine, fabric and textiles. The production of kenaf fiber in Africa is very unusual, but is locally significant, for example, in northern Ghana, Niger, and Sudan. Powdered leaves are used to treat sores and boils in western Africa and its leaf infusion is used to treat cough. In India, biliousness is mixed with juice from the flowers, while the seeds are considered stomachic and aphrodisiac. Young whole plants are an outstanding cattle fodder. The core stem

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(xylem) is used as a plant growth medium in conjunction with tourbium (Sphagnum) and fertilizer. Kenaf plants accumulate minerals such as selenium and boron and can be used to extract these metals from polluted soil through the process of bioremediation. Plants are used as border markers in West Africa.

In West and Central Africa, Kenaf leaves are sold on local markets. Production and import figures are not easily obtainable as a vegetable. Average year-on-year yute-like fiber production in 2004–2008 was about 350 000 tons, of white hen (Crotalaria juncea L.) and devil's cotton (Abroma augusta (L.) L.f., including kenaf, roselle (Hibiscus sabdariffa L.); Congo jute (Urena lobata L.), Sunshine hemp (Crotalaria juncea L.). Species figures are not available separately but kenaf accounts for a significant proportion of the total with India being the major producer. Production is small in Africa and almost every kenaf fiber is generated at home (Cheng et al., 2016).

2.5.2.1 Components of Kenaf (*Hibiscus cannabinus)*

The constituents of kenaf are especially well known in Asia as a necessary herbal medicine (Alexopoulou, Papattheohari, Christou, & Monti, 2013; Ryu et al., 2013; Odetola & Erubvetine, 2012). The seed is a source of edible oil (Kubmarawa, Andenyang, & Magomya, 2009). Some studies have shown that the components of Kenaf seed could be used for the innovation of functional food products, livestock feed, and medicinal purposes (Chan, Khong, Iqbal, Mansor, & Ismail, 2013; Yusri, Chan, Iqbal, & Ismail, 2012). Figure 2.2 demonstrates the key components and composition of the kenaf farm.

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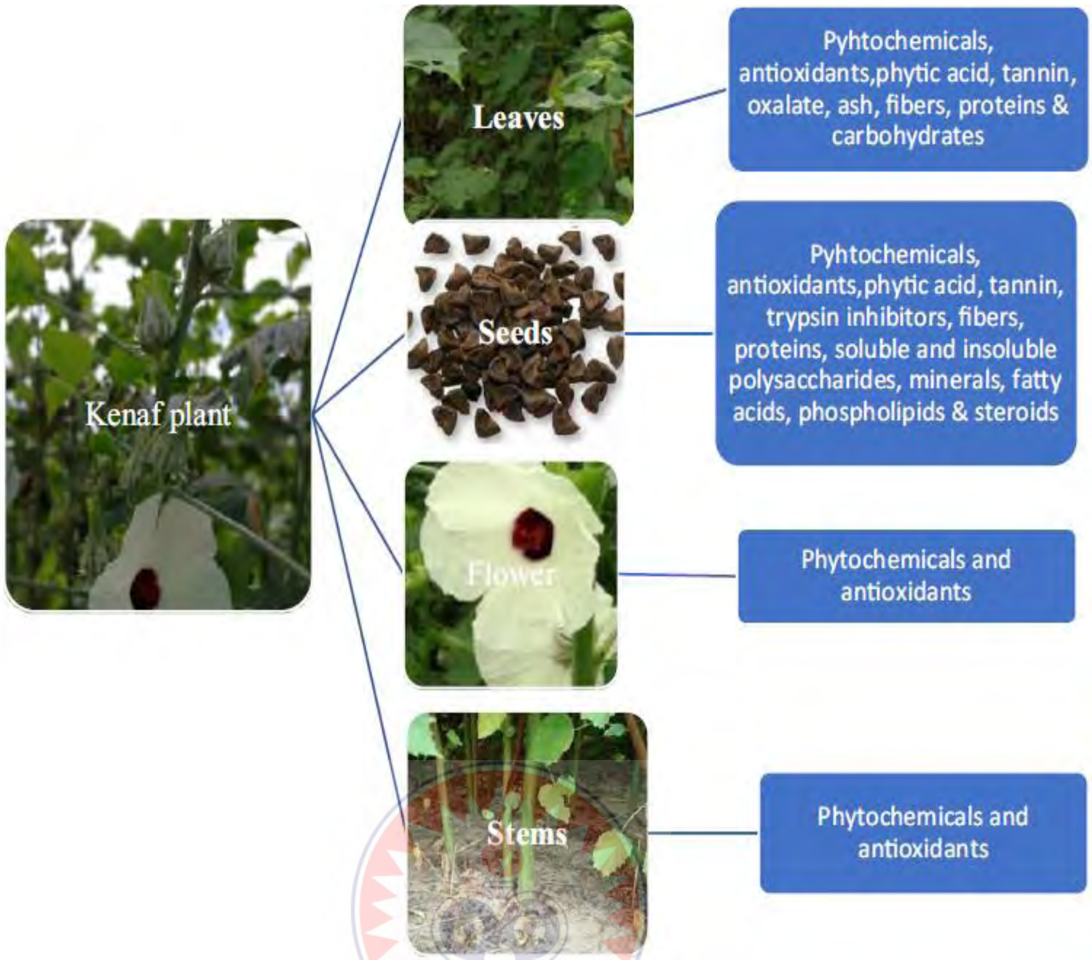

Figure 2. 2: shows the composition of different parts of kenaf plant.
Source: Adapted from Karim (2018)

Due to the nutritional and phytochemical compounds of kenaf plant, most of which can be used as potentially significant ingredients or components in foodstuffs such as appetizers, food enhancer, antioxidants, aphrodisiacs, nutricotine, other technology applications in kenaf plant has been reported (Nandagopala, Johnson Gritto, & Doss, 2015; Alexopoulou et al., 2013). In addition, researchers have made a variety of attempts to use bio-active compounds and other possible functional features of its seed in producing highly nutritious foods because of the essential chemical constituents, phytocompounds and antioxidants (Kim et al., 2018; Kim, Tsao, Yang, & Cui, 2006).

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2.5.2.2 Nutritional Functions of Kenaf (*Hibiscus cannabinus)*

Kenaf seeds has several functional roles and can be used to manufacture functional foods. Kenaf seeds are a major source of dietary fiber, oil, and essential nutrients. The oil is proposed as the latest source of functional edible oils with high antioxidant activity (Chan & Ismail, 2009) and anticancer properties (Foo, Yazan, Chan, Tahir, & Ismail, 2011; Ghafar, Yazan, Tahir, & Ismail, 2012). Several researchers documented the importance of kenaf seed items, such as kenaf seed flour (KSF), defatted kenaf seed meal (DKSM) and kenaf protein content concentrates (KSPC); (Mariod, Ibrahim, Ismail, & Ismail, 2012; Zawawi et al., 2014).

Kenaf seeds appear to be a source of usable edible oil (Cheng et al., 2016; Yanzan et al., 2011) since they have alpha-linolenic acid, essential omega 3 fatty acid with antithrombotic and anti-inflammatory action (Ruiz, Dobson, Brennan & Gordon, 2002). The comparatively high oil content of cotton seed oils, and large amounts of phospholipids and phytosterols mean that kenaf oil can be used for food and food (Nyam et al., 2009). Researchers have been able to isolate the bioactive (phytosterol) components of kenaf seed oil for safe foods (Holser et al., 2004). Phenolic and flavonoids in kenaf seed have been identified as possible angiotensin I-converting enzyme inhibitors as well as in lipid peroxidation (Jin et al., 2013).

The importance of defatted kenaf seed meal (DKSM) as an alternate dietary protein source was proposed by Chan et al. (2013). Mariod et al. (2010) have reported adequate functional properties of the protein concentrates made from the DKSM and are appropriate in food products for use as functional ingredients. DKSM produces comparatively large concentrations of total phenol compounds that could be used in the food industry as phenol chemicals such as phenolics and flavonoids (Kamath,

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Chandrashekar, & Rajini, 2004). They are effective antioxidants against the peroxidation of food lipids (Shahidi & Naczk, 2003). Vital secondary metabolites of DKSM have been documented in various foods and experiments in laboratory animals as having a strong antioxidant function has been reported (Sroka & Cisowski, 2003). This could help inhibit lipid oxidation during manufacturing and storage by applying DKSM to food products; since it inhibits free radicals chain responses in foodstuffs. Chan et al. (2013) say that DKSM is an efficient antioxidant supplement capable of avoiding hydroperoxide decomposition.

2.5.2.3 Lipids Composition of Kenaf (*Hibiscus cannabinus)*

Kenaf seed is rich in fatty acids and has been stated by several researchers to have high values of crude lipid of kenef seed ranging from 20.4% to 24.8% (Alexopoulou, et al., 2013; Chan & Ismail, 2009) higher than that of the roselle seed oil (Ismail, Ikram and Nazri, 2008; Wang, Morris, Tonnis, Davis, & Pederson, 2012) and lower than hemp seeds (Wang, Morris, Tonnis, Davis and Pederson, 2009; Vonapartis, Aubin, Seguin, Mustafa, & Charron, 2015). Kenaf seed oil has been described as a rewarding alternative source of consumable oil (Alexopoulou et al, 2013), rich in unsaturated fats such as oleic acid, linoleic acid, linolenic acid and also containing the major antioxidants tocotrienols.

Kenaf seeds are similar to Rosell seed oil in unsaturated fatty acids (Mohamed, Fernandez, Pineda, & Aguilar, 2007). Palmitic acid is the major saturated fatty acids, whereas oleic, and linoleic acids are predominant unsaturated fatty acids in kenaf seed oil (Alexopoulou et al., 2013; Mariod et al., 2010) Similar to the fatty acid composition of Roselle seed oil (Bouranga-Kalou et al.,2011; Karma, Chavan, Nimbalkar, & Kahar,2017) and that of hemp seed oil (Da Porto, Decorti, & Tubaro, 2012; Vonapartis et al., 2015). A variety of phytosterols have been found in kenaf

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seed oil, including campesterol and stigmasterol, with β- sitosterol being the predominant (Mariod et al., 2010). However, the phytosterol content of kenaf seed oil is much lower than that of Roselle seed oil (Nyam et al., 2009). Kenaf seed oil has indeed been engineered to include a broad variety of phosphatidylcholine, such as phosphatidylcholine, phosphatidylchlorine, phosphatidylcholine, phospholipid tetrahydrofuran, phosphatidyl retinol, and phosphatidylserine (Webber III & Bledsoe, 2002).

2.5.2.4 Protein composition and function ingredients of Kenaf

Studies have reported that the crude protein content of kenaf seed varies from 21.4% to 30.5% (Alexopoulou et al, 2013), which is close to the hemp seed protein composition i.e. 23.8% to 28.0% (Vonapartis et al., 2015). They are however higher than Roselle's protein content (14.9%) (Nyam et al., 2009), but they are lower than the values of 33.5% and 26.62% reported by Hainida et al, (2008) and (Mokhtari et al, (2018) respectively. The defatted kenaf seeds has higher protein content ranging from 74.4% to 81.4% than the crop as a whole (Mariod et al., 2010). But the protein contents of DKSM range from 26.19% to 33.0% (Nyam et al., 2009; Chan et al. 2013). Kenaf contains considerably amount of essential and no-essential amino acids than defatted flakes, with cysteine and lysine predominating in the essential nutrients in defatted kenaf and protein concentrates (Mariod et al., 2010).

Kenaf Seed Protein Concentrate (KSPC) is the prospective protein source for food products that can be used to verify the potential of KSPC as functional ingredients, and differential calorimeter searching (Mariod et al., 2010). KSPC's high water absorption capacity is an excellent ingredient in many foodstuffs that require high water conservation (Mariod et al., 2010). Thanks to its high oil absorption

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ability, KSPC may be used as a food ingredient in items such as mayonnaise, dressings, sauces and cake batter (Mariod et al., 2010). It can also be found in whipped toppings, cake bats, frozen desserts, cups and drinks based on the high foaming capability of KSPC.

The operational properties such as high protein stability in variet PH range of 5 to 9 and various levels of salt and sugar concentrates (0.5% to 1.5%; 5.0% to 15.0% respectively), the moisture capacities, as well as the potential for moisture and oil absorption, were comparatively high for kenaf seed protein concentrations (Mariod et al., 2010). This suggests the kenaf seed protein concentrates can be used in food systems as a possible source of protein. In comparison to the Roselle seed which has been used for the production of cookies, kenaf seed and its derived value-added components were not used effectively as ingredients in food production. Cookies have been shown to have a large content of phenol, good antioxidants and enhanced nutritional properties (Nyam, Leao, Tan, & Long, 2014; Nguyen, Le, Pham, & Tran, 2018).

2.5.2.5 Kenaf Seed in Food Applications

Kenaf seeds should be used for food application as a whole seed or processed in various ways because of their excellent nutritional quality. Depending on the intention to be used for, kenaf seed can be turned into flour by milling into various particle sizes. The seed may also be defatted and the protein content of the flakes raised. Mariod et al. (2010), using Soxhlet extraction method, removed the oil from kenaf soil. The sonication process for extracting oil from ground kenaf seed was used by Zawawi et al. (2014). The advantages were reported as reduction in extraction time, reduction in anti-oxidant destruction (Wong, Lau, Tan, Long, & Nyam, 2014),

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and also high solvent diffusion into the sample and increase the contact surface between the solvent and the solute in contrast to soxhlet extraction, where the solvent used contains the final product. Other reported potential technique is the supercritical fluid extraction (SFE). Pressure and temperature are major factors that influence the production of SFE kenaf seed oil (Abd Ghafar, Ismail et al., 2013).

Earlier research (Chan & Ismail, 2009; Yazan et al., 2011) suggested that the quantity of kenaf seed oil under pressure is more significant than the temperature. As the most favorite method for removing oil, the supercritical fluid extraction (SFE) method is preferred, since it saves time and eliminates the oil solvent entirely (Chan & Ismail, 2009). Although the Soxhlet extraction method has been stated by Chan and Ismail (2009) to offer higher oil output than the supercritical fluid extraction method. Protein concentrates are another type of kenaf seed flour. Kenaf protein compositions are more sophisticated than flour and grains and typically contain 70% or more protein than flour and grains. The concentrate is obtained from defatted kenaf flour or flakes by extracting the saccharide, ash and other inorganic elements in either of the three forms illustrated in Singh et al,(2008). The first approach is to wash the defatted flour or meal with roughly 80% alcohol.

According to Mariod et al. (2010), this method dissolves and removes the oligosaccharides, the ash and other small components from the protein. The other approach uses pH 4.5 acid to isolate protein sugars. The third approach uses wet heat to adjust the proteins in the rice. The sugar and other minor components of the protein are subsequently isolated by water. Protein concentrates produced using either method can be 70% or more, although the physical characteristics can differ according to the type of production (Mariod et al., 2010). Protein compositions have reduced their

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taste relative to flour through processes that eliminate some of the proteins during its processing.

The isolated kenaf proteins of seed are processed, obtained with oligosaccharides, insoluble polysaccharides and small ingredients extracted. Figure 3 indicates that the Kenaf seed protein content improves due to further processing of kenaf protein isolates during development. Protein isolates with other minor components can have 90% or more of protectin (Singh et al., 2008). Defatted kenaf seed meal and protein concentrate are a rich source of protein with high levels of essential amino acid relative to all seed. The flavour, low flatus and saccharid properties of protein concentrates can help promote product consistency and appropriate properties (Mariod et al., 2010).

2.6 Economic importance of indigenous vegetables

Indigenous vegetables form a large part of daily diet of Northerns and historically have been harvested in the rainy season from the habitable lands (Schippers, 2002; Ogoye-Ndegwa & Aagaard-Hansen, 2003). However, increasing population pressure on land led to their domestic cultivation in home gardens as intercrops with the main staple crop (Chweya & Eyzaguire, 1999; Schippers, 2002; Abukutsa, 2003). Indigenous vegetables are recognized for their contribution to food security and income generation (Schippers, 2000; Abukutsa, 2003; Abukutsa, 2010). In addition to managing and protecting people from chronic diseases, their variety in household diets means important micronutrients are acquired (Abukutsa, 2007; Yang & Keding, 2009; Singh et al., 2013). Although a number of studies assessed the trends of consumption of indigenous vegetables (Bundi, 2012), their share in a diet at the household level has not been fully investigated in Africa.

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Cultural contexts affect the use of various variants, so only certain variations can be used in certain populations (Croft et al., 2014). Their use and marketing must be encouraged by the thorough production and sharing of information concerning their nutritional value. This will increase the security of household nutrients and reduce micro nutrient deficit. Although indigenous vegetable were originally grown for subsistence purposes, with the surplus sold for income creation, they are currently produced for income generation (Humphry, 1993) (Schippers, 2000; Weinberger & Msuya, 2004; Ngugi et al., 2007). Their market share and contribution worth is dramatically growing in relation to other vegetables grown and marketed (Schippers, 2000; Weinberger & Msuya, 2004; Ngugi et al., 2007). This can be attributed to the improved production and supply of indigenous vegetables in both formal and informal markets.

On average, the opportunity cost of small-scale indigenous vegetable production and marketing is higher than provision of labour to agricultural related activities (High and Shackleton, 2000). Besides, poor households can still participate in their commercialization due to less capital requireme (Schippers, 2000; Abukutsa, 2003; Gockowski et al., 2003). Their income output and the growth of job opportunities (Schippers 2000) (Schackleton et al. 2000; Weinberger and Msuya 2004) have been recognised, with more women engaged in manufacturing and marketing operations (Gockowski et al., 2003). Notable social gains were also recognized to achieve higher profit margins through joint action in the processing of community goods and commercialization of indigenous plants in high demand outlets like supermarkets (Ngugi et al., 2007).

Given the consensus that indigenous vegetables are marginal to the economy, they have a strong potential for benefits including building jobs, generating income

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and catalyzing rural sector marketing (Mahlangu, 2014). In addition, Mnzava (1997) reports that the preservation of equity within a familial structure, since women consume it in their household, plays an important role in customs and traditions. Encompassing local vegetables means saving the minimal exchange used to buy locally available goods. Exotic plants need high inputs for production and sometimes poor and unpredictable returns in contrast (Masuku, 2013).

Indigenous plants of equivalent or better nutrient intake may be better grown with a relatively low level of input. Indigenous plants, because of their potential on local markets, have been described as a potential alternative to diversify the economy. In most rural communities they are famous (Mavengahama, 2013). Most indigenous vegetables can also be saved and carried for long periods and are less vulnerable to contamination than exotic vegetables during preparation or storage (Chagomoka, 2013). In large villages and towns because of the emergency of pandemic diseases, the demand for indigenous vegetables is growing. The production of local vegetables actually fails to satisfy local demand and commercialization continues to be hampered (Temu, & Marwa, 2007). This extraction of resources from indigenous vegetables is a significant source of income, especially for the rural poor who are working.

Shackleton (2009) also underlined the economic value for revenue generation and the variety of livelihoods of indigenous vegetables. A comparative analysis of indigenous plants from rural households, fields and arable lands finds that the value of indigenous plants produced by a household is 31% (Mavengahama, 2013; Shackleton, 2009). These experiments have shown that the prices of domesticated, wild or rural indigenous plants are equal to the average pay paid to farm workers in the neighbourhood, or even higher than the average wage. In comparison, although most

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trade was in the village/region, a rise in production and trade was seen in bigger regional centres (Shackleton, 2009).

A research by Ndoro (2007) indicated that 13% of farmers' household income was in indigenous vegetable advertising and management aspects. In a study by Mwaura (2013), farmers' groups have successfully entered the high-value leaf indigenous vegetable market sectors by cooperation with support networks. Shackleton (2009) said in his study that indigenous vegetables are being marketed than serving as subsistence vegetables only. Small farmers have been able to circumvent traders in relations with high demand customers, for instance supermarkets, to guarantee markets for their goods during the year and to increase profits. Group-organized farmers were able to make 35-72% higher profits than unfocused farmers.

Value added implies that good quality products enter the market and satisfy customer demands using sufficient manufacturing and postharvest techniques. Market research on pig weed (Amaranthus spinosis) purchasing and use in Nairobi have shown that urban consumers mainly care about food, sensory and protection characteristics (Mahlangu, 2014). In East Africa and Southeast Asia, selected native vegetables became attractive to the wealthiest segments of the population and gradually became the mainstream of trade in the underserved category. Attracted by strong market demand, seed companies start exploring and developing these popular crops, thereby consolidating the formal seed sector. The importance of indigenous vegetables for urban and hazardous households was highlighted throughout the supply chain in wholesaling and marketing (Chagomoka, 2013). Figure 2.3 demonstrates the development of jobs through strategic value chains.

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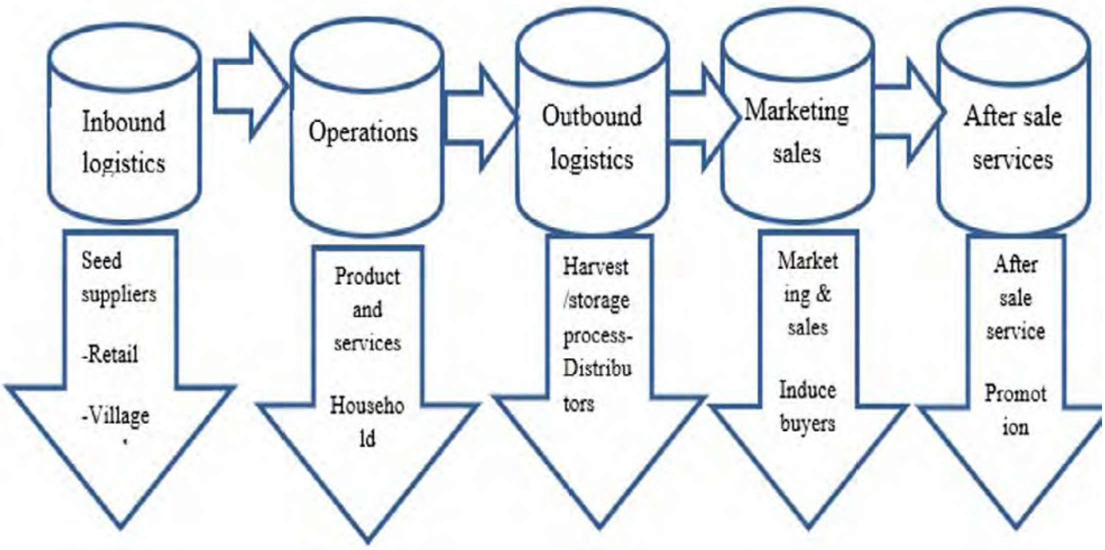

Figure 2. 3: Value chain of indigenous vegetable
Source: Adopted from Nyaruwata (2019)

Chagomoka (2013) finds that because little startup capital is needed for entry, a high level of involvement of women in indigenous vegetable marketing enables even the poor households to participate. The connection to household income is also specifically demonstrated by indigenous vegetables.

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CHAPTER THREE

MATERIALS AND METHODS

3.1 Materials

One breeding lines of two indigenous vegetables were evaluated, including one amaranths (Amaranthus cruentus L.), Alefu from the Family of Amananthaceae and Hibiscus (Subdariffa L.), Kenaf from the Family of Malvaceae. The plant parts used for the analysis were leaves and seeds for both vegetables (amaranthus and Kenaf).

The chemicals used included CONC. H_2SO_4, 40% NaOH and 4% boric acid solution (H_3BO_3).

3.2 Sample Collection and preparation

The selected indigenous vegetables Amaranthus spp and Kenaf were obtained from local farmers, processed and dried to constant mass and kept for further analysis in a refrigerator below 4°C.

3.3 Determination of Proximate composition

Moisture, ash, crude and fat of the Aramanthus and Kenaf seeds and leaves were determined using the method of AACC No.44-16, No. 08-01 and No.30-10, respectively (AACC,2000). Nitrogen content was determined by the Kjeldahl method (AACC 2000) and converted to protein content by multiplying by a factor of 6.25. All measurements were made in triplicate.

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3.3.1 Moisture content determination

Two grams of samples were weighed and transferred into a previously dried and weighed glass crucible and placed in a hot air oven to dry for 105°C for 5 h. Samples were cooled in a desiccator, weighed, and returned to the oven to dry to constant weight. Loss in weight was calculated as percentage moisture (AACC 2000).

3.3.2 Ash content determination

Two grams of sample were transferred into a pre-ignited and pre-weighed porcelain crucible and combusted in a muffle furnace at 600°C for 2 h. The crucibles containing ash were cooled and re-weighed. Loss in weight was calculated as percentage ash content (AACC 2000).

3.3.3 Crude fat content determination

Two grams of sample were transferred into a 22 x 80 mm paper thimble and capped with glass wool, dropped into a thimble holder and attached to a pre-weighed 500 ml round bottom flask containing 200 ml hexane and assembled on a semi-continuous soxhlet extractor. The contents of the thimble were refluxed for 16 h. The hexane was recovered on a steam water bath and the flask was heated for 30 min. in an oven at 103°C. The flask containing the fat was re-weighed after being cooled in a desiccator. Increase in weight was calculated as percentage crude fat (AACC 2000).

3.3.4 Protein content determination

To two grams of sample in a kjedahl flask was added 25 ml concentrated H_2SO_4 and digested till the colour of the solution turned clear. The solution was transferred into a volumetric flask and the volume made up to the 100 ml mark with

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distilled water. Ten milliliters of the solution were distilled and titrated against 0.1 M HCl against a blank. Titre values of duplicate samples were recorded and percentage nitrogen calculated using the formula (1)

$$\% \text{ Nitrogen} = \frac{(S_t - S_b)100 \times 0.1 \times 0.014 \times 100}{\text{Sample weight} \times 10} \qquad (1)$$

where S_t = titre of sample; S_b = titre of blank; Percentage nitrogen (% N) was converted to percent crude protein by multiplying by a factor of 6.25 (% Protein = % N x 6.25).

3.3.5 Crude fibre

A defatted sample of about 2.0 g was transferred into a 750 ml Erlenmeyer flask containing 200 ml of boiling 1.25% H_2SO_4 and refluxed for about 45 min. The mixture was screened with cheese cloth and residue washed with large volumes of boiling water till filtrate was longer acidic. The residue was emptied into a flask containing 200 ml boiling 1.25% NaOH and refluxed for about 45 min. The mixture was screened with cheese cloth and residue washed with large volumes of boiling water till filtrate was no longer alkali. The residue was transferred to a previously weighed porcelain crucible (M1) and dried for 1 h at 100°C and re-weighed after cooling in a desiccator (M2). The crucible was ignited in the muffle furnace at 600°C for 30 min and re-weighed after cooling in a desiccator (M3). The increase in weight was calculated as percentage crude fibre (AACC 2000).

3.3.6 Available carbohydrate

The available carbohydrate content present was calculated by difference [(100- 5m)], where m = proximate of moisture, fat, ash, fibre and protein (AACC 2000).

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3.4 Determination of anti-nutrient composition

3.4.1 Phytate content determination

To 4 g of ground sample was added 100 mL of 2% HCl. The mixture was constantly shaken for 3 h and filtered. To 25 mL of the filtrate was added 5 mL of 0.3% ammonium thiocyanate (NH_4SCN). Fifty milliliters of distilled water was added to afford the desired acidity. This solution was titrated against a 0.00195 g/mL ferric chloride solution. The end point was characterized by a persistent brownish yellow coloration.

$$\%\text{Phytic acid} = \frac{8.24t \times 100}{1000 \times \text{sample mass}} \quad (2)$$

3.4.2 Saponins content determination

Five (5g) of the sample was put into 20 % acetic acid in ethanol and allowed to stand in a water bath at $50^{O}C$ for 24 hours. This was filtered and the extract was concentrated using a waterbath to one-quarter of the original volume. Concentrated NH_4OH was then added drop-wise to the extract until the precipitate was complete. The whole solution was allowed to settle and the precipitate was collected by filtration and weighed. The saponin content was weighed and calculated in percentage.

$$\%\text{ Saponins} = \frac{W_2 - W_1 \text{ x } 100}{W_t \text{ of sample}} \quad (3)$$

W_1= weight of filter paper

W_2= weight of filter paper + residue

3.4.3 Alkaloid content determination

Five (5g) of the plant sample was placed in a 250ml beaker and 200ml of 10% acetic acid (CH_3CO_2H) in ethanol (C_2H_5OH) was added. The mixture was covered and

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allowed to stand for 4 hours at $25^{O}C$ i.e. at room temperature. It was then filtered with filter paper No. 42 and the filtrate was concentrated on a water bath until it reaches a quarter of its original volume. Concentrated NH_4OH was added drop wise until precipitation was complete. The mixture was allowed to settle and the precipitate collected on a weighed filter paper and washed with dilute NH_4OH. The precipitate, alkaloid, was dried and weighed. The percentage alkaloid was calculated

$$\% \text{ Alkaloid} = \frac{W_2 - W_1 \times 100}{W_t \text{ of sample}} \quad (4)$$

3.5 Determination of minerals content

A 500 mg sample was dried in a muffle furnace for the mineral content (Ca, mg, K, P, Zn and Fe). The ash was dissolved in a HCl/HNO_3 acid mixture and analyzed using the Atomic Absorption Spectrophotometer. The dry weight of Ca, Mg, K, and P content and μg·g-1 dry weight of Zn and Fe were expressed.

3.6 Data analysis

The obtained data from the proximate, anti nutrient and mineral analyses was submitted to the analysis of variance using the Statistical Analysis System (SAS Institute, 2006). All measurements were performed in triplicates. Means and standard deviation were used as analytical tools in comparing the variables. The significance level among the means was determined at $p<0.05$.

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CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Proximate composition of Amaranthus species (*aleefu*) and Kenaf species (*bra*)

The proximate composition of the two leafy vegetables (i.e. Amaranthus spp (*aleefu*) and Kenaf spp (*bra*)) grown and consumed in Northern Ghana is shown in Tables 4.1.

Table 4. 1: Proximate composition of Amaranthus spp (aleefu) and Kenaf spp (bra)

Test sample	Proximate composition					
	Ash (%)	Moisture (%)	Fat (%)	Fibre (%)	Protein (%)	Carbohydrate (%)
Aleefu leaves	$15.62^{b} \pm 0.03$	$7.16^{b} \pm 0.15$	$3.45^{a} \pm 0.03$	$19.50^{b} \pm 0.75$	$9.27^{b} \pm 0.06$	$45.00^{a} \pm 1.41$
Kenaf Leaves	$10.30^{a} \pm 0.14$	$6.70^{b} \pm 0.57$	$2.55^{a} \pm 0.12$	$18.50^{b} \pm 0.11$	$10.36^{b} \pm 0.03$	$51.59^{b} \pm 0.70$
Aleefu seed	$3.40^{a} \pm 0.001$	$1.65^{a} \pm 0.07$	$7.50^{b} \pm 0.53$	$6.30^{b} \pm 0.14$	$35.04^{a} \pm 0.13$	$46.11^{a} \pm 0.70$
Kenaf seed	$4.75^{a} \pm 0.35$	$2.70^{a} \pm 0.14$	$8.00^{b} \pm 1.41$	$7.46^{b} \pm 0.07$	$26.17^{b} \pm 0.76$	$58.00^{b} \pm 1.41$

4.2.1 Ash content of *Aleefu* and *Bra* samples

Results from Table 4.1 ash contained ranged from 3.40 to 15.62% with Aleefu seeds recording the lowest while Aleefu leaves recorded the highest ash content. A T-test ANOVA revealed that there was a significant difference between Aleefu and kenaf leaves ($p<0.05$) relative to their ash contents. However, there no significant difference relative to the seeds for the same parameter. This indicates that the ash content of the two indigenous vegetables (*aleefe and bra leaves*) grown in the Northern part of Ghana do not differ in their ash content relative to their seeds. Values reported for *Ipomea batatas* (11.10%), Vernonia colorate (15.86%) and Moringa oleifera (15.09%) (Lockett et al., 2000; Antia et al., 2006). Also, the ash content of Amaranthus spp (*aleefu*) and Kenaf spp (*bra*) was comparable with the study conducted by Akubugwo, Obasi, Chinyere & Ugbogu (2007) who found that the Ash

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content in *Amaranthus* hybridus L. leaves from Afikpo from Nigeria is low (13.8%). It is however, higher than that of some Nigerian leafy vegetable such as Ocimum gratissium (8.00%) and Hibiscus esculentus (8.00%) (Akindahunsi & Salawu, 2005). What this results is telling us is that for example the apparent difference in ash observed in Aleefu leaf and Kenaf leaf is statistically not different.

4.2.2 Moisture content of *Aleefu* and *Bra* samples

The mean moisture content of "*aleefu*" leaves ranged between 1.65±0.07% and 7.16±0.15%, with Aleefu seed recording the lowest while Aleefu leaf recorded the highest moisture content. Analysis of variance revealed a significant difference between the Aleefu and kenaf seed ($p<0.05$) though there was no significant difference observed between their leaves. The mean moisture content of "*bra*"/Kenaf seed was higher than that of *"aleefu"* seed. The low moisture content reveals that these vegetables can be appropriately preserved as they will not be prone to microbial deterioration. The values of the moisture contents recorded in the current study were lower than those reported by Tindal (1983); Woolfe, (1992); Suppiah (1992); Tweneboah (1998); Frank (1997); Fuglie, (2001); Antia et al., (2006). However, the current findings corroborated with those reported by Agbaire (2011), Adepoju and Oyewole (2018).

4.2.3 Fat content of *Aleefu* and *Bra* samples

The fat content ranged between 2.55% to 8.00% with Kenaf leaves recording the lowest fat content while Kenaf seeds recorded the highest. A cursory observation reveals that kenaf compositely has more fat content compared to Aramanthus. There was no statistical difference between leaves and seeds of the two vegetables under

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study. The fat content found in *"aleefu"* leaves and *"bra"*/Kenaf leaves was consistent with the fat content found in Xanthosoma sagittifolia "Kontomire", Amaranth cruentus "Aleefu", *Talinum triangulare* "Bokoboko", and *Moringa oleifera* ranging from 1.33 ± 0.04 - 3.19 ± 0.02 (Kwenin, et al., 2011). Also, the fat content found in the two indigenous vegetables were higher than the percentage fat content ranging from 0.15-0.94% in *Amaranthus spinosus* and 0.38-0.53% in *Talinum triangulare* (Oluwole, Makinde, Ogun & Nwachukwu, 2020). These values were consistent with those reported for other vegetable by Asaolu *et al.* (2012) and Oluwole *et al*. (2019) such as *A. cruentus* and *O. gratissimum* were 1.62% and 3.59% respectively. The fat content also compared favorably with the fat contents of various sweet potato leaves recorded by Oduro et al. (2008).

4.2.4 Fibre content of *Aleefu* and *Bra* samples

The fibre content was highest in "Aleefu" leaves (19.50%) followed by *"bra"*/Kenaf leaves (18.50%), though there was no significant difference ($p>0.05$). On the other hand, the *"bra"*/Kenaf seed had a high fibre content of 7.46% and *"aleefu"* seed had a fibre content of 6.30%. The mean difference between the samples investigated were not statistically significant different. The high fibre content of "*Aleefu*" leaves (19.5%) and "*bra*"/Kenaf leaves (18.5%) fell within the reported range of 8.50-20.90% by Isong & Idiong (2017) who worked on indigenous African vegetables in Africa. On the other hand, the two indigenous vegetables analyzed contradicts with the contents of dietary fibre reported for *Pterocarpus santalinoides* and *Hibiscus cannabinus* (1.62±0.07%). However, these values are relatively high when compared with data obtained by Blessing *et al.* (2011) for soybean (0.2%) and Berlandier nettle spurge seed (1.6%). Dietary fibre is essential in aiding digestion and decreasing chyme transit time in the gastrointestinal tract and increasing stool bulk,

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softening it and preventing constipation (Blessing *et al.*, 2011). These vegetables may, therefore, be very useful in the control of body weight, blood cholesterol and protection against colon cancer.

In the case of fibre requirement, either leafs of the two or their seeds would provide the consumer similar fibre needs.

4.2.5 Protein content of *Aleefu* and *Bra* samples

The protein content of the *"aleefu"* leaves was 9.27% and that of "*bra*"/Kenaf leaves was 10.36%. On the other hand, the seed of *"aleefu"* and "*bra*"/Kenaf had higher protein content of 35.04% and 26.17% respectively. The results showed a statistical significant difference between the samples investigated. Results from this study showed that the leafy vegetables analyzed had low protein content. This is inconsistent with the study of Adepoju and Oyewole (2008) that reported the protein content of *Adenia cissampeloides* and *Ceiba pentandra* were 23.0% and 18.5% respectively. In addition, the amount of protein in *"aleefu"* and "*bra*"/Kenaf leaves was lower than 16.2±3.3% reported by Ndlovu and Afolayan (2008) in *C. olitorius*, 24.9±0.02% reported in *S. nigrum* by Akubugwo *et al*. (2007) and 17.92% reported in *A. hybridus* by Akubugwo *et al*. (2007). The protein content of *aleefu"* leaves (10.27%) and "*bra*"/Kenaf leaves (10.36%) was lower than protein content of Momordica balsamia L. (11.29%), Lesianthera africana (13.1- 14.9%), Momor-dica foecide (4.6%) leaves consumed in Nigeria and Swaziland (Ogle & Grivetti, 1985; Isong & Idiong, 1997; Hassan & Umar, 2006), but lower than those of I. batatas (24.85% DW), Amaranthus candatus (20.5% DW), Piper guineeses (29.78% DW) and T. triangulare (31.00% DW) (Etuk et al., 1998; Akindahunsi & Salawa, 2005; Antia et al., 2006). However, it compares favourably with Gnetum africana (10.50%) and Leptadenia hastata (10.1%) (Sena et al., 1998; Ekop, 2007).

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However, in the case of protein requirement, Aleefu seed had a higher amount than the rest and consumers who require high protein could depend on the Aleefu seeds than aleefu leaf or bra leaf and seeds.

4.2.6 Carbohydrate content of *Aleefu* and *Bra* samples

The total carbohydrate in the current study was determined by difference. The sample with highest carbohydrate content Kenaf seed (58.00%) followed by Kenaf leaves (51.59%), with Aleefu seed and Aleefu leaves recording 46.11% and 45.00%, respectively. The study observed that there was no significant difference though Kenaf recorded higher percentage carbohydrate than Aleefu. The carbohydrate content found in *aleefu"* leaves and "*bra*"/Kenaf leaves, was higher than the total carbohydrate in *Hibiscus cannabinus* (18.30±0.12%) and *Pterocarpus santalinoides* which had the least total carbohydrate content (13.40±0.17%) as indicated by Agiang (2016). Also, compared with other vegetables reported by Adnan *et al.* (2010) and Nkafamiya *et al.* (2010) with values ranging from 13.40 ± 0.17 to18.30 ± 0.12%, the carbohydrate content of the vegetables in this study is high. The study revealed carbohydrate contents dissimilar to results obtained by Suppiah (1992); Tweneboah (1998) and Fuglie (2001) who reported values ranging from 6.80±0.04 to 13.50±0.03 for leafy vegetables such as *Xanthosoma Sagittifolia* "Kontomire", *Amaranth cruentus* "Aleefu", *Talinum triangulare* "Bokoboko" and *Moringa oleifera*.

However, in the case of carbohydrates requirement, Aleefu seed generate maximum carbohydrates than the rest and consumers who require high carbohydrates would like to depend on the Aleefu seeds than aleefu leaf or bra leaf and bra seeds.

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4.3 Anti-nutritional properties of Amaranthus species and Kenaf species

The result of anti-nutrients (phytate, Alkaloids, and Saponins) showed that they were present at varying levels in the leaves and seeds of Aleefu and Bra in low concentrations. The results of the quantitative analysis of anti-nutritional properties of Amaranthus spp (*aleefu*) and Kenaf spp (*bra*) grown and consumed in Northern Ghana are presented in Table 4.2. Test of significance revealed statistically insignificant difference of phytate in the leafs and seeds of Aleefu and Bra. Similarly the apparent difference in percentage of Alkaloids in Aleefu leaf, Aleefu seed and Kenaf leaf are not statistically different. Alkaloid content of Bra seed is significantly lower than in the leaves of Aleefu and Bra leaf.

Table 4.2: Anti nutritional properties of aleefu and bra

Test samples	**Anti-nutritional properties**		
	Phytate(%)	**Alkaloids (%)**	**Saponins (%)**
Aleefu leaves	1.54^{b} ±0.056	12.47^{b} ±.0424	52.00^{a} ±0.001
Aleefu seed	0.775^{b} ± 0.078	9.50^{b} ± .7071	1.60^{b} ±0.141
Kenaf Leaves	1.27^{b} ±0.021	7.29^{b} ±0.0212	6.14^{c} ± 0.014
Kenaf seed	0.605^{b} ±.0212	3.64^{c} ±0.0566	2.28^{b} ±0.021

Numbers in columns followed by different superscripts are significantly different at P<0.05

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4.3.1 Phytate content of *Aleefu* and *Bra* samples

As depicted in Table 4.2, results obtained for the anti-nutrient composition revealed low levels of phytate. The "*Aleefu*" leaves obtained phytate value of 1.54% whereas *"bra"*/Kenaf leaves had phytate value of 1.27%. Phytate content found in "*Aleefu*" and *"bra"*/Kenaf seed was observed to be 0.775 %± 0.078 and 0.605±0.0212 respectively. Phytate had been linked to the complexation with calcium in the gastrointestinal tract thus reducing calcium absorption and urinary calcium excretion which consequently could reduce the risk of kidney stones formations, dental decay and calcification of blood vessels. Phytic acid is known to be a very potent chelator, forming protein and mineral-phytic acid complexes thereby decreasing protein and mineral bioavailability. The ANOVA analysis shows a significant mean difference between the samples investigated at $p<0.05$. Phytaye affects the food value by binding and making mineral ions unavailable to the consumer (Marfo et al. 1990). The levels of phytates in these vegetables (Aleefu and kenaf) were lower than those reported for some seeds and some nonconventional leafy vegetables documented by Ekpo (2007). The low level of phytate in these vegetables would therefore be nutritionally advantageous, in that it will enhance bioavailability of micronutrients.

4.3.2 Alkaloids content of *Aleefu* and *Bra* samples

The level of Alkaloids was highest in "Aleefu" leaves at 12.5%, whiles *"bra"*/Kenaf leaves had Alkaloids value of 7.3%. Alkaloids found in "Aleefu" and *"bra"*/Kenaf seed were present in appreciable amounts (9.50±0.7071 and 3.64 %±0.0566). Alkaloids are one of the most therapeutically efficient bioactive substances known in plants. The results obtained found a significant mean difference

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among the samples (p<0.05). The study by Agiang, Mgbang, Essien, & Peters (2016) on lesser known leafy vegetables consumed in Northern Senatorial District of Cross River State, Nigeria showed appreciable amounts of Alkaloids present (1.12± 0.01 - 2.12± 0.01mg/100g). Alkaloids are small organic molecules that belong to a large group of chemical compounds synthesized by vascular plants (Fekadu & Ratta, 2014). They are one of the most therapeutically efficient bioactive substances known in plants.

4.3.3 Saponin content content of *Aleefu* and *Bra* samples

The saponin content of 52% although high for "*Aleefu*" leaves was still lower for *"bra"*/Kenaf leaves with saponin content of 6.14%. Also, the saponin content of "*Aleefu*" and *bra"*/Kenaf seed was 0.775% and 0.605% respectively. The saponin content, although high for "*Aleefu*" leaves, was still lower than that reported for some commonly consumed spices such as garlic and onion (Nwinuka et al. 2005). A significant mean difference was found among the samples investigated. The low level of saponin content in *"bra"*/Kenaf leaves and "*Aleefu*" seed suggests that on consumption, the probability of these vegetables to cause reduction in nutrient uptake could be low. This view is supported by the findings made by Igile *et al.* (2013) which reported that saponins were safe and non-toxic at low levels of < 10%. Saponins are glycosides containing polycyclic aglycone moiety of either C27 steroid or C30 triterpenoids attached to a carbohydrate sugar (Igile *et al.,* 2013).

4.4 Mineral composition of Amaranthus species and Kenaf species

Nutritionally, indigenous vegetables could contribute substantially to mineral intakes. Table 4.3 shows the mineral composition of Amaranthus spp (*aleefu*) and Kenaf spp (*bra*) grown and consumed in Northern Ghana.

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Table 4. 3: Mineral composition of Amaranthus spp (*aleefu*) and Kenaf spp (bra)

Test samples	Mineral composition				
	Zinc	Potassium	Iron	Calcium	Sodium
Aleefu leaves	$2.24^{b} \pm .057$	$583.00^{b} \pm 1.414$	$21.81^{b} \pm .0566$	$150.00^{b} \pm 2.828$	$7.50^{b} \pm 0.707$
Aleefu seed	$3.78^{b} \pm .007$	$127.50^{a} \pm 2.121$	$7.64^{a} \pm .0353$	$160.00^{b} \pm 8.485$	$10.50^{b} \pm 0.707$
Kenaf Leaves	$1.90^{b} \pm .141$	$754.50^{b} \pm .707$	$24.15^{b} \pm .9192$	$165.50^{b} \pm 2.121$	$12.00^{b} \pm 1.414$
Kenaf seed	$2.40^{b} \pm .141$	$424.00^{b} \pm 2.828$	$9.00^{a} \pm .1414$	$182.50^{b} \pm 2.121$	$7.50^{b} \pm 0.707$

Numbers in columns followed by different superscripts are significantly different at $P<0.05$

4.4.1 Zinc content of *Aleefu* and *Bra* samples

From Table 4.3, the zinc content was 2.24mg/kg and 1.90mg/kg for "*Aleefu*" leaves and "*bra*"/Kenaf leaves respectively. Conversely, the seed of *bra*"/Kenaf had a zinc value of 2.40mg/kg and the seed of "*Aleefu*" had a zinc content of 3.78mg/kg. A statistically insignificant mean difference was found between the samples investigated at $p<0.05$. The concentration of Zinc (Zn) found in *Aleefu*" leaves and "*bra*"/Kenaf leaves was lower than the Recommended Dietary Allowance of 10-150 mg/kg as reported Boularbah *et al.* (2006). This finding also agreed with work of Ogundele *et al.* (2013), although, the Zn levels in the plants were lower than the recommended limits of 60.0 mg/kg in normal plant. Also, concentration of Zinc (Zn) found in the seed of *bra*"/Kenaf was 2.40mg/kg and the seed of "*Aleefu*" had a zinc content of 3.78mg/kg which was lower than W.H.O standard limits of 10-150 mg/Kg as reported Boularbah *et al*. (2006). It also, concurred with findings of Ogundele *et al.* (2013) and Ogundele *et al* (2017) who reported that although, the Zn levels in the plants were lower than the recommended limits of 60.0 mg/Kg in normal plant, there is need to monitor the accumulation level. HIV sufferers had the highest zinc deficiency rate

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(Baum et al. 2003). While the number of people living with HIV has declined again (UNAIDS 2011), and the global HIV burden in Sub-Saharan Africa remains immense. Promoting Zn's high amaranth output and use can help mitigate Zn deficiency health problems.

4.4.2 Potassium content of *Aleefu* and *Bra* samples

The potassium composition of *"Aleefu"* leaves was 583.0mg/kg, and that of "*bra*"/Kenaf leaves was 754.0mg/kg. This indicates that "*bra*"/Kenaf leaves has the highest potassium composition as compared to *"Aleefu*" leaves. The seed of "*bra*"/Kenaf had a high potassium value of 424mg/kg and the seed of *"aleefu"* had a potassium value of 127.5mg/kg. The ANOVA test shows a significant mean difference among the samples investigated at $p<0.01$. The seed of "*bra*"/Kenaf had a high potassium value of 424mg/kg and the seed of *"aleefu"* had a potassium value of 127.5mg/kg. The amount of potassium (K) in the body is of great concern for prevention of high blood pressure. Hence, consumption of *"Aleefu"* and "*bra*"/Kenaf would probably reduce high blood pressure diseases. Studies indicate a positive correlation between the high intake of potassium and the risk of stroke (Demigne et al. 2004). However as noted in all the vegetables tested, the high amount of potassium combined with low sodium could be protective against many diseases (Arlington et al. 1992).

4.4.3 Iron content of *Aleefu* and *Bra* samples

Levels of iron found in the two leafy vegetables in this study are within the range of 21.81mg/kg and 24.15mg/kg. The "*bra*"/Kenaf leaves recorded the highest iron level of 24.15mg/kg as compared to *"Aleefu"* leaves. In addition, the amount of

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iron found in *"aleefu"* was 7.64mg/kg and that of "*bra*"/Kenaf seed was 9.00mg/kg. From the ANOVA test a significant mean difference was found between the Amaranthus spp (aleefu) leaves and Kenaf spp (bra) leaves at $p<0.01$ ($F(df)=613.821$, $p=.002<0.01$). Iron content of the leaves compares favourably with the value reported in I batatas (22.00 mg/100g) (Antia et al., 2006), but low compared with values of other green leafy vegetables (DW) (Ibrahim et al., 2001). Iron is an important trace element for the production of hemoglobin (Adeyeye & Otokiti, 1999). In the night shade analysis, Fe contents reported by Akubugwo et al. (2007) were higher than those reported by Weinberger and Msuya (2004). Iron is important for the production of haemoglobin (Kaya & Incekara 2000). Via its high demand, iron is also a possible source of iron for disadvantaged communities such as children up to five years old and women who are pregnant and breastfeeding. Anemia in pregnant women is strong (48.2% and 57% respectively in Southeast Asia and Africa, compared to 25.1% in Europe) (WHO 2008). Iron deficiency anemia constitutes 20% of neonatal deaths and 10% or nearly 800 000 deaths, which is 2.4% of world disease mortality per year (Black et al. 2003). Night shade intake will thus minimize anemia deaths in developed countries among pregnant women and infants.

4.4.4 Calcium content of *Aleefu* and *Bra* samples

The calcium content of the leaves of *"aleefu"* and "*bra*"/Kenaf was 150mg/kg and 165mg/kg respectively. With the seed *aleefu"* and "*bra*"/Kenaf, the calcium content was 160mg/kg and 182mg/kg respectively. The calcium content was high among the two leaves. Calcium is responsible for the growth and maintenance of bones, teeth and muscles. There was a significant mean difference among the samples investigated at $p<0.05$. Calcium composition found in *"aleefu"* and

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"*bra*"/Kenaf was higher than the calcium (Ca) composition (44.15 mg/100g) found in Amaranthus hybridus L. leaves (Akubugwo et al, 2007). In addition, the calcium content of the two indigenous vegetables compares favourably with that of *C. album*, *S. asper*, *S. nigrum* and *U. urens* (100-442.28 mg/1000g) (Afolayan & Jimoh, 2009) but is low compared to 166 – 640 mg/100 g observed in some green leafy vegetables consumed in Nigeria (Ladan et al., 1996). (Dosunmu, 1997; Turan et al., 2003). The calcium level in the leaves studied compares favourably with the value reported in some green leafy vegetables consumed in Nigeria and some wild edible leaves grown in Eastern Anatolia, Turkey (Ladan et al., 1996; Turan et al., 2003). For good Ca to P intestinal absorption, Ca/P ratio should be close to unity (Gull-Guerrero et al., 1998).

4.4.5 Sodium content of *Aleefu* and *Bra* samples

The Sodium (Na) content obtained in *"aleefu"* leaves was 7.5% and "bra"/Kenaf leaves was 12.0%. For the seed of "aleefu" leafy vegetables, the value obtained was 10.5% and "bra"/Kenaf was 7.5%. The mean difference between the samples investigated was insignificant at $p<0.05$. The sodium (Na) content present in *"aleefu"* and "bra"/Kenaf leaves was lower that the sodium (Na) present *C. album* (37%); *S. asper* (28%); *S. nigrum* (61%); and *U. urens* (92%) (Afolayan & Jimoh, 2009). The content of Na in two vegetables in the body is of great concern for prevention of high blood pressure.

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CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Nutritionally, indigenous vegetables contribute substantially to protein, mineral and crude fibre of diets. The study revealed that the two vegetables under study had higher concentration of proteins in their seeds (26.17 to 35.04%) comprared to their leaves (9.27 to 10.36%). The relatively high mineral content as observed in the total ash of the samples gives as indication that they their consumption will prevent micronutrient deficiencies such as Iron Deficiency Anaemia and Vitamin A Deficiency. The high content of total fiber in the leaves of the two vegetables (18.50 to 19.50) might be help in reducing blood cholesterol as well as speeding up peristalsis thus aiding the emptying of bowels during constipation.

The results obtained for anti-nutrient composition revealed lower levels in seeds compared to the leaves. Generally phytate recorded the lowest anti nutrient content (4.2%) followed by alkaloids (32.9%) with saponins recoding the highest anti nutrient content of 62.1%.

In terms of their mineral contents, the vegetables investigated were very good sources of calcium, potassium, and iron. Calcium (which is very important for bone growth and muscle) was most abundant in "*Aleefu*" and *bra*"/Kenaf. These indigenous vegetables could therefore meet the daily requirements of potassium for an adult and be useful in the management of hypertension and other cardiovascular diseases. Consumption of *Aleefu*" and *bra*"/Kenaf leaves and seeds which are particularly high in iron content, may help to overcome some of the nutritional problems associated with iron deficiency.

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5.2 Recommendations

According to the major findings of the study, the researcher recommended that;

- The Agricultural ministry should encourage the consumption of *Aleefu*" and *bra*"/Kenaf leaves and seeds that could help in alleviating the problem of hidden hunger at negligible cost.
- The government of Ghana should encourage and motivate farmers to increase the production of indigenous vegetables.
- Education on how to prepare indigenous vegetables to gain maximum nutritional value which will help to ensure low-cost nutrients to reach vulnerable populations must be encouraged.
- Farmers should package and market these indigenous vegetables to attract consumers attention as packaging and advertisement influence consumers purchase intention.

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APPENDIX

COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH
(SAVANNA AGRICULTURAL RESEARCH INSTITUTE)

P.O. 52 Tamale, GHANA VOICE: 03720 91205/91214 FAX: 03720 23483
E-MAIL: directorsari@gmail.com

ANALYTICAL SERVICE LABORATORY DATA SHEET-4

LAB. NO:	SAMPLE ID	% ASH	% MOISTURE	% FIBRE	MJ/kg CALORIFIC	mg/kg ZINC	mg/kg POTASSIUM	mg/kg IONS	% PHYTATE	% ALKALOIDS	% SAPOMININS
18/062	*Amaranthus spp* **"ALEEFU" LEAVES**	15.64	59.79	12	18	2.28	584	21.85	1.58	12.44	52
18/062	*Amaranthus spp* **"ALEEFU" LEAVES**	15.60	60.0	13	19	2.20	582	21.77	1.50	12.50	52

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18/063	*Amaranthus spp* **"ALEEFU" SEEDS**	3.4	1.6	8.4	23	3.78	126	7.61	0.72	9	1.7
18/063	*Amaranthus spp* **"ALEEFU" SEEDS**	3.4	1.7	8.2	21	3.77	129	7.66	0.83	10	1.5
18/064	*Hibiscus cannabinus* **"BRA"/KENAF LEAVES**	10.6	42.3	11.4	16	1.8	754	24.8	1.28	7.27	6.15
18/064	*Hibiscus cannabinus* **"BRA"/KENAF LEAVES**	10.4	43.1	11.6	15	2.0	755	23.5	1.25	7.30	6.13
18/065	*Hibiscus cannabinus* **"BRA"/KENAF SEEDS**	4.5	2.8	13.45	21	2.3	422	8.9	0.59	3.68	2.26
18/065	*Hibiscus cannabinus* **"BRA"/KENAF SEEDS**	5.0	2.6	13.46	22	2.5	426	9.1	0.62	3.60	2.29

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ANALYTICAL SERVICE LABORATORY DATA SHEET-4

NAME: MADAM AFISAH JAJAH

LAB .NO.	LEAVES & SEEDS		% PROTEIN	% CARBOHYDRATES	mg/kg CALCIUM	% FAT	mg/kg Na
142/20	*Amaranthus spp* **"ALEEFU"**	LEAVES (1)	10.25	48	148	3.4	7
143/20	*Amaranthus spp* **"ALEEFU"**	LEAVES (2)	10.28	50	152	3.5	8
144/20	*Amaranthus spp* **"ALEEFU"**	SEEDS (1)	35.13	74	166	9	10
145/20	*Amaranthus spp* **"ALEEFU"**	SEEDS (2)	34.94	73	154	8	11
146/20	*Hibiscus cannabinus* **"BRA"/KENAF**	LEAVES (1)	10.38	45	164	2.6	13
147/20	*Hibiscus cannabinus* **"BRA"/KENAF**	LEAVES (2)	10.34	44	167	2.5	11
148/20	*Hibiscus cannabinus* **"BRA"/KENAF**	SEEDS (1)	25.63	57	184	6	7
149/20	*Hibiscus cannabinus* **"BRA"/KENAF**	SEEDS (2)	26.7	59	181	8	8

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DIGESTION OF SAMPLE

By the digestion of samples all chemical nutrients in the sample are trapped into the solution an now

to be determined by various processes.

REAGENTS

1. CONC. H_2SO_4
2. 40% NaOH
3. 4% boric acid solution (H_3BO_3)

DIGESTION

1. Take a known weight into the digestion flask
2. Add 5mls of digestion mixture
3. Digest until clear and colourless
4. Allow flask to cool
5. Totally transfer the content into a 100ml volumetric flask and make up to the mark with distilled water.

Calcium, Magnesium, Potassium sodium zinc and ion in the digest are measured

CALCULATION

$$mg/Kg = \frac{(A-B)*V.E*d.f}{Wt.}$$

Where
A= Absorbance of Sample from the machine reading
B = Absorbance of Blank from the machine reading
V.E = Volume of extract
d.f = Dilution Factor
Wt. = Weight of sample taken for the extraction

PROXIMATE ANALYSIS OF FEEDSTUFF

Sampling and Preparation for Analysis

Before undertaking an analysis the results of which are to be used to represent the composition of

a consignment of a feedstuff, it is important that the sample is sufficient in amount and that it is

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selected properly from the bulk so as to be fairly representative of it. Sampling is however not a

laboratory operation. The sample to be used, if necessary, is expected to be sufficiently dried to

enable it to be finely ground.

PROXIMATE ANALYSIS

This refers to the determination of the major constituents of feed and it is used to assess if a feed

is within its normal compositional parameters or somehow been adulterated. This method

partitioned nutrients in feed into 6 components: water, ash, crude protein, crude fibre etc.…

Moisture Determination

Moisture is determined by the loss in weight that occurs when a sample is dried to a constant

weight in an oven. About 2g of sample is weighed into a silica dish previously dried and

weighed. The sample is then dried in an oven for 65^{0}C for 36 hours, cool in a desiccator and

weigh. The drying and weighing continues until a constant weight is achieved.

$$\%Moisture = \frac{\text{wt. of sample + dish before drying- wt. of sample+ dish after drying}}{\text{Wt. of sample taken}} \times 100$$

%DM = 100 - %Moisture.

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Ether Extract (Fat)

The ether extract of a feed represents the fat and oil. **Soxhlet apparatus** is the equipment used for the determination of ether extract. It consist of 3 major components

1. An extractor: comprising the thimble which holds the sample
2. Condenser: for cooling and condensing the ether vapour

soluble substances are dissolved and are carried into solution through the siphon tube back into the flask. The extraction continues for at least 4 hrs. The thimble is removed and most of the solvent is distilled from the flask into the extractor. The flask is then disconnected and placed in an oven at 65^0C for 4 hrs, cool in desiccator and weighed.

$$\%\text{Ether extract} = \frac{\text{wt of flask + extract} - \text{tare wt of flask}}{\text{wt of sample}} \times 100$$

Crude Fibre

The organic residue left after sequential extraction of feed with ether can be used to determine the crude fibre, however if a fresh sample is used, the fat in it could be extracted by adding petroleum ether, stir, allow it to settle and decant. Do this three times. The fat-free material is then transferred into a flask/beaker and 200mls of pre-heated 1.25% H_2SO4 is added and the solution is

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gently boiled for about 30mins, maintaining constant volume of acid by the addition of hot water.

Then 200mls of pre-heated 1.25% Na2SO4 is added and boiled for another 30mins. Filter under

suction and wash thoroughly with hot water and twice with ethanol. The residue is dried at 650C

for about 24hrs and weighed. The residue is transferred into a crucible and placed in muffle

furnace (400-6000C) and ash for 4hrs, then cool in desiccator and weigh.

$$\%\text{Crude fibre} = \frac{\text{Dry wt of residue before ashing - wt of residue after ashing}}{\text{wt of sample}} \times 100$$

Crude Protein

Crude protein is determined by measuring the nitrogen content of the sample and multiplying it by a

factor of 6.25. This factor is based on the fact that most protein contains 16% nitrogen. Crude

protein is determined by **kjeldahl method.** The method involves: Digestion, Distillation and

Titration.

Digestion: weigh about 2g of the sample into kjeldahl flask and add 25mls of concentrated

sulphuric acid, 0.5g of copper sulphate, 5g of sodium sulphate and a speck of selenium tablet.

Apply heat in a fume cupboard slowly at first to prevent undue frothing, continue to digest for

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45mins until the digesta become clear pale green. Leave until completely cool and rapidly add

100mls of distilled water. Rinse the digestion flask 2-3 times and add the rinsing to the bulk.

Distillation: kjeldahl distillation apparatus is used for distillation. Steam up the distillation

apparatus and add about 10mls of the digest into the apparatus via a funnel and allow it to boil.

Add 10mls of sodium hydroxide from the measuring cylinder so that ammonia is not lost. Distil

into 50mls of 2% boric acid containing screened methyl red indicator.

Titration: the alkaline ammonium borate formed is titrated directly with 0.1*N* HCl. The titre

value which is the volume of acid used is recorded. The volume of acid used is fitted into the

formula which becomes

$$\%N = \frac{14 \times VA \times 0.1 \times w \times 100}{1000 \times 100}$$

VA = volume of acid used

w= weight of sample

%crude protein = %N x 6.25

Ash

Ash is the inorganic residue obtained by burning off the organic matter of feedstuff at 550^0C

in muffle furnace for 4hrs. 2g of the sample is weighed into a pre-heated crucible. The crucible is

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placed into muffle furnace at 550^{oc} for 4hrs or until whitish-grey ash is obtained.

The crucible is then placed in the desiccator and weighed

$$\%Ash = \frac{\text{wt. of crucible + ash – wt. of crucible}}{\text{wt. of sample}}$$

The Phytochemicals are determined using an equipment called High Performance

Liquid Chromatographic

Machine (HPLC)